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Editorial Preface

Advance Sustainable Science, Engineering and Technology (ASSET)
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We are delighted to present the January 2024 issue of Advance Sustainable Science, Engineering and Technology (ASSET), Volume 6 Number 1. This edition features a diverse collection of research articles that showcase the impactful contributions made by scholars across various fields, shedding light on crucial topics in science, engineering, and technology.

This issue explores a wide spectrum of topics within the fields of technology, engineering, and computer science. The authors delve into innovative solutions and methodologies, ranging from invisible watermarking techniques based on Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD), to the application of Convolutional Neural Networks for lung diseases classification. Additionally, this issue includes studies on portable incinerator technology, quality control analysis in fertilizer production, and the implementation of self-service concepts through responsive web-based applications. The authors also address significant issues such as heart disease classification using deep neural networks, risk-based maintenance management strategies, and the optimization of predictive accuracy for oil sales forecasting. Furthermore, topics like decentralized data storage networks using blockchain technology, the Proof of Work consensus in blockchain, and the integration of artificial intelligence with messaging platforms are explored. The content reflects the diversity and depth of research conducted by scholars and practitioners in the realm of science and technology.

We extend our sincere gratitude to the 59 authors who have dedicated their expertise to enriching this issue with their research contributions. Their commitment has been pivotal in making this publication possible.

Furthermore, we acknowledge the institutions that have played a significant role in fostering this research. These include Universitas Dian Nuswantoro, Sekolah Tinggi Teknologi Ronggolawe, Universitas Muhammadiyah Gresik, Universitas Teknologi Yogyakarta, Universitas Diponegoro, Krida Wacana Christian University, Universitas Anwar Medika, Sepuluh Nopember Institute of Technology, Universitas Halu Oleo, Institut Sains Teknologi dan Kesehatan 'Aisyiyah Kendari and University of New South Wales (Australia).

We look forward to the valuable insights and contributions that the future editions of ASSET will bring to the forefront of sustainable science, engineering, and technology.

January 2024
Assoc. Prof. Mega Novita
Asst. Prof. Rizky Muliani Dwi Ujianti

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High-Quality Evaluation for Invisible Watermarking Based on Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD)

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Abstract. In this research, we propose an innovative approach that integrates Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD) to enhance the quality and security of digital images. The purpose of this technique is to embed imperceptible watermarks into images, preserving their integrity and authenticity. The integration of DCT allows for an efficient transformation of image data into frequency components, forming the basis for embedding watermarks that are nearly invisible to the human eye. In this context, SVD offers an advantage by separating singular values and corresponding vectors, facilitating a more sophisticated watermarking process. The quality evaluation using metrics such as MSE, PSNR, UQI, and MSSIM demonstrates the effectiveness of this approach. Low average MSE values, ranging from 0.0058 to 0.0064, indicate minimal distortion in the watermarked images. Additionally, high PSNR values, ranging from 67.20 dB to 67.22 dB, affirm the high image quality achieved after watermarking. These results validate that the integration of DCT and SVD provides a high level of security while maintaining optimal visual quality in digital images. This approach is highly relevant and effective in addressing the challenges of image protection in this digital era.

Keywords: Image Quality, Image Watermarking, DCT, SVD

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1. Introduction

Image quality is paramount, profoundly impacting its effectiveness and the conveyed visual impression [1]. However, the rise of sophisticated editing tools in our technology-driven era has escalated the threat to image integrity, making image manipulation effortless. To counter this challenge, digital watermarking has emerged as a promising solution. By inserting imperceptible watermarks into images as unique identifiers or authentication proofs, digital watermarking safeguards images against unauthorized modifications and ensures their authenticity [2]. Thus, the use of digital watermarking becomes highly relevant in enhancing image quality and preserving its integrity, especially in a time where visual information holds a central role across diverse sectors, spanning from security to copyright

and identification purposes [1], [3]. In addition to traditional digital watermarking, invisible watermarking stands out as an advanced technique that offers unique advantages in ensuring image integrity and security [4]. Unlike visible watermarking, invisible watermarking necessitates access to the original, unmarked image during watermark extraction [5]. This additional information allows for the implementation of more sophisticated algorithms and larger data embedding capacities, leading to enhanced resistance against various attacks and better preservation of image quality [5], [6]. Invisible watermarking proves particularly beneficial in applications where secure storage or access to the original image is feasible, such as copyright protection, media forensics, and content authentication [7]. By striking a delicate balance between imperceptibility and robustness, invisible watermarking provides a dependable and enduring method to protect the intellectual property and integrity of digital images across diverse domains.

In this research, we employ a meticulous approach by integrating Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD) techniques within the realm of invisible watermarking. The utilization of DCT, a fundamental tool in signal processing, allows for the efficient transformation of image data into frequency components, providing a foundation for embedding imperceptible watermarks. By strategically combining DCT with SVD, a powerful mathematical technique for matrix factorization, we enhance the robustness and security of our invisible watermarking method. SVD enables us to decompose the image data into singular values and corresponding vectors, facilitating a sophisticated embedding process. This synergistic integration of DCT and SVD not only ensures the imperceptibility of the watermark but also fortifies its resilience against diverse attacks, thereby elevating the overall integrity and quality of the watermarked images.

2. Methods

In the methodology section, we present a comprehensive framework for our research, outlining the systematic steps employed in the implementation of our invisible watermarking technique. Firstly, we preprocess the digital images to ensure uniformity and optimize their quality, preparing them for the watermark embedding process. We apply the DCT to the preprocessed images, breaking down the pixel data into frequency components. Simultaneously, we integrate SVD into the process, enhancing the robustness of the watermarking method by decomposing the transformed images into singular values and corresponding vectors. One limitation of our method involves the constraint of uniform image dimensions, wherein the cover image and watermark image must have the same size, such as 512 x 512 pixels, to ensure the successful application of our watermarking technique. The flow of the method used in this research can be seen in **Figure 1** and explained in the pseudocode algorithm explanation below.

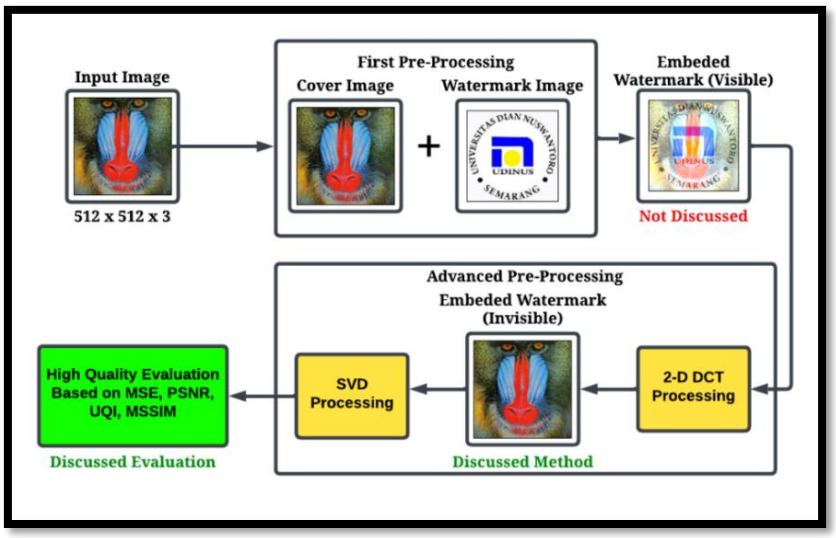

Figure 1. Flow of Proposed Method

Algorithm: Invisible Watermarking using DCT, SVD, and Quality Metrics
Input: $watermarked\_image$ (Watermarked Image), $original\_image$ (Original Image)$\leftarrow W_{in} \times H_{in} \times D_{in} \leftarrow 512 \times 512 \times 3$.
Step 1: Preprocess the $Original\_Image$ and $Watermark\_Image$: Normalize pixel values to the range $[0, 1]$
Step 2: Apply Discrete Cosine Transform (DCT) to the $Original\_Image$
- Divide the image into non-overlapping blocks of $8x8$ $pixels$
- Apply DCT to each block

Step 3: Apply Singular Value Decomposition (SVD) to $DCT\_Coefficients$
- For each DCT block:
- Apply SVD to the block
- Modify singular values based on the $watermark\_image$ and $embedding\_strength$

Step 4: Inverse SVD and Inverse DCT
- Reconstruct the modified $DCT\_coefficients$ to obtain watermarked DCT blocks
- Apply inverse DCT to obtain the $watermarked\_image$

Step 5: Calculate Quality Metrics
- Calculate Mean Squared Error (MSE) between original and watermarked images
- Calculate Peak Signal-to-Noise Ratio (PSNR) using MSE
- Calculate Universal Quality Index (UQI) to measure image quality
- Calculate Mean Structural Similarity Index (MSSIM) to evaluate structural similarity

Step 6: Output Watermarked Image and Quality Metrics
- Output the $watermarked\_image$ $(512\ x\ 512\ x\ 3)$
- Output the calculated quality metrics (MSE, PSNR, UQI, MSSIM)

2.1. Discrete Cosine Transform (DCT)

DCT plays a pivotal role in invisible watermarking, a sophisticated technique employed to embed imperceptible digital watermarks into images [8]. In this method, the input image is divided into small blocks, typically $8x8$ pixels, and DCT is applied to each block independently [9]. DCT transforms the spatial domain information of the image into frequency components, revealing the image's energy distribution across different frequencies. By manipulating the DCT coefficients, imperceptible changes are introduced into the image, allowing for the seamless embedding of watermark data. The key advantage of DCT lies in its ability to concentrate most of the image information into a few low-frequency coefficients, making it highly resilient to human visual perception [8], [10]. Consequently, when a viewer observes the watermarked image, these alterations are virtually undetectable, ensuring the invisibility of the embedded watermark.

2.2. Singular Value Decomposition (SVD)

SVD stands as a cornerstone in the realm of invisible watermarking, providing a robust framework for enhancing image quality and receiving high evaluations. In the context of invisible watermarking, SVD is applied to the transformed image data, breaking it down into singular values and corresponding vectors [11]. These singular values capture essential features of the image's structure, and by strategically modifying them based on watermark data, imperceptible changes are introduced. SVD's unique ability to represent the image in terms of its singular values allows for a meticulous control over the watermark embedding process, ensuring a delicate balance between imperceptibility and robustness [10], [12]. By leveraging SVD, watermarking algorithms can enhance the image's resistance against various attacks, such as noise addition or compression, while preserving its visual quality. Based on SVD equation, can be seen in **Equation (1),** Where, D represents mid point of the sorted D_i and n represents total number of pixels [11].

$$SVD = \frac{\sum_{i=1}(Image\ Size/n)^2\ |D_i - D_{mid}|}{(Image\ Size/n)^2} \quad (1)$$

2.3. Gaussian Noise

The addition of Gaussian noise is a critical aspect of this research, introducing a layer of complexity that significantly enhances the challenge of decryption for potential eavesdroppers [13]. In this study, the deliberate incorporation of Gaussian noise into the data transmission process serves as a formidable barrier against interception and unauthorized access. By strategically applying Gaussian noise, the transmitted information becomes obscured, making it substantially more difficult for potential adversaries to decipher the original data accurately. This intentional introduction of noise acts as a sophisticated cryptographic technique, rendering the intercepted data more resistant to decryption efforts [14]. Consequently, the utilization of Gaussian noise in this research not only ensures the integrity of the transmitted data but also bolsters its security measures, making it an invaluable component in safeguarding sensitive information against potential malicious interceptions. Based on Gaussian Noise equation, can be seen in **Equation (2).**

$$Gaussian\ Noise(x, y) = \mu + \sigma \cdot Z \tag{2}$$

2.4. Salt & Peppers Noise

The incorporation of Salt and Pepper noise constitutes a pivotal element in this research, intensifying the complexity of decryption for potential eavesdroppers [15]. The deliberate addition of Salt and Pepper noise serves as a strategic mechanism to enhance the security of transmitted data. This type of noise introduces random, sparse white and black pixels throughout the image, simulating errors or anomalies that might occur during data transmission. In the context of this study, the intentional introduction of Salt and Pepper noise acts as a sophisticated encryption layer, rendering the intercepted data significantly more challenging to decrypt accurately. The sporadic nature of this noise pattern makes it arduous for unauthorized parties to distinguish between genuine data and the noise, thereby strengthening the data's confidentiality and integrity [14]. By strategically utilizing Salt and Pepper noise, this research fortifies the security measures, ensuring that sensitive information remains safeguarded against potential adversaries aiming to intercept and decipher the transmitted data. Based on Salt & Pepper Noise equation, can be seen in **Equation (3).**

$$N(x, y) = \begin{cases} 0\ with\ Probability\ p \\ 255\ with\ Probability\ q \\ OPV\ with\ Probability\ 1 - p - q \end{cases} \tag{3}$$

2.5. Additional Noise

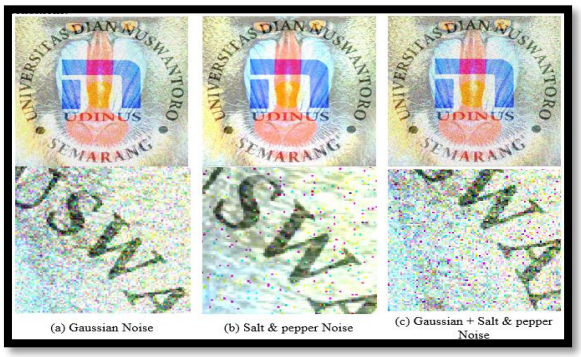

Figure 2. Additional Noise

Combination of Gaussian and Salt and Pepper noise presents a more complex challenge. It reflects the multifaceted nature of noise encountered in practical scenarios, where images can suffer from both subtle, uniform distortions and sudden, irregular errors simultaneously. Researchers often employ this combined noise model to develop image processing techniques robust enough to handle diverse noise patterns, ensuring the reliability and efficacy of their methods in real-world applications. By exploring these different types of additional noise, scientists can develop more sophisticated algorithms, enabling

digital systems to maintain image quality and integrity even under challenging and diverse noise conditions. Based on **Figure 2**. The visible addition of noise can significantly degrade the quality of a cover image, diminishing its visual appeal and overall aesthetic charm. To address this challenge, the utilization of Discrete Cosine Transform (DCT) becomes crucial. DCT enables us to modify the image imperceptibly, a technique commonly referred to as 'invisible watermarking.' By applying DCT, we can replace the noticeable addition of noise with alterations that remain imperceptible to the human eye. This approach allows the cover image to preserve its quality while simultaneously introducing hidden security measures that remain undetectable to human perception. For the inverse process leading to invisible watermarked, can be seen in the results and discussion chapter.

2.6. Quality Evaluation

Quality evaluation in the context of digital images is paramount, and it relies on several comprehensive metrics such as MSE (Mean Squared Error), PSNR (Peak Signal-to-Noise Ratio), UQI (Universal Quality Index), and MSSIM (Mean Structural Similarity Index). MSE quantifies the average squared difference between the original and watermarked images, providing a numerical measure of the overall distortion [1]. PSNR, on the other hand, offers a logarithmic scale indicating the quality of the watermarked image concerning the original, with higher values denoting superior fidelity. UQI assesses the structural similarity and luminance differences between the images, offering a more holistic evaluation. Lastly, MSSIM gauges the similarity in structural information, luminance, and contrast, providing a comprehensive insight into perceptual image quality. By employing these metrics, researchers can rigorously assess the effectiveness of various image processing techniques, ensuring that the resulting images maintain high-quality standards while being imperceptibly watermarked [1]. Based on Quality Evaluation, can be seen in **Equation (4) – (7).**

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(I(i,j) - K(i,j))^{2} \tag{4}$$

$$PSNR = 10\log 10\left(\frac{\max\ \_pixel\_value^{2}}{MSE}\right) \tag{5}$$

$$UQI = \frac{4\cdot\ \sigma_{xy}\cdot\mu_x\cdot u_y}{(\sigma_x^2 + \sigma_y^2)\cdot(\mu_x^2 + \mu_y^2)} \tag{6}$$

$$MSSIM\ = \frac{(2\mu_x\mu_y + C1)(2\sigma_{xy} + C2)}{(\mu_x^2 + \mu_y^2 + C1)(\sigma_x^2 + \sigma_y^2 + C2)} \tag{7}$$

3. Results and Discussion

In this research, three test images, namely Lena, Peppers, and Baboon, were utilized, accompanied by a watermark featuring the logo of Universitas Dian Nuswantoro. These images were chosen from standard datasets commonly used in the field of image processing. Each image is square-shaped, measuring 512 x 512 pixels, and consists of three-color channels. Additionally, the watermark applied to these images prominently features the emblem of Universitas Dian Nuswantoro, serving as an essential element for evaluation and validation within the study.

(a) Lena.jpg (b) Peppers.jpg (c) Baboon.jpg (d) Logo.jpg

Figure 3. Sample of Cover and Watermark Image

In the first pre-processing step, transforming them into a state comparable to the fourth image in the sequence. Notably, the **Figure 4**. displayed a noticeable amount of noise on the cover surface due to the deliberate introduction of additional noise during the experimental setup. To rectify this issue and restore

the image to its original quality, the Discrete Cosine Transform (DCT) method was employed. This technique effectively eliminated the unwanted noise, as demonstrated in the **Figure 6**. and showcasing the power of DCT in noise reduction and image enhancement. Before employing the noise elimination technique with Discrete Cosine Transform (DCT), a crucial preprocessing step was undertaken. This step involved reducing the initial noise level intensity from 0.5 to 0.1. By significantly decreasing the noise intensity, the image was prepared for the subsequent DCT processing. This meticulous adjustment in noise levels was pivotal, as it ensured a more precise and effective noise reduction process when utilizing DCT. The reduction from 0.5 to 0.1 not only enhanced the accuracy of the DCT method but also contributed to the overall improvement of the image quality, resulting in a clearer and more visually appealing final output. Based on **Figure 6**, the quality evaluation results obtained from Singular Value Decomposition (SVD) are meticulously presented and analyzed in **Table 1**. This figure serves as a visual representation of the in-depth assessment conducted on the effectiveness of the SVD technique in the context of the study. The detailed analysis and findings encapsulated in **Table 1** provide a comprehensive overview of the quality metrics, showcasing the robustness, accuracy, and reliability of the SVD-based methodology employed.

(a) Lena.jpg (b) Peppers.jpg (c) Baboon.jpg

Figure 4. Visible Watermarked Image

(a) Lena.jpg (b) Peppers.jpg (c) Baboon.jpg

Figure 5. Compressed Image by Alpha Values

Table 1. Matrix Quality Evaluation Based on SVD

Sample Image	Testing	MSE	PSNR	UQI	MSSIM
Lena.jpg	Image Watermarked	**0.0004**	82.34 dB	0.9945	0.9961
	Gaussian Noise	0.0162	66.03 dB	0.7477	0.1854
	Salt & Peppers Noise	0.0047	71.42 dB	0.9299	0.4226
	Gaussian + Salt & Peppers Noise	0.0112	67.65 dB	0.8290	0.2422
Peppers.jpg	Image Watermarked	**0.0003**	82.72 dB	0.9960	0.9952
	Gaussian Noise	0.0159	66.10 dB	0.8071	0.1905
	Salt & Peppers Noise	0.0048	71.34 dB	0.9436	0.4178
	Gaussian + Salt & Peppers Noise	0.0107	67.84 dB	0.8717	0.2495
Baboon.jpg	Image Watermarked	**0.0004**	81.90 dB	0.9916	0.9965
	Gaussian Noise	0.0168	65.87 dB	0.6332	0.2261
	Salt & Peppers Noise	0.0059	70.39 dB	0.8758	0.5111
	Gaussian + Salt & Peppers Noise	0.0126	67.14 dB	0.7316	0.2913

The discussion above underscores the compelling outcomes achieved through the DCT + SVD approach, as reflected in the Watermarked Images. With remarkably low MSE values ranging from 0.003 to 0.004 and exceptionally high PSNR values between 81.90 and 82.72, our results unequivocally demonstrate that the Watermarked Images closely resemble the original images.

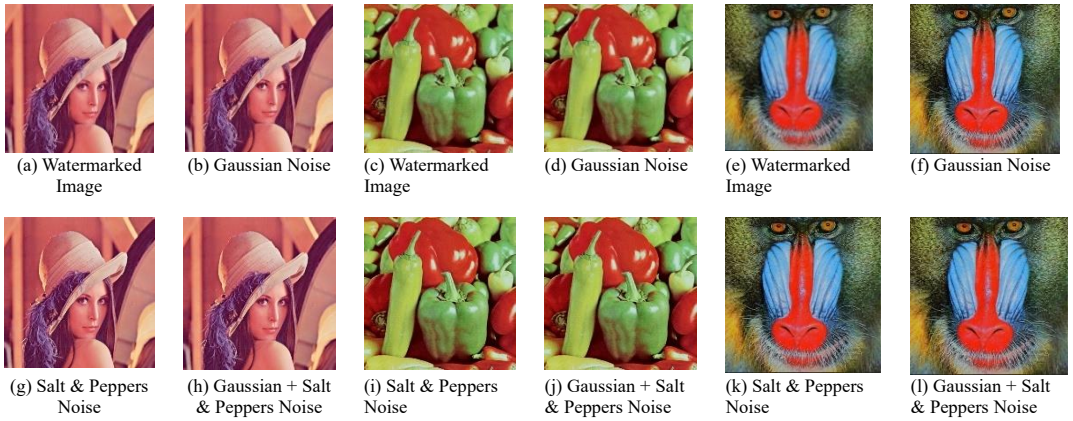

Figure 6. Invisible Watermarked Image

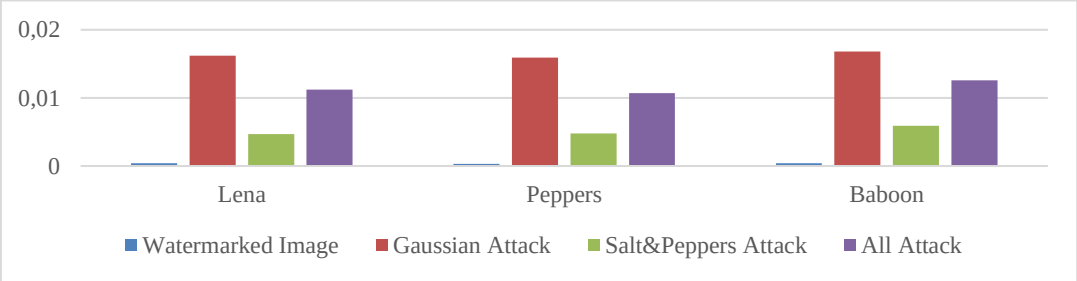

Figure 7. Comparison Results Based on MSE

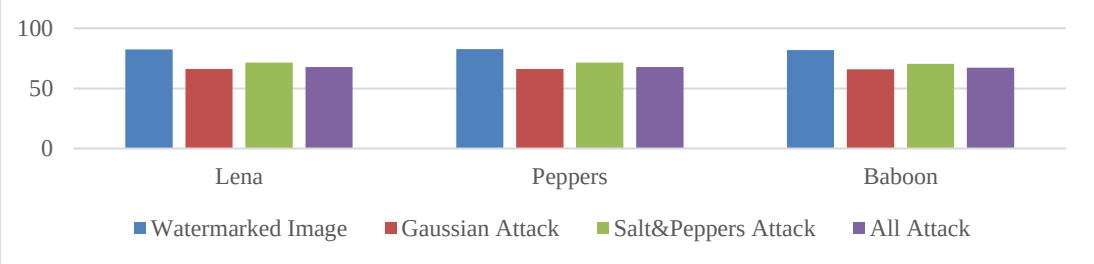

Figure 8. Comparison Results Based on PSNR

4. Conclusion

Based on the quality evaluation results using metrics such as MSE, PSNR, UQI, and MSSIM on the tested sample images, the implementation of Discrete Cosine Transform (DCT) and Singular Value Decomposition (SVD) has proven highly effective in safeguarding digital images from noise and enhancing their overall quality. The consistently low MSE values, specifically 0.0058, 0.0054, and 0.0064 for the Lena, Peppers, and Baboon images, respectively, indicate minimal distortion during the watermarking process. Additionally, the high PSNR values, measuring 67.20 dB, 67.22 dB, and 67.14 dB for the respective images, signify the remarkable image quality achieved after watermarking. UQI values nearing 1, specifically 0.9470, 0.9468, and 0.9332, demonstrate the high structural and luminance similarity between the original and watermarked images. Furthermore, the elevated MSSIM values, recorded at 0.9298, 0.9294, and 0.9176, reflect the strong structural resemblance to the original images. These results unequivocally affirm that the integration of DCT and SVD in the watermarking technique provides a high level of security to the images while maintaining optimal visual quality. Consequently, this research concludes that the combined use of DCT and SVD represents an exceptionally effective approach for enhancing and securing digital image quality in watermarking applications. For future research, researcher will explore the potential integration of the innovative DCT and SVD watermarking approach with other transformative algorithms such as Discrete Wavelet Transform (DWT), Discrete

Tchebichef Transform (DTT), and similar techniques. Comparing the efficacy of these combinations could shed light on new dimensions of image security and quality preservation. Additionally, there is a pressing need for the development of user-friendly applications that can implement this advanced watermarking technique. Creating robust, intuitive software that incorporates the DCT-SVD methodology would enable a broader spectrum of users, including institutions and individual users, to safeguard their digital assets effectively.

References

[1] U. Sara, M. Akter, and M. S. Uddin, "Image Quality Assessment through FSIM, SSIM, MSE and PSNR—A Comparative Study," *Journal of Computer and Communications*, vol. 07, no. 03, pp. 8–18, 2019, doi: 10.4236/jcc.2019.73002.

[2] P. Aberna and L. Agilandeeswari, "Digital image and video watermarking: methodologies, attacks, applications, and future directions," *Multimed Tools Appl*, 2023, doi: 10.1007/s11042-023-15806-y.

[3] A. Sinha, P. J. Panda, and M. Tech, "SECURE WATERMARKING OF DIGITAL DATA FOR COPYRIGHT PROTECTION SIGNAL PROCESSING AND DIGITAL DESIGN," 2022.

[4] A. Ray and S. Roy, "Recent trends in image watermarking techniques for copyright protection: a survey," *International Journal of Multimedia Information Retrieval*, vol. 9, no. 4. Springer Science and Business Media Deutschland GmbH, pp. 249–270, Dec. 01, 2020. doi: 10.1007/s13735-020-00197-9.

[5] W. Qi, S. Guo, and W. Hu, "Generic Reversible Visible Watermarking Via Regularized Graph Fourier Transform Coding," May 2021, doi: 10.1109/TIP.2021.3134466.

[6] H. Gulfam *et al.*, "Cryptographic Analysis of Blur-Based Encryption an in depth examination of resilience against various attack vectors," 2023, doi: 10.21203/rs.3.rs-3058158/v1.

[7] E. Elbasi, "A non-blind Watermarking Technique using Flexible Scaling Factor in Wavelet Transform," in *2022 45th International Conference on Telecommunications and Signal Processing, TSP 2022*, Institute of Electrical and Electronics Engineers Inc., 2022, pp. 150–155. doi: 10.1109/TSP55681.2022.9851257.

[8] A. O. Mohammed, H. I. Hussein, R. J. Mstafa, and A. M. Abdulazeez, "A blind and robust color image watermarking scheme based on DCT and DWT domains," *Multimed Tools Appl*, 2023, doi: 10.1007/s11042-023-14797-0.

[9] S. Dua, J. Singh, and H. Parthasarathy, "Image forgery detection based on statistical features of block DCT coefficients," in *Procedia Computer Science*, Elsevier B.V., 2020, pp. 369–378. doi: 10.1016/j.procs.2020.04.038.

[10] A. Zear and P. K. Singh, "Secure and robust color image dual watermarking based on LWT-DCT-SVD," *Multimed Tools Appl*, vol. 81, no. 19, pp. 26721–26738, Aug. 2022, doi: 10.1007/s11042-020-10472-w.

[11] A. Durafe and V. Patidar, "Development and analysis of IWT-SVD and DWT-SVD steganography using fractal cover," *Journal of King Saud University - Computer and Information Sciences*, vol. 34, no. 7, pp. 4483–4498, Jul. 2022, doi: 10.1016/j.jksuci.2020.10.008.

[12] A. Alzahrani, "Enhanced Invisibility and Robustness of Digital Image Watermarking Based on DWT-SVD," *Appl Bionics Biomech*, vol. 2022, 2022, doi: 10.1155/2022/5271600.

[13] F. Masood *et al.*, "A novel image encryption scheme based on Arnold cat map, Newton-Leipnik system and Logistic Gaussian map," *Multimed Tools Appl*, vol. 81, no. 21, pp. 30931–30959, Sep. 2022, doi: 10.1007/s11042-022-12844-w.

[14] R. Aziz, S. Banerjee, S. Bouzefrane, and T. Le Vinh, "Exploring Homomorphic Encryption and Differential Privacy Techniques towards Secure Federated Learning Paradigm," *Future Internet*, vol. 15, no. 9, p. 310, Sep. 2023, doi: 10.3390/fi15090310.

[15] M. Es-Sabry *et al.*, "Securing Images Using High Dimensional Chaotic Maps and DNA Encoding Techniques," *IEEE Access*, pp. 1–1, Sep. 2023, doi: 10.1109/access.2023.3315658.

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A Good Evaluation Based on Confusion Matrix for Lung Diseases Classification using Convolutional Neural Networks

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Abstract. CNN has been widely used to detect a pattern with image classification. This study used CNN to perform a classification analysis of lung abnormality detection on chest X-ray images. The dataset consists of 5,732 2D images with dimensions of 200 x 200 x 1 divided into training data (85%) and testing data (15%). The preprocessing process includes image resizing, enhancement to increase contrast and reduce image complexity, and filtering to improve visibility and reduce noise. CNN is used to classify imagery into three categories, Normal (no abnormalities), Pneumonia, and Tuberculosis. The results showed a good level of accuracy, with an accuracy value of 97.79% and a continuously high accuracy value of 100% in 6 trials. This research provides insights into the detection of lung disorders and encourages further exploration in medical diagnosis.
Keywords: Pneumonia, Tuberculosis, TBC, CNN, Image Classification

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1. Introduction

Lungs are one of the important organs of the human respiratory system. The lungs can experience abnormalities, such as pneumonia, and tuberculosis when exposed to pathogens in the form of bacteria, viruses, fungi, or parasites [1]. A bacterial illness called pneumonia results in swelling and inflammation of the lungs' alveoli, or air sacs [2]. In Indonesia, pneumonia is one of the leading causes of mortality among children under the age of five. Pneumonia will affect up to 278,261 children under the age of five in 2021. Meanwhile, Tuberculosis (TB) is a contagious infection caused by Mycobacterium tuberculosis [3]. According to the World Health Organization (WHO), there will be 2.97 million tuberculosis (TB) patients in Southeast Asia by 2021, with Indonesia ranking second in the area. Meanwhile, the Ministry of Health of the Republic of Indonesia says that 969 thousand individuals would be infected with tuberculosis by 2023 [4][5].

If this lung condition is not detected in time, it might lead to death. Detection can be used to determine whether or not someone has a certain disease. Detecting lung abnormalities is difficult in the medical world due to the complexity of the anatomical structure of the lungs, the diversity of illnesses that can be diagnosed, and the necessity for high precision. Based on this topic, researchers suggest study using artificial intelligence, specifically convolutional neural networks, to diagnose and categorize discovered

lung illnesses such as pneumonia and TB. From these problems, researchers proposed a study using Convolutional Neural Network (CNN) to recognize, and classify lung disorders detected in the form of Pneumonia and Tuberculosis.

CNN method for predicting abnormalities in the lungs. CNN has advantages, such as being efficient in processing images, having a high level of accuracy, resistant to noise, and having automatic feature extraction [6]. However, to get a high accuracy value, it is necessary to do augmentation if the data to be processed is relatively small. In addition, CNNs are computationally intensive to train and run models, are difficult to interpret certain models, are not always suitable for processing or processing 2D and 3D images, and CNNs are classified as vulnerable to changes in images, such as light, rotation, and/or added noise [7].

In a previous study conducted by Harshvardhan GM and colleagues in 2021 on Detecting Pneumonia Using CNN and a Chest X-ray. In his study, the authors used CNN to classify binaries with chest X-ray data describing cases of impactful and non-impacted pneumonia. The accuracy resulting from the study was 93%. Meanwhile, a study conducted by Abdulfattah Alawi and colleagues in 2021 explored the Convolutional Neural Network Model for Tuberculosis Disease Screening. According to the research, the study used a CNN-based model to separate areas of the lungs in classifying chest X-ray images whether infected with tuberculosis or not. In research conducted by Abdulfatah et al, accuracy results of 98.71% were obtained [8][9].

To recognize, detect and classify the abnormalities of this disease, you can use X-rays, magnetic resonance imaging (MRI) and computed tomography (CT). X-rays are frequently used to examine a patient's chest cavity by looking for characteristics of any bone density. These images can be used to determine whether there are abnormalities in the patient's lungs or not. The approach used in this study tries to distinguish, diagnose, and categorize anomalies in patients' lungs. As a result, it is critical to recognize and detect the existence or absence of the patient's lungs as soon as possible. The CNN approach was utilized in this work to identify these lung illnesses, particularly pneumonia and TB. Thus, artificial intelligence can be used to aid in the early detection and treatment of lung illnesses, particularly in places with high incidence rates, such as Indonesia [10][11].

2. Methods

In this study, to classify lung disorders based on X-Ray images, Convolutional Neural Network was used. The presented flow diagram illustrates the steps in the proposed method.

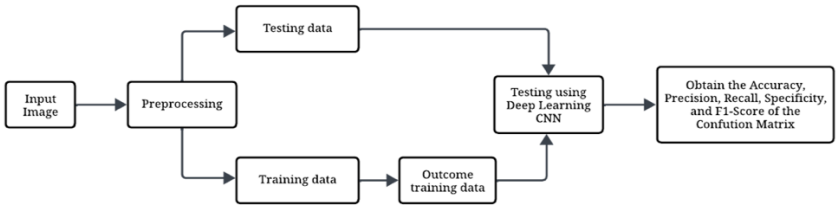


Figure 1. Research Methodology

2.1. Dataset

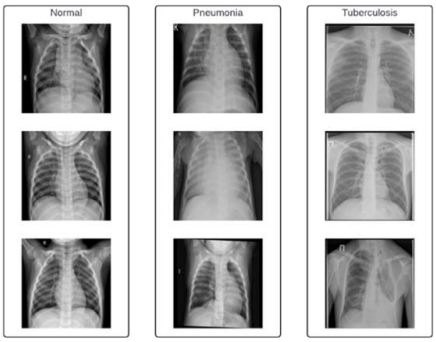


Figure 2. Normal Image Sample, Pneumonia Image, and Tuberculosis Image.

The dataset used in this study was a 2D X-ray radiography image of the lungs totaling 5,732 samples with pixel dimensions of 200 x 200 x 1. Based on the 5,732 images, categorized into two different parts, namely training data with each section including 245 images of tuberculosis, 3,054 images of pneumonia, and 1,573 images of normal lungs, and testing data totaling 860 samples. Training data is used to study and recognize the pattern of each type of lung disorder to be categorize. Data from testing is utilized to evaluate the efficacy of proposed procedures in correctly identifying the types of lung illnesses in question. This study's dataset was obtained via the Kaggle platform [12].

2.2. Preprocessing

In this step, the dataset is divided into 15% testing data and 85% training data. The first step is to resize the previous image such that all processed photos are the same size and dimensions. The image then undergoes an image enhancement process, focusing on the area that will be recognized by the next process by increasing the contrast value in the image to be processed. Then, there is a process of reducing color information's complexity and simplifying. This conversion procedure allows you to focus on pixel intensity values for simpler analysis, as well as extract characteristics from photos for additional processing or analysis. In addition, this modification is intended to boost computing efficiency and simplify some image processing processes [13][14].

2.3. Convolutional Neural Network (CNN)

Convolutional neural network is a form of artificial neural architecture that was created primarily for image processing and visual pattern detection. CNN architecture learns the internal structure of features and generalizes those features to image analysis problems, such as object recognition and computer vision. CNN is made up of three major layers: a convolutional layer, a pooling layer, and a fully connected layer [15]. Convolutional layers have filters and image maps as a list of coordinates relative to a specific image and aim to extract features from the input image by maintaining spatial relationships between pixels. The pooling layer has the effect of reducing the spatial dimension of the image features obtained from the previous process and helps reduce the number of parameters and calculations required, as well as preventing overfitting.

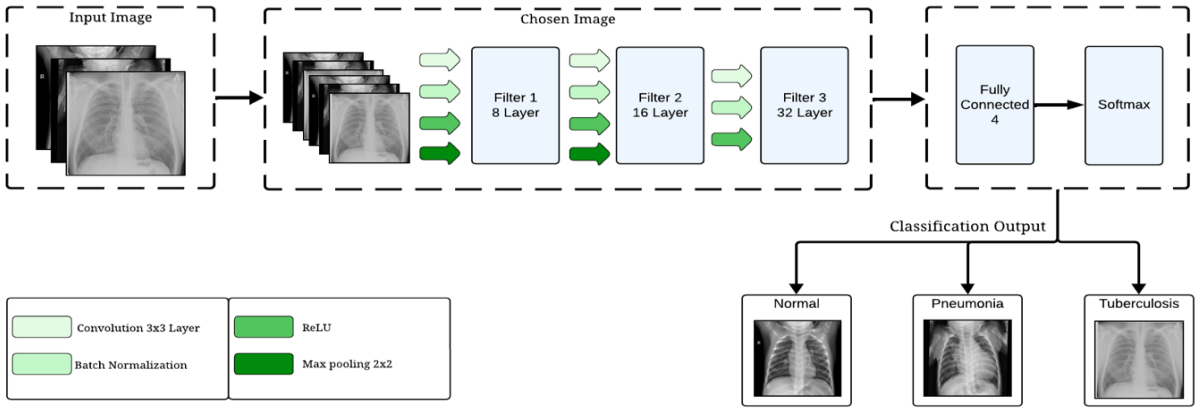


Figure 3. Chest X-Ray Classification Process with Convolutional Neural Network Method.

There are two types of pooling layers, the max pooling layer keeps the maximum value in each zone and reduces the image size and average pooling layer that maintains the average information in an image region. The fully connected layer functions as a link between the previous layers of the network and the subsequent layers. The classification process will be performed by CNN starting by processing the selected image, then applying image adjustments to provide adjustments to the image without change the intensity, in the form of increasing or decreasing contrast, adjusting brightness and color. Then, after going through the image adjustment process, the image will continue to be processed at the three major layers. The images will then be classified based on the main goal of the classification process [16][17][18][19][20][21].

2.4. Confusion Matrix

An important evaluation tool in the measurement of CNN classification models is used to understand the extent to which classification models are successful in correctly classifying data. The confusion matrix consists of four main components, True Positive (TP) denotes the value of correctly identified positive cases, True Negative (TN) denotes the value of correctly categorized negative situations, the number of negative case values classified as positive by the model is indicated by False Positive (FP), and False Negative (FN) refers to the number of cases that are truly positive but are labeled as negative by the model. To calculate the confusion matrix, you may utilize an Accuracy, Precision, Recall, and F1-Score formula [22][23].

$$Akurasi = \frac{TN + TP}{TN + TP + FN + FP} \times 100\%$$

$$Presisi = \frac{TN}{TN + FN} \times 100\%$$

$$Recall = \frac{TN}{Tn + FP} \times 100\%$$

$$F1 - Score = 2 \times \frac{Recall * Presisi}{Recall + Presisi} \times 100\%$$

3. Results and Discussion

This study used a dataset of 5,732 images with dimensions of 200 x 200 x 1 from three different classes. The dataset is divided into 15% testing data and 85% training data. Each class in the training data amounted to 245 tuberculosis images, 3,054 pneumonia images, and 1,573 normal lung images, and testing data totaling 860 samples. Then, preprocessing is applied to each image for filtering using image adjustments, such as increasing the contrast. Furthermore, the classification uses CNN to classify lung disorders, namely Normal or not experiencing pneumonia or tuberculosis, Pneumonia, and Tuberculosis. The values of the confusion matrix's four main components are as follows.

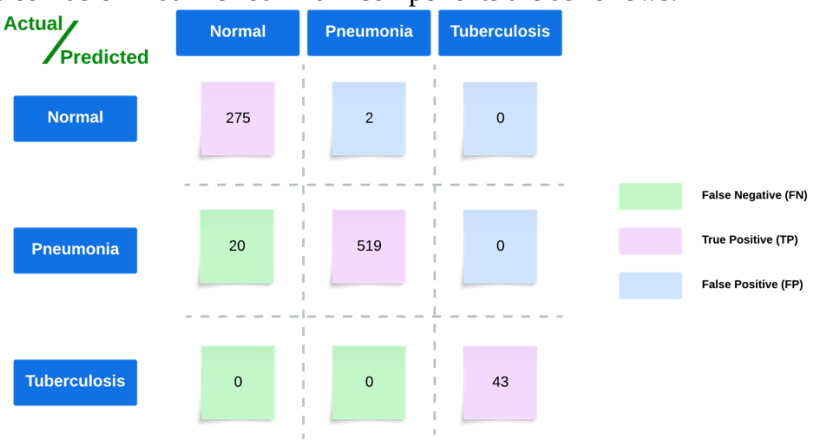


Figure 4. Confusion Matrix Result

To obtain the confusion matrix values, training data must be generated to provide the component values contained in the confusion matrix, namely True Positive, True Negative, False Positive, and False Negative. As indicated in Table 1, the performance of the classification model utilized may be determined or estimated using Accuracy, Recall (Sensitivity), Precision, Specificity, and F1-Score.

Table 1. Confusion Matrix.

No.	Partition (Testing-Training)	Training	Confusion Matrix				
			Accuracy	Recall	Precision	Specificity	F1-Score
1.	15% - 85%	1st Training	97,79%	96,73%	97,79%	98,89%	97,28%
2.	20% - 80%	2nd Training	97,03%	97,84%	93,54%	96,52%	95,64%
3.	25% - 75%	3rd Training	97,49%	95,45%	97,14%	98,55%	96,29%
4.	30% - 70%	4th Training	97,79%	96,58%	97,10%	95,51%	96,84%

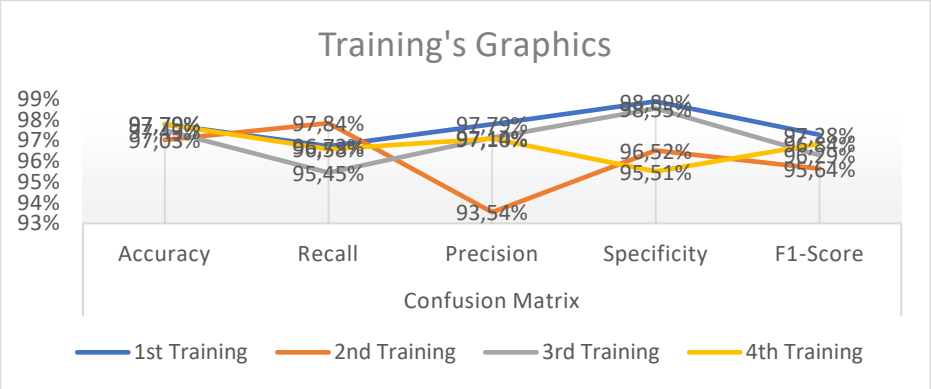


Figure 5. Training's Graphics

In Table 1 above, the author tried four divisions of testing and training data, namely the first training 15%-85%, the first training 20%-80%, the third training 25%-75%, and 30%-70%. It can be seen in Figure 5, the highest accuracy is 97.79% which is the result of 1st training and 4th training. However, for the highest Recall, Precision, Specificity, and F1 values are generated at 1st training. Thus, in this study the dataset used to detect as much as 15% of testing data and 85% of training data.

After acquiring the Confusion Matrix value, more testing is performed to evaluate the model's performance. The Confusion Matrix provides a clear picture of the extent to which the model is able to correctly classify data, comprising data on four main component of confusion matrix. With this information, we can make more informed decisions about how well the image processing model works and whether improvements or adjustments need to be made as tested in the following table.

Table 2. Dataset Testing

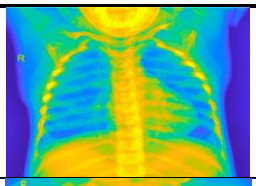
No.	Input Image	Actual Class	Classification Result	Result
1.		Normal	Normal	True
2.		Pneumonia	Pneumonia	True

Table 2. Dataset Testing Continue

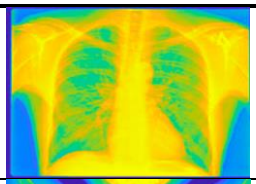
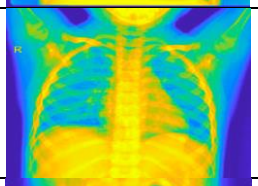
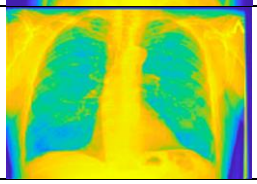
No.	Input Image	Actual Class	Classification Result	Result
3.		Tuberculosis	Tuberculosis	True
4.		Normal	Normal	True
5.		Pneumonia	Pneumonia	True
6.		Tuberculosis	Tuberculosis	True

Table 3. Comparison Results

Research	**Method**	**Total Dataset**	**Precision**	**Accuracy**	**Specificity**	**Sensitivity (Recall)**	**F1 Score**
T. Rahman *et al*. [13]	CNN with ensemble architecture	18.479	94.51%	95.11%	95.59%	94.56%	94.53%
H. Gm, M. Kumar Gourisaria, *et al.*[8]	CNN + ANN	5.847	-	-	92.16%	90.07%	77%
Rahman T., *et al.* [24]	CNN Chexnet	7.000	96.62%	96.47%	96.51%	96.47%	96.47%
Proposed Method	CNN	5.732	97.79%	97.79%	98.89%	96.73%	97.28%

Based on Table 3, lung anomalies examined by three research using different approaches, the writer recommends utilizing the CNN method in the next investigation. The CNN approach makes it feasible to operate more efficiently and accurately.

4. Conclusion

In the study above using a dataset of 5,732 samples with dimensions of 200 x 200 x 1 which were divided into 85% training data and 15% testing data. These samples include samples of normal lungs, lungs with pneumonia, and lungs with tuberculosis. Each sample class amounted to 1,573 normal lung samples, 3,054 lung samples with pneumonia, and 254 lung samples with tuberculosis. Samples categorized using the CNN approach had an accuracy value of 97.79% and a continuously high accuracy value of 100% in 6 trials. Overall, the CNN method can work well in the classification of lung abnormality detection.

In future study, the architectural evolution of CNN may be used to attain the same accuracy outcomes when deciding the amount of testing data and training data. And it may combine or compromise with

other designs to improve accuracy and efficacy in detecting lung problems, such as CNN ChexNet, Recurrent Neural Network, or Long-Short Term Memory (LSTM). Combining CNN with ChexNet, RNN, or LSTM can result in a more comprehensive method to medical image processing, focusing on the spatial correlations between pixels in CNN pictures and comprehending the temporal sequence in sequential images like CT-Scans and MRIs. This can assist the medical community in dealing with issues linked to changes in medical pictures during the illness detection process, such as rotation and the addition of noise.

References

[1] H. H. Hussain, N. T. Ibraheem, N. K. F. Al-Rubaey, M. M. Radhi, N. K. K. Hindi, and R. H. K. AL-Jubori, "A review of airborne contaminated microorganisms associated with human diseases," *Medical Journal of Babylon*, vol. 19, no. 2. Wolters Kluwer Medknow Publications, pp. 115–122, Apr. 01, 2022. doi: 10.4103/MJBL.MJBL_20_22.

[2] P. J. Shermila, A. D. Anusha, Akila. M, and Abirami. S, "Pneumonia Detection from X- Ray Images using Convolutional Neural Networks," in *2023 Eighth International Conference on Science Technology Engineering and Mathematics (ICONSTEM)*, IEEE, Apr. 2023, pp. 1–7. doi: 10.1109/ICONSTEM56934.2023.10142295.

[3] R. Gopalaswamy, S. Shanmugam, R. Mondal, and S. Subbian, "Of tuberculosis and non-tuberculous mycobacterial infections - A comparative analysis of epidemiology, diagnosis and treatment," *Journal of Biomedical Science*, vol. 27, no. 1. BioMed Central, Jun. 17, 2020. doi: 10.1186/s12929-020-00667-6.

[4] "World Health Organization TB Reports." Accessed: Nov. 10, 2023. [Online]. Available: https://www.who.int/teams/global-tuberculosis-programme/tb-reports/global-tuberculosis-report-2022/covid-19-and-tb

[5] "TB by the Republic of Indonesia's Ministry of Health." Accessed: Nov. 10, 2023. [Online]. Available: https://tbindonesia.or.id

[6] A. R. Hawas, H. A. El-Khobby, M. Abd-Elnaby, and F. E. Abd El-Samie, "Gait identification by convolutional neural networks and optical flow," *Multimed Tools Appl*, vol. 78, no. 18, pp. 25873–25888, Sep. 2019, doi: 10.1007/s11042-019-7638-9.

[7] K. Alomar, H. I. Aysel, and X. Cai, "Data Augmentation in Classification and Segmentation: A Survey and New Strategies," *J Imaging*, vol. 9, no. 2, Feb. 2023, doi: 10.3390/jimaging9020046.

[8] H. Gm, M. Kumar Gourisaria, S. S. Rautaray, and M. Pandey, "PNEUMONIA DETECTION USING CNN THROUGH CHEST X-RAY," 2021.

[9] Abdulfattah E. Ba Alawi, Amer Al-basser, Amer Sallam, Amr Al-sabaeei, and Hesham Al-khateeb, "Convolutional Neural Networks Model for Screening Tuberculosis Disease," *IEEE*, pp. 1–5, Apr. 2021, doi: 10.1109/ICTSA52017.2021.9406520.

[10] M. Siddiq, "ML-BASED MEDICAL IMAGE ANALYSIS FOR ANOMALY DETECTION IN CT SCANS, X-RAYS, AND MRIS." [Online]. Available: http://devotion.greenvest.co.id

[11] R. Jain *et al.*, "Chest X-Ray as the First Pointer in Various Skeletal Dysplasia and Related Disorders," *Indographics*, vol. 01, no. 02, pp. 196–207, Dec. 2022, doi: 10.1055/s-0042-1759845.

[12] "Chest X-Ray ," Kaggle. Accessed: Oct. 07, 2023. [Online]. Available: https://www.kaggle.com/datasets/jtiptj/chest-xray-pneumoniacovid19tuberculosis/data

[13] T. Rahman *et al.*, "Exploring the effect of image enhancement techniques on COVID-19 detection using chest X-ray images," *Comput Biol Med*, vol. 132, May 2021, doi: 10.1016/j.compbiomed.2021.104319.

[14] K. Maharana, S. Mondal, and B. Nemade, "A review: Data pre-processing and data augmentation techniques," *Global Transitions Proceedings*, vol. 3, no. 1, pp. 91–99, Jun. 2022, doi: 10.1016/j.gltp.2022.04.020.

[15] N. R. D. Cahyo, C. A. Sari, E. H. Rachmawanto, C. Jatmoko, R. R. A. Al-Jawry, and M. A. Alkhafaji, “A Comparison of Multi Class Support Vector Machine vs Deep Convolutional Neural Network for Brain Tumor Classification,” in *2023 International Seminar on Application for Technology of Information and Communication (iSemantic)*, IEEE, Sep. 2023, pp. 358–363. doi: 10.1109/iSemantic59612.2023.10295336.

[16] D. Bhatt *et al.*, “Cnn variants for computer vision: History, architecture, application, challenges and future scope,” *Electronics (Switzerland)*, vol. 10, no. 20. MDPI, Oct. 01, 2021. doi: 10.3390/electronics10202470.

[17] E. Saralioglu and O. Gungor, “Semantic segmentation of land cover from high resolution multispectral satellite images by spectral-spatial convolutional neural network,” *Geocarto Int*, vol. 37, no. 2, pp. 657–677, Jan. 2022, doi: 10.1080/10106049.2020.1734871.

[18] H. Gholamalinezhad and H. Khosravi, “Pooling Methods in Deep Neural Networks, a Review,” Sep. 2020.

[19] N. Akhtar and U. Ragavendran, “Interpretation of intelligence in CNN-pooling processes: a methodological survey,” *Neural Comput Appl*, vol. 32, no. 3, pp. 879–898, Feb. 2020, doi: 10.1007/s00521-019-04296-5.

[20] S. R. D. V. P. S. M. S.H. Shabbeer Basha, “Impact of fully connected layers on performance of convolutional neural networks for image classification,” *IEEE*, vol. 378, pp. 112–119, 2020, Accessed: Oct. 22, 2023. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0925231219313803

[21] Z. Zhu, H. Wei, G. Hu, Y. Li, G. Qi, and N. Mazur, “A Novel Fast Single Image Dehazing Algorithm Based on Artificial Multiexposure Image Fusion,” *IEEE Trans Instrum Meas*, vol. 70, pp. 1–23, 2021, doi: 10.1109/TIM.2020.3024335.

[22] D. S. V. J. G. Chicco, “The Benefits of the Matthews Correlation Coefficient (MCC) Over the Diagnostic Odds Ratio (DOR) in Binary Classification Assessment,” *IEEE Access*, vol. 9, pp. 47112–47124, 2021, Accessed: Oct. 17, 2023. [Online]. Available: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9385097&isnumber=9312710

[23] C. Cao, D. Chicco, and M. M. Hoffman, “The MCC-F1 curve: a performance evaluation technique for binary classification,” Jun. 2020.

[24] T. Rahman *et al.*, “Reliable Tuberculosis Detection Using Chest X-Ray With Deep Learning, Segmentation and Visualization,” *IEEE Access*, vol. 8, pp. 191586–191601, 2020, doi: 10.1109/ACCESS.2020.3031384.

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Portable Incinerator Capacity of 5000 Grams with Used Fuel Oil

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Abstract. Waste is a significant problem that needs to be urgently addressed. If waste is left untreated and disposed of improperly, it can become contaminated by bacteria, viruses, and other toxins that pose serious risks to humans. In this study, researchers designed and created a portable incinerator that utilizes used oil fuel. The study aimed to determine the highest temperature that can be achieved when incinerating wet and dry waste at weights of 5000 grams, 3000 grams, and 1000 grams. Additionally, performance of portable incinerator was evaluated based on the combustion rate and fuel consumption. The result show that the maximum temperature generated by both dry and wet waste is 450 degrees Celcius. The maximum volume of waste that can be loaded into the combustion chamber is 5000 grams. The results show that the maximum combustion rate of the portable incinerator for dry waste weighing 1000 grams is 196.85 gr/s.The maximum burning rate for wet waste weighing 1000 grams is 165.56 gr/s. The minimum fuel consumption produced from dry waste weighing 1000 grams is 300 ml of used oil. And the maximum fuel consumption is produced from wet waste weighing 5000 grams, namely 1000 ml of used oil.

Keywords: Burner, Furnace, Incinerator

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1. Introduction

The disposal of medical waste generated from the Covid-19 pandemic has emerged as a critical concern, raising pivotal questions regarding its safe and efficient management. The urgent need to address this issue stems from the unprecedented surge in healthcare waste due to the pandemic's prolonged duration and unique characteristics.

Covid-19 is an infectious disease caused by the SARS-CoV-2 virus. Despite efforts to control its spread, the virus continues to affect populations worldwide, leading to a significant number of cases. Blora Regency, located in Central Java, has also experienced the impact of this global pandemic. Until

February 28, 2021, there were a total of 5,550 Covid-19 cases reported in the region, with 4,908 individuals recovering, 396 people under surveillance, and 246 fatalities[1]. These statistics serve as a reminder that vigilance and strict adherence to health protocols are necessary to prevent a further increase in Covid-19 cases in the Blora area.

In recent times, allegations of improper disposal of Covid-19 medical waste have surfaced. In one instance, medical waste, including infectious and hazardous materials, generated from hotels housing asymptomatic Covid-19 patients or those with mild symptoms, was reportedly disposed of carelessly in Tangerang City. The Bogor Resort Police took action by summoning the parties involved in this case of irresponsible waste disposal at the Toll Rest Area and TPS [2].

Improper management of medical waste, categorized as toxic and hazardous materials (B3), can pose potential risks to both human health and the environment. Environmental pollution resulting from the mishandling of medical waste can have adverse effects on individuals and communities. The entire waste management process, from collection and storage to transportation and disposal, presents potential hazards. These hazards include aesthetic disturbances, foul odors, and the creation of breeding grounds for viruses and nuisance animals . Certain compounds found in medical waste, such as pesticides used to eradicate insects or animals and radioactive materials, may even cause genetic disorders or damage to the human reproductive system [3] [4].

Medical waste categorized as B3 waste comprises materials that cannot be reused and may be contaminated with infectious substances or have come into contact with Covid-19 patients or healthcare staff. Such waste includes used masks, gloves, bandages, tissues, plastic items, syringes, infusion sets, personal protective equipment (PPE), and leftover patient food, among other items. These materials originate from various healthcare service areas, including emergency rooms, isolation rooms, intensive care units, treatment rooms, and other service rooms [5].

To address the proper management of Covid-19 medical waste, the Circular of the Minister of Environment and Forestry Number SE.2/MENLHK/PSLB3/PLB.3/2020, dated March 24, 2020, provides guidelines for the handling of infectious waste and Portable waste related to Covid-19. The circular outlines steps for managing infectious waste at home, such as cutting medical masks before disposal, segregating infectious waste in closed containers labeled "Waste Infectious," and designating specific collection locations before transferring the waste to authorized B3 waste processors [6]. These regulations emphasize the need for distinct handling procedures for Covid-19 medical waste compared to general Portable waste, especially for patients undergoing independent isolation at home. In this context, the development of a tool suitable for at-home use during the final disposal process of Covid-19 medical waste becomes essential. One such tool is a portable incinerator designed specifically for the treatment of waste generated by Covid-19 patients.

Previous research on this topic has explored various aspects of medical waste management related to Covid-19. A study in 2021 titled "Covid-19 Medical Waste Processing Vehicle Design" focused on integrating medical waste management with vehicles [7]. Although this research provided valuable insights, there are still obstacles in managing Covid-19 medical waste through local wisdom, as identified in the study conducted by [3] titled "Covid-19 Medical Waste Management through Local Wisdom." This study employed a literature review methodology, using secondary data sources to explore the challenges faced in managing Covid-19 medical waste through local wisdom. It emphasized the importance of government efforts in conducting counselling sessions and increasing supervision to enhance community participation in the management of Covid-19 medical waste through local wisdom.

The use of used oil as fuel of the incinerator has been developed by [8]. The objective of their research was to understand the functionality of the incinerator, test its parameters, such as temperature and waste capacity, and evaluate its efficiency. The incinerator consisted of five main components: the main combustion chamber, chimney, filtering chamber, fuel tank, and burner furnace. The dimensions of the main combustion chamber were 930 x 580 mm, with a waste volume capacity of 0.245 m^3 or 8-15 kg per burn. The highest temperatures achieved during the combustion process were recorded as 443.2°C for dry leaf waste and 480.7°C for dry plastic waste. The efficiency of the incinerator was measured at 96.94% for dry leaf waste and 90.68% for dry plastic waste.

An experimental study titled "The Effectiveness of Used Oil Burner Incinerator Design and Construction," the research utilizes used oil as an alternative fuel and constructs an iron-based apparatus designed like a stove. In this study, the incineration process is conducted at specified temperatures ranging from 100°C to 250°C until the waste is reduced to ash. This combustion process can generate heat energy compared to open-air burning [9].

Another research study on an oil-based incinerator titled Design and Construction of an Incinerator Device Using Used Oil [8] addresses the issue of waste management. Open-air waste burning can cause disturbances and air pollution in the surrounding environment. This study aims to design and create an incinerator device that utilizes waste oil as fuel, capable of burning waste and transforming it into smaller and more manageable forms. This process produces sterile combustion residue that can be directly disposed of in the soil. The energy generated by the incinerator device can also be used as an alternative energy source for heating or drying. The combustion process requires temperatures ranging from 200°C to 300°C to reduce waste that cannot be recycled and completely burn it to ash.

The objective of this paper is to systematically address the Covid-19 or any future pandemic associated medical waste problem. Based on the existing research gap and the potential benefits of a portable incinerator for Covid-19 medical waste management, the present study aims to develop a device referred to as Portable Incinerator with a capacity of 5000 grams using used oil fuel. This incinerator utilizes used oil as a fuel source and is designed to facilitate the processing of waste generated by Covid-19 patients. The scalehold incinerator offers a practical and efficient solution for the final disposal of medical waste, ensuring the proper treatment and prevention of potential environmental and health hazards.

1.1. Incinerator

The incinerator is a device used to burn solid waste and operates by utilizing combustion technology at a specific temperature until the solid waste is transformed into gas and ash. The most commonly applied types of incinerators for burning hazardous solid waste are portable head, multiple hearth, and fluidized bed [10].

1.2. Portable Head Incinerator

The Portable Head Incinerator is a device used to burn both wet and dry waste and can be operated by utilizing combustion technology at a specific temperature. This device is capable of destroying waste such as masks, gloves, and tissues. The temperature during the incineration process of this device reaches 400°C to 700°C. The fuel used for this device is liquefied petroleum gas (LPG) and charcoal, which serves as auxiliary fuel for heat within the combustion chamber.

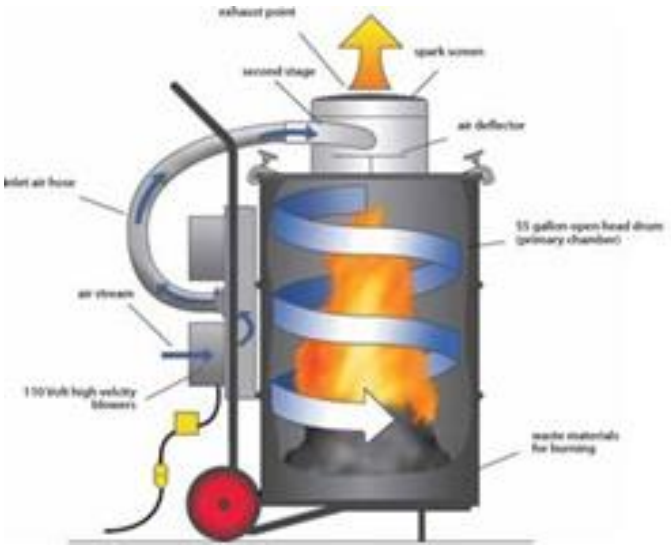

Figure 1. Insinerator Head Portable [10]

1.3. Multiple Hearth Incinerator

Multiple Hearth Incinerator consists of a framework of fire-resistant steel layers with a series of vertically arranged hearths, one above the other, usually numbering 5-8 hearths. The waste feed is continuously introduced from the top of the hearths, and the ash resulting from the combustion process is discharged. The burner is installed on the side wall of the combustion hearth where the combustion takes place, with air being fed from below and waste being fed from the top.

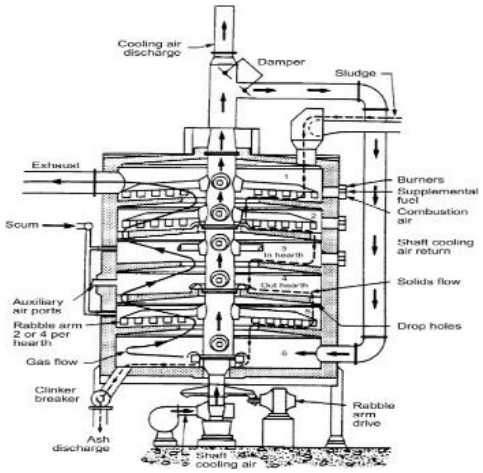

Figure 2: Multiple Hearth Incinerator [10]

1.4. Fluidized Bed Incinerator

The fluidized bed incinerator is a combustion chamber that utilizes a mixing medium such as sand, such as quartz sand or silica sand, to achieve homogeneous mixing between the air and the sand particles. The constant mixing between the particles promotes rapid heat transfer and complete combustion

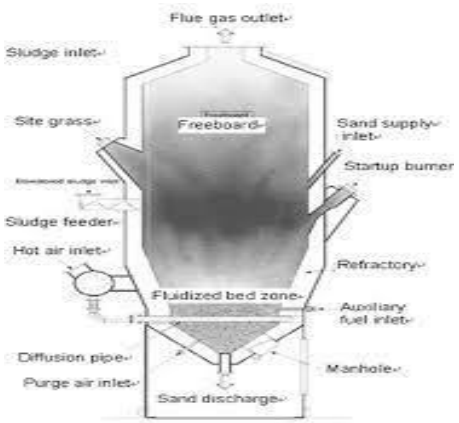

Figure 3: Fluidized Bed Incinerator [10].

1.5. Fuel

Used oil is one of the suitable fuel criteria for this incinerator, in line with the urban and regional development where the volume of used oil continues to increase with the growing number of motor vehicles and other motorized machines. Even in rural areas, small workshops can be found where one of the waste products is used oil. In other words, the distribution of used oil is already widespread from large cities to rural areas throughout Indonesia.

1.6. Combustion Process

The combustion process generally occurs in two ways: complete combustion and incomplete combustion. Complete combustion is a process where all carbon reacts with oxygen to produce CO2, while incomplete combustion is a process where the fuel is not fully burned, resulting in incomplete conversion to CO2.

1.7. Combustion Gas

In the combustion process, oxygen is provided with an excess air-to-fuel ratio to achieve complete combustion reactions. The main reaction of the combustion process between carbon and oxygen will produce carbon monoxide (CO) and carbon dioxide (CO2).

1.8. Combustion Rate

Combustion Rate The combustion rate testing is a process of burning waste to determine the burning duration of a fuel and then weighing the mass of the burned waste. The ignition time is measured using a stopwatch, and the mass of the waste is measured using a digital scale [11]. The equation used to determine the combustion rate is as follows in equation (1).

$$\text{Combustion rate} = m/t \quad (1)$$

Explanation :
m = Mass of remaining burned material (grams)
t = Burning time (minutes)

2. Methods

In this methode is consist of design specifications, operational procedures, and data collection methods.

2.1 Design Specifications

Part of portable incinerator can describe in Figure 4 below.

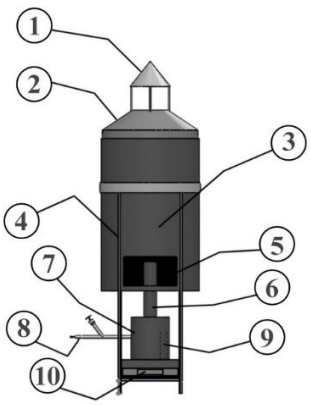

Figure 4: Part of Portable Incinerator

.
Figure 4 describe the portable incinerator that consists of several parts, namely:

1. Smokestack. The smokestack functions to release the residual smoke from combustion and expel pollutants contained in the exhaust gases into the air.
2. Combustion Chamber Door. It serves to input various waste materials into the combustion chamber.
3. Combustion Chamber. It functions as the location for burning the waste materials and acts as a filter for the residual combustion.
4. Support Pillar. Its purpose is to support the weight of the incinerator.
5. Ash Residue Drawer It is used to collect the remaining ash or combustion residues from the waste materials.
6. Flame Stack. Its function is to emit flames to burn the waste materials inside the combustion chamber.
7. Burner. It serves as a container to store boiled water for generating steam inside the burner.
8. Water Inlet. It is a hole for adding water into the burner.
9. Nozzle. It is the opening where steam from the burner will come out and meet the flame from the fuel source. This process will propel the flame upward towards the flame stack.
10. Fuel Compartment. Its function is to hold used oil as fuel for the ignition process.

Specifications of the design a portable incinerator can describe in tsble 1 below.

Table 1. Portable Scale Incinerator Specification Data

Name	Dimension
Fuel Compartment	220 x 150 x 30 mm
Combustion Chamber	D = 380 mm, H = 590 mm
Combustion Chamber Door	D= 380 mm, H = 120 mm
Water Inlet	D= ½ inch, L = 220 mm
Nozzle	H = 140 mm, D= ½ inch
Burner	D = 6 inch, H = 170 mm
Flame Stack	D = 2 inch, H = 220 mm
Ash Residue Drawer	L = 210 mm, W = 100 mm
Support Pillar	H = 800 mm, L = 290 mm
Smokestack	H = 200 mm

2.2 Operational Procedures

There is an operational procedures for operating the incinerator portable :

1. Preparation of materials
   Gather an adequate amount of oil and water as required for the operation.
2. Water inlet setup
   Pour the prepared water into the designated water inlet connected to the burner.
3. Fuel compartment preparation:
   Pour the prepared oil into a small tray specifically designed for the fuel compartment.
4. Ignition process
   Ignite the oil within the fuel compartment using a safe and approved method.
5. Waiting period
   Allow approximately 8-10 minutes for the water inside the burner to reach boiling point and produce steam.
6. Flame generation
   As steam is generated, expect the emergence of a large flame passing through the designated flame stack.
7. Waste Input

Once the flame is established, carefully introduce the waste materials into the combustion chamber for incineration.

8. Monitoring and safety
   Regularly monitor the incineration process to ensure proper combustion and safe operation. Adhere strictly to safety protocols during waste input and combustion phases.
9. Emission process:
   Expect the emission of smoke resulting from the incineration process through the designated smokestack.
10. Post-Operation Protocol:
    After completion, allow the incinerator to cool down before any maintenance or further operation. Then dispose of any remaining waste material properly as per regulations and guidelines.
11. Maintenance and Cleaning:
    Perform routine maintenance and cleaning of the incinerator as per manufacturer's instructions and maintenance schedule.
12. Documentation:
    Keep detailed records of operational activities, maintenance, and any incidents for reference and regulatory compliance.

These operational procedures followed meticulously to ensure safe and efficient operation of the incinerator while complying with all safety and environmental regulations.

2.3 Data Collection Methods.

2.3.1 Data of Incinerator Furnace

Based on the provided information about the portable incinerator device and its capacity calculation, here are some data collection methods that could be employed :

1. Measurement and verification. We conducted a physical measurements of the incinerator furnace to confirm its actual dimensions (diameter and height) to ensure accuracy in capacity calculation. Use precise measuring tools like calipers, tape measures, or laser distance meters.
2. Prototype testing. We developed a prototype of the incinerator and perform controlled tests to validate the calculated volume capacity. Use materials similar to those intended for incineration and measure the actual volume it accommodates.
3. User survey and feedback. We collected a feedback from users who have used the incinerator. Gather information on the amount and type of waste they typically dispose of and their experience with the incinerator's capacity in handling their waste.
4. Manufacturer specifications and documentation. It’s refer to the technical documentation or specifications provided by the manufacturer to verify and cross-reference the calculated capacity against the intended design specifications.
5. Field observations and case studies. It conducted on-site observations at locations where these incinerators are deployed. Monitor and record the actual volume of waste being incinerated over a specific period to understand real-world usage and compare it against the calculated capacity.
6. Comparative analysis. It compare the calculated capacity against similar incinerator models available in the market. Gather data on their stated capacities and conduct comparative analysis to validate the accuracy of the calculations.
7. Expert consultation. We seek an advice or consultation from experts in the field of incineration technology or engineering to evaluate the methodology used for capacity calculation and gather insights on potential factors that might influence the actual capacity

2.3.2 Data of Combustion Rate

Here are some data collection methods based on the information provided about the portable incinerator device and the measurements :

1. Testing and measurement log. First we maintain a comprehensive logbook during the testing phase, recording the mass of the waste placed into the combustion chamber and the corresponding combustion time for each trial or test run.
2. Sensor integration. Then install sensors or measurement devices within the combustion chamber of the incinerator to automatically track and record the mass of the waste loaded and the time taken for complete combustion.
3. Video recording and analysis. Next step is record video footage during the testing process, focusing on the loading of waste into the incinerator and the duration of combustion. This can be reviewed later for precise measurements and time tracking.
4. Manual observation and timekeeping. Have trained observers manually record the mass of waste added and the time taken for complete combustion during each test. This method may involve using timers or stopwatches.
5. Multiple test runs. We conducted a multiple test runs under varying conditions (different types of waste, varying quantities, etc.) to gather a more comprehensive dataset and assess the consistency of combustion rates.
6. Data Logging Software. Utilize specialized software or applications that enable real-time data logging of the incineration process. This can automatically capture the mass of waste and combustion times, ensuring

The method used in this research is explained in the flow diagram in Figure 2.

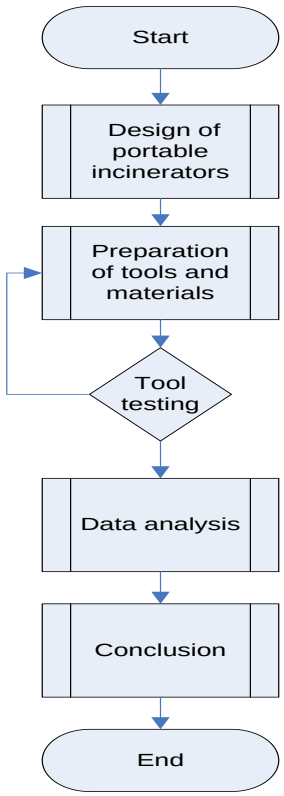

Figure 5. Flow diagram

3. Results and Discussion

Incineration is a waste processing process that involves burning at temperatures above 150°C to reduce combustible waste that cannot be recycled, remove bacteria, viruses and toxic chemicals. A portable incinerator is a tool designed to burn waste [12], both wet and dry waste, including waste produced by Covid-19 patients. Examples of wet waste from Covid-19 patients are leftover food, rice, vegetables, leaves, rotten fruit, while dry waste is plastic waste, food wrappers, masks, gloves, syringes and tissue.

The following is the result of making a portable incinerator as shown in Figure 5.

Figure 6. Portable Incinerator

3.1. Calculation Results of Incinerator Furnace

From the overall design and construction process of this portable incinerator device, the capacity of the incinerator furnace is 380 mm x 590 mm in cylindrical shape, which can be calculated using the formula for a cylinder and the device specifications as follows: Vcyt = π x r^2 x h (3.1) Explanation: π = 3.14 r = radius of the incinerator furnace h = height of the incinerator furnace Vcyt = volume of the incinerator furnace Vcyt = 3.14 x 192 cm x 59 cm Vcyt = 66878.86 cm^3 = 0.066 m^3 Therefore, in this incinerator, the volume of waste that can be placed into the incinerator furnace is 0.066 m^3.

3.2. Calculation of Combustion Rate

During the testing of the portable incinerator device, measurements were taken for the mass of the waste being placed into the combustion chamber and the required combustion time. Based on the measurement results, the mass of the waste was determined to be m grams, and the combustion time was t seconds.

By using the combustion rate formula m/t, the combustion rate of the portable incinerator device can be calculated. The formula m/t represents the mass of the waste (in grams) divided by the combustion time (in seconds). Here are the results of the combustion rate calculation.

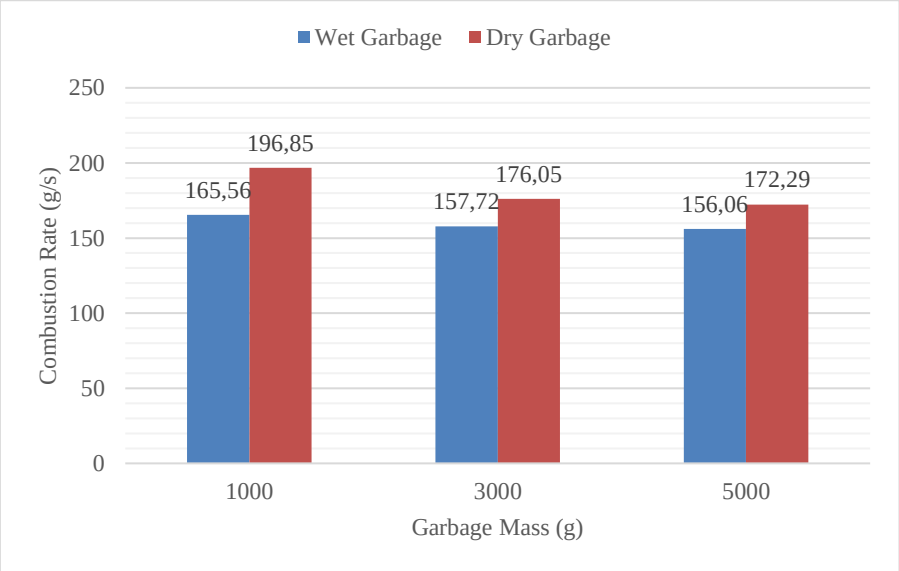

Figure 7. Calculation results of the combustion rate

Based on research conducted, the maximum burning rate of 1000 grams of waste was achieved by dry waste, namely 196.85 g/s. Meanwhile, for waste weighing 3000 grams, the maximum burning rate achieved by dry waste is 176.05 g/s, and for waste weighing 5000 grams, the maximum burning rate achieved by dry waste is 172.29 g/s. This is in line with the results of research [13], where an incinerator fueled by used oil waste was able to burn 12 kg of dry leaf waste in 20 minutes at a burner furnace temperature of 712.30 C and an incinerator combustion chamber temperature of 443.20 C with a fuel consumption of 0. 4 liters. The burning rate obtained from a waste weight of 8 kg is 24.24 kg/hour. As the mass of waste burned increases, the resulting combustion rate decreases. In other words, if the burning rate is low, the waste burning time will be longer. Household scale incinerators that perform well are those that have the fastest combustion rate.

3.3. Calculation of Fuel Consumption

Fuel consumption can be observed based on the combustion time. The longer the combustion time of the incinerator device, the more fuel is required. Conversely, a shorter combustion time requires less fuel. The fuel consumption results for the portable incinerator device can be seen in the following Figure 7.

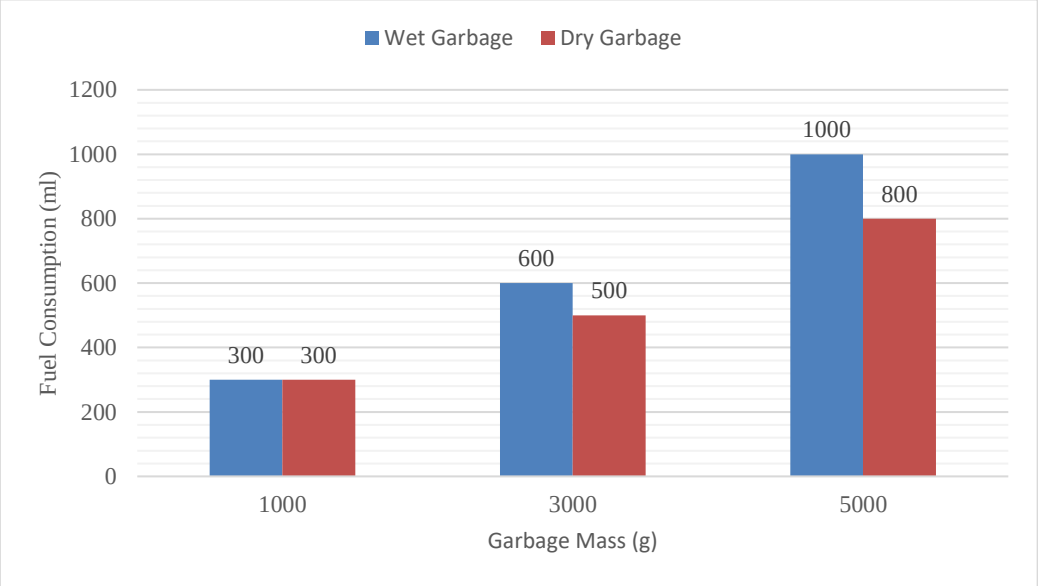

Figure 8. The Fuel Consumption Results

The fuel consumption used in this portable incinerator is minimal when burning 1000 grams of waste, namely 300 ml of used oil. Meanwhile, the highest fuel consumption is obtained from burning 5000 grams of wet waste, which is equivalent to 1000 ml of used oil. This is in line with the results of research [13], where to burn 12 kg of dry leaf waste at a burner furnace temperature of 712.30C and an incinerator combustion chamber temperature of 443.20C it takes 20 minutes with a fuel consumption of 0.4 liters of used oil waste. . The reason is, fuel consumption is determined based on the burning time required for the waste to turn to ash. Dry waste burns quickly and turns to ash, resulting in lower fuel consumption. On the other hand, wet waste requires a longer burning time, causing higher fuel consumption.

4. Conclusion

A portable incinerator with a maximum capacity of 5000 grams of waste has been successfully created. The performance of the portable incinerator is seen from the highest combustion rate for burning 1000 grams of dry waste at 196 g/s, and the lowest for burning 5000 grams of wet waste at 156.06 g/s. The minimum fuel consumption used in this portable incinerator is for burning 1000 grams of waste, namely 300 ml, while the highest fuel consumption is obtained from burning 5000 grams of wet waste at 1000 ml.

Acknowledgements

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References

[1] M. Nanda and B. Febriana, “Setahun Corona , Lebih 200 Warga Blora Meninggal,” *GATRA Com*, 2021.

[2] A. Ikhsan, “Kasus Limbah Medis Covid-19 Dibuang Sembarangan , Polisi : Pihak Hotel Rakus , Pakai Jasa Laundry,” *Kompas.com*, 2021.

[3] D. Pudjiastuti, Y. Rahmatiar, and D. Guntara, “Pengelolaan Limbah Medis Covid 19 Melalui

Kearifan Lokal," *Justisi J. Ilmu Huk.*, vol. 6, no. 2, pp. 81–101, 2021, doi: 10.36805/jjih.v6i2.1919.
[4] R. Adhani, *Pengelolaan Limbah Medis Pelayanan Kesehatan*, 1st ed. Banjarmasin: Lambung Mangkurat University Press, 2018.
[5] P. P. E. Sitompul, "Menilik Kebijakan Pengolahan Limbah B3 Fasilitas Pelayanan Kesehatan Selama Pandemi COVID-19 di Provinsi Jawa Barat," *Din. Lingkung. Indones.*, vol. 8, no. 1, p. 73, 2021, doi: 10.31258/dli.8.1.p.73-79.
[6] E. Laelasari, "Manajemen Pengelolaan Limbah Medis Rumah Tangga Era Pandemi Covid-19 di Indonesia: Narrative Literature," in *Prosiding Seminar Nasional Penelitian dan Pengabdian*, 2021, vol. 1, no. 1, pp. 447–458.
[7] M. S. Hastoanggoro, "Desain Kendaraan Pengolah Limbah Medis Covid-19." Repository Universitas Trisakti, 2021.
[8] A. Lasmana, Junaidi, and E. Kurniawan, "Rancang Bangun Alat Pembakar Sampah (Incinerator) Dengan Burner Oli Bekas," *J. Teknol. Rekayasa Tek. Mesin,* vol. 2, no. 1, pp. 35–40, 2021.
[9] R. Trihaditia and M. L. Agustiawan, "Efektifitas Rancang Bangun Alat (Burner) Oli Bekas Dalam Mendukung Proses Sterilisasi Media Jamur Tiram (Pleurotus astreatus)," *Pro-STek*, vol. 1, no. 2, p. 96, 2020, doi: 10.35194/prs.v1i2.828.
[10] Z. Zulfahmi, "Fabrikasi insinerator portabel untuk kebutuhan Puskesmas," *J. Polimesin*, vol. 14, no. 2, p. 42, 2017, doi: 10.30811/jpl.v14i2.342.
[11] E. Damanhuri and T. Padmi, "Pengelolaan Sampah," in *Pengelolaan Sampah*, vol. 3, no. 2, 2010, p. 7.
[12] I. Abdullah, Y. N. Manik, B. Barita, and J. Jufrizal, "Desain Insinerator Menggunakan Bahan Bakar Cangkang Kelapa Sawit," *J. Rekayasa Mater. Manufaktur dan Energi*, vol. 2, no. 1, pp. 34–43, 2019, doi: 10.30596/rmme.v2i1.3067.
[13] J. Junaidi, E. Kurniawan, and A. Lasmana, "Analisis Laju Aliran Udara dan Laju Aliran Massa Bahan Bakar Terhadap Beban Pembakaran Sampah pada Incinerator Berbahan Bakar Limbah Oli Bekas," *J. Engine Energi, Manufaktur, dan Mater.*, vol. 5, no. 1, p. 17, 2021, doi: 10.30588/jeemm.v5i1.838.

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Quality Control Analysis Using Statistical Quality Control (SQC) And Failure Mode Effect Analysis (FMEA) In The Production Process Of Za Plus Fertilizer

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Abstract. The company PT.XYZ is an industrial logistics entity that has a main division in the field of warehousing and MBU, with a special focus on fertilizer bagging activities. The problems faced by this company are related to defects that occur in the fertilizer bagging process. This research aims to identify the most common defects, the factors that cause defects, and develop proposed corrective actions to improve the quality of fertilizer bagging. The research methodology applied involves Statistical Quality Control (SQC) and Failure Mode Effect Analysis (FMEA), using tools such as check sheets, pareto diagrams, control maps, and fishbone diagrams. The results of the research using the Statistical Quality Control (SQC) method showed that the most significant defect in the fertilizer bagging process was the tear defect, reaching a percentage of 58%, followed by the seam defect at 27%, and the underweight defect at 15%. Meanwhile, analysis with the Failure Mode Effect Analysis (FMEA) method shows that the type of tear defect has the highest Risk Priority Number (RPN) value, caused by a lack of caution when carrying out the process of putting fertilizer into pallets. As a recommendation for improvement, it is recommended to organize training on work procedures for employees to improve their understanding of the work procedures that apply at PT.XYZ. This step is expected to address the main problems identified in the study, especially related to the lack of care in the process of bagging fertilizer into pallets, so as to improve the quality of fertilizer bagging in the company.
Keywords: Quality Control, Statistical Quality Control, Failure Mode Effect Analysis

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1. Introduction

The manufacturing industry evolved from the need to improve product quality, process efficiency, and fulfill customer satisfaction. Each company is required to have its own quality standards to ensure that the products produced are acceptable to consumers. One strategy to improve quality is to reduce or suppress the number of product defects and improve the overall quality level[1]. From the results of the initial survey, the researcher found that in the production process of bagging ZA Plus fertilizer at PT.XYZ there were still defects in the bagging results, such as torn fertilizer bags. This situation has the potential to cause losses for the company, especially if the delivered fertilizer products do not match the specifications of consumer orders, which can result in product returns for further repairs. Therefore, this study aims to identify the most dominant percentage of defects and provide recommended actions to improve bagging quality[2].

The results of this study are expected to provide useful input for companies in analyzing the quality of products produced and designing production quality control policies to achieve company standards

[3]. One method that can be applied is Statistical Quality Control (SQC), which is an effective tool for maintaining product quality standards. As explained by[4], the SQC method and Failure Mode and Effect Analysis (FMEA) can help identify the root cause of defects in products and provide appropriate improvement suggestions[5]. Therefore, in accordance with the context described, this study adopts the SQC method to uncover the causes of defects in fertilizer products and uses FMEA analysis to formulate improvement recommendations on the quality control of ZA Plus fertilizer bagging."

2. Methods

Customer satisfaction is fundamentally influenced by quality factors [6]. Therefore, quality control is very important to maintain the quality of a product[7]. This research on quality control in ZA Plus fertilizer products is carried out through several main stages, namely the preliminary stage, data collection, data processing, and conclusion drawing. The preliminary stage includes field studies and literature studies to understand the existing situation, which is then put together with theories related to Statistical Quality Control (SQC) and Failure Mode and Effects Analysis (FMEA) methods. At this stage, problem formulation is also carried out. Furthermore, the data collection stage involves production data and the number of defects of ZA Plus fertilizer at PT XYZ. The data is then processed using the Statistical Quality Control method, an industrial approach to measure, monitor, and regulate the quality of products or services through statistical tools and data analysis techniques such as Check sheets, Histograms, Pareto charts, Control Charts, and Fishbone diagrams[8].

Furthermore, prioritization of improvements is done with the help of the Failure Mode and Effects Analysis (FMEA) method, a structured and systematic method for analyzing failures, identifying potential failures, and providing priorities[9]. In FMEA risk assessment, a parameter known as RPN (Risk Priority Number) is used, calculated by multiplying the severity, frequency of occurrence, and detectability of the failure [10]. The severity rating scale is presented in Table 1[11]."

Table 1 RPN severity rating scale

Ranking	Severity	Description
10	Hazardous without warning	System failures that cause very serious impacts.
9	Hazardous with warning	System failures that cause harmful effects
8	Very High	The system cannot operate
7	High	Although the system can operate, it does not reach its full capacity
6	Moderate	Operational and safe, but experiencing performance degradation affecting output.
5	Low	Progressive decline in performance
4	Very Low	Minimal impact on system performance.
3	Small	Affects system performance to a small degree
2	Very Small	Mempengaruhi kinerja sistem pada tingkat yang kecil
1	No Effect	No impact on system performance.

In the context of the analysis, the O value reflects the degree of likelihood or probability of a failure occurring. To determine this occurrence value, a rating scale from 1 to 10 is used. This occurrence rating scale can be found in Table 2 [11].

Table 2 RPN occurrence rating scale

Ranking	*Occurrence*	*Description*
10 - 9	*Very High*	*Frequent failures*
8 - 7	*High*	*Repetitive failures*
3 - 2	*Low*	*Very rare instances of failure*
1	*No impact*	*Almost no failures*

The D value indicates the probability of detecting a failure before it occurs. The detection assessment uses a scale from 1 to 10. This detection assessment can be found in Table 3, as evaluated based on McDermott 2009 found in reference [11].

Table 3 RPN detection scale

Ranking	*Detection*	*Description*
10	*Uncertain*	*Conducting inspections consistently lacks the capacity to identify potential causes or failure mechanisms and failure modes.*
9	*Very Small*	*Very limited checking opportunities in detecting potential causes, failure mechanisms, and failure modes.*
8	*Small*	*The probability of inspection to identify potential causes, failure mechanisms, and failure modes is very low.*
7	*Very Low*	*Low inspection probability in identifying potential causes and failure modes.*
6	*Low*	*Inspection opportunities to identify potential causes, failure mechanisms, and failure modes are low..*
5	*Moderate*	*Inspection capacity in identifying potential causes, failure mechanisms, and failure modes has a moderate level.*
4	*Intermediate to high*	*The probability of checking to identify potential causes, failure mechanisms, and failure modes is high.*
3	*High*	*The probability of inspection to identify potential causes, failure mechanisms, and failure modes can be considered high.*
2	*Very High*	*The probability of checking in identifying potential causes, failure mechanisms, and failure modes is very high.*
1	*Almost certain*	*Consistency in checking has the capacity to identify potential causes, failure mechanisms, and failure modes.*

3. Results and Discussion

3.1 Statistical Quality Control (SQC)

Data management was performed using five statistical tools for quality control, followed by analysis using the Statistical Quality Control (SQC) method.

3.1.1 Check Sheet

In implementing quality control using the Statistical Quality Control method, there are several steps that need to be followed. The first step involves creating and filling out a check sheet. A check sheet is a simply designed inspection form that lists elements that need to be recorded both qualitatively and quantitatively. Its function is to structure and organize the data collection process in a systematic and structured manner as data appears on the scene[12]. Details of the check sheet can be found in Table 4.

Table 4 data chect sheet

NO	WEEK	JUMLAH PRODUKSI(BEG)	TYPES OF DAMAGE			AMOUNT OF DAMAGE (BEGS)
			RIPPED	SEWING	BALANCE	
1	Week 1	354	49	29	15	93
2	Week 2	377	59	20	13	92
3	Week 3	377	50	20	10	80
4	Week 4	377	60	25	12	97
5	Week 5	375	40	19	15	74
6	Week 6	375	44	30	17	91
7	Week 7	375	55	29	14	98
8	Week 8	377	56	23	11	90
TOTAL		2987	413	195	107	715

Based on Table 4. Check sheet above there are 3 types of defects. Torn defects as many as 413 bags, not sewn as many as 195 bags, and the size of the scales is less as many as 107 bags.

3.1.2 Histogram

Once the inspection form has been compiled, the next stage involves creating a histogram. A histogram is a useful tool in identifying variation in a process. Histograms are bar graphs that illustrate the grouping of data based on its values[13].

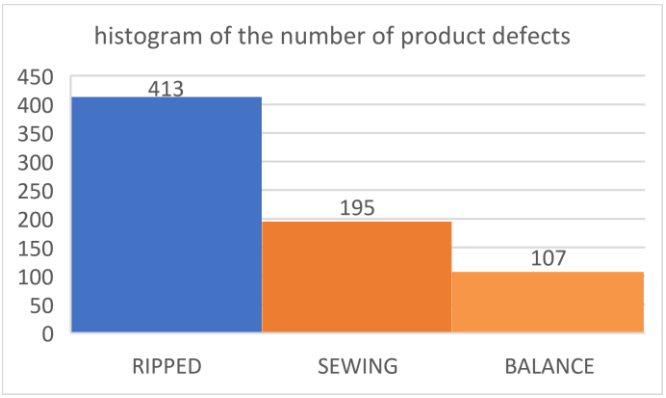

Figure 1 histogram of product defects

Based on the histogram graph in Figure 1 above, it can be concluded that the most common type of damage is torn fertilizer packaging, with the number of damaged products reaching 413 bags. The second most common type of damage is unstitching of the packaging, which caused damage to 195 bags of product. Meanwhile, the damage that ranked third in frequency was underweight, with a total damage of 107 bags.

3.1.3 Control Map

After identifying the type of defect through the use of histograms, the next action involves creating a control map to evaluate whether a particular defect crosses the control limits. A control map is a visual tool used to monitor and evaluate whether an activity or process is in quality control, on the basis of statistical analysis[14]. The steps in creating a control map are as follows[15]:

Calculating the Percentage of Damage $[P = \frac{np}{n}]$ (1)

$P = \frac{np}{n} = \frac{93}{354} = 0{,}2627$ (2)

Calculating the Centerline The centerline is the average of product damage $[CL = p = \frac{\sum np}{\sum n}]$ (3)

$CL = p = \frac{\sum np}{\sum n}$ (4)

$CL = p = \frac{715}{2987} = 0{,}239$ (5)

Calculating the Upper Control Limit $[UCL = p + 3\frac{\sqrt{p(1-p)}}{n}]$ (6)

$UCL = p + 3\frac{\sqrt{p(1-p)}}{n}$ (7)

$UCL = 0{,}259 + 3\frac{\sqrt{0{,}259\,(1-0{,}259)}}{2987} = 0{,}263$ (8)

Calculating the lower control limit $[LCL = p - 3\frac{\sqrt{p(1-p)}}{n}]$ (9)

$LCL = p - 3\frac{\sqrt{p(1-p)}}{n}$ (10)

$LCL = 0{,}259 - 3\frac{\sqrt{0{,}259\,(1-0{,}259)}}{2987} = 0{,}216$ (11)

Table 5 control map p

NO	PRODUCTION QUANTITY (BEGS)	AMOUNT OF DAMAGE (BEGS)	BROKEN PERCENTAGE %	CL	UCL	LCL
1	354	93	0.26	0.239	0.263	0.216
2	377	92	0.24	0.239	0.262	0.216
3	377	80	0.21	0.239	0.262	0.216
4	377	97	0.26	0.239	0.262	0.216
5	375	74	0.20	0.239	0.262	0.216
6	375	91	0.24	0.239	0.262	0.216
7	375	98	0.26	0.239	0.262	0.216
8	377	90	0.24	0.239	0.262	0.216
TOTAL	2987	715	0.24	0.239	0.262	0.216

After knowing the percentage value of each subgroup, including the center line (CL), upper limit (UCL), and lower limit (LCL) values from table 5, the next step is to generate a p-control map (p-chart), which can be observed in figure 2.

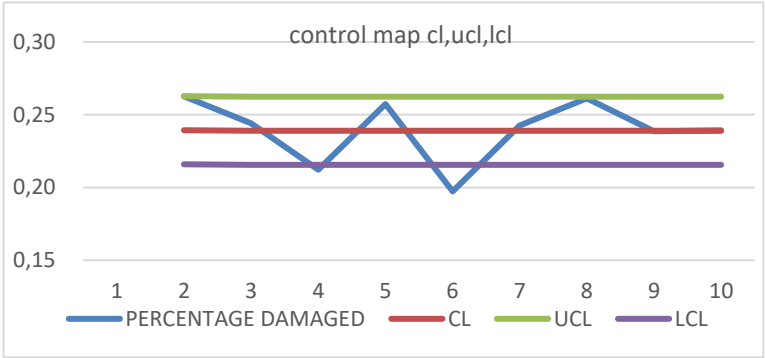

Figure 2 control map cl,lcl,ucl

From the image on the p control map above, it can be noted that the data still shows a point outside the control limits at point 6, and the most significant factor in this case is the presence of damage or defects in the torn packaging. Therefore, it can be concluded that this process is out of control or has deviations[16]. The presence of points outside the control limits indicates that there are still problems that need to be addressed in the production process. Therefore, further analysis is required to understand the causes of deviations in the production process at PT.XYZ. The approach to be used involves the use of a fishbone diagram to explore the factors that cause deviations in the product.

3.1.4 Pareto diagram

After obtaining information about the type of product damage, a pareto diagram is prepared. Pareto diagram is a form of graphical representation in the form of bars that show the frequency distribution of attribute data that has been classified, helping in identifying the types of product damage[17].

Table 6 damage data, damage percentage and cumulative percentage

NO	DAMAGE TYPE	QUANTITY OF DAMAGE (BAGS)	BROKEN PERCENTAGE	CUMULATIVE PERCENTAGE
1	RIPPED PACKAGING	413	58%	58%
2	UNSEWN PACKAGING	195	27%	85%
3	LESS FERTILIZER WEIGHT	107	15%	100%
	TOTAL	715	100%	

Based on the results of data calculations in table 6, it can be depicted in a pareto diagram showing the comparison of the types of damage that occur

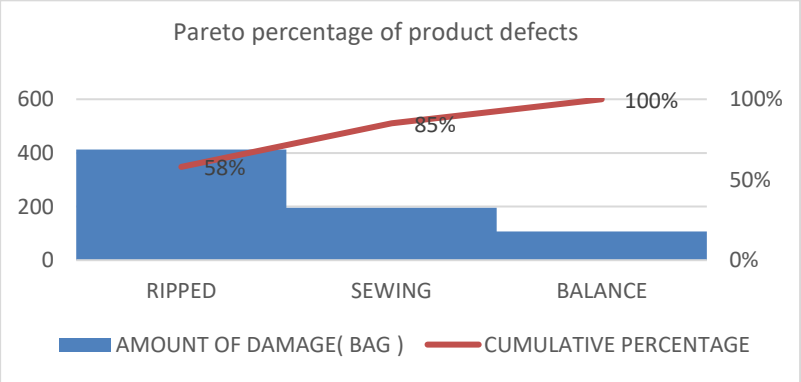

Figure 3 pareto percentage of product defects

By referring to the Pareto Chart in Figure 3, it can be identified that the most common type of damage is torn packaging, with a total damage of 413 units or 58%. Furthermore, the second most common type of damage is unsewn packaging, with a total damage of 195 units or around 27%. Meanwhile, the third most common damage is the lack of scales, with a total damage of 107 units or around 15%.

3.1.5 Cause-and-effect Diagram

After knowing the types of defects that occur most often, then identify what factors affect these defects using a fishbone diagram. Fishbone diagrams, also known as cause-and-effect diagrams, are used to uncover and identify the triggering factors underlying the failure or defect[18]. The causal factors of the three types of defects (defective products) in ZA plus fertilizer products are depicted using the fishbone diagram below:

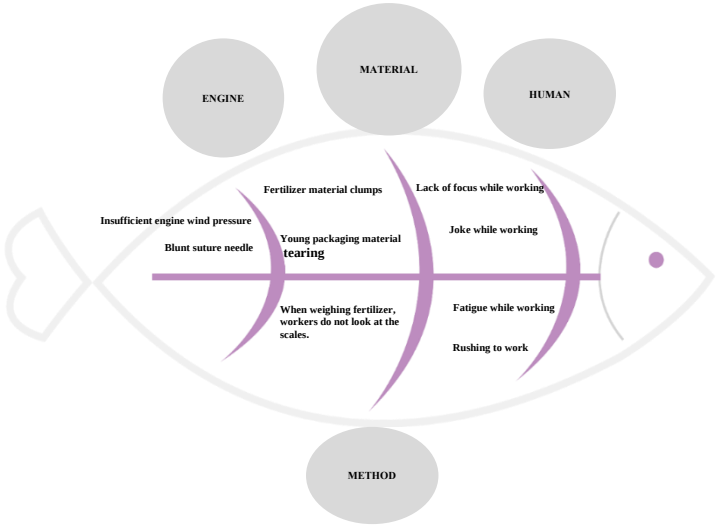

Figure 4 cause-and-effect diagram

If we observe the Cause-and-Effect Diagram in Figure 4 above, there are four factors that cause defects identified, namely humans, machines, materials, and methods.

3.2 Failure Mode Effect Analysis (FMEA)

After the data was processed using Statistical Quality Control, it was found that the most frequent defects were tear defects, followed by stitch defects and crust defects. Then, by referring to the cause-and-effect diagram, the causes of defects in jimbe drum production can be identified[19]. Thus, corrective actions can be proposed through Failure Mode Effect Analysis (FMEA), by assigning Risk Priority Number (RPN) values, as listed in the following table

Table 7 RPN assessment

Potential Failure Mode	*Potential Effect of Failure*	S	*Potential Cause*	O	*Current Control*	D	RPN
Ripped packaging	Fertilizer products will not be able to be sold and will do the work twice because they have to change the packaging	9	1.workers lack focus when arranging pallets	5	1.Always supervise workers so that they do not focus on other things.	2	90
			2. workers are in a hurry when placing fertilizer on pallets	9	2.Supervise workers not to be hasty in arranging fertilizer onto pallets.	4	324
			3.workers talking to fellow workers	5	3.reprimand workers who talk	2	90
			4.worker fatigue due to heavy fertilizer load	6	4.implementing changes every few minutes to avoid fatigue	2	108
			5.compressor wind pressure to hydraulic less	8	5.perform regular maintenance to the compressor	3	216
Unsewn packaging	Fertilizer will spill and scatter and the fertilizer will have to be re-sewn.	7	1.the stitches wear out so that there is often a jam when sewing	6	1.change sutures at regular intervals	3	126
			2.workers are in a hurry when sewing so they do not pay attention to the position of the sack when sewing	7	2.inspect the stitches when they are completed	4	196
			3.talking to fellow workers so as not to pay attention to the position of the sack when sewing	5	3.reprimand workers who talk	3	105
Weighing the packaging scales less	Workers have to repackage until the weight matches the size	5	1.less wind pressure makes the automatic weighing machine inaccurate	5	1.always check the pressure indicator	3	75
			2.haste - haste does not see the indicator scales	4	2.check the scale again	1	
			3.less thorough when looking at the weighing indicator	4	3.make sure the scale indicator is correct	2	20
							40

Table 8 RPN rank assessment

Priority	*Potential Failure Mode*	*Potential Cause*	RPN	*Recommendation*
1	Ripped packaging	workers are in a hurry when putting fertilizer onto pallets	324	Provide them with work procedure training
2	Ripped packaging	compressor to hydraulic air pressure is less	216	Before carrying out work activities, you should check the work tools.
3	Unsewn packaging	workers are in a hurry when sewing so they do not pay attention to the position of the sack when sewing.	196	Provide them with training on work procedures
4	Unsewn packaging	stitches wear out so there is often slippage when sewing	126	Check the condition of the sewing needle when it will be used and replace it regularly

		worker fatigue due to heavy fertilizer load	**108**	Changing workers to avoid fatigue
5	Ripped packaging			
6	Unsewn packaging	talking to fellow workers so that they do not pay attention to the position of the sack when sewing	**105**	Briefing workers on work procedures and supervising them.
7	Weighing the packaging scales less	insufficient wind pressure makes the automatais machine scales inaccurate.	**75**	Look at the pressure indicator first to see if it is correct before doing the work.
8	Ripped packaging	workers talk to fellow workers while working	**90**	Reprimand and give witnesses to workers who violate the rules.
9	Ripped packaging	workers lack focus when arranging palet	**90**	Give one kind of workload so that workers are more focused.
10	Weighing the packaging scales less	less careful when looking at the weighing indicator	**40**	Rechecking fertilizer weights
11	Weighing the packaging scales less	in a hurry not looking at the scale indicator	**20**	Rechecking fertilizer weights

Based on the results of the Risk Priority Number (RPN) calculation in Tables 7 and 8, it is revealed that the causes of failure that are significant in causing product defects have been sorted in order based on the calculation value, starting from the highest to the lowest. Next, improvement recommendations were made for each potential cause of failure according to the order of the RPN values in the table. The table highlights the defect cause with the highest RPN, i.e. 324, which is caused by tearing of the packaging due to workers rushing to put the fertilizer into the pallets to achieve the target, causing the fertilizer to slam. The proposed improvement recommendations include setting targets that match the capacity of workers to ensure optimal performance and prevent damage from occurring due to rushing.

4. Conclusion

Based on research conducted by researchers in the production sector of PT.XYZ related to ZA Plus fertilizer products, it can be stated that the dominating defect in the fertilizer production process is tearing, reaching a percentage of 58%. Furthermore, seam defects reached 27%, while crust defects amounted to 15%. Some of the factors causing tear defects include the lack of human accuracy in the process of arranging fertilizers on pallets, the state of the hagit needle that has been mechanically worn or blunted, and the condition of the packaging that is too worn out so that it is prone to tearing in terms of material[20].

Through the calculation of Risk Priority Number (RPN) in the Failure Mode Effect Analysis (FMEA) for fertilizer products, certain risks were identified, with some of them having the highest priority requiring improvement to reduce potential errors. The highest RPN recorded was 324, related to tear defects caused by a lack of caution in the process of arranging fertilizer on pallets or bouncing, causing fertilizer to fall off. Nonetheless, further research with a more comprehensive dataset and longer research period is required for validation and deeper understanding.

References

[1] M. E. Setiabudi, P. Vitasari, and T. Priyasmanu, "Analisis Pengendalian Kualitas Untuk Menurunkan Jumlah Produk Cacat Dengan Metode Statistical Quality Control Pada Umkm. Waris Shoes," *J. Valtech*, vol. 3, no. 2, pp. 211–218, 2020, [Online]. Available: https://ejournal.itn.ac.id/index.php/valtech/article/view/2734

[2] J. Saka *et al.*, "Dual Statistical Quality Control Charts with Table of Quality Determinant in Manufacturing Industries," *Int. J. Inf. Process. Commun. (IJIPC*, vol. 7, no. 1, pp. 242–252, 2019, [Online]. Available: https://www.researchgate.net/publication/339508539

[3] I. Andespa, "Analisis Pengendalian Mutu dengan Menggunakan Statistikal Quality Control (SQC) pada PT . PRATAMA ABADI INDUSTRI (JX) Sukabumi Ira Andespa Fakultas Ilmu Administrasi dan Humaniora Universitas Muhammadiyah Sukabumi , Jawa Barat , Indon," *E-Jurnal Ekon. dan Bisnis Univ. Udayana*, vol. 2, pp. 129–160, 2020.

[4] N. A. Cahaya Mulia and R. Rochmoeljati, "Pengendalian Kualitas Pengelasan Menggunakan Metode Statistical Quality Control (SQC) dan Failure Mode Effect Analysis (FMEA) di PT. PAL Indonesia," *Juminten*, vol. 2, no. 6, pp. 60–71, 2021, doi: 10.33005/juminten.v2i6.346.

[5] D. Hendrawan, M. Wirawati, and H. Wijaya, "Analisis Pengendalian Kualitas Pada Proses Boning Sapi Wagyu Menggunakan Statistical Quality Control (Sqc) Di Pt. Santosa Agrindo," *J. Ind. Eng. Manag. Res. (Jiemar)*, vol. 1, no. 2, pp. 2722–8878, 2020.

[6] Y. Walujo, D. A., Koesdijati, T., & Utomo, *pengen dalian kualitas*, 1st ed. secopindo media pustaka, 2020.

[7] I. I. S. Haryanto, P. Sari, and I. B. Suardika, "Penerapan Metode SQC Untuk Mengetahui

Kecacatan Produk Shuttlecock Pada UD. Ardiel Shuttlecock," *J. Teknol. Ind. Dan Manaj.*, vol. 1, no. 1, p. 6, 2019.
[8] M. H. Cipta Dinata, D. Andesta, and H. Hidayat, "Analisis Pengendalian Kualitas Produk Tangga Besi Pt. Ajg Untuk Mengurangi Kecacatan Produk Menggunakan Metode Statistik Quality Control (Sqc)," *J. Ind. Eng. Oper. Manag.*, vol. 5, no. 1, pp. 27–36, 2022, doi: 10.31602/jieom.v5i1.7181.
[9] W. B. Setiawan, "Vulkanisir Dengan Metode Statistical Quality," *J. Valtech*, vol. 1, no. 1, pp. 1–6, 2020, [Online]. Available: https://ejournal.itn.ac.id/index.php/valtech/article/view/5%0A
[10] M. S. Arianti, E. Rahmawati, D. R. R. Y. Prihatiningrum,) Magister, and A. Bisnis, "Analisis Pengendalian Kualitas Produk Dengan Menggunakan Statistical Quality Control (Sqc) Pada Usaha Amplang Karya Bahari Di Samarinda," *Ed. Juli-Desember*, vol. 9, no. 2, pp. 2541–1403, 2020.
[11] B. A. C. Putra, "Risk Assessment Alat Produksi Gula Cane Knife Pada Stasiun Gilingan Di Pt. X," *Indones. J. Occup. Saf. Heal.*, vol. 7, no. 3, p. 273, 2019, doi: 10.20473/ijosh.v7i3.2018.273-281.
[12] M. S. A. Fath and R. A. Darajatun, "Tinjauan Perancangan Produksi dan Kualitas Pada Produk Rak Dies di CV Sarana Sejahtera Tehnik," *J. Ilm. Wahana Pendidik.*, vol. 8, no. 2, pp. 159–168, 2022, doi: 10.5281/zenodo.6105126.
[13] I. Revita, A. Suharto, and A. Izzudin, "Studi Empiris Pengendalian Kualitas Produk Pada Vieyuri Konveksi Empirical Study of Quality Control in Vieyuri Konveksi," *Bisnis-Net J. Ekon. dan Bisnis*, vol. 4, no. 2, pp. 39–49, 2021, doi: 10.46576/bn.v4i2.1695.
[14] M. Abdurrahman, A. W. Rizqi, and M. Jufriyanto, "Pengendalian Kualitas Kayu Kering pada Mesin Kiln Dryer untuk Mengurangi Produk Cacat dengan Metode Seven Tools dan Failure Mode Effect Analysis," vol. VIII, no. 4, pp. 7065–7077, 2023.
[15] C. Choi, J. Kim, J. Kim, D. Kim, Y. Bae, and H. S. Kim, "Development of heavy rain damage prediction model using machine learning based on big data," *Adv. Meteorol.*, vol. 2018, 2018.
[16] B. Lesmana, "Pengaruh Cost of Quality Terhadap Tingkat Design Quality Produk (Study Kasus Pada PT. Unindo Nusantara Perkasa Sentosa UNPS, Tangerang – Banten," *Dwijacendekia J. Ris. Pedagog.*, vol. 1, no. 1, pp. 1–9, 2021.
[17] J. Laili and M. D. Kurniawan, "Optimalisasi Standar Kualitas Sarung Tenun Dengan Aplikasi Seven Tools Pengerajin Sarung Indonesia," vol. 17, no. 1, pp. 35–45, 2023.
[18] Z. M. Firmansyah, P. Studi, T. Industri, and F. Sains, "Analisis Pengendalian Kualitas Produksi Carica Menggunakan Metode Seven Tools Studi Kasus Pada CV Gemilang Kencana," vol. 2, no. 3, 2023.
[19] M. Anggraini, Sulastri, and N. A. Anggriawan, "Analisis Pengendalian Kualitas Pengolahan Produk Karet Remah SIR 20 dengan Pendekatan Statistical Quality Control," *Rekayasa, Teknol. dan Sains*, vol. 3, no. 1, pp. 21–26, 2019.
[20] T. P. Matondang and M. M. Ulkhaq, "Aplikasi Seven Tools untuk Mengurangi Cacat Produk White Body pada Mesin Roller," *J. Sist. dan Manaj. Ind.*, vol. 2, no. 2, p. 59, 2018, doi: 10.30656/jsmi.v2i2.681.

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Overcoming The Buildup Of Queues By Carrying Out The Concept Of Self-Service Using Responsive Web-Based Applications

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Abstract. With today's technological advances, all things can be done with the internet, one of which is a web-based food and beverage menu self-order system. This system was created to make it easier for waiters and customers in the ordering process. Because of the problems that occur today, namely the queue in the ordering process and busy waiters who make customers neglected. Therefore, this system was designed to facilitate service, and waiters no longer need to record food menus manually, customers can also order menus directly through the system without having to queue. Before designing the system, an analysis is carried out first, in the design of the system is designed with a quantitative method where researchers take the necessary data and information by conducting direct interviews with related parties. This system will be designed in the form of a responsive website and designed using the PHP programming language and MySQL which is used as a database storage. With the final result, this system can help and facilitate the ordering process and data collection of incoming orders. And the system can run according to the needs of restaurants and customers who use this system.

Keywords: Self order, ordering, website, food, restaurant, internet.

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1. Introduction

In line with the times where there is a lot of competition [1] which can cause many companies to have to improve better services [2] to realize customer satisfaction. Therefore the company must have a good ordering system [3], because ordering is the initial activity that consumers always do before the buying process [4]. Several things can trigger a decrease in consumer satisfaction with a restaurant, such as decreased taste, increased prices, poor service systems, or technological competition that has begun to spread to the use of the internet because currently, the internet acts as a broad information and communication suggestion [5].

One of the most widely used forms of internet application is the website, with a website someone can get the desired information quickly, easily, and efficiently [6] and can be seen by anyone connected to the internet network [7]. The rapid dissemination of information is also an advantage of a website [8].

In addition, with the development of technology today, many activities require technology to facilitate work [9]. A web-based menu ordering information system also helps in improving the sales strategy created. With this system, customers will get the right information without taking much time [10].

In addition, a good restaurant must have good service as well as serving food quickly and correctly [11]. In providing services to customers, sometimes restaurants experience difficulties in the process of data collection of food and drinks ordered by customers when crowded [12]. Then in that situation, it will also trigger a queue of customers [13] and the waiters are also required to work fast. With these demands can cause waiters to be less concentrated and result in errors, such as delivering the wrong food order to the customer's table and recording the wrong food menu. As well as recording menus that are still manual [11] such as using stationery [14] also causes the ordering process to take longer and is prone to errors in writing orders [15]. In the end, errors that occur can interfere with the serving process, resulting in a decrease in the reputation of the restaurant [11].

Seeing the various problems that occur above, a web-based food and beverage ordering self-order application system is designed. As for previous research that has been done before in designing a web-based food and beverage ordering system that is used as a reference in this study, among them:

a. In research conducted by Dinni Indriani, Asep Saeful, dan Ardi Taryanto (2021) with the title "Perancangan Sistem Informasi Pemesanan Makanan Berbasis Web di Foodcourt RSKIA Bandung". The results obtained from the research literature that has been carried out are the creation of a website with 2 types of actors including admin and cashier. With admin access, namely managing menus, order processes, reports, and managing expenses. Cashier access is tasked with managing the order process and managing expenses [16].
b. Other research is conducted by Heri setiawan, Wanti Rahayu, and Indra Kurniawan (2020) with the title "Perancangan Aplikasi Pemesanan Makanan dan Minuman Padarumah Makan Cepat Saji D'Besto". The results obtained from this research are the creation of a website with one user, namely Admin, who can only access the website and customers still place orders manually. Access owned by the admin includes managing the menu, making transactions, and recapitulating orders [17].

From From previous research references, we can see that a website-based food and beverage ordering application system can facilitate the process of ordering food menus [18]. However, from the customer side, they still place orders manually and maybe this can trigger queues of customers in the menu ordering process. That way this system can be developed again by adding access features for customers so that customers can directly order food using the existing system. Based on the previous explanation, a web-based food and beverage ordering self-order application system was designed, and developed with the PHP programming language and the web-based food and beverage ordering system PHPmyAdmin to manage MySQL databases as a database repository. One important aspect of using phpMyAdmin is information security in database management because phpMyAdmin offers security features that can help protect databases from attacks and unauthorized access [19]. This system is made in the form of a responsive web to make it easier for customers to use the system. This system is also designed with three user accesses, namely Admin, Cashier, and Customer. With admin access, they can manage all available activities including managing menus, placing orders, making payments, and managing reports. Then for the access given to the cashier, namely viewing the menu, placing orders, making payments, and managing reports. While the access given to customers can only see the menu and place orders. The purpose of designing this system is to assist customers in the food ordering process so that customers do not have to queue for a long time. In addition, it also makes it easier for employees to record and manage incoming orders so that there are no errors in order data, besides that employees can also perform other tasks without having to go to each customer to record orders.

2. Methods

In this research, the method used is using qualitative research methods. The qualitative method is a research technique that uses narratives or words to explain and describe the meaning of each

particular social situation. In qualitative research, the researcher is the key instrument to interpret and interpret every phenomenon, symptom, and certain social situation. Therefore, researchers need to master the theory to analyze the gaps that occur between theoretical concepts and the facts that occur [20]. By using this qualitative method, we can take the information needed through the interview process directly to the relevant parties. The interview process is carried out so that the data obtained is to the desired needs. In this study, there are several stages of research which are divided into several stages including identification, collecting data by conducting an interview process, designing a system, results, testing, and finally there are evaluation results and conclusions.

2.1 Data Collection

The data used in this study is a list of food menus along with prices, which will later be used in the system to fill in the menu list. The data is obtained using an interview method where researchers will collect the information needed through questions that will be asked by researchers to restaurant owner sources such as when the company was founded, the level of restaurant crowds, previous ordering systems, and the price of each food menu.

2.2 System design

The system that will be proposed is a self-order application for web-based food and beverage ordering. This aims to make it easier for customers to carry out the food ordering process, that way customers do not need to queue or wait for the waiter to come to record the menu they want to order. Then the cashier also makes it easier for employees to calculate orders. As well as making it easier for employees to collect data on orders that have been made. The details of this system are that newly arrived customers can directly order food menus through the web system. After the customer places an order, the customer is then directed to pay for the order at the cashier by showing the order number. Then the cashier will see the order amount and the customer can immediately complete the payment. After the order is paid off, the order will be processed by the kitchen according to the menu that has been ordered. Finally, when the order is cooked the order is ready to be served to the customer.

3. Results and Discussion

3.1 Results

The result of the designed system is a responsive website so that users can open the website using a cellphone. The result of the designed system is a food menu ordering system that can be done online when the customer is at the restaurant. The results of this system can facilitate customers in ordering food menus and employees in recording incoming orders.

On the website created there are several features including for admins can access the menu, order, user, and report features. Then cashiers can access the menu, order, and report features. Meanwhile, customers can only access the menu and order features. Then the process of inputting, updating, and deleting from several existing features. The results of the implementation of the system that has been made can be run using the Google Chrome browser. The implementation of the interface on the system can be seen in the following figure:

3.1.1 Home view

The following is a home view of the system that can be made. This can be seen in Figure 1 which shows the appearance of the entire page and shows the responsive website display.

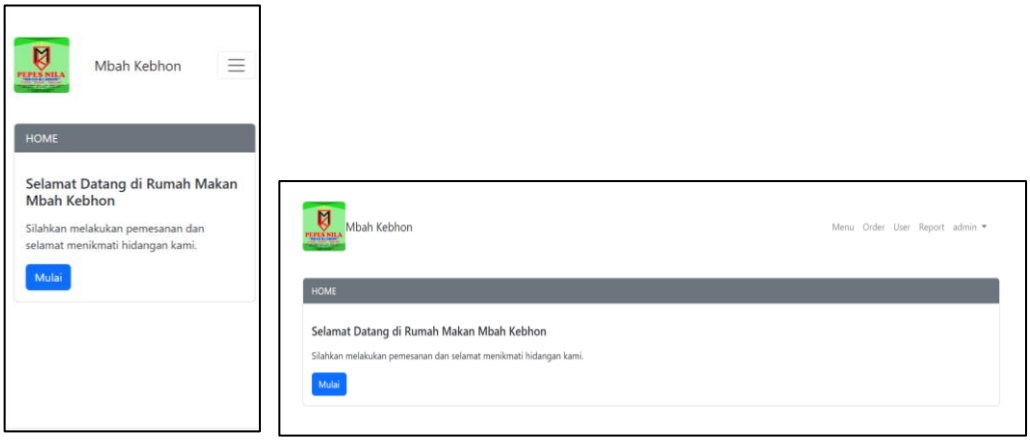

Figure 1 Website view

The main display shows a selection of features that can be seen by the user, namely the menu, order, user, report, and status features for the admin. While the main display for cashiers displays menu, order, report, and status features. For customers on the main page displays menu, order, and status features.

3.1.2 Menu View

On the menu page display will display a list of menus and buttons to add menus, view menu details, edit menus, and delete menus can only be accessed to log in as admin, but if logged in as a cashier and customer the add menu button does not exist. Cashiers and customers can only see the menu that is displayed only, for details of the display can be seen in Figure 2.

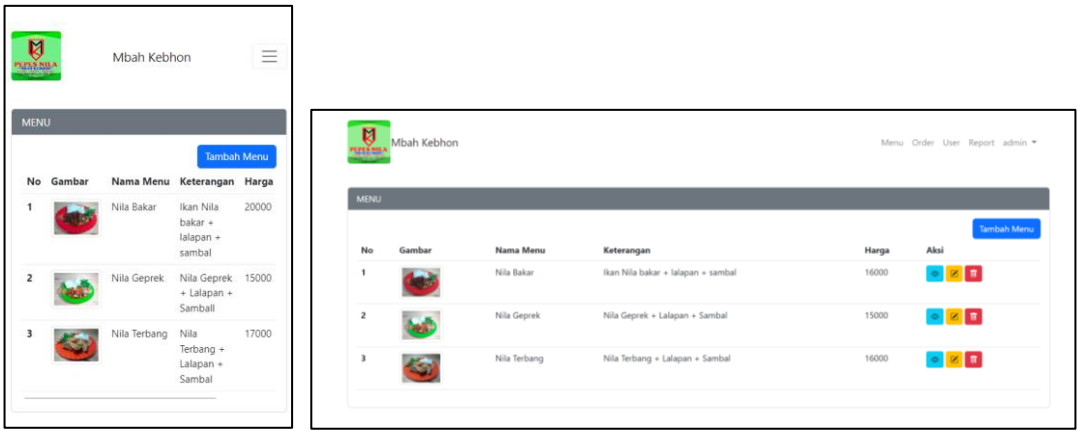

Figure 2 Menu view

3.1.3 Order view

On the Order page, customers can add, edit, or delete menus that have been added previously. The order page can be seen in Figure 3.

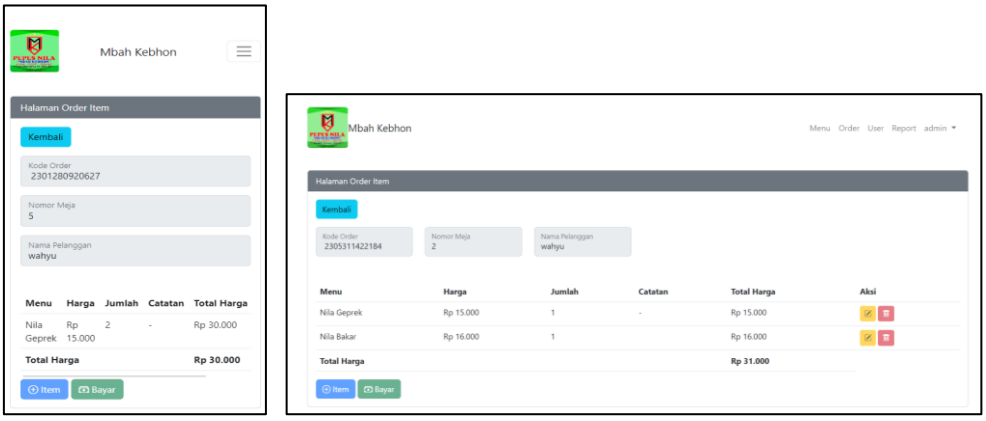

Figure 3 Order view

3.1.4 *Report view*

On the report feature page can only be accessed by admins and cashiers, the report page only displays orders that have been paid. For more details on the report page display can be seen in Figure 4.

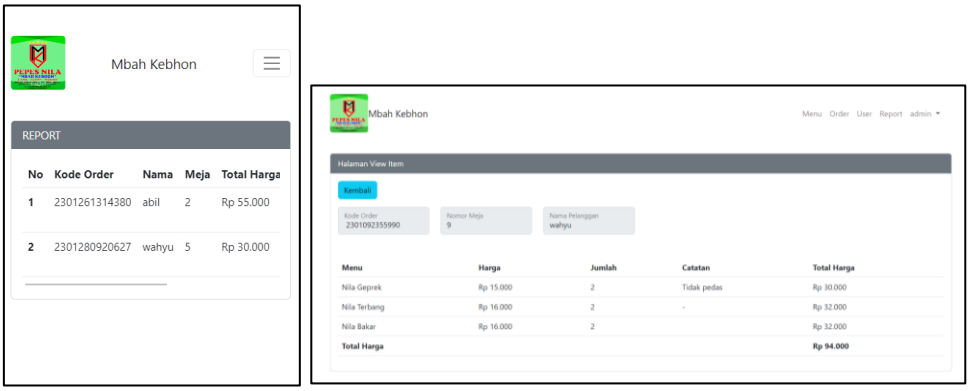

Figure 4 Report view

3.1.5 *Database*

In this research, the data used in the designed system is stored using the phpMyAdmin database. So that the website that has been designed must always be connected to the database so that users can input data, display data, edit data, or delete data. The database created to store data from this system can be seen in Figure 5.

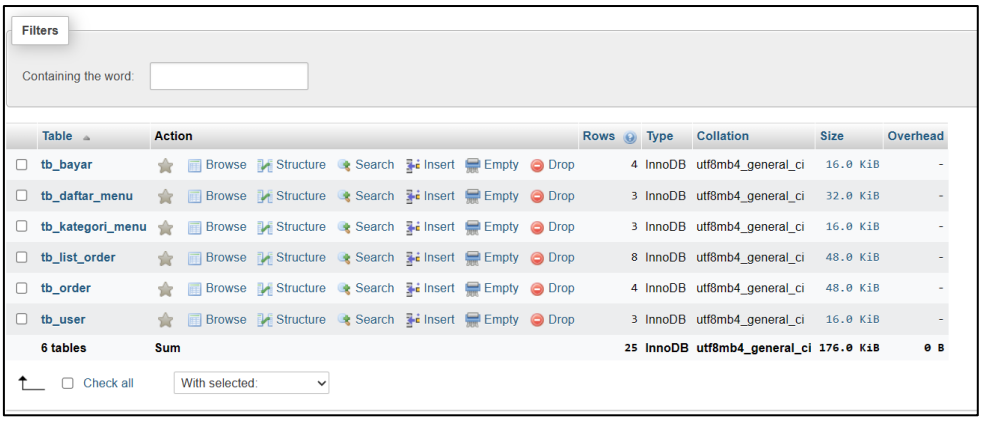

Figure 5 Database

3.2 Testing

This testing process is carried out to test the feasibility of the system and minimize the occurrence of failures in the system. The following is a table of test results on the system created.

3.1.2 Menu Feature Testing

Testing on the menu feature is done to test the button command whether it can run according to its function or not. And the table of test results on the menu feature can be seen in table 1.

Table 1 Menu Feature Testing

Incoming Data	Expected	Observation	Conclusion
Menu list input	Data is successfully saved when pressing the save change button on the add menu form.	Button input can perform its function well.	Accepted
Edit menu list	Data is successfully edited after pressing the save button on the edit menu form.	The save button can perform its function properly.	Accepted
Delete menu list	Data is successfully deleted after pressing the delete button.	The delete button can perform its function properly.	Accepted
View Menu Details	Successfully display the entire data when pressing the view button.	The view button can perform its function properly.	Accepted

3.1.3 Order Feature Testing

Testing on the menu feature is done to test the button command whether it can run according to its function or not. The table of test results on the order feature can be seen in Table 2.

Table 2 Order feature testing

Incoming Data	Expected	Observation	Conclusion
Order Input	Data is successfully saved when pressing the save change button on the add order form.	Button input can perform its function well	Accepted
Edit order	Data is successfully edited after pressing the save button on the edit order form.	The save button can perform its function well.	Accepted
Delete menu list	Data is successfully deleted after pressing the delete button.	The delete button can perform its function well.	Accepted
View Menu Details	Successfully display the entire data when pressing the view button.	The view button can perform its function well.	Accepted

3.2.3 User Feature Testing

Testing on the user feature is done to test the button command whether it can run according to its function or not. The table of test results on user features can be seen in Table 3.

Table 3 User feature testing

Incoming Data	Expected	Observation	Conclusion
Input user	Data is successfully saved when pressing the save change button on the add menu form.	Button input can perform its function properly.	Accepted
Edit user	Data is successfully edited after pressing the save button on the edit menu form.	The save button can perform its function well.	Accepted
Delete user	Data is successfully deleted after pressing the delete button.	The delete button can perform its function well.	Accepted
View user	Successfully displaying overall data when pressing the view button.	The view button can perform its function properly.	Accepted

Conclusions

The conclusion that can be drawn from the research on the implementation of a web-based food ordering self-order application system that has been carried out is that the creation of a web-based food and beverage ordering self-order application system can make it easier for customers and employees to carry out the ordering process and order data collection. The results of trials conducted on a web-based food ordering self-order application system can run well. How ever there is still a need for development to make users more comfortable, such as the need to change the UI display so that it can look more attractive and make users comfortable in using this system.

Acknowledgments

The author would like to thank the University of Yogyakarta especially the Informatics study program for supporting this project.

References

[1] R. H. Saputra, J. Raya, T. No, K. Gedong, P. Rebo, and J. Timur, "Sistem Informasi Penjualan Berkonsep Pemesanan Mandiri Rm Perang Kerang Depok," *Jurnal Riset dan Aplikasi Mahasiswa Informatika*, vol. 2, no. 3, pp. 405–412, 2021.

[2] T. B. Kurniawan, "Perancangan Sistem Aplikasi Pemesanan Makanan Dan Minuman Pada Cafetaria No Caffe Di Tanjung Balai Karimun Menggunakan Bahasa Pemograman Php Dan Mysql," *TIKAR*, vol. 1, no. 2, 2020.

[3] F. Rahman and Santoso, "Aplikasi Pemesanan Undangan Online," Jl. A Yani Km 6 Pelaihari Tanah Laut Kalimantan Selatan, Nov. 2015. Accessed: Dec. 11, 2022. [Online]. Available: https://jsi.politala.ac.id/index.php/JSI/article/download/30/29

[4] E. Aprilla, "Design And Implementation Of Food Order System And Sales Promotion Program In Mie Pangsit Ayam Sudi 189," *2020*.

[5] Y. P. Aldi and M. I. Wahyuddin, “Sistem Informasi Penjualan Makanan Menggunakan Metode User Centered Design Berbasis Web,” *Jurnal Media Informatika Budidarma*, vol. 6, no. 2, p. 786, Apr. 2022, doi: 10.30865/mib.v6i2.3568.

[6] B. Kurniawan and M. Romzi, “Perancangan Sistem Pemesanan Makanan Berbasis Web menggunakan PHP dan MySQL,” Baturaja UNMAHA; Jalan A. Yani. No. 267 A. Baturaja 32113 , 2021. [Online]. Available: https://bitlabs.id/blog/rad-adalah/

[7] A. Oktarini, S. ; Ari, and A. ; Sunarti, *Web Programming*, 1st ed. Jambusari 7A Yogyakarta 55283: 2019, 2019.

[8] H. H. Batubara, “Pembelajaran berbasis Web dengan Moodle versi 3.4,” *2018*, 2018, doi: 10.13140/RG.2.2.20230.88643.

[9] A. S. Pradisthi and J. Aryanto, “Monitoring and Automation System for Bird Feeding and Drinking Based on Internet of Things Using ESP32,” *Advance Sustainable Science Engineering and Technology*, vol. 5, no. 3, p. 0230308, Oct. 2023, doi: 10.26877/asset.v5i3.17182.

[10] S. Rejeki, K. Fadhilla Ramdhania, and K. Hantoro, “Sistem Informasi Pemesanan Menu Makanan Berbasis Web,” 2021.

[11] A. Julianti and A. Mubarok, “Sistem Informasi Pemesanan Makanan Dan Minuman Berbasis Web Pada Café Coffee Holidays,” 2021. [Online]. Available: http://eprosiding.ars.ac.id/index.php/psi

[12] L. Ananda Hadist and Himawan, “Sistem Pemesanan Makanan Warung Makan Osaka Ramen Berbasis Website,” Asem Dua No. 22, Kel. Cipete Selatan, Kec. Cilandak Jakarta Selatan, 2021. Accessed: Dec. 11, 2022. [Online]. Available: https://maklumatika.i-tech.ac.id/index.php/maklumatika/article/download/120/125

[13] A. D. O. Putri, F. Fauziah, and A. Iskandar, “Algoritma Content-Based Filtering Dan Algoritma Multilevel Feedback Queue Pada Proses Pemesanan Makanan Berbasis Web,” *JIPI (Jurnal Ilmiah Penelitian dan Pembelajaran Informatika)*, vol. 8, no. 1, pp. 266–280, Feb. 2023, doi: 10.29100/jipi.v8i1.3426.

[14] E. D. Handoyo, S. Santoso, and D. J. Surjawan, “Pengembangan Aplikasi Mobile Pemesanan dan Pembayaran Makanan Berbasis Cloud Storage,” *Jurnal Teknik Informatika dan Sistem Informasi*, vol. 8, no. 1, Apr. 2022, doi: 10.28932/jutisi.v8i1.4393.

[15] D. R. Marbun, “Perancangan Sistem Informasi Pemesanan Menu Makanan di Twin Seafood & Resto Rantauprapat Berbasis Web,” vol. 9, no. 2, 2021.

[16] D. Indriani, A. Saeful, A. Taryanto, and P. Piksi Ganesha Bandung, “Web Di Foodcourt Rskia Bandung”.

[17] H. Setiawan, W. Rahayu, and I. Kurniawan, “Perancangan Aplikasi Pemesanan Makanan Dan Minuman Pada Rumah Makan Cepat Saji D’besto,” *JRAMI (Jurnal Riset dan Aplikasi Mahasiswa Informatika*, 2020.

[18] M. Afiksih, “Web-Based Food Ordering Application Design at the PT. Pegadaian Regional Office I Medan,” *JOURNAL OF COMPUTER SCIENCE AND INFORMATICS ENGINEERING (CoSIE)*, vol. 01, no. 2, pp. 66–77, 2022, [Online]. Available: http://creativecommons.org/licenses/by-sa/4.0/

[19] Z. R. Saputri *et al.*, “Rancang Bangun Sistem Informasi Pemesanan Makanan Berbasis Web Pada Cafe Surabiku.”

[20] M. W. Magister, A. Pendidikan, U. Kristen, and S. Wacana, “Pendekatan Penelitian Pendidikan: Metode Penelitian Kualitatif, Metode Penelitian Kuantitatif dan Metode Penelitian Kombinasi (Mixed Method)”.

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Implementation Of A Web-Based Chatbot Using Machine Learning For Question And Answer Services In Universities

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Abstract. Advances in communication technology in line with information technology, Chatbot is an innovation that combines communication technology and information technology, is an application that can communicate with humans like a virtual assistant who can respond and answer every question asked. A university must already have a website that can be accessed by the general public so that information about the college can be accessed by everyone anywhere and anytime. To make it easier to get information on the website, chatbots can be the solution because most prospective students and students who are on the campus feel reluctant to browse further into the website that has been provided and usually only open the main homepage page of the website. Parents of students also find it difficult to find out what is on campus if a lot of information is provided in certain tabs of the website. In this study, I utilized Chatbot technology which is a Machine Learning that can process every text that inputted then analyze it and conduct machine training using the Neural Network algorithms that have been provided. This research uses a case study methodology, with Yogyakarta University of Technology as the subject, to develop a chatbot website that incorporates machine learning to facilitate the processing of user input questions.

Keywords: Chatbot, Machine Learning, Question and Answer, Neural Network, Python.

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Introduction

Educational institutions have an important role in the development of the nation's children, especially in terms of science and personality, especially in a lecture institution which requires students (students) to be active, creative, and have critical thinking. A university must already have a website that can be accessed by the public so that information about the university can be accessed by everyone anywhere and anytime. To support these things, the institution also needs to have an adequate system in terms of services, especially the availability of information services that can be accessed easily anytime anywhere such as Chatbot. Chatbot is a simple system to facilitate conversations by using "pattern matching rules" to have conversations with users, but chatbots have limited language understanding capabilities [1]. In its application, chatbots can be built independently or use chat applications that provide services to

develop chatbots [2]. Chatbot in conducting conversations (understanding and answering chat) requires certain methods commonly referred to as applying natural language processing methods.

For several journal reviews related to the creation of chatbots which are the basis for this research, there is a research study by Agung[3]. This research uses the AutoResponder Application for WhatsApp and WhatAuto - Reply App to create its chatbot and uses Google Sheets for its database so that the chatbot can only be used for the WhatsApp application. The next research is by Teddy Wijaya[4] . The research discusses creating a Chatbot on a web platform using the PHP programming language and using the MySQL database to create it, in the database there are several keywords and bot replays that the system uses to automatically reply to chats to users. The next research is by Ahmad Cucus[5]. This research uses NLP (Natural Language Processing) for text processing and also uses a database to store data, the implementation of the program is carried out on the Android Platform. From several journals mentioned, chatbots that are made vary in type, some of which use the WhatsApp platform, Website, and Android, the features provided are also different, such as those using WhatsApp can only be used by users who are only registered in the WhatsApp application and only provide a choice of questions that have been provided, they cannot type their imputed questions.

This research implements the Python programming language is used by novice programmers as well as by highly skilled professional developers. It is being used in academia, at web companies, in large corporations, and in financial institutions[6]. The Chatbot that will be created has several features such as machine learning to process the questions that have been given and the user does not need to register to be able to access the chatbot created because the chatbot will be on the UTY website that is already operating which can be accessed by everyone. There are many methodologies related to the generation of chatbots ranging from simple pattern matching to complex neural networks and other heuristic solutions[7], And Machine learning can substantially reduce the computational costs and shorten the development cycle [8]. Based on these problems, the authors are interested in taking the title "Implementation of Web-Based Chatbot Using Machine Learning for Question and Answer Services in Higher Education". The application of this Chatbot system uses Yogyakarta University of Technology for a case study[9] which is expected to be able to overcome the problems that occur by utilizing machine learning that has been made.

Methods

The methodology of this research is shown in Figure 1, which describes the flow of the research. It starts with the identification of Problem, Data Collection, Designing System, Implementation System, Testing System, and conclusion.

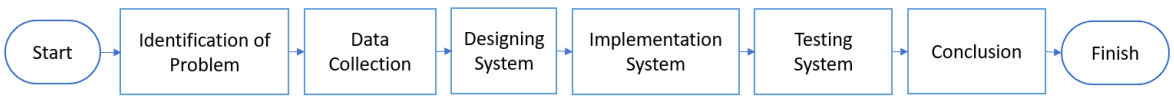

Figure 1 Research Methodology

2.1 Identification of Problem

The analysis of the system that runs at the University of Technology Yogyakarta can be seen in Figure 2.

Figure 2 Current System

Figure 3 Proposed System

From Figure 2 it can be concluded that when students or parents of students have questions about anything related to UTY there are 2 ways. The first way is that parents or students can enter the UTY SIA web and search through all the tabs to get the information they want. The second way is to contact the UTY admin and ask questions about the desired information but have to wait for the admin to answer first to get the information. The analysis of the proposed system in the study can be seen in Figure 3 which can be concluded when parents or students want to find out the desired information about UTY, they only need to enter the UTY website after that ask questions with the chatbot that has been provided in real-time and get answers to the questions asked so that parents or students do not need to search thoroughly on the UTY website or wait for the admin to answer the question.

This research also has problem limitations that include the following:

1. Making this Chatbot uses data available on the UTY website[10] page and the UTY PMB website[11] provided by the University of Technology Yogyakarta.
2. The data that has been obtained is entered into a JSON format file.
3. System design is done using the Python programming language.
4. Using the Neural Network Algorithm to process incoming conversations and send answers that match the User's questions.

2.2 Data Collection

This stage involves collecting the data needed to create a Chatbot for prospective new students, parents or guardians, and students of Yogyakarta University of Technology. At this stage, problems related to the registration of prospective new students are sought and solutions are formulated to overcome them. This research collected data directly through interviews with students to obtain data relevant to the purpose of this research. In addition, we also developed a questionnaire that will be distributed to each respondent to record their responses, which will be the main source of data in this study.

The data used in this study was also sourced from the official website of Yogyakarta University of Technology, which can be accessed through the URLs UTY website[10] and UTY registration website[11]. The accuracy of this data was also ensured by consulting with staff and lecturers working at the Yogyakarta Technological University. The data collection process is carried out on an ongoing basis starting from November 2022 to June 2023. Data was collected by accessing and recording information from the websites into a Word document. The data was then used to formulate questions and corresponding answers. Furthermore, this question-and-answer data is compiled in JSON format[12].

2.3 System design

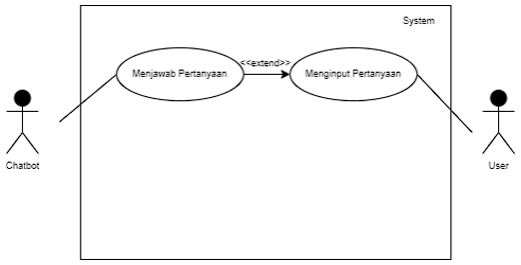

Figure 4 Use Case Diagram.

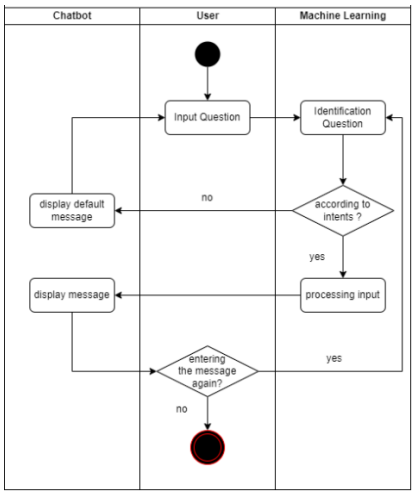

Figure 5 Activity Diagram

The detailed design stage is used to determine the system to be built including making use case diagrams, activity diagrams, and flowcharts. Figure 4 shows the use case diagram[13] of this system. Activity Diagram[14] describes the workflow or activity of a system business process or menu in the software. Figure 5 shows the machine learning activity diagram implemented on the website. The system flowchart[15] is built to be able to provide a complete picture of the existing data requirements. The flowchart of how machine learning is implemented on the website is shown in Figure 6.

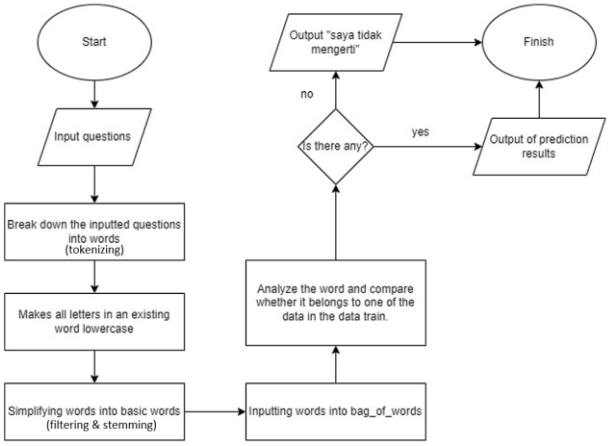

Figure 6 Flowchart.

2.4 Implementation Phase

The development of this website[16] adopts Python programming language for machine learning with neural network algorithm[17] and combines HTML[18], CSS, and JavaScript[19] to connect machine learning with the website being created. It also uses several libraries available in Python, such as Sastrawi[20], Flask[21], NumPy, etc. The detailed implementation of Chatbot can be divided into several stages, namely the preprocessing stage, the transformation of existing data into data.JSON, the data training stage, the "bag of words" model building stage, and the final stage of full connection.

1. Text preprocessing

   The stage of text preprocessing[22] is the stage where the system selects the data that is processed in

each document. The preprocessing process includes 3 stages, tokenizing, filtering, and stemming.

2. Transformation of existing data into data.JSON
   Data transformation into data.JSON is needed for the system to be able to read each question pattern that appears along with the target answer. The way to transform data into data.JSON is by separating each word in the data into several parts, namely:
   a. Tags (category) is a knowledge or category that becomes a reference for the system in determining the response.
   b. A Pattern is a series of letters that are expected to match or match one or even more with user input.
   c. Responses (output) are the results of answers that will be issued based on index tags and patterns determined by the system.
3. Data training stage
   After the data is collected, the system tests the data to get a good and satisfactory level of output accuracy. The data training[23] steps are as follows:
   a. Transform the pattern form in the data.JSON into matrix form[24].
   b. Flattering or inserting each row of the matrix into the input layer nodes will signal to the hidden layer.
   c. Assessing the output after completing the calculation from the input layer to the hidden layer which will be given each weight by the system.
4. "bag of words" model building stage
   At this stage, the bag of words value is transformed by transforming the input text from the user into a binary number[25].
5. Full connection
   After getting a binary value from the input text, the binary value is entered into the input layer which will signal the hidden layer of the neural network architecture.

2.5 Testing phase

The performance measurement of the Chatbot application made in this study is based on the results of the confusion matrix by calculating the accuracy, precision, and recall levels.

1. Accuracy
   Accuracy[26] is the ratio of correct predictions (positive and negative) to the overall data. Calculation of accuracy using Equation.

$$Akurasi = \frac{TP+TN}{TP+TN+FP+FN} * 100\%$$

2. Precision
   Precision[27] is the ratio of positive correct predictions compared to the overall results that are predicted to be positive. Calculation of precision using Equation.

$$Presisi = \frac{TP}{FP+TP} * 100\%$$

3. Recall
   Recall[27] is the ratio of true positive predictions compared to the overall true positive data. Recall is calculated using Equation .

$$Recall = \frac{TP}{FN+TP} * 100\%$$

Results and Discussion

3.1 Results

The results of the implementation of the design of the Chatbot website for questions and answers about the Yogyakarta University of Technology are the main page for conducting these question-and-

answer activities. By using machine learning to answer questions inputted by users, the answers given will be given automatically and output that matches the question if the question is in the existing system, otherwise the default answer will be provided. The chat page has an initial appearance that can be seen in Figure 7 it shows if the chatbot button is clicked it will display a conversation window that will be used to conduct questions and answers.

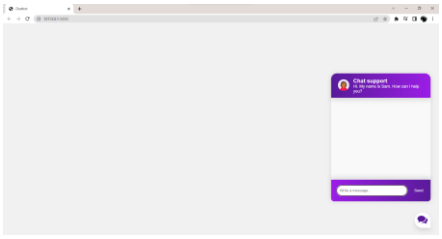

Figure 7 Chatbot Window

In the text preprocessing stage, the first step is to perform case folding. In this research, case folding is used to convert all letters in the document into lowercase letters. The next step is tokenizing, which is the process of separating the input string based on the words that make it up. An example of the tokenizing result can be seen in Figure 8.

Figure 8 Tokenizing

Figure 9 Filtering

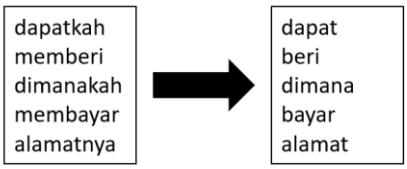

Figure 10 Stemming.

The next stage in text preprocessing is filtering. At this stage, a stop list is used to remove less important words or a wordlist to keep relevant words. An example of filtering can be seen in Figure 9. Stemming is another important stage needed to reduce the number of different indices in a document, as well as to group words that have similar roots and meanings, despite having different forms. Figure 10 shows an example of the stemming result. After data collection is complete, the system performs data testing to achieve an optimal and satisfactory level of output accuracy. Table 1 is an example of the training data used in this study.

Table 1 Sample Data

tag	patterns			responses
Salam	Hai	Selamat pagi	Hallo	Ada yang bisa dibantu ?
Alamat	Dimana Alamat kampus?	Kampus dimana?	Kampus di dekat mana?	Alamat kampus ada di …
Selesai	Terima kasih	thanks	bye	Sampai jumpa kembali

Table 1 is an example of data in JSON format that will be used in the data training process. This data training is done so that the machine can recognize patterns or patterns of user input text, which will later be used to help answer questions from users in the Chatbot system. The steps in data training are as follows:

1. Converting data patterns in JSON format into matrix form, as shown in Figure 11.
2. Perform flattening or take each row of the matrix and put it into the input layer which will send signals to the hidden layer. An example of the flattening result can be seen in Figure 12.
3. The output value of the training data can be seen in Figure 14.

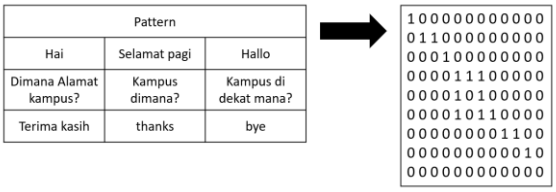

Figure 11 Converting data into a matrix

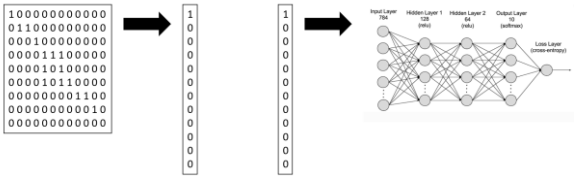

Figure 12 Filtering result

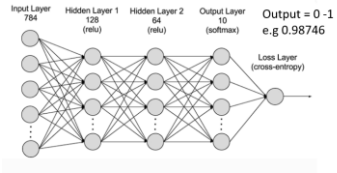

Figure 13 Training data output

The values in the hidden layer cannot be entered directly by the user as they are automatically determined by the system and used as the accuracy level based on existing patterns. The next step is the transformation of the "bag of words" value. An example of the results of the "bag of words" value transformation can be seen in Figure 14.

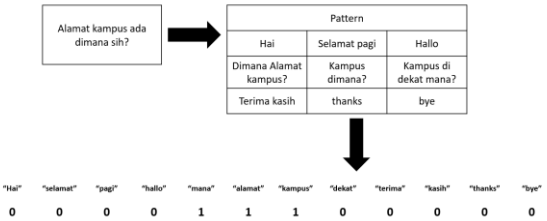

Figure 14 Transformation result of "Bag of Words" value.

After obtaining the binary value of the input text, the next stage is the fully connected stage, where this binary value is input into the input layer which will then send signals to the hidden layer in the neural network architecture as seen in Figure 15. The output value is determined by the system after performing calculations from the input layer to the hidden layer so that the Chatbot system can determine the right answer. After getting the output values of the various patterns, the next step is to take the highest value to respond to the question, as shown in Figure 16.

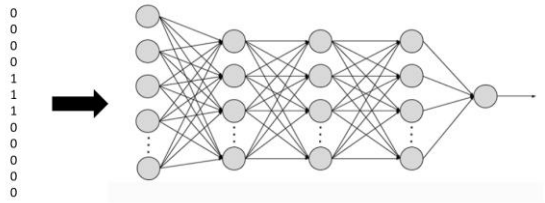

Figure 15 Full connected phase

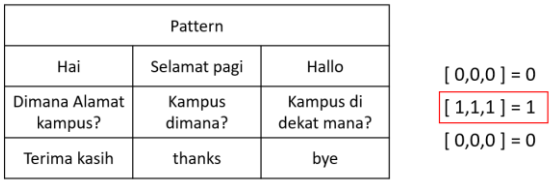

Figure 16 Example of response determination

3.2 Testing

The test will perform a series of inputting questions that follow different patterns, writing with typos, and asking questions that do not have available data. The purpose of this test is to examine the chatbot's capabilities in the face of diverse input variations. This test aims to evaluate the extent to which the chatbot can provide relevant and useful responses to the user, regardless of constraints such as typos and questions without available data.

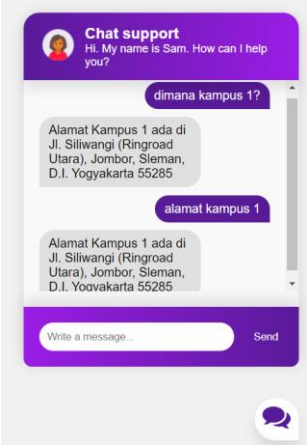

Figure 18 Testing Chatbot 1

Figure 19 Testing Chatbot 2

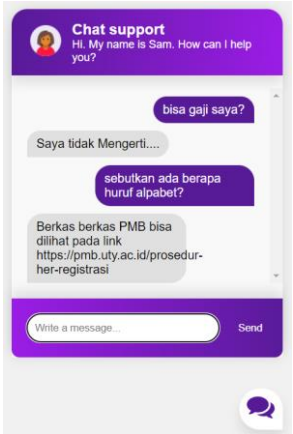

Figure 20 Testing Chatbot 3

From Figure 18, the chatbot can provide answers that match the question about campus address 1, even though there are several different question patterns. This shows that the chatbot has the flexibility to understand variations of questions related to campus address 1, so that users can receive relevant answers to the questions asked. From Figure 19, it can be concluded that even though there are several words with typos, the chatbot is still able to provide answers to user expectations. This shows that the chatbot can recognize and understand the intent of the message received, even when there are writing errors. From Figure 20, when there is a question, whose pattern does not exist in the data prepared, the chatbot will answer I don't understand. Meanwhile, if the question deviates but there is a slight allusion to the pattern chatbot gives a random or inappropriate answer. From the tests that ware carried out with the patterns described above, this study conducted 50 trials to calculate the accuracy, precision, and recall of the chatbot that has been made. After conducting the test, the results can be seen in Table 2.

Table 2 Confusion matrix value

	Positive	Negative
Positive	40	4
Negative	2	4

Performance measurement based on confusion matrix results in Table 2 by calculating the level of accuracy, precision, and recall as follows:

$$Accuracy = \frac{40+4}{40+4+4+2} = \frac{44}{50} = 88\%$$

$$Precicion = \frac{40}{40+2} = \frac{40}{42} = 95\%$$

$$Recall = \frac{40}{40+4} = \frac{40}{44} = 91\%$$

Based on the results of the chatbot performance calculation, it has an accuracy of 88%, precision of 95%, and recall of 91%. This test will perform a series of inputting questions that follow different patterns, writing with typos, and asking questions that do not have available data. The purpose of this test is to examine the chatbot's capabilities in dealing with a wide variety of inputs. This test aims to evaluate the extent to which the chatbot can provide relevant and useful responses to the user, regardless of constraints such as typos and questions without available data.

Conclusions

Based on the results of testing the system that has been implemented in the research on Web-Based Chatbot with Machine Learning Utilization for Question-and-Answer Services in Higher Education, the author concludes several important points.

First, the developed system can effectively overcome the problems faced, where this system successfully responds to chats from users automatically. In other words, Chatbot can provide satisfactory responses to users. Secondly, the system has also proven to be able to provide correct and accurate answers when faced with questions that match the patterns that have been documented in the data, without experiencing errors. This shows the system's ability to understand and respond appropriately to user questions. In addition, the results of this study also indicate great potential in the development of machine learning based Chatbot to improve question and answer services in higher education, especially at Yogyakarta University of Technology.

As a student and lecturer, the author has great hopes for the future, which is that the implementation of the Chatbot website that has been developed can be officially integrated into the website of Universitas Technology Yogyakarta (UTY). The authors believes that this will bring many significant benefits, especially for new students and parents, to provide easier and faster access to the various information available on the UTY website.

With this Chatbot, it is hoped that prospective students and parents will feel more comfortable and efficient in finding the information they need, and this will enhance their experience in undergoing education at UTY.

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References

[1] A. Augello, G. Pilato, G. Vassallo, and S. Gaglio, “Chatbots as Interface to Ontologies,” vol. 260, pp. 285–299, 2014.

[2] F. Ishlakhuddin, “Chatbot Berbasis Ontologi untuk Mendukung Pemantauan Kinerja dan Keamanan Server dengan Rule-Base,” 2020.

[3] Agung Siswanto Bayu Aji, “Membangun Chatbot Layanan Helpdesk Perpajakan Kpp Pratama Jakarta Setiabudi Satu,” *Sebatik*, vol. 26, no. 1, pp. 194–201, Jun. 2022, doi: 10.46984/sebatik.v26i1.1916.

[4] Teddy Wijaya, Muhammad Rusli, Erwin Syah Rany, and Harfebi Fryonanda, “Membangun Aplikasi Chatbot Berbasis Web Pada CV. Unomax Indonesia,” 2019.

[5] Ahmad Cucus, Robby Yuli Endra, and Tiya Naralita, “Chatter bot untuk konsultasi akademik di perguruan Tinggi,” *Jurnal Sistem Informasi dan Telematika*, vol. 10, no. 1, 2019.

[6] A. Menura Mukhiddinovna, “PROGRAMMING LANGUAGE PYTHON METHODOLOGY FOR CREATING AND USING DIDACTIC MATERIALS FOR STUDENTS,” 2022.

[7] A. Trivedi and Z. Thakkar, “Chatbot generation and integration: A review,” 2019. [Online]. Available: www.IJARIIT.com

[8] J. Wei *et al.*, “Machine learning in materials science,” *InfoMat*, vol. 1, no. 3. Blackwell Publishing Ltd, pp. 338–358, Sep. 01, 2019. doi: 10.1002/inf2.12028.

[9] D. Assyakurrohim, D. Ikhram, R. A. Sirodj, and M. W. Afgani, “Metode Studi Kasus dalam Penelitian Kualitatif,” *Jurnal Pendidikan Sains dan Komputer*, vol. 3, no. 01, pp. 1–9, Dec. 2022, doi: 10.47709/jpsk.v3i01.1951.

[10] Universitas Teknologi Yogyakarta, “UTY Homepage,” 2023. https://uty.ac.id/ (accessed Sep. 20, 2023).

[11] Universitas Teknologi Yogyakarta, “PMB UTY,” 2023. https://pmb.uty.ac.id/ (accessed Sep. 20, 2023).

[12] B. Cecconi, C. K. Louis, X. Bonnin, A. Loh, and M. B. Taylor, “Time-frequency catalogue: JSON implementation and python library,” *Frontiers in Astronomy and Space Sciences*, vol. 9, Feb. 2023, doi: 10.3389/fspas.2022.1049677.
[13] O. Filipova and O. Nikiforova, “Definition of the Criteria for Layout of the UML Use Case Diagrams,” *Applied Computer Systems*, vol. 24, no. 1, pp. 75–81, May 2019, doi: 10.2478/acss-2019-0010.
[14] J. Lang and D. Spišák, “Activity Diagram as an Orientation Catalyst within Source Code,” 2021.
[15] J. Li, “Using Flowchart to Help Students Learn Basic Circuit Theories Quickly,” *Sustainability (Switzerland)*, vol. 14, no. 12, Jun. 2022, doi: 10.3390/su14127516.
[16] R. R. Rerung, M. Fauzan, and H. Hermawan, “Website Quality Measurement of Higher Education Services Institution Region IV Using Webqual 4.0 Method,” *International Journal of Advances in Data and Information Systems*, vol. 1, no. 2, pp. 89–102, May 2020, doi: 10.25008/ijadis.v1i2.185.
[17] Z. Li, F. Liu, W. Yang, S. Peng, and J. Zhou, “A survey of convolutional neural networks: analysis, applications, and prospects,” *IEEE Trans Neural Netw Learn Syst*, 2021.
[18] R. Tabarés, “HTML5 and the evolution of HTML; tracing the origins of digital platforms,” *Technol Soc*, vol. 65, p. 101529, 2021, doi: https://doi.org/10.1016/j.techsoc.2021.101529.
[19] A. Wirfs-Brock and B. Eich, “JavaScript: The first 20 years,” *Proceedings of the ACM on Programming Languages*, vol. 4, no. HOPL, Jun. 2020, doi: 10.1145/3386327.
[20] M. A. Rosid, A. S. Fitrani, I. R. I. Astutik, N. I. Mulloh, and H. A. Gozali, “Improving Text Preprocessing for Student Complaint Document Classification Using Sastrawi,” in *IOP Conference Series: Materials Science and Engineering*, Institute of Physics Publishing, Jul. 2020. doi: 10.1088/1757-899X/874/1/012017.
[21] V. Rama Vyshnavi and A. Malik, “Efficient Way of Web Development Using Python and Flask,” 2019.
[22] T. A. Koleck, C. Dreisbach, P. E. Bourne, and S. Bakken, “Natural language processing of symptoms documented in free-text narratives of electronic health records: a systematic review,” *Journal of the American Medical Informatics Association*, vol. 26, no. 4, pp. 364–379, Apr. 2019, doi: 10.1093/jamia/ocy173.
[23] A. Rajšp and I. Fister, “A Systematic Literature Review of Intelligent Data Analysis Methods for Smart Sport Training,” 2020, doi: 10.3390/appxx010005.
[24] C. R. Harris *et al.*, “Array programming with NumPy,” *Nature*, vol. 585, no. 7825. Nature Research, pp. 357–362, Sep. 17, 2020. doi: 10.1038/s41586-020-2649-2.
[25] Z. Huang *et al.*, “Binary tree-inspired digital dendrimer,” *Nat Commun*, vol. 10, no. 1, Dec. 2019, doi: 10.1038/s41467-019-09957-6.
[26] D. Chicco, N. Tötsch, and G. Jurman, “The matthews correlation coefficient (Mcc) is more reliable than balanced accuracy, bookmaker informedness, and markedness in two-class confusion matrix evaluation,” *BioData Min*, vol. 14, pp. 1–22, 2021, doi: 10.1186/s13040-021-00244-z.
[27] M. Heydarian, T. E. Doyle, and R. Samavi, “MLCM: Multi-Label Confusion Matrix,” *IEEE Access*, vol. 10, pp. 19083–19095, 2022, doi: 10.1109/ACCESS.2022.3151048.

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A Good Result for Blowfish Image Encryption Based on Stepic

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Abstract. Information security is important in the era of evolving communications. Security methods are needed to protect data. Strong cryptographic algorithms, such as Blowfish, developed by Bruce Schneier in 1993, offer fast and reliable encryption. Blowfish uses 64 bit blocks and key lengths between 32 and 443 bits. This algorithm is famous for its robustness and encryption speed, with a Feistel Network structure and 16 rounds. This research implements Blowfish with Python and integrates it with steganography to insert secret data in digital images. Evaluation involves metrics such as Mean Squared Error (MSE), Peak-Signal-to-Noise Ratio (PSNR), Average Visibility (AVA), Uniform Average Change Intensity (UACI), and Percentage Pixel Change Value (NPCR) to measure quality and reliability encryption and decryption process by Blowfish.

Keywords: Blowfish, MSE, AVA, PSNR, NPCR, UACI

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1. Introduction

Information security plays a very important role in the current era of communication media development. In an era where data moves rapidly over digital networks, the challenge of protecting data confidentiality and integrity is increasingly complex. Security threats, such as hacking and theft of confidential information, are becoming increasingly serious. In fact, several high-profile security incidents have revealed inherent vulnerabilities in existing systems and protocols. Therefore, alternative security methods are needed to maintain data confidentiality and integrity [1]. Strong cryptographic algorithms are needed so that only authorized parties can access and understand the information [2]. One cryptographic algorithm that has been widely used and proven to be effective is Blowfish [3].

Blowfish was developed in 1993 by Bruce Schneier as an open-source encryption alternative that does not require a license. Its advantages in terms of compatibility and efficiency have been widely recognized, making it a fast and reliable encryption algorithm [4]. Blowfish is a cryptographic block cipher with a fixed block length of 64 bits and a key length that can vary between 32 to 443 bits [5]. Apart from being renowned for its resistance to attacks, Blowfish also stands out for its optimal speed of data encryption and decryption, both on hardware and various software platforms [6].

In this research, we aim to implement the Blowfish algorithm using the Python programming language. In addition, we will integrate the Blowfish algorithm with steganography, a technique that

allows us to embed secret data into digital images. We will also evaluate this research by measuring the quality and reliability of the encryption and decryption process using the Blowfish algorithm. Some of the evaluation metrics that will be used include Mean Squared Error (MSE), Peak-Signal-to-Noise Ratio (PSNR), Average Visibility (AVA), Uniform Average Change Intensity (UACI), and Percentage Pixel Change Value (NPCR) [7].

2. Methods

2.1. Blowfish Algorithm

Blowfish is a block cipher algorithm that uses blocks of the same 64-bit size during the encryption and decryption process. In this process, the message to be encrypted is divided into blocks of k bits of a fixed size, namely 64-bit [5]. The encryption process in the blowfish algorithm is carried out on data blocks with a fixed length of 8 bytes, although the key length can vary. Addition of bits (padding) will be done if there is a message size that is not a multiple of 8 bytes, so that the size of each block is the same so that with a uniform size Blowfish can encrypt data effectively [7].

Blowfish is a block cipher algorithm that has two main processes, namely key expansion and data encryption. In the key expansion process, the initial key with a maximum length of 448 bits is converted into several subkeys which are stored in an array with a total size of 4168 bytes. Meanwhile, the data encryption process consists of 16 iterations of a simple function that operates the data repeatedly with the resulting sub-keys.

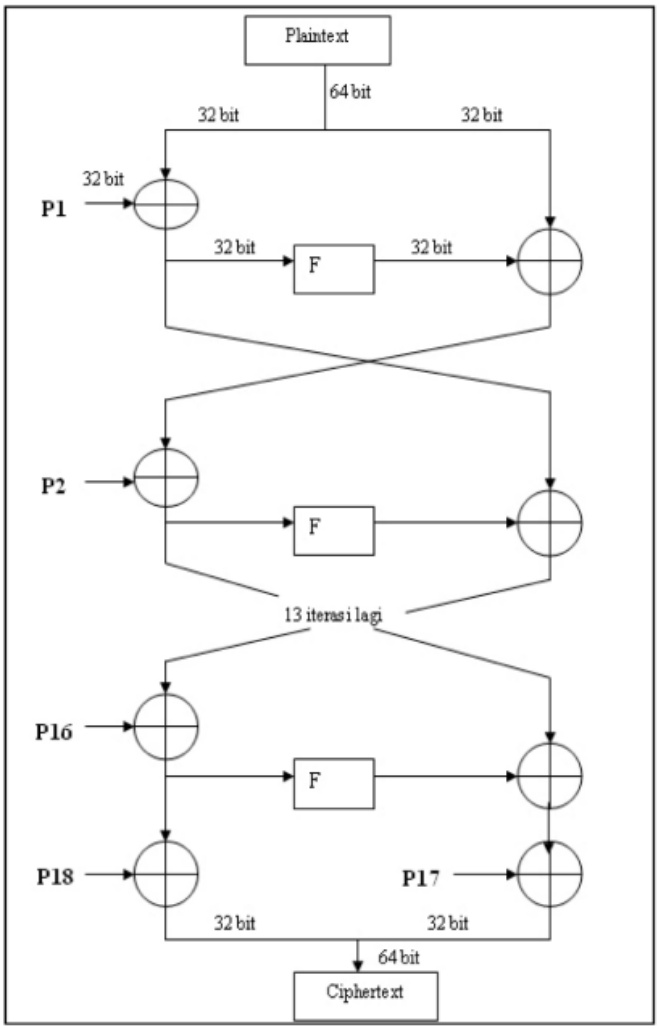

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Figure 3. Blowfish Scheme

In the key expansion stage, the initial key with a maximum length of 448 bits will be converted into several subkeys. These subkeys will be stored in an array with a total size of approximately 4168 bytes. The data encryption process itself consists of 16 iterations of a simple function that operates on the data with the resulting subkeys.

The Blowfish encryption process begins by dividing the data to be encrypted (X) into two parts, namely XL and XR, each consisting of 32 bits [8]. Next, a series of steps are carried out as follows:

1. Iterate 16 times, starting from i = 1 to 16.
2. At each iteration, XL is XORed with the Pi subkey. Then XR is XORed with the result of the function F(XL) and XORed with the previous XR.
3. After that, the XL and XR values are swapped.
4. After the 16th iteration, a final exchange is carried out between XL and XR.
5. Next, XR is XORed with subkey P17, and XL is XORed with subkey P18.
6. Finally, XL and XR are combined again to get the ciphertext.

This process uses addition and XOR operations on 32-bit variables. With these steps, data can be encrypted using the Blowfish algorithm

2.2. Data Embedding with Steganography

In this research, steganography is used for the purpose of hiding the existence of important information by inserting messages into objects or media that look harmless. This aims to make this information difficult for unauthorized third parties to detect, so that the data can be better protected. By using steganography, secret messages can be effectively hidden in objects or media that do not appear suspicious [9].

In the steganography process, two files are needed, namely the container file and the important data [10]. Container files are media where important data will be inserted. The types of media that can be used as container files vary, such as text, images, audio, or video. In this study, specifically, we use images as container files. By using an image as a container file, important data will be inserted into the pixels of the image without being visible, so that the desired information can be hidden properly.

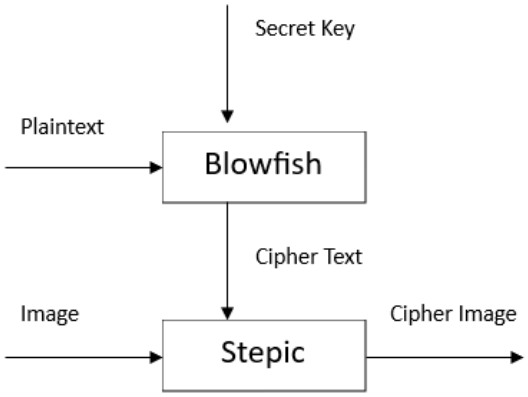


Figure 2. Encryption Scheme

This process involves implementing the Blowfish algorithm described previously. Once the ciphertext is encrypted, it is saved and then inserted into an image selected by the user. This hiding process aims to protect data by inserting it invisible in the image.

3. Results and Discussion

In this stage, testing is carried out on the system, which looks at the quality of the storage media, whether it experiences changes during the data insertion process. We here use 3 media containers in the form of images.

Table 1. List of Dataset

Container Media	File Name
	Image1
	Image2
	Image3

The image quality resulting from this process can be measured using MSE, AVA and PSNR. MSE is a measure of the average square error between the original image and the image containing a hidden message. PSNR is the comparison of pixel values between the image (original and stego image) produced [9]. A cryptographic algorithm will fulfill the avalanche effect if every change in one input bit causes half of all output bits to change [11].

The formula for calculating MSE is as follows: Information :

$$MSE_{AVG} = \frac{MSE_R + MSE_B + MSE_G}{X.Y} \quad [12]$$

Information :
MSE : Mean Square Error Value of the Image
XY : Dimensions of the image

The formula for calculating PSNR is as follows:

$$PSNR = 20 * \log 10 \left(\frac{255}{\sqrt{MSE}}\right) \quad [10]$$

Information :
PSNR:Image PSNR value
MSE : MSE value

After calculating the MSE and PSNR, it was found that the MSE did not change much, the highest PSNR value was 86.54 and the highest AVA value was 35.85. And also obtained an average MSE value of 0.00, Ava 34.87 and meanwhile the average PSNR value obtained was 79.22. From these results, a low MSE value means the better the quality of data insertion. On the other hand, a high PSNR value indicates that the resulting image quality is getting better. We also evaluated the image using the 3 existing images. Testing uses UACI and NCPCR where we try to encrypt images with different message length variants.

Table 2. MSE dan PSNR Test Result

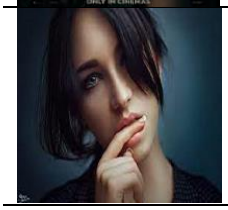
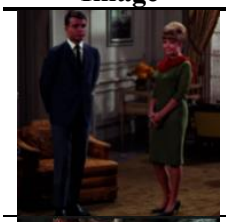
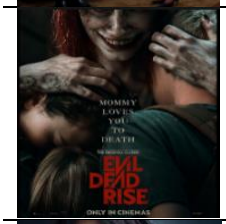
Image	Messsage Size (byte)	MSE	PSNR	AVA
	13.716	0,00	80,94	35,85
	89.154	0,00	74,36	34,10
	185.166	0,00	71,36	34,66
	13.716	0,00	86,04	35,85
	89.154	0,00	79,68	34,10
	185.166	0,00	76,59	34,66
	13.716	0,00	86,54	35,85
	89.154	0,00	80,26	34,10
	185.166	0,00	77,27	36,66

Table 3. UACI and NPCR Test Result

Image	Messsage Size (byte)	UACI	NPCR
	13.716	36,75	99,9
	89.154	36,76	99,56
	185.166	36,78	99,12
	13.716	33,77	99,97
	89.154	33,77	99,88
	185.166	33,77	99,76
	13.716	20,55	99,98
	89.154	20,55	99.89
	185.166	20,56	99,79

Judging from these results, the UACI results can be seen that when the message inserted is longer, the UACI value increases, whereas, conversely, the longer the message inserted, the lower the NCPCR value, which shows that the image changes when the message is inserted. Overall, the average UACI was 30.36 and NCPCR was 99.76. To see in more detail the changes in the image before the message is inserted with the image that has been inserted in the message. In Figure 3, where Image1 has not had a message inserted, it can be seen in the histogram that there are many spikes compared to Figure 4, where Image1 has had a message inserted, which has a different spike than Figure 3. This shows the change in the image when a message is inserted.

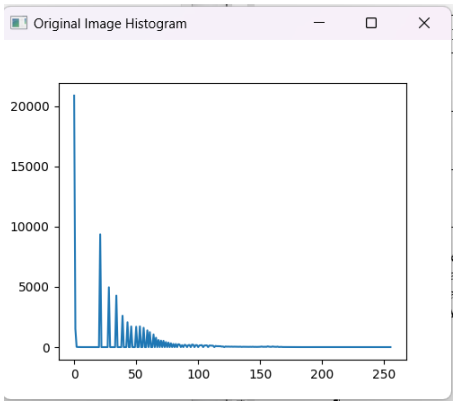


Figure 3. Plain Image1

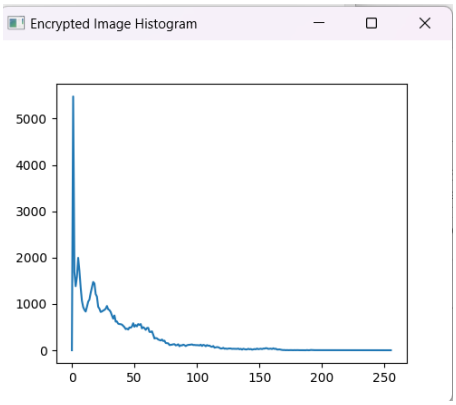


Figure 4. Cipher Image1

In Figure 5, the plain Image2 histogram which can be seen from the Image2 plain histogram has spikes. It can be compared with Figure 6, the Image2 image after getting the hidden message, the spikes shown in the histogram have changed.

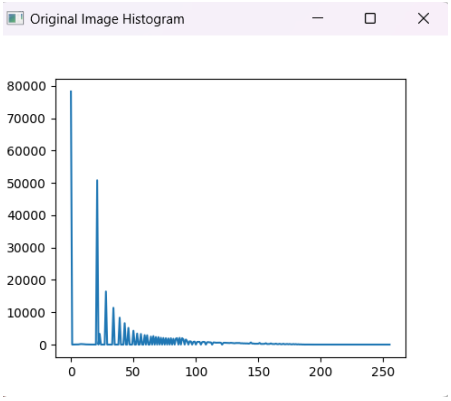


Figure 5. Plain Image2

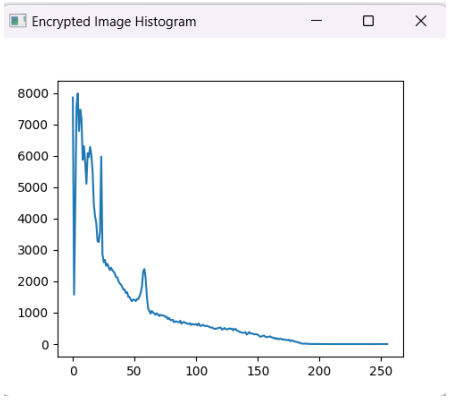


Figure 6. Cipher Image2

In Figure 7, it can be seen that the histogram of the original Image3 image shows a spike in the histogram value. However, if we compare it with Figure 8, which is an Image3 cipher image that has received a hidden message, we can see that the previously visible spikes in the histogram have undergone changes.

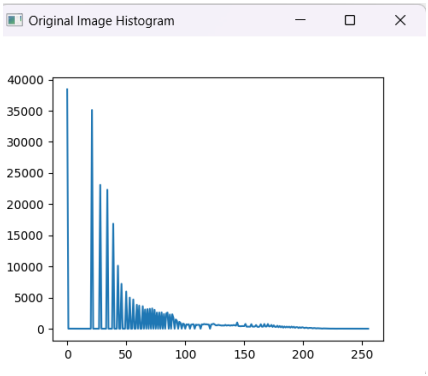


Figure 7. Plain Image3

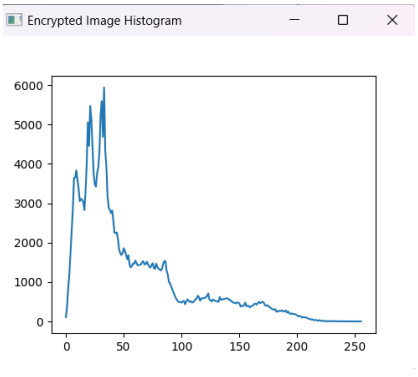


Figure 8. Cipher Image3

Based on tests carried out on the system using 3 image storage media, it was found that the image quality resulting from data insertion could be measured using the MSE, PSNR, UACI and NCPCR methods. The test results show that the lower the MSE value, the better the data embedding quality, while the higher the PSNR value, the better the resulting image quality. In addition, it was also found that the UACI value increased along with increasing the length of the inserted message, while the NCPCR value tended to decrease. This shows that the image changes when the message is inserted. Evaluation using the histogram also indicates a change in the histogram spike after the message insertion process.

4. Conclusion

From the results of this research, it can be concluded that the cryptographic method using the Blowfish algorithm which is used to insert data into images produces good image quality. This evaluation test using MSE, PSNR, AVA, UACI, NCPCR shows that this method is able to maintain image quality with a low MSE value, namely with an average of 0.00, and an average PSNR value of 79.22. This indicates that the changes that occur in the image as a result of data insertion are relatively small and not visually significant. In addition, the UACI and NCPCR test results show that the data insertion system has the desired avalanche effect where changing one input bit causes half of all output bits to change. This shows that the cryptographic system used is safe and can maintain the confidentiality of the inserted message.

References

[1] S.- Muryanah, "MENYISIPKAN PESAN RAHASIA KEDALAM GAMBAR DENGAN METODE BLOWFISH DAN LEAST SIGNIFICANT BIT (LSB)," *JIKA (Jurnal Informatika)*, vol. 4, no. 3, Art. no. 3, Nov 2020, doi: 10.31000/jika.v4i3.2869.

[2] S. Muryanah dan S. Syam, "Aplikasi Enkripsi Kriptografi Dengan Algoritma Blowfish Dan Kompresi Huffman Dalam Security Dokumen," *Syntax : Jurnal Informatika*, vol. 10, no. 02, Art. no. 02, Nov 2021, doi: 10.35706/syji.v10i02.5541.

[3] - Muhammad Reyhan Zelvian, "KRIPTOGRAFI GAMBAR DENGAN MENGGUNAKAN ALGORITMA BLOWFISH," other, Universitas Pendidikan Indonesia, 2023. Diakses: 4 Juli 2023. [Daring]. Tersedia pada: http://repository.upi.edu

[4] Hairullah, C. Pramartha, dan I. Putra, "Aplikasi Keamanan E-Commerece Berbasis Web Menggunakan Metode Algoritma Blowfish," vol. 1, hlm. 79–87, Nov 2022.

[5] I. A. W. Arnawa, "PERBANDINGAN WAKTU ENKRIPSI ANTARA METODE ELECTRONIC CODEBOOK (ECB) DAN CHIPHER BLOCK CHAINING (CBC) DALAM ALGORITMA BLOWFISH," no. 1, 2020.

[6] B. W. Rauf, "Kombinasi Steganografi Bit Matching dan Kriptografi Playfair Cipher, Hill Cipher dan Blowfish," *JurTI*, vol. 4, no. 2, hlm. 228–233, Des 2020, doi: 10.36294/jurti.v4i2.1346.

[7] Y. P. Astuti, E. H. Rachmawanto, dan C. A. Sari, "OPTIMASI ENKRIPSI PASSWORD MENGGUNAKAN ALGORITMA BLOWFISH," vol. 15, no. 1.

[8] B. Prasetiyo, M. A. Muslim, dan H. Susanto, "Penerapan Kriptografi Algoritma Blowfish pada Pengamanan Pesan Data Teks," *tc*, vol. 16, no. 4, hlm. 358–366, Jun 2017, doi: 10.33633/tc.v16i4.1452.

[9] G. C. M. Purba dan A. ID Hadiana, "Pengamanan Citra Medis Berbasis Steganografi d an Kriptografi Dengan Menggunakan Metode End Of File Dan Advanced Encryption Standard," *INDEX*, vol. 4, no. 1, hlm. 1–9, Jul 2022, doi: 10.36423/index.v4i1.878.

[10] R. Maharani, S. H. Sitorus, dan D. Prawira, "PENGAMANAN DATA RIWAYAT PENYAKIT PADA PASIEN MENGGUNAKAN STEGANOGRAFI MOST SIGNIFICANT BIT (MSB) (Studi Kasus: Penyakit Hiv/Aids Rumah Sakit Soedarso Pontianak)," *Coding Jurnal Komputer dan Aplikasi*, vol. 8, no. 1, Art. no. 1, Jan 2020, doi: 10.26418/coding.v8i1.39207.

[11] C. Irawan, E. H. Rachmawanto, C. A. Sari, dan C. A. Sugianto, "SUPER ENKRIPSI FILE DOKUMEN MENGGUNAKAN BEAUFORT CIPHER DAN TRANSPOSISI KOLOM," 2020.

[12] G. Wibisono, T. Waluyo, dan E. I. H. Ujianto, “KAJIAN METODE METODE STEGANOGRAFI PADA DOMAIN SPASIAL,” *JITK (Jurnal Ilmu Pengetahuan dan Teknologi Komputer)*, vol. 5, no. 2, Art. no. 2, Feb 2020, doi: 10.33480/jitk.v5i2.1212.

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Heart Disease Classification Using Deep Neural Network with SMOTE Technique for Balancing Data

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Abstract. Heart disease is the leading cause of premature death worldwide. According to the WHO, heart disease causes about 30% of the total 58 million deaths and mainly occurs in individuals who are in their productive age. Several studies have been conducted to anticipate this heart disease. Various algorithms, methods, and data balancing techniques have been applied, but still need to be done to get better accuracy results. Therefore, this research aims to classify heart disease using the Deep Neural Network algorithm and SMOTE technique to overcome data imbalance. This research resulted in a validation accuracy of 90% with a precision evaluation of 0.85, recall of 0.92, and f1-score of 0.88. Based on the results, the Deep Neural Network algorithm after SMOTE is superior to the model without SMOTE.
Keywords: Classification, Deep Neural Network, Heart Disease, SMOTE

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1. Introduction

One of the organs of the human body that plays an essential role in human life and functions to pump blood to transport oxygen and nutrients throughout the body is the heart. When the heart is damaged, the function of other organs will be affected. Damage to the heart can occur in the form of heart valve abnormalities, coronary arteries, or abnormalities in the heart muscle [1]. This is called heart disease. However, heart disease is one type of disease that is not contagious and is the leading cause of disability and premature death worldwide. Heart disease occurs due to disturbances in the performance of the heart and blood vessels. About 44% of the cases are coronary heart disease, and the rest come from various other types of diseases [2].

According to WHO [3], In 2005, heart disease caused about 30% of a total of about 58 million deaths, and is expected to increase by about 17% between 2006 and 2015. Most of the deaths caused by heart disease occur in individuals under the age of 70 and are still in their productive years. Many people do not realize that they are experiencing heart disease due to a lack of knowledge about their heart health condition. This can happen to anyone, including individuals who do not show symptoms of heart disease [1]. Various studies have identified several risk

factors associated with heart disease, including age, gender, high blood pressure, obesity, peripheral arterial disease, socioeconomics, and diabetes mellitus. In Indonesia, the main risk factors involved in heart disease are high blood pressure, emotional and mental health problems, and diabetes mellitus [4]. Socioeconomic impacts such as increased treatment costs, long treatment duration, and additional examinations required during the treatment process make the importance of prevention through early detection and control indispensable [2].

One way to perform early detection of heart disease is by implementing deep learning. In recent years, deep learning has experienced rapid development. This is because deep learning algorithms can learn complex features, recognize more complicated and abstract patterns, and overcome problems that are difficult to solve by traditional methods [5]. Classification, computer vision, and pattern recognition often utilize deep learning algorithms [6]. Pooja Rani, Rajneesh Kumar, and Anurag Jain conducted research by creating an intelligent system for diagnosing heart disease and utilizing the Deep Neural Network algorithm. The research focuses on using a Regularized Deep Neural Network (Reg-DNN) given dropout and L2 Regularization for regularization purposes. This research resulted in the best accuracy of 94.79% [7].

The research was conducted by Wiharto, Esti Suryani, Sigit Setyawan, and Bintang Pe Putra using the Z-Alizadeh Sani dataset, which was accessed online. This research uses a Deep Neural Network where a feature selection model is applied that considers the examination cost. Using five features, an AUC of 93.7% was obtained, an Accuracy of 87.7%, and a Sensitivity of 87.7% [8]. Furthermore, in 2021, research was conducted using deep neural networks to predict heart disease by combining embedded feature selection, LinearSVC, and Deep Neural Network methods and using a dataset sourced from Kaggle containing 14 attributes and 1025 records. The designed model produces an accuracy of 98.56%, recall of 99.35%, precision of 97.84%, F1-score 0.983, and AUC 0.983 [9].

Based on several studies that have been conducted, early detection of heart disease using a deep neural network is proposed. This study compares the performance results of the Deep Neural Network algorithm before and after applying SMOTE optimization in classifying heart disease. It is expected that the SMOTE technique used can overcome data imbalance and produce the best accuracy for early detection of heart disease.

2. Methods

2.1. Research Flow

This research is carried out with several stages of methods, such as grooves or research steps to run according to the initial objectives. This research compares the performance results of the Deep Neural Network algorithm before and after optimization using SMOTE. The research flow design can be seen in Figure 1.

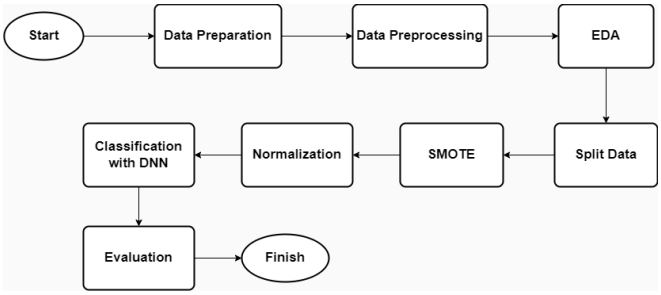

Figure 1. Research Flow

In Figure 1, there are eight stages carried out by this research, starting from data preparation, data preprocessing, EDA (Exploratory Data Analysis), splitting data into training data and test data, applying SMOTE to balance data, normalization, data classification using Deep Neural Network algorithm, and performance evaluation.

2.2. Data Preparation

At this stage, the Cleveland dataset was retrieved from the machine learning repository at the University of California, Irvine (UCI) [10]. It comprises 76 attributes, but some related studies use 14 characteristics to classify heart disease [11]. This study used 14 attributes, including age, gender, chest pain type, patient's blood pressure, cholesterol level, maximum heart rate, fasting blood sugar, exercise-induced angina, resting ECG, ST depression, ST slope, thalassemia, number of blood vessels stained by fluoroscopy, and target [12]. Detailed information about the dataset characteristics is described in Table 1.

Table 1. Cleveland dataset attribute description

Name	Type	Description
age	integer	Patient age
sex	categorical	0 = female dan 1=male
cp	categorical	Type of chest pain (1: typical angina, 2: atypical angina, 3: non-anginal pain, 4: asymptomatic)
trestbps	integer	Resting blood pressure (mm Hg)
chol	integer	Serum cholesterol (mg/dl)
fbs	categorical	Fasting blood sugar >120 mg/dl (0: no, 1: yes)
restecg	categorical	ECG results at rest (0: normal, 1: ST-T wave abnormality, 2: left ventricular hypertrophy)
thalach	integer	Max heart rate
exang	categorical	Exercise induced angina (0: no, 1: yes)
oldpeak	integer	Exercise induced depression
slope	categorical	Slope of peak training ST segment (1: uphill, 2: flat, 3: downhill)
ca	integer	Number of blood vessels stained by fluoroscopy
thal	categorical	Thalium voltage test results (3: standard, 6: fixed, 7: reversible defect)
target	integer	Heart disease potential status (0: no, 1: yes)

2.3. Data Preprocessing

The data pre-processing stage is for cleaning data from missing values, separating features and targets, and mapping values on the target variable y. The data cleaning stage is carried out because some rows have missing values. Removing missing values can improve model accuracy and prevent bias in analysis [13]. Therefore, a method is applied to remove rows containing at least one NaN value from the data frame. Furthermore, after the rows containing missing values are deleted, clean data will be accommodated in the new DataFrame.

The next stage separates features and targets to prepare data that has a role as input (features) and output (targets). The features are needed as input to train the model, while the target is used as the value the model wants to predict. This separation produces variable X with 13 features as input and variable y with one target as output. Furthermore, the target will go through value mapping to facilitate the heart disease classification process.

The purpose of value mapping is to reduce the value of the previous target class from 5 target classes, namely 0, 1, 2, 3, and 4, to 2 target classes, namely 0 as not heart disease and one as heart disease. Classes that were previously 1, 2, 3, and 4 will shrink to class 1 as heart disease, and class 0 will remain as class 0. This stage is carried out to facilitate the classification process of heart disease [14].

2.4. Exploratory Data Analysis

Exploratory Data Analysis (EDA) is an analytical process to analyze and understand data before building a heart disease classification model. This is important in heart disease classification, as it provides insight into the relationships between features, data characteristics, distributions, and

patterns [15]. The EDA used in this stage includes univariate analysis of the target variable to provide a visual image of the proportion or distribution of each class data in the target variable. This visualization can be used to see how balanced or unbalanced the distribution between healthy and sick classes is in the dataset. In addition, a correlation metric analysis between features is used. The aim is to provide a more detailed visual picture of the relationship between features in the dataset.

2.5. Split Data

This stage aims to divide the dataset into two different subsets. Generally, the dataset is divided into three subsets: training, test, and validation. However, this research divides the dataset into two subsets: the training and the test. Data division uses the train_test_split function from the Scikit-learn (sklearn) library. The ratio is 80:20, where 80% is used to train the model and 20% to test the model's performance. Data splitting is essential in the heart disease classification process to avoid overfitting and evaluate model performance objectively.

2.6. Synthetic Minority Over-sampling Technique

SMOTE is one of the oversampling techniques used for handling class imbalance in datasets. Class imbalance occurs when the number of samples in one class is much less compared to other courses. SMOTE works by selecting instances from the minority class and finding the k-nearest neighbors for each instance. Next, it combines the selected instances to generate synthetic cases. The application of SMOTE can overcome the problem of overfitting and help improve model accuracy [16]. The SMOTE technique in this research is part of data preprocessing, carried out after the training and test data division. The following is the formula of SMOTE:

$$X_{syn} = Xi + (X_{knn-Xi}) \times \delta \quad (1)$$

Notes:

X_{syn} = Data synthesis to be created
X_i = Data to be replicated
X_{knn} = Data that hisfarfrom data X_i
δ = random number between 0 and 1

2.7. Normalization

Data normalization is an essential step in data pre-processing before training the model. One commonly used normalization method is StandardScaler. StandardScaler comes from the Scikit-learn library and rescales features in a dataset by subtracting the mean and then scaling it to the unit variance. In this research, StandardScaler is used to reduce the influence of outliers and improve the consistency of the feature scale after applying the SMOTE technique. Here is the formula for StandardScaler normalization:

$$X_{stand} = \frac{x - mean(x)}{Standard\ Deviation\ (x)} \quad (2)$$

2.8. Classification using Deep Neural Network

A deep Neural Network is a type of neural network architecture that consists of many interconnected layers. DNN training involves feedforward and backpropagation processes. The DNN structure can be divided into three layers: the input, hidden, and output. Each hidden layer has interconnected neurons [9]. The DNN structure diagram in this study is shown in Figure 2. Experiments were conducted to find the best model for heart disease classification. Then, the best model was used to perform classification. The model consists of an input layer with 64 neurons, five hidden layers with different numbers of neurons, a dropout layer of 0.5, and an output layer with one neuron and a sigmoid activation function for binary classification. Each

layer has a ReLU activation function and a kernel regularizer with L2 regularization that prevents overfitting.

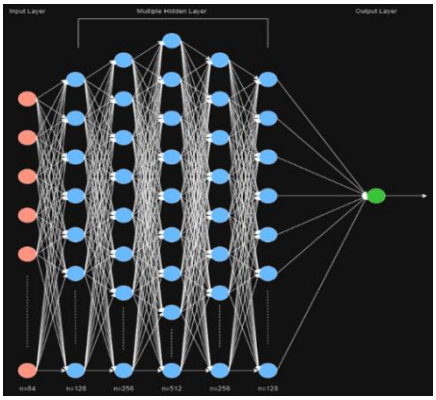

Figure 2. Diagram Structure of the Deep Neural Network

Adam optimizer (Adaptive Moment Estimation) is an optimization method that combines the Momentum and RMSprop algorithms. Adam is the result of the SGD method, which has decreased the adaptive estimation of first and second-order moments [17]. The following is the Adam optimization calculation formula:

$$\theta_{t+1} = \theta_t - \frac{\eta}{\sqrt{\hat{v}t + \varepsilon}} \cdot \hat{m}t \quad (3)$$

Notes:

θ_{t+1} = Parameter update result
θ_t = Previous update result parameter
η = Learning rate
$\hat{v}t$ = Squared gradient of second-order moments
ε = Small scalar to prevent division by zero
$\hat{m}t$ = Squared gradient of the first moment

The Early Stopping technique aims to prevent the model from learning too much training data, which can lead to poor performance, and to stop the model training process early if there are signs of overfitting in the validation data [18]. This study implemented a callback function to monitor the val_loss metric during training. For ten consecutive epochs, val_loss does not decrease, the training will be stopped, and the model weights will be restored to the best weights. Details of the parameters used for the Deep Neural Network model are shown in Table 2.

Table 2. Deep Neural Network model parameters

Parameters	**Value**	**Parameters**	**Value**
Number of layers	8	Number of neurons in the output layer	1
Number of neurons in the input layer	64	Regularizer kernel L2	0.001
Number of neurons in hidden layer 1	128	Learning Rate	0.001
Number of neurons in hidden layer 2	256	Epoch	50
Number of neurons in hidden layer 3	512	Batch Size	16
Number of neurons in hidden layer 4	256		
Number of neurons in hidden layer 5	128		
Dropout	0.5		

2.9. Evaluation

Model evaluation is the process of measuring the performance of a pre-trained model. This is important to understand the extent to which the model can perform classification accurately. Meanwhile, the confusion matrix is a table commonly used to describe model performance by

comparing model predictions with the actual labels on the test dataset. There are four main components to the confusion matrix, namely true positive (TP), true negative (TN), false positive (FP), and false negative (FN). Some commonly used evaluation metrics in model evaluation are accuracy, precision, recall, and f1-score, among others:

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (4)$$

$$Precision = \frac{TP}{TP+FP} \quad (5)$$

$$Recall = \frac{TP}{TP+FN} \quad (6)$$

$$F1-score = 2 \times \frac{(Precision \times Recall)}{Precision + Recall} \quad (7)$$

3. Results and Discussion

3.1. Results

This research uses the Cleveland dataset, which consists of 14 attributes and 303 samples. The preprocessing stage was carried out by analyzing the dataset and found six rows containing missing values. After cleaning the data from missing values, the clean data amounted to 297 samples and 14 attributes. The feature and target separation stage resulted in an X variable of 13 features that acted as input to train the model and a y variable of 1 target. The details of the y variable are shown in Table 3.

Table 3. Target Number of Each Class in Variable y

Target	
0	160
1	54
2	35
3	35
4	13

Variable y contains five target classes, 0, 1, 2, 3, and 4, and then goes through the value mapping process. This aims to reduce the target value from 5 targets to 2 targets, namely 0 and 1. The change in variable y is shown in Figure 3. The bar chart explains that target 0 is 160 samples, and target one is 137.

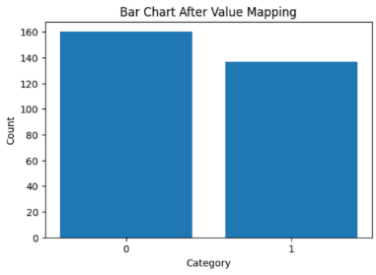

Figure 3. Visualization of y variable after value mapping

The EDA stage that has been carried out results in the analysis of 2 types of analysis: univariate and multivariate. The diagram shows that the target data from the "no heart disease" sample is 53.9%. Meanwhile, the target data from the "heart disease" sample is 46.1%. It can be concluded that the dataset is not balanced. Multivariate analysis using the Pearson correlation matrix aims to find the correlation between variables. The Pearson correlation matrix is shown in Figure 5. A value close to 0 indicates no linear relationship between two variables. The feature with a low correlation with the target feature is "fbs" (fasting blood sugar). Two features are close to the value of 1, namely the features "ca" (Number of major vessels) and "thal" (Thalassemia). These two features show a strong positive linear relationship with the target feature.

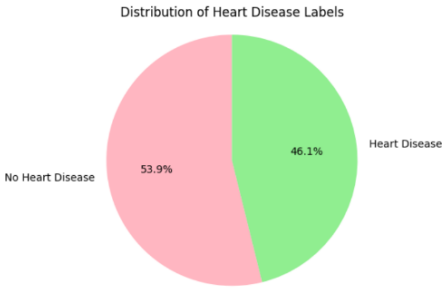

Figure 4. Distribution of Target Data

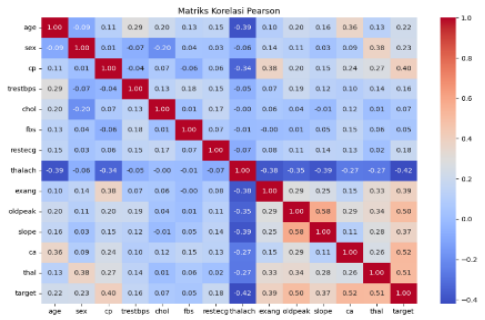

Figure 5. Pearson Correlation Matrix

The data was divided with a ratio of 80% as the training subset and 20% as the testing subset. This stage produces four variables, namely X_train, X_test, y_train, and y_test. Where X_train serves as the training subset of the feature matrix, X_test as the testing subset of the feature matrix, y_train as the training subset of the target, and y_test as the testing subset of the target. This research applies the SMOTE technique to overcome the imbalance in the dataset. The results of using the SMOTE technique increased the target value of "1" from 137 samples to be equivalent to the target value of "0", which is 160 samples. This change is shown in Table 4. After applying the SMOTE technique, the data becomes balanced, and there can be changes in the distribution of feature values. Therefore, a normalization stage using StandardScaler was performed to ensure that the scale of the features in the synthetic and original data were consistent.

Table 4. Target data after SMOTE

Target	
0	160
1	160

Heart disease data that has gone through the SMOTE stage is then used in the heart disease classification process using the Deep Neural Network algorithm with the best model determined from several previous experiments. The model was chosen based on the accuracy of the results produced when classifying heart disease. This is compared with the classification of heart disease using a Deep Neural Network without SMOTE. The comparison before and after SMOTE can be seen in Table 5.

Table 5. Comparison of Accuracy Results

Model	val_accuracy	val_loss
SMOTE	90%	0,9008
Without SMOTE	86,67%	0,7710

Based on the comparison in Table 5. it can be explained that the accuracy results after SMOTE increased val_accuracy by 3.33%, which was previously 86.67% to 90%. But in this case, val_loss has increased by 0.1298, from 0.7710 to 0.9008. This may occur because applying SMOTE increases the number of samples in the minority class by generating synthetic samples. The model can become more complex and result in val_accuracy increasing as the model obtains a better minority class and val_loss increasing as the model becomes complex. In the heart disease classification stage using the Deep Neural Network algorithm without SMOTE, the epoch process stops at stage 20/50. This is because the callback function successfully analyzes val_loss and does not decrease after 20 epochs, and the weight is returned at the 10th epoch as an accurate result.

The final stage of this research is to evaluate the model using a confusion matrix and three evaluation metrics, including precision, recall, and f1-score. The purpose of the confusion matrix is to provide insight into the model's performance in correctly or incorrectly classifying data within each class. The confusion matrices of the models without and using SMOTE are shown in Figures 8 and 9. Based on Figure 8, the DNN model with SMOTE can correctly classify 32 patients as positive and 22 as negative. In Figure 9, the model without SMOTE can correctly type 33 patients as positive and 19 as negative.

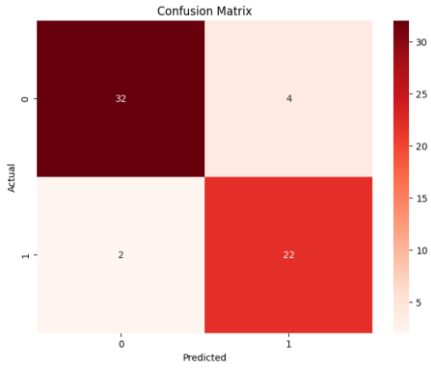

Figure 6. Confusion Matrix DNN with SMOTE

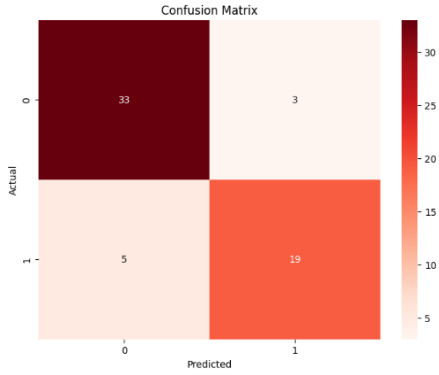

Figure 7. Confusion Matrix DNN without SMOTE

From the confusion matrix, three evaluation metrics can be calculated, namely precision, recall, and f1-score, to understand better the performance of the Deep Neural Network model in classifying heart disease. The results of the evaluation metrics of both models are shown in Table 6.

Table 6. Comparison of Evaluation Metrics

Model	Class	Precision	Recall	F1-score
SMOTE	0	0.94	0.89	0.91
	1	0.85	0.92	0.88
Without SMOTE	0	0.87	0.92	0.89
	1	0.86	0.79	0.83

Based on the comparison of the evaluation metrics of the two models, it can be confirmed that the Deep Neural Network model, by applying SMOTE, produces a recall of 0.92, which is suitable for classifying heart disease detected as positive cases. There was an increase of 0.13 in recall when the SMOTE technique was applied. Recall or sensitivity aims to measure the ability of the model to detect actual positive cases of heart disease correctly. With this, recall is essential in the case of heart disease classification, thus minimizing the possibility of missed positive cases.

3.2. Discussion

Based on the results obtained, the validation accuracy value for the proposed method reaches 90% compared to some previous studies. Although studies [7] and [19] achieved a higher accuracy value of about 4% compared to this study, This study managed to improve the accuracy by 3.33% from before the model was SMOTE to overcome data imbalance. On the other hand, compared to [8], this study achieved higher accuracy and recall of about 2.3% using different datasets. With these promising results, the proposed method can be further developed and used in heart disease classification. In addition, this research focuses on heart disease classification with data imbalance handling using SMOTE. It does not rule out the possibility for further development using other data balancing techniques such as ADASYN, undersampling, or a combination of techniques to improve model performance in classifying minority classes.

4. Conclusion

This research was conducted on the classification of heart disease by applying the SMOTE technique to the Deep Neural Network algorithm. Before using SMOTE, the Deep Neural Network model produced an accuracy of 86.67% with a precision of 0.86, recall of 0.79, and f1-score of 0.83. By applying the SMOTE technique, the data becomes balanced and successfully improves the accuracy of the Deep Neural Network model. This research has seven trials, and the best results are in the 4th trial with 90% accuracy, precision of 0.85, recall of 0.92, and f1-score of 0.88. Based on the results obtained, it can be said that the Deep Neural Network algorithm after SMOTE is superior to the algorithm without SMOTE. It is hoped that this research can be helpful for future research to understand better the advantages of SMOTE and deep neural networks in heart disease classification tasks.

References

[1] F. Novitasari, E. Haerani, A. Nazir, J. Jasril, and F. Insani, "Sistem Klasifikasi Penyakit Jantung Menggunakan Teknik Pendekatan SMOTE Pada Algoritma Modified K-Nearest Neighbor," *Building of Informatics, Technology and Science (BITS)*, vol. 5, no. 1, pp. 274–284, Jun. 2023, doi: 10.47065/bits.v5i1.3610.

[2] I. J. Johanis, I. A. T. Hinga, and A. B. Sir, "Faktor Risiko Hipertensi, Merokok dan Usia Terhadap Kejadian Penyakit Jantung Koroner pada Pasien di RSUD Prof. Dr. W. Z. Johannes Kupang," *Media Kesehatan Masyarakat*, vol. 2, no. 1, pp. 33–40, 2020, [Online]. Available: https://ejurnal.undana.ac.id/MKM

[3] World Health Organization. *Prevention of Cardiovascular Disease : Guidelines for assessment and management of cardiovascular risk.* World Health Organization, 2007.

[4] L. Ghani, M. D. Susilawati, and H. Novriani, "Faktor Risiko Dominan Penyakit Jantung Koroner di Indonesia," *Buletin Penelitian Kesehatan*, vol. 44, no. 3, pp. 153–164, Dec. 2016, doi: 10.22435/bpk.v44i3.5436.153-164.

[5] I. Javid, A. K. Z. Alsaedi, and R. Ghazali, "Enhanced Accuracy of Heart Disease Prediction using Machine Learning and Recurrent Neural Networks Ensemble Majority Voting Method," *(IJACSA) International Journal of Advanced Computer Science and Applications*, vol. 11, no. 3, pp. 540–551, 2020, [Online]. Available: www.ijacsa.thesai.org

[6] M. A. Aslam *et al.*, "Deep Neural Networks for Prediction of Cardiovascualr Diseases," *Nano Biomed Eng*, vol. 14, no. 1, pp. 81–89, May 2022, doi: 10.5101/nbe.v14i1.p81-89.

[7] P. Rani, R. Kumar, and A. Jain, "An intelligent system for heart disease diagnosis using regularized deep neural network," *Journal of Applied Research and Technology*, vol. 21, no. 1, pp. 87–97, Feb. 2023.

[8] Wiharto, E. Suryani, S. Setyawan, and B. P. Putra, "The Cost-Based Feature Selection Model for Coronary Heart Disease Diagnosis System Using Deep Neural Network," *IEEE Access*, vol. 10, pp. 29687–29697, Mar. 2022, doi: 10.1109/ACCESS.2022.3158752.

[9] D. Zhang *et al.*, "Heart Disease Prediction Based on the Embedded Feature Selection Method and Deep Neural Network," *J Healthc Eng*, vol. 2021, pp. 1–9, 2021, doi: 10.1155/2021/6260022.

[10] R. R. Sarra, A. M. Dinar, and M. A. Mohammed, "Enhanced accuracy for heart disease prediction using artificial neural network," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 29, no. 1, pp. 375–383, Jan. 2023, doi: 10.11591/ijeecs.v29.i1.pp375-383.

[11] A. Janosi, W. Steinbrunn, M. Pfisterer, and R. Detrano, "Heart Disease," *UCI Machine Learning Repository*. 1988. Accessed: Nov. 19, 2023. [Online]. Available: https://doi.org/10.24432/C52P4X.

[12] B. T. Vasantrao, Dr. S. Rangasamy, and Dr. C. J. Shelke, "A Deep Learning Classification Approach using Feature Fusion Model for Heart Disease Diagnosis," *(IJACSA) International Journal of Advanced Computer Science and Applications*, vol. 13, no. 6, pp. 646–654, 2022.

[13] S. Dehnavi, M. Emamipour, and A. Golabpour, "Combining random forest and neural networks algorithms to diagnose heart disease," *Frontiers in Health Informatics*, vol. 9, pp. 1–6, Jun. 2020, doi: 10.30699/fhi.v9i1.214.

[14] A. Al Shammari, H. Al Hadeaf, and H. Zardi, "Prediction of Heart Diseases (PHDs) based on Multi-Classifiers," *(IJACSA) International Journal of Advanced Computer Science and Applications*, vol. 11, no. 5, pp. 230–236, 2020, [Online]. Available: www.ijacsa.thesai.org

[15] R. Indrakumari, T. Poongodi, and S. R. Jena, "Heart Disease Prediction using Exploratory Data Analysis," in *Procedia Computer Science*, Elsevier B.V., 2020, pp. 130–139. doi: 10.1016/j.procs.2020.06.017.

[16] A. M. A. Rahim, I. Y. R. Pratiwi, and M. A. Fikri, "Klasifikasi Penyakit Jantung Menggunakan Metode Synthetic Minority Over-sampling Technique Dan Random Forest Clasifier," *Indonesian Journal of Computer Science*, vol. 12, no. 5, pp. 2995–3011, Oct. 2023.

[17] P. Dileep *et al.*, "An automatic heart disease prediction using cluster-based bi-directional LSTM (C-BiLSTM) algorithm," *Neural Comput Appl*, vol. 35, no. 10, pp. 7253–7266, Mar. 2023, doi: 10.1007/s00521-022-07064-0.

[18] U. N. Oktaviana, R. Hendrawan, A. D. K. Annas, and G. W. Wicaksono, "Klasifikasi Penyakit Padi berdasarkan Citra Daun Menggunakan Model Terlatih Resnet101," *Jurnal RESTI (Rekayasa Sistem dan Teknologi Informasi)*, vol. 5, no. 6, pp. 1216–1222, Dec. 2021, doi: 10.29207/resti.v5i6.3607.

[19] V. Sapra *et al.*, "Integrated approach using deep neural network and CBR for detecting severity of coronary artery disease," *Alexandria Engineering Journal*, vol. 68, pp. 709–720, Apr. 2023, doi: 10.1016/j.aej.2023.01.029.

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Improving Analysis of Risk-Based Maintenance Management Strategies Through Reliability Centered Maintenance. Case Study : Coal Crushing Plant. Central Kalimantan. Indonesia

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Abstract. PT XYZ as a company operating in the coal mining sector has 7 production lines on the in-loading system in its coal crushing plant. In-loading system production line no. 7 is the system that has the lowest mechanical availability; therefore, it is necessary to search for a systematic method to obtain an appropriate maintenance mode and not only consider operational aspects but also pay attention to occupational health & safety aspects. RCM is a qualitative analysis (which can be developed into quantitative analysis) which formulates maintenance task selection based on safety, environmental and operational considerations. From the results of the FMEA research, it was found that there were 28 failure modes with 6 components of which had an unacceptable risk level and a critical level of "very critical" so that LTA analysis was carried out on these 6 components and obtained maintenance tasks for each component, namely scheduled on condition tasks (HPU pump, Drag Chain, Hydraulic Pipe) and redesign (Flight bar, Flap Plate).

Keywords: Risk Analysis, Reliability, FMEA, RCM Feeder System

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1. Background of the problem

Especially for companies in the coal mining sector, increasing productivity in the production system is an absolute must. If a machine experiences a breakdown, the company's productivity will be disrupted because downtime has the effect of decreasing the amount of output, increasing operational costs, and affecting customer service [1]. One indicator of increasing productivity is the level of reliability of the company's production machines. “Reliability is the possibility that a system will carry out its function/performance satisfactorily; in certain work environments and operating conditions” [2]. In measuring how good the reliability of a production machine is, an effective and efficient maintenance process is needed for the company.

PT. XYZ is a coal company that has a business license to carry out mining activities under the Coal Mining Concession Contract Agreement with the Indonesian government in the South Kalimantan

and Central Kalimantan regions. Specifically, in Central Kalimantan, PT XYZ has placed a coal crushing plant which mainly functions to crush the coal into smaller pieces according to consumer demand before the coal is sent out using barges. Delays in coal production operations due to frequent downtime and long repair times due to repairs during downtime are obstacles to achieving targets that need to be anticipated and maintenance program policies taken by the maintenance department also need to be carried out with careful consideration so that maintenance results are optimal.

In this research, it focuses on production equipment in the crushing plant area. It is known that PT XYZ divides the production line into two lines, namely the inloading (upstream) and outloading (downstream) lines. From the results of processing historical data on production equipment maintenance for the 2022 period, the inloading line is the line that has a lower Mechanical Availability value than the outloading line, namely 97.81%, while the Mechanical Availability value for outloading is 99.22%, where the target of Mechanical Availability is 96%. PT XYZ itself has 7 inloading lines in which there is a hopper system, feeder system, screening system, crushing system and conveyor system. When processing production equipment maintenance history data for the 2022 period, the Mechanical Availability value of the 7 inloading lines is obtained where there is 1 production line that has Mechanical The lowest availability is inloading route number 7 at 95.36% of the target that must be achieved at 96% with the MTBF (mean time between failure) value on inloading line number 7 having an average of 272.43 hours with an MTBF target of 950 hours.

Preventive maintenance, corrective maintenance, predictive maintenance, breakdown maintenance and improvement maintenance (design-out maintenance) activities have been carried out by PT XYZ in order to maintain the function of each system or subsystem continues to run normally and in carrying out maintenance activities both in terms of intervals and maintenance modes, there are conditions based and the majority are based on considerations from the manual book for each production equipment and trends in the usage life of production equipment. From existing maintenance activities, there needs to be a systematic, risk-based method to maximize decision making regarding maintenance mode management. One way is through RCM (Reliability Centered Maintenance). RCM is a systematic approach based on risk to create an accurate, focused, and optimal maintenance mode [3] and RCM is a process used to determine what must be done to ensure that any physical asset continues to do what its users want it to do in its present operating context. RCM is used to develop a maintenance plan with a certain level of operation, with a certain level of risk, which is efficient and price effective [4]. RCM is continuous, which means that this process can (even at best) be repeated to get a higher reliability value, which makes decisions related to determining maintenance intervals and modes more scientific, effective, and efficient.

Several previous studies regarding the RCM-based maintenance process, one of which was carried out by Ma, et al [6] which was applied to heavy equipment vehicles in coal mining in China to determine the maintenance period and maintenance mode from three basic maintenance modes, namely corrective maintenance, periodic maintenance, and status maintenance. using the RCM approach which provides an increase in economic benefits, then other RCM-based research conducted by Wu and Wang [7] which is applied to the maintenance management system of electromechanical equipment in coal mining companies and provides the impact of saving maintenance costs and improving operational quality of equipment, and then from other research on RCM, it is concluded that many organizations are exploring alternative maintenance methods that seek to improve the reliability and availability of the plant and equipment and the RCM is the most successful method for developing failure management policies with the aim of sustaining the performance of physical assets, reduced preventive maintenance costs, reduced corrective maintenance costs, reduced labor costs, reduced outage costs, reduced spare parts costs, increased plant availability, increased plant reliability, reduced maintenance frequency and an increase in production . [8].

Based on previous research conducted regarding RCM, it is hoped that analysis of risk-based maintenance management strategies through RCM which is carried out at the PT XYZ crushing plant, especially on the no.7 inloading production line system, can increase the availability and reliability of the system.

2. Research Methods

This research was conducted from November 2022 to May 2023 at the PT XYZ crushing plant which is operational in Central Kalimantan. Research starts from collecting data such as machine/component data, machine/component downtime (damage) data and machine/component uptime (repair) data which conducted from November 2022 to Januari 2023. After that, steps are taken to prepare RCM-based improvement activities which were carried out from February 2023 to May 2023. There are 7 steps in making RCM [9], namely : (1) Defining system boundaries, (2) Explanation of system and function block diagrams, (3) Explanation of system functions and functional failures, (4) Preparation of FMEA and analysis of critical components, (5) Logic Tree Analysis, which is a continuation of FMEA to add consideration in selecting maintenance activities, (7) analysis of selecting maintenance activities based on the RCM flowchart decision diagram [9] In addition, Pareto analysis and fault trees are also used in FMEA analysis. Pareto a theory maintaining that 80 percent of the output from a given situation or system is determined by 20 percent of the input while Fault Tree Analysis (FTA) is a technique used to identify risks that contribute to failure [15]. Pareto is useful for determining the priority of systems, sub-systems or critical components that will be analyzed further and FTA is used to determine existing failure modes and causes.

3. Results and Discussion

3.1 System definition and Functional Block Diagram

Inloading production line system no.7 has 9 sub-systems, namely feeder sub-system, S17 conveyor, S18 conveyor, S19 conveyor, diverter, primary crusher, secondary crusher, tertiary crusher, screener. Through the use of the Pareto diagram, it is obtained that the feeder sub-system has a high percentage as seen from the frequency and duration of damage using component damage data in the unplanned maintenance schedule category or in this case reactive maintenance/ breakdown maintenance for the period January 2019 – December 2022 as seen in the Pareto diagram (80:20) which shows that the feeder sub-system is a priority for RCM analysis in this research

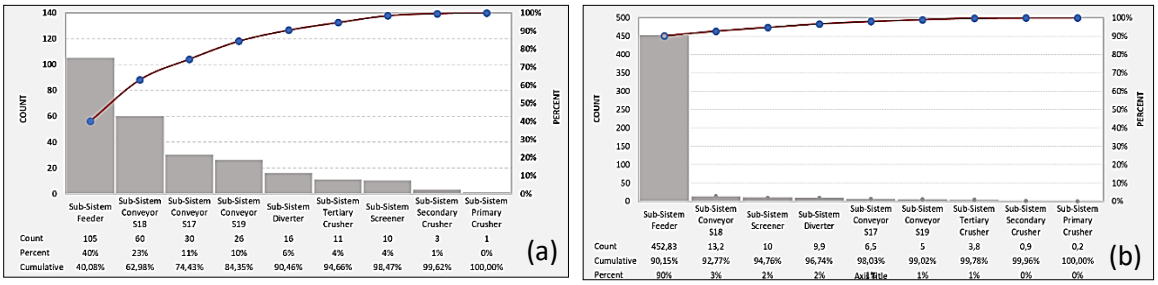


Figure 1. (a) Frequency & (b) Duration of Damage Production System of Inloading line no.7

Through field observations and data observations, information and work processes were obtained which were outlined in function block diagrams [10] to visualize the flow of function processes from the feeder sub-system into a simple diagram.

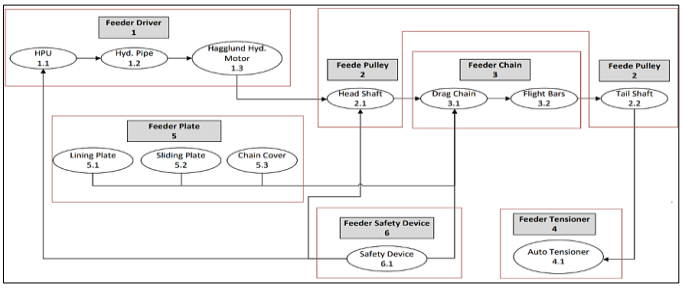


Figure 3. Functional Block Diagram of Feeder Sub-System FD0055-007

3.2 FMEA Results

FMEA is one of the most fundamental methods for evaluating the level of risk as a prelude to risk reduction [11]. In this research, FMEA is prepared based on the description of the feeder sub-system with the identity FD0055-007 which is divided into several components to arrive at an acceptable one. The main components of the feeder sub-system are:

1. Feeder drivers which consists of a hydraulic power unit, hydraulic pipe, Hagglund hydraulic motor
2. Feeder pulley which consists of a head shaft assembly and a tail shaft assembly
3. Feeder chains which consists of a 5.5" drag chain, flight-bar
4. Feeder tensioner which consists of an auto-tensioner
5. Feeder plates which consists of lining plate, sliding plate, chain cover
6. Feeder safety device consisting of a safety device ("slack" sensor, electric motor and pump sensor, "under-speed" sensor)

Then, based on the component details from FD0055-007, functional failure, failure mode and causes of failure are searched using the fault tree analysis method.

Table 1. FMEA Analysis (Component, Function, Function Failure, Failure Mode)

C	Component	F	Function	FF	Function Failure	FM	Failure Mode
1	Hydraulic Power Unit	A	Increase oil pressure to move the Hagglund (hydraulic drive) within the specified vibration pressure and temperature limits	1	Failed to increase oil pressure to move the Hagglund (hydraulic drive) within the specified vibration pressure and temperature limits	1	The hydraulic pump experiences abnormal conditions (oil leaks, extreme increases in pressure, temperature and vibration) so that the pump cannot operate normally
						2	Electric motor damage
						3	Rubber coupling damage
						4	Clogging filter
						5	Fan drive motor failure
						6	The fan does not rotate optimally
						7	There is a leak in the tank
2	Pipe/ Hose	A	Connects and delivers high pressure oil throughout the hydraulic system without leaks	1	Failed to connect and deliver high pressure oil throughout the hydraulic system without leaks	1	Oil leaks in pipes/hoses
3	Hagglund Hydraulic Motor	A	Provides rotational force/torque on the head shaft within the specified vibration pressure and temperature limits	1	Failed to provide rotational force/torque on the head shaft	1	The hydraulic motor experiences abnormal conditions (oil leaks, extreme increases in pressure, temperature and vibration) so that the pump cannot operate normally
4	Head Shaft Assembly	A	Continuing the torque produced by the hydraulic motor (hagglund) to rotate the sprocket and pull the drag chain	1	Failed to transmit the torque produced by the hydraulic motor (hagglund) to rotate the sprocket	1	Broken Shaft
						2	Worn sprockets
						3	Damage to bearing components
5	Tail Shaft Assembly	A	Connect the idler and pull up the drag chain	1	Failed to connect the idler and pull up the drag chain	1	Broken Shaft
						2	Flap Plate Dislodged
						3	Worn idler
						4	Damage to bearing components
6	Drag Chain 5.5	A	Moving the coal load to the crushing process	1	Failed to move the coal load to the crushing process	1	Dragchain disconnected
						2	Dragchain does not move
7	Flightbar	A	Pushing the load into the crusher area	2	Failed to push the coal load to the crusher area optimally	1	Flightbar Detached

8	Auto Tensioner	A	Drag chain tension adjuster	1	Failed to provide drag chain tension adjustment	1	autotensioner is not working optimally
9	Lining Wall Plates	A	Holds coal in the feeder	1	Failed to hold coal and flightbar located on the feeder	1	Lining wall plate worn
						2	The lining wall plate is peeling off
10	Sliding Plates	B	drag chain base	1	Failed to provide support to the drag chain	1	The sliding plate is worn
11	Floor Plates	C	The coal platform goes to the crusher	1	Failed to provide support for the coal going to the crusher	1	Floor plate worn
12	Chain Cover	D	Protects the chain from direct coal impact	1	Failed to protect the chain from direct coal impact	1	Peeling/loose
13	Safety devices	A	Protect feeder components from anomalous conditions when the feeder is operational	1	Protect feeder components from anomalous conditions when the feeder is operational	1	Electric sensor problem
						2	Damage to the slack sensor
						3	Underspeed fault

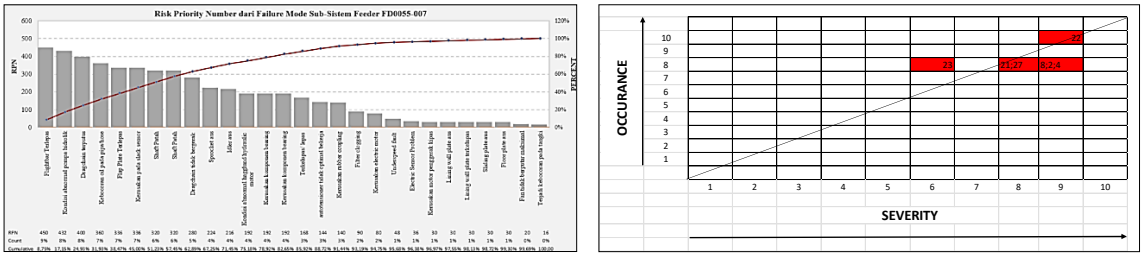
After that, a risk priority number assessment is carried out by multiplying severity, occurrence, and detection for each failure mode.

Table 2. FMEA Analysis (RPN, Risk Level, Critical Level)

No. C	**No. F**	**No. FF**	**No. FM**	**S**	**O**	**D**	**RPN**	**Risk Level**	**Critical Level**
1	A	1	1	9	8	6	432	Unacceptable	Very Critical
			2	8	2	5	80	Tolerable	High
			3	6	4	3	72	Tolerable	High
			4	5	4	2	40	Tolerable	Medium
			5	5	2	3	30	Acceptable	Minor
			6	5	2	2	20	Acceptable	Minor
			7	8	2	1	16	Acceptable	Minor
2	A	1	1	9	8	5	360	Unacceptable	Very Critical
3	A	1	1	8	2	2	32	Tolerable	Medium
4	A	1	1	10	2	7	140	Tolerable	High
			2	7	2	3	42	Tolerable	Medium
			3	7	2	3	42	Tolerable	Medium
5	A	1	1	10	1	7	70	Tolerable	High
			2	8	6	7	336	Unacceptable	Very Critical
			3	9	4	6	216	Unacceptable	Very High
			4	7	2	4	56	Tolerable	Medium
6	A	1	1	9	8	5	360	Unacceptable	Very Critical
			2	7	8	5	280	Unacceptable	Critical
7	A	2	1	9	10	5	450	Unacceptable	Very Critical
8	A	1	1	5	6	3	90	Tolerable	High
9	A	1	1	5	6	1	30	Acceptable	Minor
			2	5	6	1	30	Acceptable	Minor
10	B	1	1	5	6	1	30	Acceptable	Minor
11	C	1	1	5	6	1	30	Acceptable	Minor
12	D	1	1	6	6	2	72	Tolerable	High
13	A	1	1	4	4	3	36	Tolerable	Medium
			2	6	8	7	336	Unacceptable	Very Critical
			3	4	4	3	48	Tolerable	Medium

After processing the RPN values for the 28 failure modes found, the risk level and criticality level of the components are determined based on the RPN values obtained from multiplying the severity, occurrence and detection factors with the predetermined assessment criteria. After that, a more in-depth criticality level analysis is carried out through Pareto creation to determine the components that play a

role in the decline in performance of FD0055-007 and a criticality level matrix that will visualize the values of severity and occurrence so that each failure mode that has the same RPN value can be sorted based on the impact it will have. felt when the failure occurs.



(a) (b)

Figure 4. (a) Pareto risk priority number of feeder sub-system failure mode FD0055-007, (b) Critical matrix

From the results of mapping the criticality level on the critical matrix, the priority of failure modes in the FD0055-007 feeder sub-system is sequentially, namely fligtbarloose (22) on the flightbar component, the hydraulic pump experiences an abnormal condition (oil leak, extreme increase in pressure, temperature and vibration) so that the pump cannot operate normally (2) on the hydraulic power unit component, oil leaks on the pipe/hose (4) on the hydraulic power unit component, the drag chain broke (21) on the 5.5" chain component, the flap plate came off (27) on the tail shaft assembly component, and damage to the slack sensor (23) on the drag chain component – chain slack sensor.

3.3 Logic Tree Analysis and Maintenance Task Selection

LTA is a continuation of FMEA analysis and has the aim of giving priority to each damage mode and reviewing and functioning failures so that the status of the damage modes is not the same [12]. the results will be used as input in the logic tree analysis analysis to add consideration to the selection of maintenance tasks in RCM [13]. The following is a flowchart for the analysis of logic tree analysis and maintenance selection tasks [4].

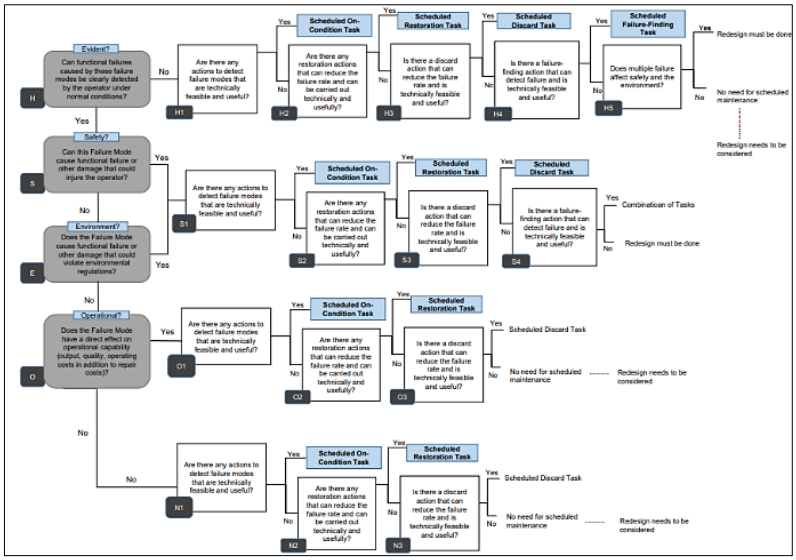


Figure 6. Flowchart of RCM decision diagram

From the results of the logic tree analysis and maintenance task analysis, recommendations for types of maintenance are produced which are outlined in the RCM II worksheet. RCM II decision worksheet is the next phase after the FMEA, or the RCM II information worksheet is done. Decision

worksheet is a summary of every question listed in the RCM II decision diagram [14]. The RCM II decision worksheet is as follows:

Tabel 3: RCM II Decision Worksheet

Information Reference				Consequences Evaluation				H1 S1 O1 N1	H2 S2 O2 N2	H3 S3 O3 N3	Default Action			Proposed Maintenance Task
C	**F**	**FF**	**FM**	**H**	**S**	**E**	**O**				**H4**	**H5**	**S4**	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	
7	A	2	1	Y	N	N	Y	N	N	N				*Redesign* : Dimensions and geometry of the flight bar need to be considered for changes
1	A	1	1	Y	N	N	Y	N	N	Y				*Scheduled on-condition task* : Checking & replacing the input bearing & seal, replacing pump when it fails
6	A	1	1	N	N	N	Y	N	N	Y				*Scheduled on-condition tasks*: Checking link plate thickness, elongation and replacing the drag chain when it fails
2	A	1	1	N	N	N	Y	Y						*Scheduled on-condition tasks*: Replacement of pipe/hose when the thickness of the pipe is no longer able to withstand the operational pressure of the HPU
5	A	1	2	Y	N	N	Y	N	N	N				*Redesign:* Dimensions and geometry of the flap plate need to be considered for changes
13	A	1	2	Y	N	N	Y	Y						*Scheduled on-condition task:* Checking the accuracy of the sensor regarding the installed mechanical trigger, checking the overall chain slack sensor

From the results of the risk evaluation outlined in the RCM decision worksheet, maintenance modes for each critical component were obtained to increase the reliability of the production line for inloading system no. 7 is by re-engineering or redesigning the flight-bar (chain 5.5") and flap plate (tail shaft assembly) components and carrying out repair/replacement activities when abnormal conditions are found on the equipment or scheduled on-condition tasks for the components hydraulic pump (HPU), drag chain (chain 5.5"), hydraulic pipe (HPU), slack sensor (safety device).

4. Conclusion

In this research, through the Reliability Centered Maintenance process, several conclusions were obtained, Through Pareto diagram analysis, the feeder sub-system FD0055-007 is a contributor to the low availability value of the production line for inloading system no.7. The FMEA process shows several components that are categorized as having an "unacceptable" risk level. Then a critical level analysis is carried out to obtain 6 components which are sorted based on the negative impact they have and are categorized as "very critical". Components with a "very critical" status are then subjected to a logic tree analysis which is connected to the maintenance mode through a flowchart decision diagram based on safety, environmental, operational, and non-operational aspects. RCM in qualitative analysis can be used as a systematic method that formulates maintenance mangement strategies based on safety, environmental, operational, and non-operational factors. RCM analysis can also be developed with quantitative reliability analysis using statistical distribustion (weibull, lognormal, normal exponential,

etc) to obtain maintenance activity intervals as well as considering maintenance costs so that maintenance management strategies become more comprehensive.

References

[1] Moubray, J. (2019). Reliability Centered Maintenance (RCM) II. 2nd. New York: Industrial Press Inc.

[2] Odeyar, P., & Apel, P., & Hall, R., & Zon, B., & Skrzypkowski, K. (2022). A Review of Reliability and Fault Analysis Methods for Heavy Equipment and Their Components Used in Mining. Energies. 15. DOI:10.3390/en15176263

[3] Calixto, E.. (2013). Gas and Oil Reliability Engineering. Gas and Oil Reliability Engineering. DOI:10.1016/C2011-0-69838-2.

[4] Rahmadhanty, S., & Pitana, T., & Siswantoro, N. (2019). Reviewing the Reliability-Centered Maintenance on Cooling Water Pump of LNG Production Company. International Journal of Marine Engineering Innovation and Research. 3. DOI: 10.12962/j25481479.v3i3.4826.

[5] Jafarpisheh, R., & Karbasian, M., & Asadpour, M. (2020). A hybrid reliability-centered maintenance approach for mining transportation machines: a real case in Esfahan. International Journal of Quality & Reliability Management. ahead-of-print. DOI:10.1108/IJQRM-09-2020-0309

[6] Ma, X. M., Wu, X. R., & Zhang, Y. Q. (2014). Research on Maintenance Strategy of Coal Mining Vehicles Based on RCM. Applied Mechanics and Materials, 543-547, 126-129. DOI: 10.4028/www.scientific.net/AMM.543-547.126

[7] Wu, X., & Wang, L. (2016). Research on Maintenance Management System of Coal Mine Electromechanical Equipment Based on RCM. 4th International Conference on Advanced Materials and Information Technology Processing, 424-426. DOI: https://doi.org/10.2991/amitp-16.2016.81

[8] Medoh, C., & Ramagaga, T. (2018). Critical Success Factors for the Implementation of Reliability Centered Maintenance. Dissertation. University of Johannesburg. South Africa

[9] Hoseinie, SH, Kumar, U., & Ghodrati, B. (2016). Reliability Centered Maintenance (RCM) for Automated Mining Machinery.

[10] Sajaradj, ZH, Listiani N., & Sinulingga, S. (2019). The Application of Reliability Centered Maintenance (RCM) Methods to Design Maintenance Systems in Manufacturing (Journal Review). IOP Conference Series: Materials Science and Engineering. DOI: 10.1088/1757-899X/505/1/012058

[11] Soltanali, Hamzeh & Ramezani, Saeed. (2023). Smart Failure Mode and Effects Analysis (FMEA) for the Safety-Critical Systems in the Context of Industry 4.0. DOI: 10.1007/978-981-19-9909-3_7.

[12] Handjoyo, D.K.S., & Susanto, N., & A. Susanty. (2018) Identifikasi Penyebab Kerusakan Mesin Asphalt Mixing Plant (AMP) PT Puri Sakti Perkasa Menggunakan Metode FMEA & LTA," Industrial Engineering Online Journal, vol. 6, no. 4.

[13] Ramirez, I., Chuchuca, F., Erazo-Bone, R.A., Gonzalo, R., Freire-Caiza, J., Mármol-Hermosa, D., Ramírez-Chávez, Í., … (2021). Development of Reliability Centered Maintenance Plan RCM, Through Pulling Operations to Wells of a Marginal Oil Field. LACCEI Proceedings.

[14] Singgih, M., Prasetyawan, Y., Sutikno, S., Hartanto, D., Kurniawan, Franto., Wicaksana, W. (2019). Maintenance management improvement based on reliability centered maintenance II in energy generating industries. IOP Conference Series: Materials Science and Engineering. 528. 012054. DOI: 10.1088/1757-899X/528/1/012054.

[15] Salamuk, D., & Wahyudien, N.A.M., & Rachmadhani, M. M., & Ashar,. (2023). System Analysis of Causes of Damage to Generator Series 3516 FTA Method. Industrial Engineering Journal. DOI: 01. 42-46. 10.33506/system.v1i02.2284.

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Optimizing Predictive Accuracy: A Study of K-Medoids and Backpropagation for MPX2 Oil Sales Forecasting

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Abstract. This study evaluates the use of K-Medoids and Backpropagation methods for predicting MPX2 Oil sales in the automotive workshop industry, which is crucial for meeting customer demands and refining sales strategies. Utilizing transaction data from 2022 to 2023, the study involves normalizing and processing this data with these algorithms to forecast stock levels, focusing on accuracy measures such as Mean Absolute Deviation (MAD) and Mean Squared Error (MSE). K-Medoids assist in identifying customer purchase patterns through clustering, while Backpropagation effectively predicts sales trends, enhancing accuracy through training. Implementing K-Medoids and Backpropagation algorithms in the research resulted in MSE value of 0.01969 and MAD value of 0.12200. These values indicate a high level of accuracy in the MPX2 Oil sales predictive model, as lower MSE and MAD values suggest greater accuracy and precision in forecasting. These findings provide valuable insights into the dynamics of MPX2 Oil sales, enabling companies to improve marketing strategies, transaction management, and inventory strategies.

Keywords: K-Medoids, Backpropagation, Sales Forecasting, Predictive Accuracy, MPX2 Oil Sales.

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1. Introduction

In the business world, sales forecasting methods are a crucial component of planning and decision-making in the corporate sector. This is especially true in the automotive care sector, where oil sales are a key variable that must be accurately anticipated. The implementation of effective and accurate prediction methods is vital in enhancing sales tactics and meeting client demands. In this article, we analyze the implementation of two popular forecasting methods, K-Medoids and Backpropagation, in predicting the sales of Mpx2 oil brand [1].The K-Medoids method is a clustering algorithm used to group data into several clusters based on similarities. This method aids in identifying different purchasing patterns among customer groups, allowing companies to tailor their sales strategies to meet the needs of each group. Additionally, we examine the implementation of the Backpropagation method, a technique commonly used in neural networks. This method enables neural networks to learn from historical sales data and generate future sales predictions. Using training and testing data, neural

networks can be trained to recognize complex purchasing patterns and make more accurate sales predictions.

The K-Medoids and Backpropagation methods are often used in oil sales prediction research for specific reasons that make them suitable for data analysis in this context. K-Medoids is primarily used for its data clustering capabilities [2]–[4]. As an effective clustering technique, K-Medoids helps group similar objects into clusters. In oil sales, this is useful for identifying different patterns or market segments based on sales characteristics. Another advantage of K-Medoids is its real cluster representation. Unlike other clustering methods such as K-Means, K-Medoids uses actual data points (medoids) as cluster centers, making clustering results more interpretable and relevant for real-world applications, like in oil sales [5], [6]. On the other hand, Backpropagation is used in neural networks (Artificial Neural Networks, ANN) for its ability to model experience and knowledge [7]–[9]. This is invaluable in forecasting oil sales trends, providing flexibility in altering forecasting rules based on historical data and market trends. This method is also particularly suited to adjustments in time-series data, crucial in oil sales predictions as sales changes often relate to time factors like seasons, economic trends, and industry policies. Moreover, Backpropagation allows for high optimization and accuracy in predictions, essential in a business context where decisions must be based on accurate and reliable forecasts [10], [11]. When both methods are used together, they can provide deep insights into oil sales patterns, aiding in better market segmentation and enabling more accurate predictions based on historical data and current trends.

This analysis aims to assist the automotive repair sector enhance their MPX2 Oil sales forecasts and marketing approaches. Unlike previous studies, it fills a research gap by specifically comparing the K-Medoids and Backpropagation methods for MPX2 Oil sales forecasting. Raeisi & Kabir (2022) focused on general sales forecasting using Artificial Neural Networks (ANN), emphasizing time series data [12]. Safar et al. (2019) explored Backpropagation for electric sales forecasting, addressing non-linear and non-stationary data challenges [13]. Berahmana et al. (2020) investigated customer segmentation using RFM models and algorithms like K-Means, K-Medoids, and DBSCAN [14]. The novelty of this study lies in its direct comparison of K-Medoids and backpropagation for MPX2 oil sales and its exploration of K-Medoids for customer categorization based on purchasing habits. Thus, the research question is to evaluate the effectiveness of implementing the K-Medoids and Backpropagation methods in predicting the sales of Mpx2 brand oil. Specifically, this study addresses the sales prediction challenges in the automotive workshop industry using transaction data from 2022 to 2023. The K-Medoids method is employed to identify customer purchase patterns through clustering, while Backpropagation is used to predict sales trends by enhancing accuracy through training. The results of this research are expected to provide valuable insights into the dynamics of MPX2 oil sales, enabling companies to improve marketing strategies, transaction management, and inventory strategies.

2. Methods

2.1. System Analysis

The data input for this study was obtained through observations and interviews related to the sales of MPX2 Oil in stores. The data used to determine stock predictions are derived from transaction information spanning from 2022 to 2023. It is essential to note that the research context is specifically centered around MPX2 Oil Sales Forecasting, aligning with the adjusted research title for a more accurate depiction.

Table 1. Sales Transaction Samples Year 2022-2023

Date	Item Name	Quantity	Total Price
02/02/2022	AHM OIL MPX 2 0.8L	8	323.000,00
02/11/2022	AHM OIL MPX 2 0.8L	7	292.000,00
10/19/2022	AHM OIL MPX 2 0.8L	11	443.000,00

11/10/2022	AHM OIL MPX 2 0.8L	14	560.000,00
01/12/2022	AHM OIL MPX 2 0.8L	12	486.000,00
03/19/2022	AHM OIL MPX 2 0.8L	11	464.000,00
07/04/2022	AHM OIL MPX 2 0.8L	10	415.500,00
10/10/2022	AHM OIL MPX 2 0.8L	14	595.000,00
11/27/2022	AHM OIL MPX 2 0.8L	11	472.000,00
01/25/2023	AHM OIL MPX 2 0.8L	10	446.000,00

The table contains information about the date, item code, item name, type, brand, quantity, unit, and total price. From this table, data will be processed to obtain predictions for stock levels of the items.

2.2. Process Overview

Based on the sales data of MPX2 Oil, the prediction process in this research is carried out by processing normalized sales data using the K-Medoids and Backpropagation algorithms. Subsequently, the data resulting from the Backpropagation process will be denormalized to obtain the Mean Absolute Deviation (MAD) value. Based on this MAD value, the system will provide information to the owner regarding the sales prediction of MPX2 Oil stock.

2.3. Output Data

a. Determining the number of clusters: The first step involves performing k-medoids clustering by calculating the cluster data for the quantity of sales stock as follows:

Table 2. Early literacy

Literacy 1 with Early Center C			
Cluster 1 = C1	8	7	11
Cluster 2 = C2	14	12	11
Cluster 3 = C3	10	14	11

C1 is cluster 1,
C2 is cluster 2,
C3 is cluster 3. Calculate the distance between clusters.

Calculating K-Medoids Proximity Distance, with a resulting K-Medoids proximity of 33.8

b. Solution

Facilitating owners in predicting the stock of goods to be ordered next month. So that customers do not switch to other vendors when MPX2 lubricant stock is available. Based on transaction data, prediction calculations can be performed using the following equation:

Prediction Calculation Formula

$$Xnew = 0{,}1 + 0{,}8\ x\ \frac{Xold - Xmin}{max - min} \quad (1)$$

2.4. Analysis of Device Requirements

Involves main components consisting of hardware and software. For hardware requirements, the specifications include an Intel® Core™ i3-7020 CPU 2.30GHz processor, 8 GB PC19200/2400 Mhz DDR4 SODimm RAM, Toshiba 1 TB Version MQ04ABF100 SATA HDD, and LOGITECH M187 (Wireless) mouse. As for software requirements, it includes Visual Studio Code Version 1.61.2 (user setup), OS Windows 10 Home Single Language (64 bit) Version 21H1, Google Chrome Version 94.0.4606.81 (Official Build) (64 bit) browser, Git Version 2.32.0.2 (64 bit), and Xampp Version 3.3. Non-functional requirements analysis involves these aspects to ensure the smooth development and operation of the application.

Specific hardware and software specifications were chosen for this system based on several important considerations:

a. The Intel® Core™ i3-7020 CPU 2.30GHz processor balances performance and power efficiency, suitable for applications that do not overly burden the processor.
b. The DDR4 SODimm 8 GB PC19200/2400 Mhz RAM provides sufficient memory to run modern applications smoothly, enabling seamless multitasking.
c. The Toshiba 1 TB Version MQ04ABF100 SATA HDD offers ample storage capacity for storing application data and the operating system, while the LOGITECH M187 (Wireless) mouse adds convenience with its wireless design.

In terms of software, Visual Studio Code Version 1.61.2 was selected as it is a lightweight and versatile code editor that supports multiple programming languages and extensions. The Windows 10 Home Single Language (64-bit) Version 21H1 operating system is stable and widely used, ensuring compatibility with various software. Google Chrome Version 94.0.4606.81 provides fast and efficient browsing performance, which is essential for research and development. Git Version 2.32.0.2 supports effective code version management, which is crucial in software development. Finally, Xampp Version 3.3 provides an easy-to-use local web development environment, allowing efficient testing of web applications. These specifications were chosen to ensure that the system has stable, reliable, and efficient performance for application development, considering both functional and non-functional aspects of the system.

2.5. System Design (Architecture)

This process involves steps such as ordering training data, data preprocessing, clustering using the K-Medoids method, generating Backpropagation values, denormalizing results, and calculating Mean Absolute Deviation (MAD) to produce prediction results. If the data has not been trained, then preprocessing with the K-Medoids method will be chosen. This entire process helps in designing an efficient stock prediction system.

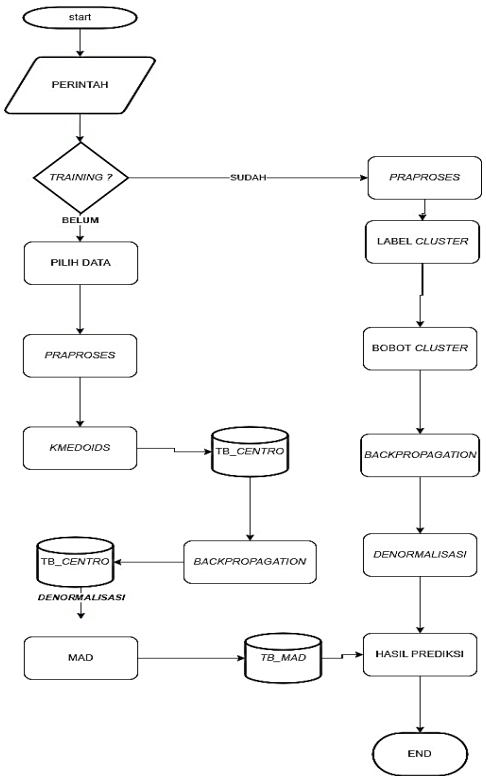

Figure 1. System Flowchart

Furthermore, there is a database design explained in Figure 2 with the Class Diagram as follows: the process of predicting goods involves entities such as user, incoming goods, unit, supplier, and type.

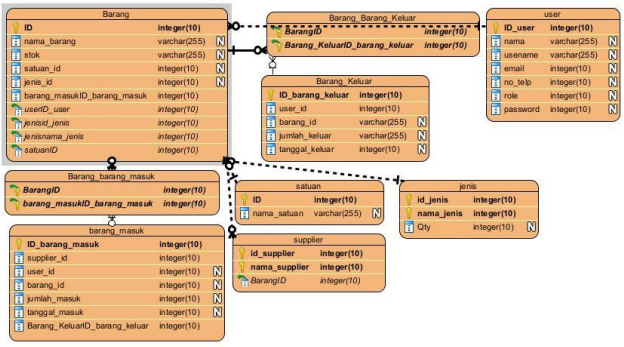

Figure 2. Database Server Design

2.6. K-Medoids

K-Medoids, also known as Partitioning Around Medoids (PAM) or K-Medians, is a clustering algorithm that serves as a modification of the K-Means technique. It is believed to overcome a significant limitation of K-Means, which is its sensitivity to outliers. In situations where an object with an extreme value might deviate significantly from the dataset's distribution, the average of each cluster does not lead to the use of a medoid. Due to severe values in the dataset, the goal is to reduce the sensitivity of the partitioning. Medoid objects are resistant to outliers because they are positioned at the center of clusters. The proximity of medoid and non-medoid objects is considered when forming clusters. The K-Medoids algorithm performs better with very large datasets, similar to the K-Means algorithm. Data normalization is advised before determining distances for data with various parameters to ensure balance.

The workings of K-Medoids are as follows:

a. Determine the number of cluster centers, k (clusters).
b. Randomly create k initial medoids using n data points.
   Use Euclidean Distance to calculate the distance of objects from each selected medoid, as given by Equation (2):

$$\sqrt{(xi - X)2 + \ldots + (yn\ Y)2} \quad (2)$$

c. After randomly selecting a new medoid, determine the distance of objects from each chosen medoid using Euclidean Distance. Determine the shortest distance across all the new medoids.
d. Apply Equation (3) to determine the total deviation (S) using the following equation:

$$S = b - a \quad (3)$$

where a: the sum of the nearest distances between objects to the original medoid,
and b: the sum of the nearest distances between objects to the new medoid.

If S < 0, then swap the object with data to produce a new set of k medoids.
Repeat steps 3-5 until no more changes in medoids occur, resulting in a number of clusters and their members.

2.7. Backpropagation

Multi-layer perceptrons typically use backpropagation, a supervised learning technique, to adjust weights connecting neurons in the hidden layers. Before the backpropagation method can utilize output errors, an initial step must be completed.
The training algorithm for a backpropagation network with one hidden layer is as follows:

a. Initialize the weights by assigning random values (small random values from 0 to 1).
b. As long as the stop condition is false, perform steps 3-9.
c. For each training data pair (x_setb, tb) where b=1,…,l, perform steps 4-8.
d. Starting the forward process, each input unit (Xi, I = 1,…, n) receives an input signal xi and forwards it to the hidden layer. Each hidden unit (Zj, j= 1,…,p) sums the weighted input signals:

$$\sum_{f=1}^{n} x_i v_{ij} \quad (4)$$

e. Use the activation function to compute its output signal (Yk,k = 1,….., m)

$$y\_in_{k} = wo_k + \sum_{i=1}^{p} z_j w_{jk} \quad (5)$$

f. Use the activation function to calculate its output signal:

$$yk = f(y_{in_k}) \quad (5.1)$$

And proceed to the backward process

Each output unit (yk, k=1,..., m) receives a target pattern related to the learning input pattern, calculate error information δ_k,

$$\delta_k = (t_k - y_k) f^1(y\_in_k) \quad (6)$$

Calculate weight correction Δwjk

$$\Delta w_{jk} = ab_k z_j \quad (6.1)$$

Calculate bias correction Δ*wok*:

$$\Delta wo_k = ab_k \quad (6.2)$$

And send the error information value to its lower layer.

g. Each hidden unit sums the product of error information with Weight:

$$\delta_{-inj} = \sum_{k=1}^{m} \delta_k w_{jk} \quad (7)$$

Calculate error information δ_j:

$$\delta_j = \delta_{ini} f^1(z\_in_f) \quad (7.1)$$

Calculate weight correction Δv_{ii}:

$$\Delta v_{ii} = \propto \delta_i x_t \quad (7.2)$$

And bias correction Δv_{oj}:

$$\Delta v_{oj} = a\delta_j \quad (7.3)$$

Continue to the weight update stage.

h. Each output unit (Yk, k = 1,..., m) adjusts its weights and bias (j = 0,..., p):

$$w_{jk}(New) = w_{jk}(Old) + \Delta w_{jk} \quad (8)$$

Each hidden unit (Zj, j = 1,..., p) adjusts its weights and bias (i=0,...,n),

$$v_{ii(baru)} = v_{ii\ (lama)} + \Delta v_{ii} \quad (8.1)$$

Proceed to the condition test. If true, training stops.

2.8. Data Normalization in K-Medoids and Backpropagation

Data normalization is a crucial step in data processing before applying machine learning algorithms such as K-Medoids and Backpropagation. This process involves adjusting the scale of data values to a specific range, such as 0 to 1, or having a mean of 0 and variance of 1. The main goal is to transform data into a more easily processed format by algorithms, avoiding biases towards features with larger scales and enhancing algorithm convergence. Using K-Medoids and Backpropagation with normalized data effectively provides profound insights into customer purchasing behavior and sales trends, which are crucial for sales strategies and inventory management in the automotive industry. The contribution of data normalization to the effectiveness of K-Medoids and Backpropagation algorithms is significant. For K-Medoids, the normalization process enhances clustering accuracy by ensuring that all features contribute equally to cluster formation. This prevents features with larger ranges from dominating the clustering process, resulting in a more balanced and accurate representation of each cluster. Additionally, normalization reduces the impact of outliers, allowing medoids to represent each cluster, thus improving overall clustering quality more accurately. Meanwhile, in Backpropagation, data normalization plays a crucial role in speeding up the convergence process during training. Normalizing data prevents issues with vanishing gradients, often occurring when inputs have highly varied ranges. This enables the neural network to adjust its weights more efficiently, leading to faster and more effective learning. Moreover, normalization enhances the generalization ability of the neural network by providing data in a similar range, allowing the model to handle new inputs more effectively. Overall, data normalization significantly contributes to the effectiveness of both methods in predicting MPX2 Oil sales in the automotive workshop industry.

2.9. Feedforward, Backpropagation, and MSE

Calculation

The implementation of the backpropagation algorithm in predicting sales includes a step-by-step explanation of the model training process, starting from output calculation, error measurement, adjustment of weights (w1, w2), and bias (b), to the calculation of Mean Squared Error (MSE). These steps aim to train the model using the backpropagation algorithm to forecast oil sales.

a. Feedforward:

1) Formula (9) illustrates the feedforward step where the output is calculated based on input (x1, x2), weights (w1, w2), and bias (b).

$$Output = (x1 \times w1) + (x2 \times w2) + b \quad (9)$$

2) Formula (9.1) measures the error between the generated output and the target value (y).

$$Error = y - Output \quad (9.1)$$

b. Backpropagation:

1) The backpropagation process updates weights (w1, w2) and bias (b) based on the measured error.
2) Formulas (10) and (10.1) show the changes in weights w1 and w2 based on the gradient of error with respect to the corresponding weights and input.

$$w1 = w1 \text{ sensitivity} + (\eta \times x1 \text{ sensitivity} \times Error) \quad (10)$$
$$w1 = w2 \text{ sensitivity} + (\eta \times x2 \text{ sensitivity} \times Error) \quad (10.1)$$

3) Formula (11) describes the change in bias value (b) based on the gradient of error with respect to bias.

$$b = b\ sebelumnya + (\eta \times Error) \quad (11)$$

4) Formula (12) shows the calculation of the new output after updating weights and bias.

$$Output = (x1 \times w1) + (x2 \times w2) + b \quad (12)$$

c. Iterative Training:
An iterative process where the backpropagation step is repeated for each training data.
d. Mean Squared Error (MSE) Calculation:

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(yi - \hat{y}i)^2 \quad (13)$$

1) MSE is calculated after the iterations are complete, providing an indication of how well the model can predict the target compared to actual values.
2) MSE is calculated by summing the squared errors and dividing by the number of data points.

By following these steps, the research can systematically train the model using the backpropagation algorithm to enhance accuracy in forecasting oil sales. This overall process can assist in achieving the study's goal of improving the accuracy of oil sales predictions by combining K-Medoids and Backpropagation.

3. Results and Discussion

After analyzing the system requirements, the next step is the system design, which includes the design of a Flowchart, ERD, DFD, table relationships, Context Diagram, and application interface using case tools such as Draw.io, Visio, and Balsamiq Wireframes. The next process is the writing of the program code, broken down into small modules that will be integrated. The author utilizes Visual Studio as the code-writing platform, taking into consideration the previous system design. Subsequently, the modules are integrated and tested to ensure compatibility with the design. The final stage is system maintenance, where errors are corrected, and additional features may be added after the system is implemented.

3.1. Implementation of the Program (Development)

The implementation of the user interface views of the application created by the researcher will be presented below:

3.1.1. Transaction Page

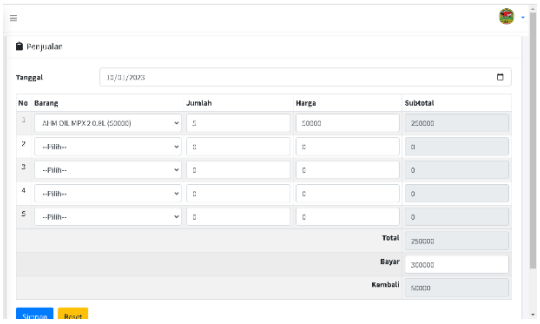

Figure 3. Add Transaction Form Page

The page is used to add transactions when there is a purchase of goods. Once the transaction form is filled out, you can press the "Add" button, and the data will appear on the right side of the page, which is the list of sales transactions. To continue the transaction, press the "Pay" button. Then, the payment form shown in figure 4 will appear.

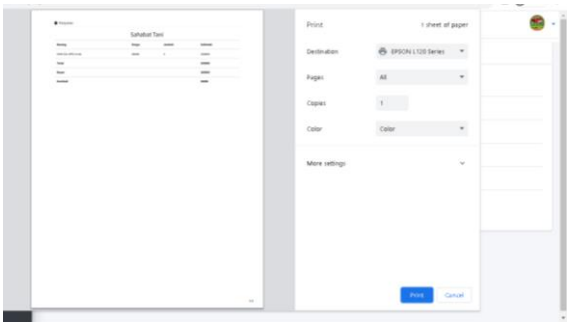

Figure 4. Payment Form Page

3.1.2. Transaction List Management Page

In figure 5, there is a transaction list page that has been previously executed. On this page, the admin can view the details of each transaction that has been conducted by clicking the eye icon button in the "Action" column.

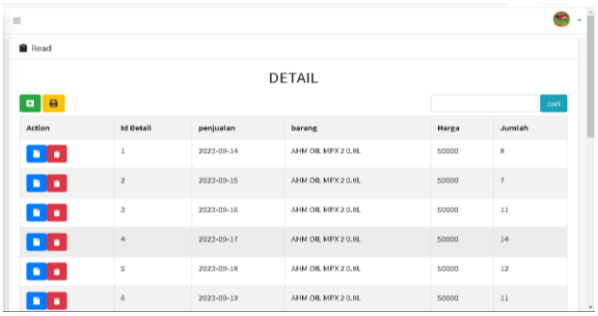

Figure 5. Manage Transaction List page

3.1.3. Algorithm Implementation Page

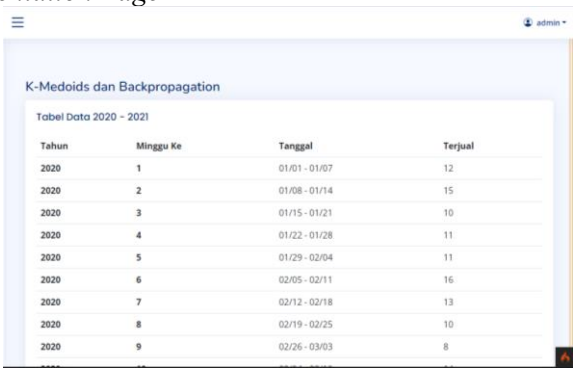

Figure 6. Algorithm Implementation Page

Algorithm Implementation is the page displaying the implementation of the algorithm, presenting data by week and the corresponding weekly quantity of sold items.

3.1.4. Prediction Results

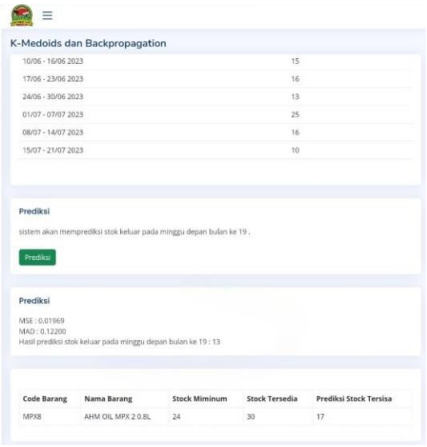

Figure 7. Prediction results

Figure 7 shows the prediction results, which are a crucial part of the system evaluation. On this page, there is highly relevant information regarding the performance of the implemented predictive model. The Mean Squared Error (MSE) value of 0.01969 and Mean Absolute Deviation (MAD) value of 0.12200 provide an insight into how well the model can predict the sales of Mpx2 oil. MSE and MAD are commonly used evaluation metrics in forecasting contexts, where lower values indicate higher accuracy. In this case, the low MSE value (0.01969) indicates that the difference between predicted and actual values tends to be small. This implies that the model tends to provide accurate estimates regarding the sales of Mpx2 oil. Meanwhile, the MAD of 0.12200 also indicates that the model has a low deviation level in predicting data, indicating high precision in performance assessment. Based on these results, it can be concluded that the implementation of the Backpropagation and K-Medoids algorithms in the store procurement system effectively produces a reliable predictive model for sales forecasting. With low MSE and MAD values, the system can provide accurate and valuable predictive information for decision-making at operational and managerial levels.

3.2. Results of Feedforward, Backpropagation, and MSE Calculation

This process utilizes the artificial neural network (ANN) learning method, consisting of several main steps, including feedforward, error calculation, backpropagation, and Mean Squared Error (MSE) calculation. In the feedforward phase, the network's output is calculated based on the current input and parameters, including weights (w1, w2) and bias (b). This process is evident in the 'Output' column of the table, calculated using the formula Output = (x1 × w1) + (x2 × w2) + b. Subsequently, error calculation is performed by subtracting the generated output from the expected value (y), reflected in the 'Error' column. After that, the backpropagation step is taken. Weights and bias are adjusted based on the obtained error, as reflected in the changing values of weights and bias from epoch to epoch in the table.

Tabel 3. The calculation results

Epoch	x1	x2	y	b	w1	w1	Output	Error	MSE
1	1	1	1	1	3	2	6	-5	
	1	0	0	0.2	2.5	1.5	3	-3	
	0	1	0	0.2	2.2	1.5	1.7	-1.7	
	0	0	0	0.03	2.2	1.33	0.03	-0.03	9.22273

Epoch	x1	x2	y	b	w1	w1	Output	Error	MSE
2	1	1	1	0.027	2.2	1.33	3.557	-2.557	
	1	0	0	-0.2287	1.9443	1.0743	1.7156	-1.17156	
	0	1	0	-0.40026	1.77274	1.0743	0.67404	-0.67404	
	0	0	0	-0.46766	1.77274	1.006896	-0.46766	0.467664	2.53864
3	1	1	1	-0.4209	1.77274	1.006896	2.358738	-1.35874	
	1	0	0	-0.55677	1.636866	-0.871022	1.080095	-1.08009	
	0	1	0	-0.66478	1.528857	0.871022	0.206241	-0.20624	
	0	0	0	-0.68541	1.528857	0.850398	-0.68541	0.685405	0.88127

In the first epoch, the Mean Squared Error (MSE) value is 9.22273, indicating a high level of error in the initial predictions. However, as the learning process progresses, there is a decrease in the MSE value to 2.53864 in the second epoch and further decrease to 0.88127 in the third epoch. This decline indicates an improvement in the model's accuracy in predicting Mpx2 oil sales. The process involves continuous adjustments of weights and biases based on the error gradient, calculated through the backpropagation process. These adjustments aim to minimize MSE, thus enhancing the model's prediction accuracy. The overall process demonstrates how the Backpropagation method, along with K-Medoids, can be effective in predicting sales, as reflected in the gradual decrease in MSE values during the training process.

3.3. Evaluation Results

The evaluation results obtained from various tests of system implementation and program implementation in this study indicate the successful implementation of the K-Medoids and Backpropagation algorithms in the Goods Procurement System at the store. The system has been successfully developed to provide quick information or data reports. The testing results for the goods procurement system show the following scores:

Table 4. Test Results Score

Feature	Testing Scores		Amount	Maximum Score
	Succeed	Fail		
Login Page	1	0	1	1
Add Transaction Page	1	0	1	1
Transaction Edit Page	1	0	1	1
Transaction List Page	1	0	1	1
Manage Item Data Page	1	0	1	1
Edit Item Data Page	1	0	1	1

The evaluation results of the implementation of the procurement system in the store indicate success in implementing the K-Medoids and Backpropagation algorithms. Table 3 provides an overview of the testing scores for various features within the system, indicating that each feature, such as the Login Page, Add Transaction Page, Edit Transaction Page, List Transaction Page, Manage Item Data Page, and Edit Item Data Page, all successfully achieved the maximum scores. These scores reflect excellent performance in building a responsive and functional system. Thus, the testing results confirm that the implementation of this program provides an effective and reliable solution in supporting transaction management and procurement of goods in the store, delivering information and data reports with the expected speed and accuracy.

Table 5. Advanced Testing Results Score

Feature	Testing Scores		Amount	Maximum Score
	Succeed	Fail		
Manage Supplier Data page	1	0	1	1
Add Supplier Data page	1	0	1	1
Edit Supplier Page	1	0	1	1
Manage Unit Data Page	1	0	1	1
Item Unit Data Edit Page	1	0	1	1
Manage Incoming Stock Data Page	1	0	1	1
Incoming Stock Data Edit Page	1	0	1	1
Out of Stock Data Page	1	0	1	1
Algorithm Implementation Page	1	0	1	1

The results of the evaluation of the procurement system implementation indicate excellent achievement, with all features successfully tested and achieving maximum scores. The evaluation table includes several key features in the system, such as the supplier data management page, add supplier data page, edit supplier page, manage unit data page, edit unit data page, manage incoming stock data page, edit incoming stock data page, outgoing stock data page, and algorithm implementation page. Each feature successfully obtained a maximum score, demonstrating the success of implementing the K-Medoids and Backpropagation algorithms in the store's procurement system. This success reflects the system's ability to provide information and data reports quickly and effectively, providing crucial support for operational-level management processes and decision-making.

Discussion

The results of this study indicate that the approach taken to design, implement, and test the procurement system in the store, including the integration of K-Medoids and Backpropagation algorithms, has successfully achieved excellent outcomes. The system development process began with a comprehensive design phase, involving the creation of flowcharts, Entity-Relationship Diagrams (ERD), Data Flow Diagrams (DFD), table relationships, Context Diagrams, and application interfaces. Subsequently, the program implementation phase was carried out by breaking down the program code into small modules using Visual Studio, adhering to the previously designed system. The integration and testing of these modules were conducted to ensure compliance with the designed framework. In terms of user interface (UI), the implementation results were demonstrated through key pages, such as the Transaction Form Addition Page, Payment Form Page, Transaction List Management Page, and Algorithm Implementation Page. The interface design created using case tools such as Draw.io, Visio, and Balsamiq Wireframes provided a clear and efficient visual overview for system users, covering transaction processes and algorithm visualization results. The implementation process of the K-Medoids and Backpropagation algorithms, as depicted in the calculation results, showed that the model could learn patterns from data and improve the accuracy of Mpx2 oil sales predictions. Despite initially high error rates, the backpropagation steps resulted in a gradual decrease in Mean Squared Error (MSE) values during the training process. This reduction reflects an enhancement in the model's accuracy in predicting Mpx2 oil sales, providing strong support for the effectiveness of the Backpropagation and K-Medoids methods in the sales forecasting context. In the evaluation phase, test result scores affirmed the success of the system implementation, with each feature, including the Login Page, Transaction Addition Page, Transaction Edit Page, Transaction List Page, Product Data Management Page, and Product Data Edit Page, successfully achieving maximum scores. This indicates that the system is reliable and responsive in supporting the operational functions related to transactions and procurement. Further evaluation of features such as Supplier Data Management Page, Unit Data Management Page, Stock In Data Management Page, and Algorithm Implementation Page also demonstrated success in implementing the K-Medoids and Backpropagation algorithms.

The findings of this study are relevant to previous research indicating the effectiveness of artificial neural network learning methods in sales prediction [15]–[17]. In contrast to research emphasizing Backpropagation methods on non-linear and non-stationary data [18], this study applies

Backpropagation to forecast Mpx2 oil sales, contributing additional insights into understanding historical purchasing patterns and predicting sales trends in the future, particularly in the automotive industry context. References to previous studies, such as by Berahmana et al. (2020), discussing customer segmentation with RFM models and K-Means, K-Medoids, and DBSCAN algorithms, provide a framework for understanding customer purchasing behavior.

The strengths of this research lie in choosing the K-Medoids and Backpropagation methods over other methods for the context of inventory procurement in a store. K-medoids is selected for their superior ability to handle outliers compared to other clustering methods like K-means. This is crucial in retail sales, where purchasing patterns can be highly variable and often contain outliers. By using K-Medoids, the system can identify customer purchasing patterns more accurately, grouping them based on similar buying characteristics and enhancing the effectiveness of sales and inventory procurement strategies. On the other hand, Backpropagation, as a technique in artificial neural network learning, is chosen for its superior capability in handling complex and non-linear data commonly encountered in sales data. This method allows the model to learn patterns from historical data of Mpx2 oil sales and predict future sales trends with higher accuracy. Backpropagation also enables the system to dynamically adapt to changes in data, which is crucial in the rapidly changing retail sales environment. The combination of these two methods reflects a profound understanding of the characteristics of sales data in the automotive industry and the need for predictive tools that can handle the variability and complexity of such data. By integrating K-Medoids for customer cluster analysis and Backpropagation for sales prediction, this research successfully achieves an efficient, accurate inventory procurement system that is highly relevant to the dynamics of the current market. Thus, the results of this study have significant implications in the context of developing transaction management systems and predicting stock in the retail industry, especially for Mpx2 oil products. The integration of K-Medoids and Backpropagation algorithms in the store's procurement system has proven successful in improving sales prediction accuracy. These implications reflect the potential application of artificial neural network learning methods, such as Backpropagation, in addressing sales forecasting challenges in non-linear and non-stationary environments. The system's success in achieving maximum scores across various features, including transaction management and procurement, instills confidence that this solution can be relied upon to support store operations with high efficiency and responsiveness. These implications may also serve as inspiration for the automotive industry and other sectors to adopt similar approaches in enhancing inventory management efficiency and predicting customer needs.

4. Conclusion

The results of this study indicate that the integration of K-Medoids and Backpropagation algorithms in the store's procurement system has successfully improved the accuracy of Mpx2 oil sales predictions. The designed, implemented, and evaluated system achieved excellent outcomes, with all features obtaining maximum scores in testing. Nevertheless, the limitations of this research include a restricted evaluation of data and a comparison with other potentially relevant methods in a similar context. For future research, it is recommended to conduct further experiments with a broader dataset and compare the results with alternative methods. Additionally, the study could be expanded by considering external factors that may influence sales predictions, such as changes in market trends or economic factors.

References

[1] N. S. Atmaja and D. Lianda, “Jaringan Syaraf Tiruan Menggunakan Metode Backpropagation Dalam Prediksi Persediaan Bahan Baku (Studi Kasus : Pt. Bintang Toba Lestari),” *J. Inf. Interaktif*, vol. 6, no. 3, 2021.

[2] S. Nirmal, “Comparative study between k-means and k-medoids clustering algorithms,” *Int. Res. J. Eng. Technol.*, vol. 839, no. 1, pp. 839–844, 2019, [Online]. Available: https://www.irjet.net/archives/V6/i3/IRJET-V6I3154.pdf

[3] A. V. Ushakov and I. Vasilyev, "Near-optimal large-scale k-medoids clustering," *Inf. Sci. (Ny).*, vol. 545, no. 1, pp. 344–362, 2021, doi: 10.1016/j.ins.2020.08.121.
[4] S. Balakrishna, M. Thirumaran, R. Padmanaban, and V. K. Solanki, "An efficient incremental clustering based improved K-Medoids for IoT multivariate data cluster analysis," *Peer-to-Peer Netw. Appl.*, vol. 13, no. 4, pp. 1152–1175, 2020, doi: 10.1007/s12083-019-00852-x.
[5] F. Rahman, I. I. Ridho, M. Muflih, S. Pratama, M. R. Raharjo, and A. P. Windarto, "Application of Data Mining Technique using K-Medoids in the case of Export of Crude Petroleum Materials to the Destination Country," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 835, no. 1, pp. 1–7, 2020, doi: 10.1088/1757-899X/835/1/012058.
[6] H. Jiang, Y. Wu, K. Lyu, and H. Wang, "Ocean Data Anomaly Detection Algorithm Based on Improved k-medoids," in *11th International Conference on Advanced Computational Intelligence, ICACI 2019*, IEEE, 2019, pp. 196–201. doi: 10.1109/ICACI.2019.8778515.
[7] W. Wei and X. Yang, "Comparison of Diagnosis Accuracy between a Backpropagation Artificial Neural Network Model and Linear Regression in Digestive Disease Patients: An Empirical Research," *Comput. Math. Methods Med.*, vol. 1, no. 1, pp. 1–10, 2021, doi: 10.1155/2021/6662779.
[8] B. Dai, H. Gu, Y. Zhu, S. Chen, and E. F. Rodriguez, "On the Use of an Improved Artificial Fish Swarm Algorithm-Backpropagation Neural Network for Predicting Dam Deformation Behavior," *Complexity*, vol. 1, no. 1, pp. 1–13, 2020, doi: 10.1155/2020/5463893.
[9] M. Madhiarasan and M. Louzazni, "Analysis of Artificial Neural Network: Architecture, Types, and Forecasting Applications," *J. Electr. Comput. Eng.*, vol. 1, no. 1, pp. 1–23, 2022, doi: 10.1155/2022/5416722.
[10] J. Veri, S. Surmayanti, and G. Guslendra, "Determination of Accuracy at Backpropagation Method in Prediction Crude Oil Prices," *SAR J. - Sci. Res.*, vol. 4, no. 4, pp. 181–184, 2021, doi: 10.18421/sar44-05.
[11] A. Purwinarko and F. Amalia Langgundi, "Crude oil price prediction using Artificial Neural Network-Backpropagation (ANN-BP) and Particle Swarm Optimization (PSO) methods," *J. Soft Comput. Explor.*, vol. 4, no. 2, pp. 99–106, 2023, doi: 10.52465/joscex.v4i2.159.
[12] R. Raeisi and A. Kabir, "Implementation of Artificial Neural Network on Sales Forecasting Application," *J. Intell. Decis. Support Syst.*, vol. 5, no. 4, pp. 124–131, 2022, [Online]. Available: http://ilin.asee.org/Conference2006program/Papers/Raeisi-P59.pdf
[13] N. Z. M. Safar, A. A. Ramli, H. Mahdin, D. Ndzi, and K. M. N. K. Khalif, "Rain prediction using fuzzy rule based system in North-West Malaysia," *Indones. J. Electr. Eng. Comput. Sci.*, vol. 14, no. 3, pp. 1572–1581, 2019.
[14] R. W. B. S. Berahmana, F. A. Mohammed, and K. Chairuang, "Customer Segmentation Based on RFM Model Using K-Means, K-Medoids, and DBSCAN Methods," *Lontar Komput. J. Ilm. Teknol. Inf.*, vol. 11, no. 1, p. 32, 2020, doi: 10.24843/lkjiti.2020.v11.i01.p04.
[15] N. Caglayan, S. I. Satoglu, and E. N. Kapukaya, "Sales forecasting by artificial neural networks for the apparel retail chain stores," in *Advances in Intelligent Systems and Computing*, Springer International Publishing, 2020, pp. 451–456. doi: 10.1007/978-3-030-23756-1_56.
[16] S. Haque, "Retail Demand Forecasting Using Neural Networks and Macroeconomic Variables," *J. Math. Stat. Stud.*, vol. 1, no. 1, pp. 1–6, 2023, doi: 10.32996/jmss.
[17] N. T. Nguyen, R. Chbeir, E. Exposito, and P. Aniorté, "An approach to imbalanced data classification based on instance selection and over-sampling," in *11th International Conference, ICCCI 2019*, 2019, pp. 601–610. doi: 10.1007/978-3-030-28377-3_50.
[18] Y. F. Utami, G. Darmawan, and R. S. Pontoh, "Forecasting Electricity Sales Using the Artificial Neural Network Backpropagation Method," *Asian J. Appl. Educ.*, vol. 2, no. 4, pp. 581–594, 2023, [Online]. Available: https://journal.formosapublisher.org/index.php/ajae/article/view/6589

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Zonation Method for Efficient Training of Collaborative Multi-Agent Reinforcement Learning in Double Snake Game

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Abstract. This paper proposes a zonation method for training the two reinforcement learning agents. We demonstrate the method's effectiveness in the double snake game. The game consists of two snakes operating in a fully cooperative setting to maximize the score. The problem in this game can be related to real-world problems, namely, coordination in autonomous driving cars and the operation of collaborative mobile robots in warehouse applications. Here, we use a deep Q-network algorithm and the zonation method to train the two agents to play the double snake game collaboratively through a decentralized approach, where distinct state and reward functions are assigned to each agent. To improve training efficiency, we utilize the snake sensory data of the surrounding objects as the input state to reduce the neural network complexity. The results show that after 100 episodes, agents that are trained with the zonation method achieve a game score four times higher than without the zonation method. Furthermore, with the optimized hyperparameters, the agents earn an average game score of 15.4 with just under 140 training episodes. The results demonstrate that the proposed approaches can be used to train collaborative multi-agents efficiently, especially in the limited computing resources and training time environment.

Keywords: Zonation method, double snake game, collaborative multi-agent reinforcement learning, training efficiency

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1. Introduction

Machine learning has been widely used for many applications especially for, prediction, data clustering, and even chatbot [1]–[4]. Methods in machine learning can be classified into three learning paradigms: supervised learning, unsupervised learning, and reinforcement learning (RL) [5]. Supervised learning utilizes data and labels trained in a single process to generate a model that can generate predictions of unseen data. On the other hand, unsupervised learning uses data to train a model that can extract the intrinsic pattern in the corresponding data. In contrast to supervised and unsupervised learning, RL uses trial and error in the training process of an agent to learn the best policy, which can determine an action that can maximize total reward in a particular environment [6]. In RL, we often engage in a complex

environment that is suitable to be solved with deep reinforcement learning (DRL), which is an RL method that uses the prediction ability of neural networks to assist an agent in learning in an environment with a considerable number of actions and states [7], [8].

DRL has been applied to different fields, such as robotics, automobile, and game [9], [10]. The study of DRL in games often aims to minimize the risk of DRL implementation in the real world by creating a virtual world that can simulate actual conditions. This virtual world can be used as the testbed to evaluate the possible DRL solutions and benchmark the agent performance [11], [12]. Different games are commonly used in the study of DRL, including single-player games such as Atari and Super Mario, as well as multi-player games such as Mahjong [13], multi-player Texas Hold'em [14], and StarCraft [15].

The deep Q-Network (DQN) algorithm is typically used in the game to study DRL due to its superior performance compared to the previous algorithms [16], [17]. This algorithm combines neural network and Q-learning algorithms to predict optimal action value and policy in sequential decision-making [5], [7], [18]. DQN has been applied to train agents to play various games, such as multiple classic Atari 2600 games and Snake Game [19]. By utilizing the image pixels of the game screen, DQN-based agents can be trained to play various video games with a decent performance. However, this approach requires a complex neural network and a considerable amount of training time to achieve a sufficient level of performance [5], [20]. To reduce the amount of training time, Sebastianelli et al. proposed an approach that uses sensory data to train the agent under 150 episodes in their snake game environment [5]. The proposed approach works well with a simple neural network, which makes it efficient.

Recently, DQNs have been used in various multi-agent games with different settings, including competitive or cooperative settings. In cooperative setting games, there are generally two approaches for agents' reward functions: common reward function and team-average reward [21]. In the common reward function approach, all agents usually share a common reward function; meanwhile, team-average reward addresses each agent with a different reward function [22]–[24]. Team average reward allowed privacy among agents, recently called the decentralized approach in multi-agent games. Ardi Tampu et al. developed a multi-agent with DQN algorithms for Pong, and Lei Han et al. studied a multi-agent for Starcraft II; both groups successfully used DQN for multi-agent applications [25], [26]. However, both studies require millions of steps to train the agents until they reach a significant performance. Efficiency in multi-agent training time is necessary, mainly when the computing resources and time are limited.

In this paper we proposed a zonation method for training the two reinforcement learning agents to play a double snake game. The proposed double snake game involves two snakes collaborating to maximize the game score. The rules of this game are derived from the classic snake game, such as a point is collected when a snake eats the apple, both snakes are forbidden to hit the edge of the snake field, and a snake is not permitted to strike its own body or another snake. With this double snake game, we can simulate the characteristics of real-world problems, such as the operation of collaborative mobile robots for automated picking systems in warehouse applications and lane coordination and parking coordination for autonomous driving cars [27]–[30]. We train agents by using DQN to play a double snake game collaboratively with the decentralized approach by assigning each agent's different state and reward functions. We use snake sensory data of the surrounding objects to minimize the neural network complexity and training time. The zonation method that we use in this collaborative multi-agent setting is compatible with the simplicity of the neural network and input state that merely needs a small number of episodes to train the multi-agent.

2. Methods

2.1. Double Snake Game

The classic snake game in which the player controls the snake to eat the spawned apple at a random place to maximize the game score. The snake’s body will increase by one pixel and the game score will increase by one point when the snake eats the apple. Moreover, in this classic snake game, the player needs to avoid the collision of the snake’s head either with the wall or with the snake’s body. In this

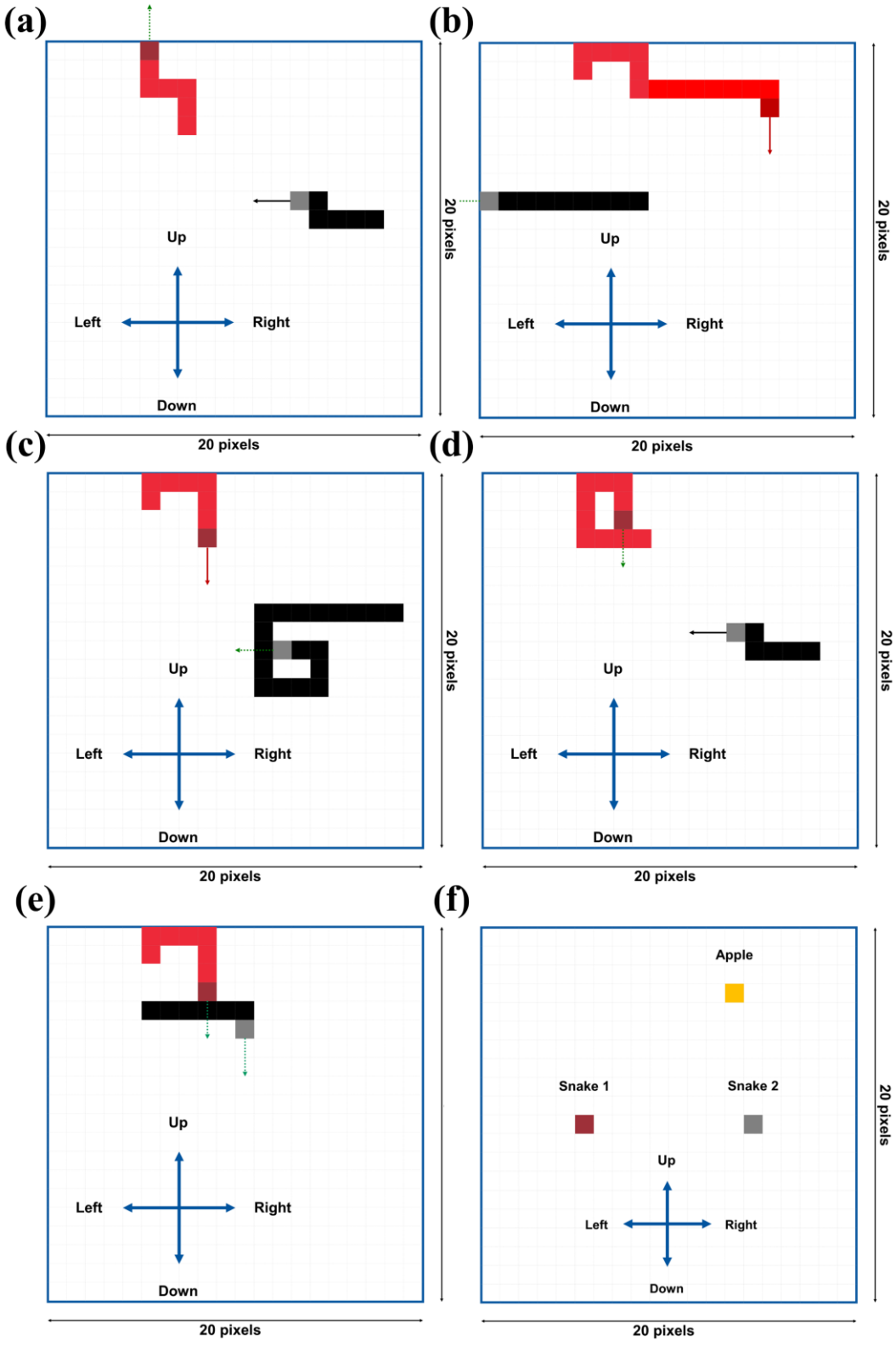
(a)
(b)
(c)
(d)
(e)
(f)
Up
Left
Right
Down
20 pixels
Apple
Snake 1
Snake 2

Figure 1. The game will be terminated **(a), (b)** if a snake head hits the edge of the snake field, **(c), (d)** if a snake hits its own body, or **(e)** if two snakes collide with each other. **(f)** Initial conditions of double snake game.

paper we propose the double snake game which is derived from the classical snake game. The double snake game consists of two snakes, an apple, and snake field with the size of 20 × 20 pixels. Each pixel in the field can only be occupied by an apple or a single snake part (either body or head), if there are two parts of snake (either the same snake or different snake) in the same pixel then the game will be over. When a snake hits the edge of the snake field the game will be over as well. The conditions that can make the double snake game terminate can be seen in **Figure 1**.

The double snake game starts with an apple in a random position and two motionless snake heads, as depicted in **Figure 1(f)**. When a snake eats the apple, when the snake's head is in the same pixel as the apple, the associated snake will elongate by one pixel. At the same time, the apple will be respawned at a new random position, and the score will be increased by one point. Correspondingly, the agent who plays the associated snake will receive 10 reward points. During the game, there is only one apple in the snake field. When a snake hits its own body, or hits another snake, or the edge of the snake field, the game will be over and restarted, and the snake will get -10 points as the punishment.

The input states used to train the agent consist of a vector with 18 elements. Elements of the input states are:

states = [apple up, apple right, apple down, apple left,
danger up, danger right, danger down, danger left,
move up, move right, move down, move left,
flag up, flag right, flag down, flag left,
game over, zone].

Every element in the input state is filled by a binary value of 0 or 1. The first to the fourth element of the input state represents the position of the apple relative to the snake head, and these states will assist the agent in finding the position of positive reward. The fifth to the eighth element of the input state shows the sides of the snake head that are in touch with an object (its own body, another snake, or the wall). These states will assist the agent in avoiding the position of negative reward. The ninth to the twelfth element of the state shows the direction of the snake head movement. This information will assist the agent in calculating the current movement toward the direction of reward. The thirteenth to the sixteenth element of the state shows the position of the zone flag relative to the head of the snake. This zone flag position assists the agent in staying in the zone while waiting for the apple to spawn in the agent's zone. The seventeenth element represents whether the game is still on or over. This is the state that is triggered if the agent takes the wrong action when one or more of the danger states is on. The eighteenth element of the state shows whether the snake is in its zone. When the agent is out of the zone, it will be rewarded negatively. The description of the zone and zone flag will be explained in section 2.3.

2.2. RL Agent

The double snake game is played by RL agents, which consist of neural network that can predict the value of actions when a particular input state is given. In the training process of an agent, the neural network learns a policy that is a function of an optimal action value. This policy is obtained by training the neural network through trial and error to maximize total reward while playing the double snake game. Each time the agent chooses an action, it will obtain a reward that can be a positive or a negative value, depending on the impact of the corresponding action. The agent training process aims to maximize the sum of rewards that can be achieved in a given state.

Figure 2 shows the agent architecture comprising of five fully-connected neural network layers. The first layer is an input layer with 18 nodes to proceed with the 18 input state elements. The subsequent three layers extract the intrinsic features in an input state. These features are then used as the parameters to predict optimal action value. Each layer in this layer group is followed by a Rectified Linear Unit

(ReLU). The last layer is an output layer, which consists of four nodes that generate the prediction value of each action. The agent will execute the action with the highest value.

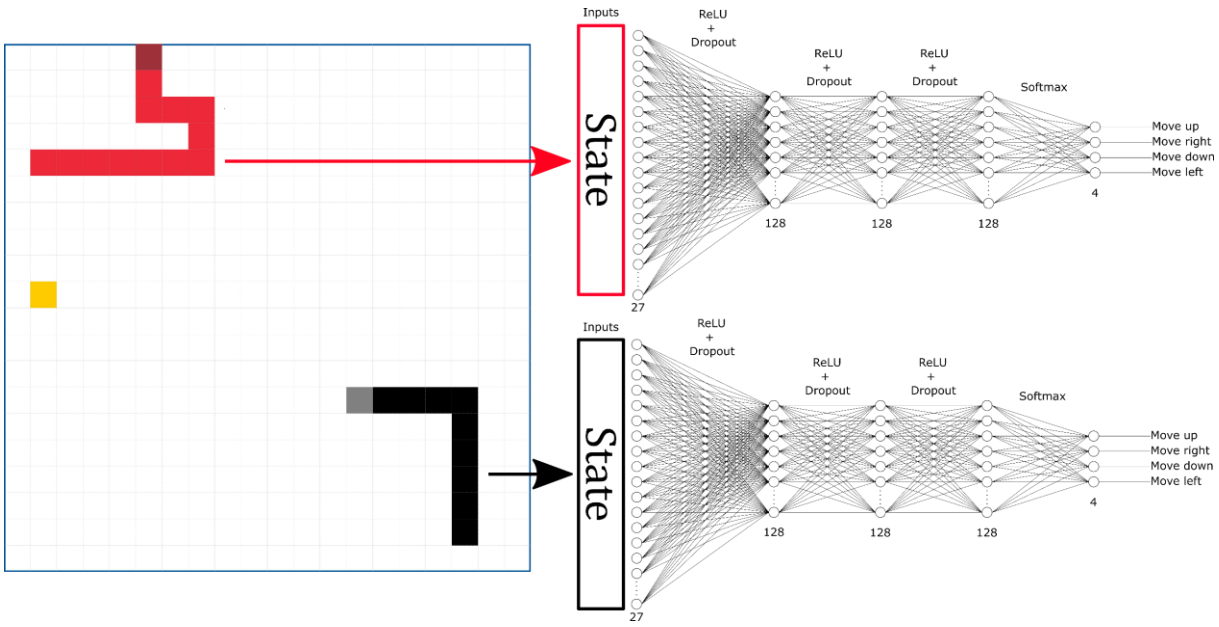

Figure 2. Neural network architecture of the RL agent.

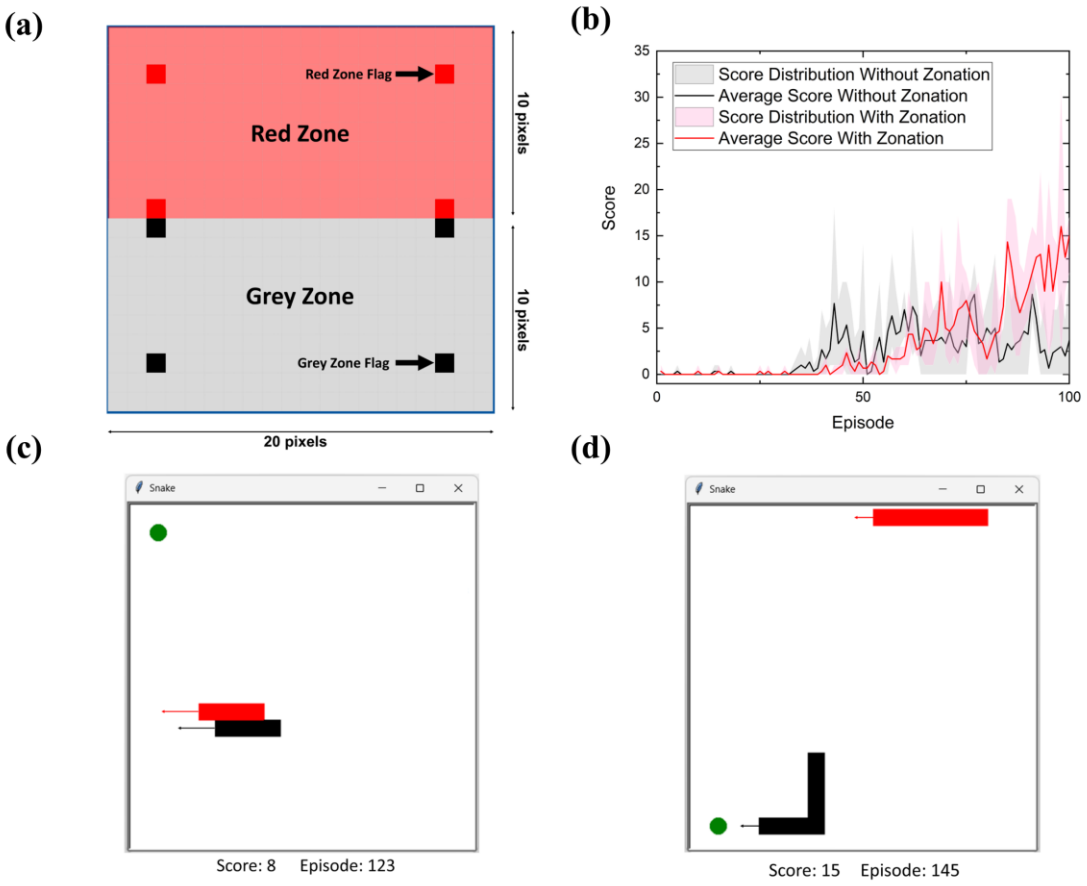

Figure 3. (a) Snake zone coordination in apple consumption for each snake during the game. **(b)** The game score comparison with and without zonation. Behavior of the snakes **(c)** without zonation and **(d)** with zonation.

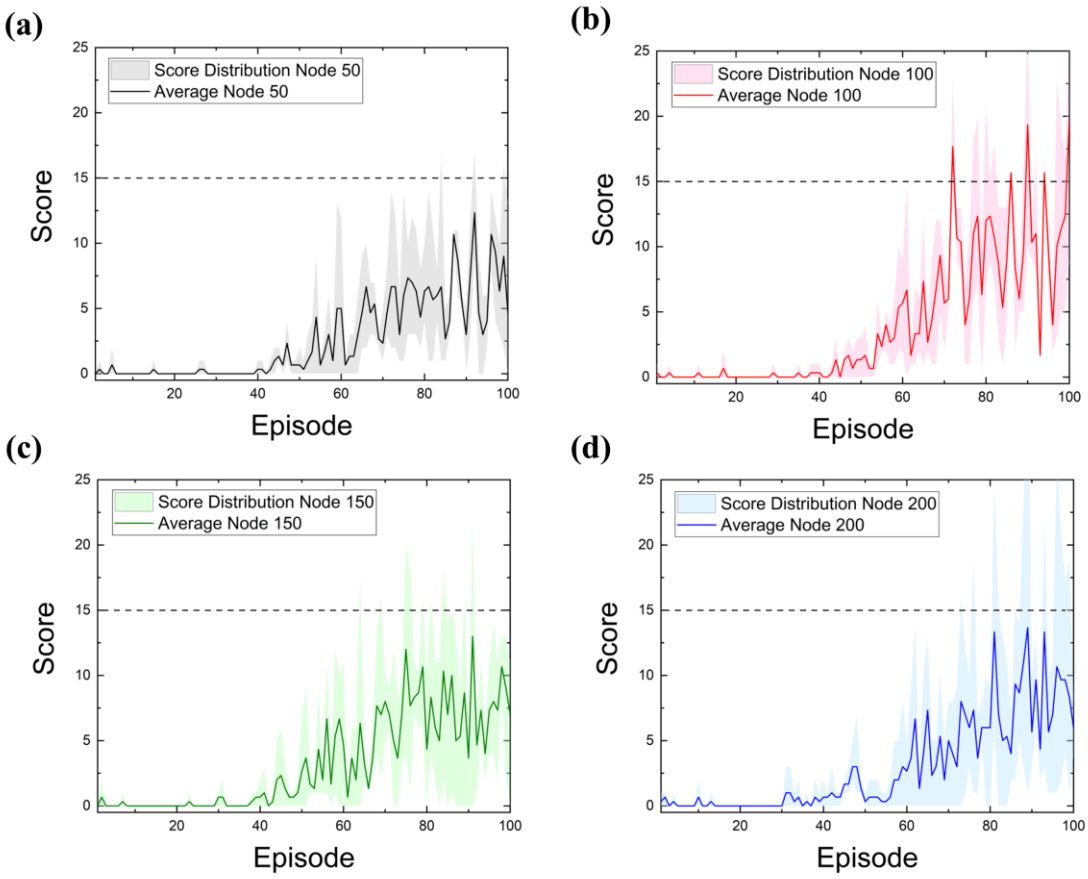

Figure 4. Score distribution of node **(a)** 100, **(b)** 150, **(c)** 200, and **(d)** 250.

2.3. Snake Zonation Method

The snake zonation method is proposed in this paper to optimize the collaboration between the two agents in playing the double snake game. As shown in **Figure 3(a)**, the snake field is divided into two zones: red zone for the first snake and grey zone for the second snake. Each agent is responsible for controlling the snake to eat the apple in their own zone; respectively, the first snake will eat the apple in the red zone, and the second snake will eat the apple in the grey zone. When the apple is spawned in the red zone, the second snake will be waiting in the grey zone by looping around the flag in the respective zone. Conversely, the first snake will be looping around the red zone flag when the apple is spawned in the grey zone. To measure the effectiveness of this method, we compare the agent performance in terms of the game score with and without the zonation method.

3. Results and Discussion

In training the MARL for the double snake game, the results may differ from one trial to another. To visualize the difference, we provide the shade color in the data to elucidate the score distributions during training.

3.1. Zonation

Agents' performance with and without the zonation method can be seen in **Figure 3(b)**. It is shown that the game score without the zonation method is higher in the early episodes, while the agents with the

zonation method show a higher game score in the later episodes. This situation can be caused by the smaller number of states owned by the agents without the zonation method, so fewer training processes are required in neural networks to reach convergence. On the other hand, in the case of the zonation method, the agents have a larger number of states to train. In the higher episodes, we can see that the agents without the zonation method show a steady performance without further improvement. The lower game score resulting from the agents without the zonation method in the higher episode can be attributed to the behavior of the snakes that move closely to each other while searching for the apple as can be seen in **Figure 3(c)**. On the other hand, the agents with the zonation method show a better game score due to the better coordination of snake positioning in the respective zone, as shown in **Figure 3(d)**. We have shown that with the extra input states, including zone flag states and zone states, the training process is much more efficient especially when the training reach more than 70 episodes that resulting the efficient coordination of snakes to search for the apple in their respective zone.

3.2. Hyperparameters Optimizations

The hyperparameters tuned in the optimization are the number of nodes in neural network layers, memory, sampling memory, and episodes. As shown in **Figure 4**, by training the agents for 100 episodes with node variation of 50, 100, 150, 200. We can see that the agents with 100 nodes show the highest game score compared to other node variations, which is the most optimum trade-off between prediction accuracy and neural network complexity. The agent with 50 nodes shows a lower game score due to a lack of complexity in the neural network to be able to predict an appropriate action in each state. Variations with more nodes, such as 150 and 200, suffer from excessive neural network complexity, resulting in a lower game score.

The following optimizations are memory and sampling memory; the memory variation is 1000, 1500, 2500, and 3500, while the sampling memory is 500 and 1000 for every memory variation. To simplify the data analysis, we calculate the average score for every ten episodes and visualize it in a bar chart, as can be seen in **Figure 5** and **Figure 6**. In **Figure 5**, we can see the comparison of average scores for

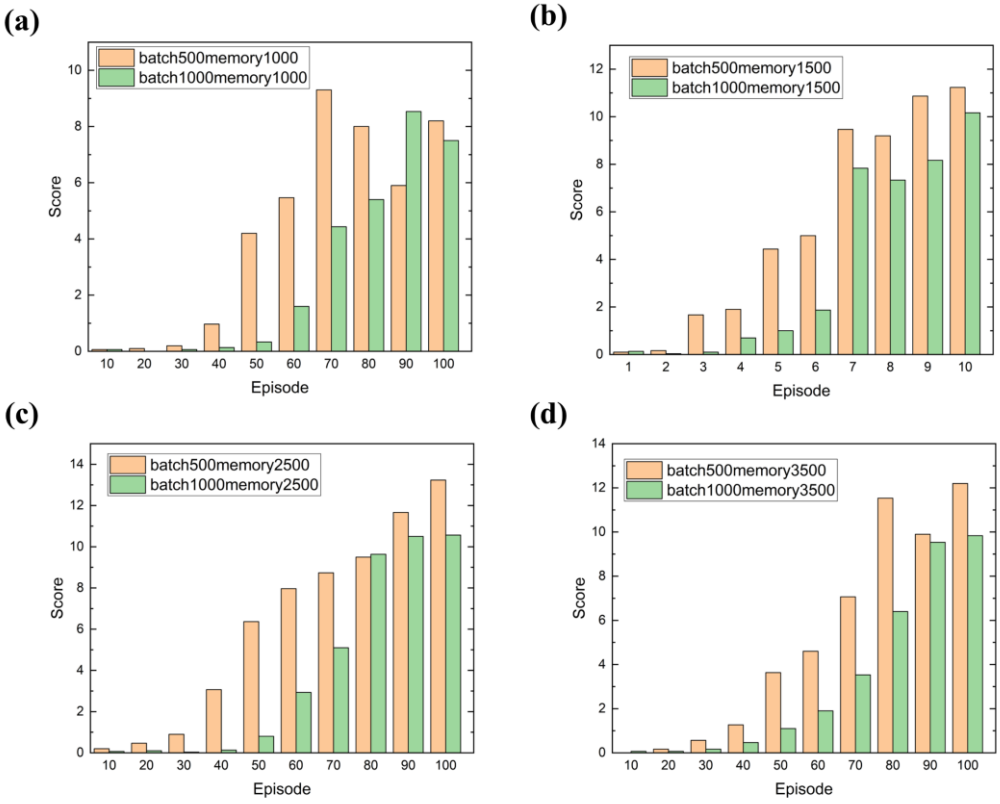

Figure 5. Comparison of average game scores for batches 500 and 1000 in every ten episodes for memory of **(a)** 1000, **(b)** 1500, **(c)** 2500, and **(d)** 3500.

different batches in respective memory sizes. For all memory sizes, it is shown that a batch size of 500 exhibits a higher average score than a batch size of 1000. Furthermore, we can see the average score difference between a batch size of 500 and a batch size of 1000; the average score difference is smaller as the episode increases. The batch size is the size of experience that the agent memorizes; in the lower episode, a batch size of 1000 keeps ineffective experiences, and as the episode increases, the batch size will eventually replace the earliest experience with the latest experience due to the size constraint. At this time, the batch size of 1000 starts to collect more effective experiences, resulting in better agent performance and increasing the average score. However, the batch size of 1000 still holds more ineffective experiences than effective experiences, resulting in a lower average score than the batch size of 500. Apart from the fact that the batch size of 500 holds a sufficient number of effective experiences, it also collects experiences faster than the batch size of 1000. These reasons yield a superior performance of batch size 500 than batch size 1000.

Figure 6 compares the average score for memory 1000, 1500, 2500, and 3500 for a batch size of 500 and 1000, respectively. For batch sizes 500 and batch sizes 1000, the memory size of 2500 exhibits an overall higher average score compared to memory sizes of 1000, 1500, and 3500. From the batch size of 500 and batch size of 1000, we can see a similar trend of the average score when the memory size increases from 1000 to 3500; the average score increases as the memory size increases to 2500, then the average score decreases when the memory size increase to 3500. The improvement of the average score when the memory size increases to 2500, can be attributed to a better prediction from the network of the agent as the network complexity increases, while the reduction of the average score when the memory size increases to 3500 is due to the excessive complexity of the agent's network, this complexity makes the agent learns less efficient than the agent with the memory size of 2500. We can see that when the episodes increase, the average memory score size of 3500 is nearly the average score of 2500.

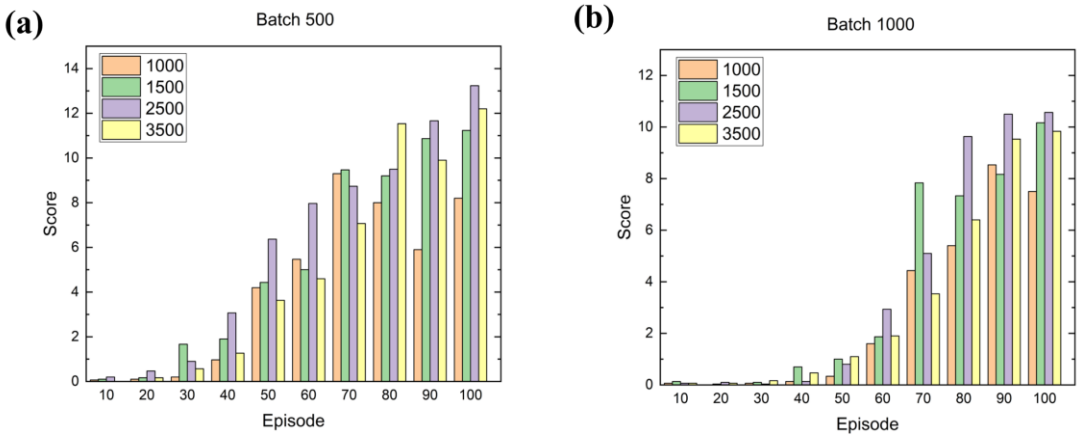

Figure 6. Comparison of average game score for memory 1000, 1500, 2500, and 3500 in every 10 episodes for **(a)** batch of 500 and **(b)** batch of 1000.

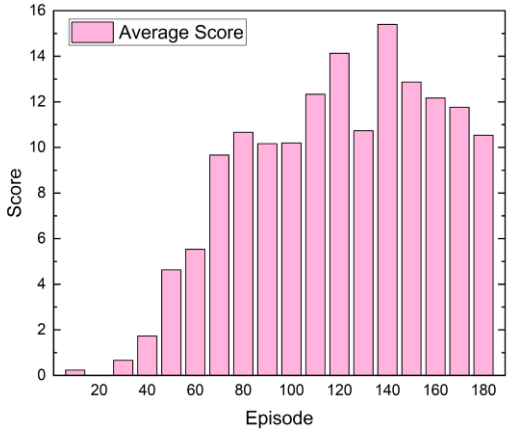

Figure 7. Average game score for every 10 episodes from 1st to 180th episode.

Another hyperparameter we optimize is episode; since we aim to minimize the training process time, the episode is limited to 180 episodes at maximum. By observing the average game score for every ten episodes, we can see that the highest score lies between 120-140 episodes, with an average score of around 15. As can be seen from **Figure 7**, the average game score increases due to more experience in the memory as the episode rises. However, when the memory is full, new memories will replace the early memory, and the agents will eventually forget most of the early memories, especially how to avoid collision; hence, the score will reduce as the episodes increase.

4. Conclusion

In summary, we have demonstrated the zonation method in the double snake as a simple method to improve the collaborative performance between two agents in the game. We have shown that by dividing the field into two zones, red zone, and grey zone, the agents offer a significantly better positioning to avoid collision between two snakes. Furthermore, the hyperparameters can be made efficient by employing sensory data as the input state, that is, under 180 episodes. Under the optimization of hyperparameters, we have shown that the game score increases as the number of nodes, memory size, and episodes increase to an extent, and then the score decreases as those hyperparameters increase. With the optimized hyperparameters, we obtain the highest average game score of 15.4 with respective hyperparameters: the number of nodes of 100, memory size of 2500, batch sampling of 500, and episode of 140. These results suggest that our approaches can be used to train collaborative multi-agents efficiently, especially when computing resources and time are the main considerations. In future work, we will develop methods for agents to play a competitive game and then further develop the complete setup game, including collaborative and competitive game strategy.

Considering the application of MARL in the physical world, we need to ensure the safety issues due to the nature of these agents learning by trial and error. The exploration nature of MARL must be designed carefully to ensure the agents are safe when deployed. Moreover, we need to design a proper environment to safely train the agents.

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References

[1] M. T. Anwar, S. Nugrohadi, V. Tantriyati, and V. A. Windarni, "Rain Prediction Using Rule-Based Machine Learning Approach," *Adv. Sustain. Sci. Eng. Technol.*, vol. 2, no. 1, May 2020, doi: 10.26877/asset.v2i1.6019.

[2] R. L. Islami and P. R. Sihombing, "Application Biplot and K-Medians Clustering to Group Export Destination Countries of Indonesia's Product," *Adv. Sustain. Sci. Eng. Technol.*, vol. 3,

no. 1, p. 0210105, Apr. 2021, doi: 10.26877/asset.v3i1.8451.
[3] P. R. Sihombing, "Implementation of K-Means and K-Medians Clustering in Several Countries Based on Global Innovation Index (GII) 2018," *Adv. Sustain. Sci. Eng. Technol.*, vol. 3, no. 1, p. 0210107, Apr. 2021, doi: 10.26877/asset.v3i1.8461.
[4] A. S. Dewantara and J. Aryanto, "Implementation Of A Web-Based Chatbot Using Machine Learning For Question And Answer Services In Universities," *Adv. Sustain. Sci. Eng. Technol.*, vol. 6, no. 1, pp. 0240106-01 ~ 0240106-10, 2024.
[5] A. Sebastianelli, M. Tipaldi, S. L. Ullo, and L. Glielmo, "A Deep Q-Learning based approach applied to the Snake game," in *2021 29th Mediterranean Conference on Control and Automation (MED)*, Jun. 2021, pp. 348–353, doi: 10.1109/MED51440.2021.9480232.
[6] R. S. Sutton and Andrew G. Barto, *Reinforcement learning: An introduction*, Second Edi. MIT Press, 2018.
[7] K. Arulkumaran, M. P. Deisenroth, M. Brundage, and A. A. Bharath, "Deep Reinforcement Learning: A Brief Survey," *IEEE Signal Process. Mag.*, vol. 34, no. 6, pp. 26–38, Nov. 2017, doi: 10.1109/MSP.2017.2743240.
[8] D. P. Bertsekas, "Feature-based aggregation and deep reinforcement learning: a survey and some new implementations," *IEEE/CAA J. Autom. Sin.*, vol. 6, no. 1, pp. 1–31, Jan. 2019, doi: 10.1109/JAS.2018.7511249.
[9] Y. Li, K. Fu, H. Sun, and X. Sun, "An Aircraft Detection Framework Based on Reinforcement Learning and Convolutional Neural Networks in Remote Sensing Images," *Remote Sens.*, vol. 10, no. 2, p. 243, Feb. 2018, doi: 10.3390/rs10020243.
[10] S. Kuutti, R. Bowden, Y. Jin, P. Barber, and S. Fallah, "A Survey of Deep Learning Applications to Autonomous Vehicle Control," *IEEE Trans. Intell. Transp. Syst.*, vol. 22, no. 2, pp. 712–733, Feb. 2021, doi: 10.1109/TITS.2019.2962338.
[11] M. Tipaldi, L. Feruglio, P. Denis, and G. D'Angelo, "On applying AI-driven flight data analysis for operational spacecraft model-based diagnostics," *Annu. Rev. Control*, vol. 49, pp. 197–211, 2020, doi: 10.1016/j.arcontrol.2020.04.012.
[12] G. D'Angelo, M. Tipaldi, F. Palmieri, and L. Glielmo, "A data-driven approximate dynamic programming approach based on association rule learning: Spacecraft autonomy as a case study," *Inf. Sci. (Ny).*, vol. 504, pp. 501–519, Dec. 2019, doi: 10.1016/j.ins.2019.07.067.
[13] J. Li *et al.*, "Suphx : Mastering Mahjong with Deep arXiv : 2003 . 13590v2 [cs . AI] 1 Apr 2020," pp. 1–28, doi: https://doi.org/10.48550/arXiv.2003.13590.
[14] N. Brown and T. Sandholm, "Superhuman AI for multiplayer poker," *Science (80-.).*, vol. 365, no. 6456, pp. 885–890, Aug. 2019, doi: 10.1126/science.aay2400.
[15] M. Samvelyan, T. Rashid, C. Schroeder, and D. W. Gregory, "The StarCraft Multi-Agent Challenge," no. NeurIPS, pp. 1–14, 2019, doi: https://doi.org/10.48550/arXiv.1902.04043.
[16] S. Yoon and K.-J. Kim, "Deep Q networks for visual fighting game AI," in *2017 IEEE Conference on Computational Intelligence and Games (CIG)*, Aug. 2017, pp. 306–308, doi: 10.1109/CIG.2017.8080451.
[17] E. A. O. Diallo, A. Sugiyama, and T. Sugawara, "Learning to Coordinate with Deep Reinforcement Learning in Doubles Pong Game," in *2017 16th IEEE International Conference on Machine Learning and Applications (ICMLA)*, Dec. 2017, pp. 14–19, doi: 10.1109/ICMLA.2017.0-184.
[18] I. Goodfellow, Y. Bengio, and A. Courville, *Deep Learning*. MIT Press, 2016.
[19] J. Wang, D. Xue, J. Zhao, W. Zhou, and H. Li, "Mastering the Game of 3v3 Snakes with Rule-Enhanced Multi-Agent Reinforcement Learning," in *2022 IEEE Conference on Games (CoG)*, Aug. 2022, pp. 229–236, doi: 10.1109/CoG51982.2022.9893608.
[20] Z. Wei, D. Wang, M. Zhang, A.-H. Tan, C. Miao, and Y. Zhou, "Autonomous Agents in Snake Game via Deep Reinforcement Learning," in *2018 IEEE International Conference on Agents (ICA)*, Jul. 2018, pp. 20–25, doi: 10.1109/AGENTS.2018.8460004.
[21] K. Zhang, Z. Yang, and T. Başar, "Multi-Agent Reinforcement Learning: A Selective Overview

of Theories and Algorithms," 2021, pp. 321–384.
[22] W. Zhao, E.-A. Rantala, J. Pajarinen, and J. P. Queralta, "Less Is More: Robust Robot Learning via Partially Observable Multi-Agent Reinforcement Learning," 2023, [Online]. Available: http://arxiv.org/abs/2309.14792.
[23] K. Zhang, Z. Yang, and T. Başar, "Decentralized multi-agent reinforcement learning with networked agents: recent advances," *Front. Inf. Technol. Electron. Eng.*, vol. 22, no. 6, pp. 802–814, 2021, doi: 10.1631/FITEE.1900661.
[24] K. Zhang, Z. Yang, H. Liu, T. Zhang, and T. Başar, "Fully decentralized multi-agent reinforcement learning with networked agents," *35th Int. Conf. Mach. Learn. ICML 2018*, vol. 13, pp. 9340–9371, 2018.
[25] A. Tampuu *et al.*, "Multiagent cooperation and competition with deep reinforcement learning," *PLoS One*, vol. 12, no. 4, p. e0172395, Apr. 2017, doi: 10.1371/journal.pone.0172395.
[26] L. Han *et al.*, "Grid-wise control for multi-agent reinforcement learning in video game AI," *36th Int. Conf. Mach. Learn. ICML 2019*, vol. 2019-June, pp. 4558–4571, 2019.
[27] O. Tanner, "Multi-Agent Car Parking using Reinforcement Learning," *arXiv*, no. June, pp. 1–122, 2022, [Online]. Available: http://arxiv.org/abs/2206.13338.
[28] F. D'Souza, J. Costa, and J. N. Pires, "Development of a solution for adding a collaborative robot to an industrial AGV," *Ind. Robot Int. J. Robot. Res. Appl.*, vol. 47, no. 5, pp. 723–735, May 2020, doi: 10.1108/IR-01-2020-0004.
[29] H. Lee, J. Hong, and J. Jeong, "MARL-Based Dual Reward Model on Segmented Actions for Multiple Mobile Robots in Automated Warehouse Environment," *Appl. Sci.*, vol. 12, no. 9, p. 4703, May 2022, doi: 10.3390/app12094703.
[30] Troullinos and M. Dimitrios and Chalkiadakis, Georgios and Papamichail, Ioannis and Papageorgiou, "Collaborative Multiagent Decision Making for Lane-Free Autonomous Driving," in *Proceedings of the 20th International Conference on Autonomous Agents and MultiAgent Systems*, 2021, pp. 1335–1343, doi: doi/10.5555/3463952.3464106.

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Stroke Classification Comparison with KNN through Standardization and Normalization Techniques

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Abstract. This study explores the impact of z-score standardization and min-max normalization on K-Nearest Neighbors (KNN) classification for strokes. Focused on managing diverse scales in health attributes within the stroke dataset, the research aims to improve classification model accuracy and reliability. Preprocessing involves z-score standardization, min-max normalization, and no data scaling. The KNN model is trained and evaluated using various methods. Results reveal comparable performance between z-score standardization and min-max normalization, with slight variations across data split ratios. Demonstrating the importance of data scaling, both z-score and min-max achieve 95.07% accuracy. Notably, normalization averages a higher accuracy (94.25%) than standardization (94.21%), highlighting the critical role of data scaling for robust machine learning performance and informed health decisions.

Keywords: KNN, Z-Score Standardization, Min Max Normalization, Stroke Classification, Data Scaling

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1. Introduction

The implementation of AI and ML in the medical field holds revolutionary potential, enhancing the accuracy of diagnosis, treatment planning, and patient monitoring [1]. Its ability to process vast medical data enables the development of innovative diagnostic tools and treatment plans that can improve patient outcomes, identify individual risks, and personalize treatment plans. [2].In the context of classifying stroke datasets, the process of data standardization and normalization demonstrates significant urgency. Standardization and normalization are crucial steps in data preprocessing that play a major role in improving the performance of classification models. Through standardization, attributes in the dataset are transformed into a uniform scale, ensuring that each variable has an equal impact in the classification process [3]. Meanwhile, normalization adjusts attribute values into a more controlled range, minimizing the impact of outliers and improving the distribution of data [4].

In this study, the focus on data standardization and normalization aims to enhance the accuracy and reliability of classification models, particularly machine learning algorithms like KNN, in identifying stroke risk patterns. Both processes are crucial because health attributes in the stroke dataset exhibit diverse scales. By avoiding the dominance of large-scale attributes, standardization and normalization ensure a balanced contribution of each attribute, enabling the model to provide more accurate and consistent predictions. Through the analysis of its positive impact, this research highlights the vital role of standardization and normalization in improving prediction accuracy, providing a reliable foundation for result interpretation, and supporting more precise health decision-making.

Based on previous research related to the topic of this study, which is the Evaluation of Stroke Classification with KNN through Standardization and Normalization Techniques, there are several findings. The results obtained from the study titled 'Analysis of the Influence of Data Scaling on the Performance of Machine Learning Algorithms for Plant Identification' [5] indicate that the difference in accuracy and recall between standardization and normalization is not significantly different for the KNN machine learning algorithm. For standardization, the accuracy obtained is 76%, while the normalization result is slightly higher, with an accuracy of 77.33%.

Similar research on the comparison of data scaling, specifically standardization and normalization, is also found in a journal regarding the comparison of data normalization for wine classification using the K-NN algorithm [6]. The accuracy results from Min-Max normalization are 57.41%, while for Z-score standardization, it is 56.40%.

A similar journal discussing the difference in the Evaluation of Stroke Classification with KNN through Standardization and Normalization techniques is also found in the following journal. This journal compares Min-Max normalization with Z-Score standardization to test the accuracy of Breast Cancer types using the KNN algorithm [7]. The accuracy results obtained are 97% for standardization and 98% for Min-Max normalization.

2. Methods

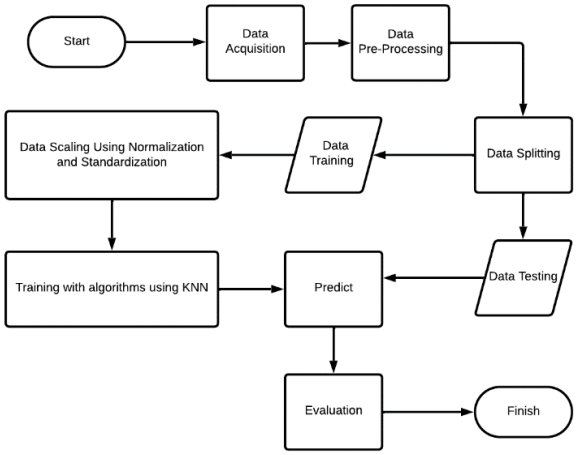

Figure 1. Research Methodology

This study focuses on comparing the performance of the K-Nearest Neighbors (KNN) model in stroke classification. The process begins with data acquisition, followed by data preprocessing. Subsequently, the dataset is divided into training and testing data. The training data undergoes three different preprocessing conditions: Z-score standardization, Min-Max normalization, and no preprocessing (raw data). The KNN model is then trained on the preprocessed training data to identify patterns in stroke detection. Its performance is evaluated on the testing data using standard metrics such as accuracy, precision, and recall. The research aims to provide a comprehensive understanding of the impact of data preprocessing on model performance in the context of stroke classification using KNN.

2.1. Data Acquisition

The dataset used in this study, sourced from Kaggle.com ('stroke prediction'), contains 5110 rows and eleven columns. The dataset for stroke classification encompasses several attributes. The 'Id' serves as a unique identifier for each record. Gender information is provided in the 'Gender' column, categorized as 'Male,' 'Female,' or 'Other.' The 'Age' column denotes the patients' ages, while 'Hypertension' and 'Heart_Disease' are binary attributes indicating specific health conditions. Marital status is detailed in the 'Ever_married' column, and employment type is specified in 'Work_type.' The 'Residence_type'

column distinguishes between rural and urban residences. Health metrics include 'Avg_glucose' for blood sugar levels and 'Bmi' for Body Mass Index. Smoking habits are described in the 'Smoking_status' column, and the 'Stroke' column indicates the stroke status (label).

2.2. Data Pre-processing

In the data preprocessing process for the stroke dataset study, crucial steps are undertaken to ensure the quality of the dataset used in stroke classification. Firstly, irrelevant attributes, such as identification numbers, are removed to simplify the dataset and focus on attributes that have a significant impact on stroke risk, such as age, blood pressure, and smoking history. Next, handling missing values becomes a primary focus, where missing values are deleted from the dataset with the consideration that their presence could affect the quality and integrity of stroke classification analysis. Finally, label encoding is performed as a technique to transform categorical data into numeric form. This allows machine learning algorithms to more effectively understand and analyze categorical variables in the dataset, ensuring accurate representation in the model. By using label encoding, data analysis and modeling become more efficient, preparing the dataset optimally for the training and prediction processes of the model.

2.3. Outlier Handling

Identifying and addressing outliers in data is crucial in the context of machine learning and predictive modeling. This action helps reduce noise, detect erroneous records, and prevent overfitting, providing insights into patterns and trends in the data. In model development, handling outliers is necessary to enhance reliability and accuracy. This study utilizes the Interquartile Range (IQR) method to identify outliers in relevant attributes. The initial steps involve calculating the first quartile (q1) and third quartile (q3), which are used to compute the IQR as the difference between q3 and q1 [8].

$$IQR = q3 - q1 \tag{1}$$

Outliers are identified by calculating the lower bound as q1 minus 1.5 times the IQR and the upper bound as q3 plus 1.5 times the IQR [9].

Outlier handling is performed on the numerical attributes 'bmi' and 'avg_glucose_level' using the interquartile range (IQR) method. Visualization with boxplots is used for outlier identification, and the outliers are removed from the dataset to ensure data integrity and quality. This process enhances the reliability of analysis and modeling by eliminating potentially disruptive data. After outlier handling, the dataset is reduced from 4909 to 4260 rows.

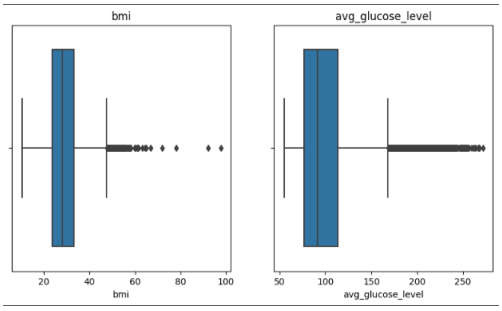

Figure 2. Before Outliers Handling

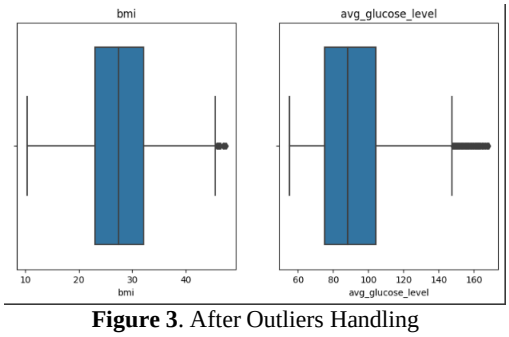

Figure 3. After Outliers Handling

2.4. Data Spliting

In the preprocessing stage, the dataset is divided into training and testing subsets using five variations of ratios, namely 90%:10%, 80%:20%, and 70%:30%. This process aims to objectively test the stroke classification model on data not used during training, preventing overfitting, and ensuring the model's generalizability. The division is performed randomly for objectivity and data representation in both training and model validation.

Table 1. Rasio Split Train Data and Test Data

Rasio Split Train Data and Test Data	Jumlah Data Training	Jumlah Data Testing
90:10	3834	426
80:20	3408	852
70:30	2982	1278

2.5. Imbalance data Handling

The research employs the SMOTE technique to address imbalanced data, a method effective in classification tasks. SMOTE creates synthetic samples from the minority class by selecting reference points and generating synthetic samples through a formula incorporating a parameter δ, allowing flexibility in adjusting synthetic results to the dataset's characteristics [10].

$$\text{Xsyn} = \text{Xi} + (\text{Xknn} - \text{Xi}) * \delta \quad (2)$$

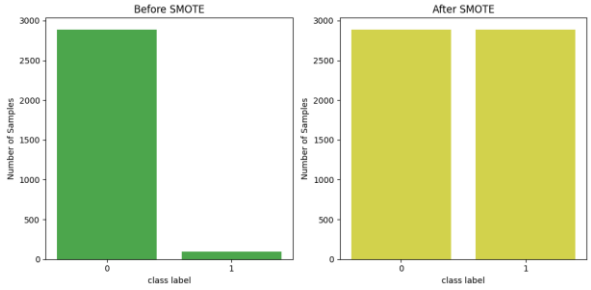

Figure 4. comparison of the amount of data before and after SMOTE Oversampling

The implementation of SMOTE increases the number of stroke samples from 3408 to 6610 in the training data.

2.6. Min Max Normalization

MinMax normalization is a process to transform the range of data values into between 0 and 1[6]. The primary objective of this normalization is to ensure that all data attributes have a uniform scale, avoiding the dominance of attributes with large scales over others. By rescaling the data value range, the interpretation of analysis results becomes more consistent, and the performance of classification models can be enhanced [11], especially in the task of stroke risk classification. The MinMax normalization process is applied to each data value (*xi*) using the formula:

$$X' = \frac{xi - \min(x)}{max(x) - \min(x)} \quad (3)$$

Where *x'* is the normalized result value of the original observation value or initial value of a data point (*xi)*, while min(*x*) and max(*x*) represent the minimum and maximum values across all the data.

2.7. Z-Score Standardization

Z-Score standardization is a standardization technique that uses the mean and standard deviation of each feature attribute to transform the scale of data values. This standardization procedure is applied to reduce the impact of outliers and ensure that each attribute has a consistent scale. The main goal of Z-Score standardization is to enhance the stability of analysis results and improve the consistency of data interpretation [12].

The Z-Score standardization process is applied to each data value (*xi*)using the formula:

$$Z = \frac{X - \mu}{\sigma} \quad (4)$$

The z-score formula standardizes data by transforming its distribution to a mean of 0 and a standard deviation of 1, facilitating comparisons. It involves subtracting the observation value from the population mean and dividing by the population standard deviation. The resulting Z score indicates the value's distance from the mean in standard deviation units, crucial for statistical analysis and machine learning.

2.8. KNN

The K-Nearest Neighbors (KNN) algorithm falls into the category of supervised learning, classifying data based on their proximity or distance to other data points. In the implementation of KNN, the Euclidean distance formula is commonly used to measure the proximity between training and test data points [13].

$$di = \sqrt{\sum_{i=1}^{n}(xi - yi)^2} \quad (5)$$

The K-Nearest Neighbors (KNN) algorithm employs the Euclidean formula, where 'di' represents the distance between training and test data, 'xi' is the training data, 'yi' is the test data, 'n' is the data dimension, and 'i' is the data variable. KNN's operation involves initializing 'K', calculating distances, sorting distances, selecting the nearest 'K' neighbors, applying majority rule, and predicting the category. This method focuses on the relationships among data points in feature space, with the value of 'K' determining the number of nearest neighbors considered, a critical factor in stroke classification[14]. For model development, cross-validation is used to find the optimal 'K'. The model is trained and evaluated on subsets, with accuracy recorded as an evaluation metric. The optimal 'K' is selected based on the average evaluation metric across all cross-validation iterations, ensuring the best choice for stroke classification.

2.9. Evaluate metrics

In this study, the evaluation of the classification model heavily relies on the Confusion Matrix, a powerful tool that summarizes model performance. The matrix's four main components—True Positive (TP), False Positive (FP), True Negative (TN), and False Negative (FN)—facilitate the measurement of accuracy, precision, recall, and F1-score. These metrics offer comprehensive insights into the model's ability to distinguish between different classes. The confusion matrix table forms the foundation for calculating accuracy, precision, recall, and F1-score, essential in evaluating the model's effectiveness and accuracy in class prediction. [15].

$$\text{Accuracy} = \frac{(TP+TN)}{(TP+TN+FP+FN)} \quad (6)$$

$$\text{Presicion} = \frac{TP}{(TP+FP)} \quad (7)$$

$$\text{Recall} = \frac{TP}{(TP+FN)} \quad (8)$$

$$\text{F1-Score} = 2 * \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}} \quad (9)$$

3. Results and Discussion

3.1. Preprocessing

Several steps are taken in preprocessing the stroke dataset as follows. First, remove irrelevant attributes such as identification numbers. Second, address missing values by removing them from the dataset. Finally, apply label encoding to convert categorical data into numerical form. This process enhances the efficiency of data analysis and modeling, preparing the dataset optimally for model training and prediction.

	id	gender	age	hypertension	heart_disease	ever_married	work_type	Residence_type	avg_glucose_level	bmi	smoking_status	stroke
0	9046	Male	67.0	0	1	Yes	Private	Urban	228.69	36.6	formerly smoked	1
1	51676	Female	61.0	0	0	Yes	Self-employed	Rural	202.21	NaN	never smoked	1
2	31112	Male	80.0	0	1	Yes	Private	Rural	105.92	32.5	never smoked	1
3	60182	Female	49.0	0	0	Yes	Private	Urban	171.23	34.4	smokes	1
4	1665	Female	79.0	1	0	Yes	Self-employed	Rural	174.12	24.0	never smoked	1

Figure 5. Dataset Before Pre-processing

	gender	age	hypertension	heart_disease	ever_married	work_type	Residence_type	avg_glucose_level	bmi	smoking_status	stroke
2	1	80.0	0	1	1	0	1	105.92	32.5	1	1
6	1	74.0	1	1	1	0	1	70.09	27.4	1	1
7	0	69.0	0	0	0	0	0	94.39	22.8	1	1
9	0	78.0	0	0	1	0	0	58.57	24.2	3	1
10	0	81.0	1	0	1	0	1	80.43	29.7	1	1

Figure 6. dataset after Pre-processing

3.2. Data Scaling

Here are the results of the data that have undergone Z-Score standardization and Min-Max normalization.

```
array([[1.        , 0.74340176, 0.        , ..., 0.23068061, 0.88978495,
        0.66666667],
       [1.        , 0.74340176, 0.        , ..., 0.75983694, 0.63709677,
        0.66666667],
       [1.        , 0.18132942, 0.        , ..., 0.0871145 , 0.3844086 ,
        1.        ],
       ...,
       [1.        , 0.78040887, 0.        , ..., 0.16761628, 0.49438401,
        0.98566909],
       [1.        , 0.93943462, 0.        , ..., 0.72027028, 0.43853531,
        0.        ],
       [0.        , 0.70469002, 0.        , ..., 0.46023389, 0.75668409,
        0.01401407]])
```

Figure 7. Data after normalization

```
array([[ 1.29173623,  0.32715671, -0.45883538, ..., -0.4815554 ,
         2.57731674,  0.54535679],
       [ 1.29173623,  0.32715671, -0.45883538, ...,  2.17202351,
         0.987685  ,  0.54535679],
       [ 1.29173623, -1.6985405 , -0.45883538, ..., -1.20150144,
        -0.60194673,  1.55768981],
       ...,
       [ 1.29173623,  0.46052958, -0.45883538, ..., -0.79780632,
         0.08989569,  1.51416686],
       [ 1.29173623,  1.03365513, -0.45883538, ...,  1.97360718,
        -0.26144194, -1.47930924],
       [-0.92286263,  0.18764039, -0.45883538, ...,  0.66959354,
         1.7399948 , -1.43674851]])
```

Figure 8. Data after standardization

3.3. Modelling

Searching for the best K value for each ratio with accuracy testing experiments for K values ranging from k=1 to k=8. The following is the experimental table.

Table 2. Best k value in each ratio.

Rasio Split	**Akurasi**							
	K=1	K=2	K=3	K=4	K=5	K=6	K=7	K=8
90% and 10%	92.71%	92.72%	90.43%	90.99%	89.56%	90.33%	88.97%	89.24%
80% and 20%	93.50%	93.64%	91.54%	91.96%	90.51%	90.98%	89.83%	90.25%
70% and 30%	93.61%	93.73%	91.67%	91.92%	90.96%	91.19%	90.19%	90.72%

In the results of searching for the optimal K value using cross-validation and performance curves, based on the table above utilizing three ratios (90% and 10%, 80% and 20%, 70% and 30%), it is found that the best K value is at k=2.

3.3.1. KNN using Standardization k = 2

Here is the KNN model evaluation table for Z-Score standardization in each data splitting ratio.

Table 3. Classification report for KNN using Standardization

Rasio Split Train Data and Test Data	Accuracy	Presisi	Recall
90% and 10%	95.07%	98.3%	96.65%
80% and 20%	93.9%	97.44%	96.26%
70% and 30%	93.66%	96.76%	96.68%

3.3.2. KNN using Normalization k =2

Here is the KNN model evaluation table for Min Max Normalization in each data splitting ratio.

Table 4. Classification report for KNN using Normalization

Rasio Split Train Data and Test Data	Accuracy	Presisi	Recall
90% and 10%	95.07%	98.3%	96.65%
80% and 20%	93.54%	97.2%	96.14%
70% and 30%	94.13%	97.33%	96.62%

3.3.3. KNN without Standardization and Normalization

Here is the KNN model evaluation table for data without Z-Score standardization and Min-Max normalization in each data splitting ratio.

Table 5. Classification report for KNN without Data Scaling

Rasio Split Train Data and Test Data	Accuracy	Presisi	Recall
90% and 10%	88.73%	90.75%	97.39%
80% and 20%	88.85%	91.33%	96.9%
70% and 30%	87.8%	89.87%	97.28%

4. Conclusion

In the study during the data preprocessing stage, two different conditions were applied. The first condition involved Z-Score standardization of the stroke classification dataset, and the second condition involved Min-Max normalization. Subsequently, training was conducted using the KNN machine learning algorithm. Based on the results and discussions, several conclusions can be drawn:

a. The highest accuracy for both Z-Score standardization and Min-Max normalization is 95.07% for the 90:10 data splitting ratio.
b. The average accuracy of Z-Score standardization is lower at 94.21% compared to the average accuracy of normalization at 94.25%.
c. The optimal K value after cross-validation is found to be k=2 after comparing for each ratio.
d. The comparison results between Z-Score standardization and Min-Max normalization with data without Z-Score standardization and Min-Max normalization reveal differences. This underscores the importance of performing data scaling on the dataset to achieve high machine learning performance.

References

[1] F. D. Telaumbanua, P. Hulu, T. Z. Nadeak, R. R. Lumbantong, and A. Dharma, "Penggunaan Machine Learning Di Bidang Kesehatan," *JURNAL TEKNOLOGI DAN ILMU KOMPUTER PRIMA (JUTIKOMP)*, vol. 2, no. 2, Art. no. 2, 2019, doi: 10.34012/jutikomp.v2i2.657.

[2] A. S. Fahmy *et al.*, "An Explainable Machine Learning Approach Reveals Prognostic Significance of Right Ventricular Dysfunction in Nonischemic Cardiomyopathy," *JACC: Cardiovascular Imaging*, vol. 15, no. 5, pp. 766–779, May 2022, doi: 10.1016/j.jcmg.2021.11.029.

[3] Mohammed Z. Al-Faiz, Ali A. Ibrahim, and Sarmad M. Hadi, "The effect of Z-Score standardization (normalization) on binary input due the speed of learning in back-propagation

neural network," *Iraqi Journal of Information and Communications Technology(IJICT)*, vol. 1, no. 3, pp. 42–48, Feb. 2019, doi: 10.31987/IJICT.1.3.41.

[4] Lei Huang, ie Qin, Yi Zhou, Fan Zhu, Li Liu, and Ling Shao, "Normalization Techniques in Training DNNs: Methodology, Analysis and Application," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 45, no. 8, pp. 10173–10196, Aug. 2023, doi: 10.1109/tpami.2023.3250241.

[5] gus Ambarwari, Qadhli Jafar Adrian, and Yeni Herdiyeni, "Analysis of the Effect of Data Scaling on the Performance of the Machine Learning Algorithm for Plant Identification | Jurnal RESTI (Rekayasa Sistem dan Teknologi Informasi)," *JURNAL RESTI (Rekayasa Sistem dan Teknologi Informasi)*, vol. 4, no. 1, pp. 117–122, 2020, doi: https://doi.org/10.29207/resti.v4i1.1517.

[6] D. A. Nasution, H. H. Khotimah, and N. Chamidah, "Perbandingan Normalisasi Data untuk Klasifikasi Wine Menggunakan Algoritma K-NN," *CESS (Journal of Computer Engineering, System and Science)*, vol. 4, no. 1, Art. no. 1, Jan. 2019, doi: 10.24114/cess.v4i1.11458.

[7] Henderi, Tri Wahyuningsih, and Efana Rahwanto, "Comparison of Min-Max normalization and Z-Score Normalization in the K-nearest neighbor (kNN) Algorithm to Test the Accuracy of Types of Breast Cancer," *International Journal of Informatics and Information System*, vol. 4, no. 1, pp. 13–20, Mar. 2021, doi: 10.47738/IJIIS.V4I1.73.

[8] MADISON WENZLICK, OSMAN MAMUN, RAM DEVANATHAN, KELLY ROSE, and JEFFREY HAWK, "Assessment of Outliers in Alloy Datasets Using Unsupervised Techniques," *JOM*, vol. 74, no. 7, pp. 2846–2859, May 2022, doi: 10.1007/s11837-022-05204-4.

[9] Amerah Alabrah, "An Improved CCF Detector to Handle the Problem of Class Imbalance with Outlier Normalization Using IQR Method," in *Sensors*, Apr. 2023, pp. 4406–4406. doi: 10.3390/s23094406.

[10] Shobha Aswal, Neelu Jyothi Ahuja, and Ritika Mehra, "Feature Selection Method Based on Honeybee-SMOTE for Medical Data Classification," *Informatica*, vol. 46, no. 9, pp. 111–118, Feb. 2023, doi: 10.31449/inf.v46i9.4098.

[11] Gde Agung Brahmana Suryanegara, Adiwijaya, and Mahendra Dwifebri Purbolaksono, "Peningkatan Hasil Klasifikasi pada Algoritma Random Forest untuk Deteksi Pasien Penderita Diabetes Menggunakan Metode Normalisasi | Jurnal RESTI (Rekayasa Sistem dan Teknologi Informasi)," *JURNAL RESTI (Rekayasa Sistem dan Teknologi Informasi)*, vol. 5, no. 1, pp. 114–122, 2021, doi: https://doi.org/10.29207/resti.v5i1.2880.

[12] I. Permana and F. N. S. Salisah, "Pengaruh Normalisasi Data Terhadap Performa Hasil Klasifikasi Algoritma Backpropagation: The Effect of Data Normalization on the Performance of the Classification Results of the Backpropagation Algorithm," *Indonesian Journal of Informatic Research and Software Engineering (IJIRSE)*, vol. 2, no. 1, Art. no. 1, Mar. 2022, doi: 10.57152/ijirse.v2i1.311.

[13] S. K. P. Loka and A. Marsal, "Perbandingan Algoritma K-Nearest Neighbor dan Naïve Bayes Classifier untuk Klasifikasi Status Gizi Pada Balita: Comparison Algorithm of K-Nearest Neighbor and Naïve Bayes Classifier for Classifying Nutritional Status in Toddlers," *MALCOM: Indonesian Journal of Machine Learning and Computer Science*, vol. 3, no. 1, Art. no. 1, May 2023, doi: 10.57152/malcom.v3i1.474.

[14] R. D. Y. Prakoso, B. S. Wiriaatmadja, and F. W. Wibowo, "Sistem Klasifikasi Pada Penyakit Parkinson Dengan Menggunakan Metode K-Nearest Neighbor," *Seminar Nasional Teknologi Komputer & Sains (SAINTEKS)*, vol. 1, no. 1, Art. no. 1, Feb. 2020.

[15] Dubravka Bożi´ c, Biserka Runje, Dragutin Lisjak, and Davor Kolar, "Metrics Related to Confusion Matrix as Tools for Conformity Assessment Decisions," *Applied Sciences*, vol. 13, pp. 8187–8205, Jul. 2023, doi: 10.3390/app13148187.

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Implementation of a Decision Support System with a Simple Additive Weighting Method for the Selection of Quality Bird Breeder

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Abstract. Indonesia is a country blessed with abundant natural resources, one of which is the diverse variety of chirping birds that captivate the attention of many. The high demand for these birds has led to a decline in the population of wild chirping birds due to increased illegal capture. To address this issue, bird breeding programs have been implemented. The selection of superior quality chirping birds will determine the offspring produced. Superior quality bird brooders can also increase the selling price of the resulting chicks. Therefore, the determination of superior quality bird breeders is very crucial for decision makers who are related in this case are chirping bird breeders. If it is not done properly and accurately, the wrong selection of chirping birds often results in various problems. Some of the problems that arise include the results of tillers that have low quality to the difficulty of selling livestock produced tillers. Decision-making models can be used to help chirping bird breeders make decisions. The Simple Additive weighting (SAW) method is expected to be able to help overcome the problems encountered. The purpose of this study was to create a decision-making system for the selection of superior quality chirping birds. It is hoped that there will be no mistakes in the selection of chirping birds.

Keywords: Chirping Birds, Decision Support System, Ranch, Selection, Simple Additive Weighting, Superior Quality.

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1. Introduction

Indonesia is a country rich in natural wealth, and one of its natural wealth is the existence of various kinds of biological and animal in Indonesia[1]. The variety of fauna in Indonesia makes it a special attraction for local and foreign residents. This results in many individuals who want to keep some types of fauna. Birds play a crucial role in the ecosystem, serving as natural pest control, pollinators, and seed dispersers. They also serve as indicators of environmental changes and health, including seasonal changes[2]. Because their attractive colors and melodious chirps can be used by some people as stress relievers. Indonesian endemic songbirds have a wide variety of species, ranging from protected to

unprotected, from cheap to expensive. Some of the songbird species that are in demand as pets include Murai Batu (Copsychus Malabaricus), Cucak Rowo (Pycnonotus Zeylanicus), Kacer (Copsychus Saularis), and Cucak Hijau (Chloropsis Sonnerarti)[3]. These types of songbirds are in demand because they have melodious chirps and can mimic the chirps of other birds. Because of the large number of songbirds in demand, there has been a massive capture in the wild. Excessive wild capture has caused the population of some songbird species to decline dramatically. This can lead to the extinction of some species[4].

The decline in population due to excessive illegal capture can be overcome by conducting conservation to carry out cultivation or what is familiarly called breeding. Captive breeding also cannot be carried out arbitrarily, it is necessary to pay attention to several aspects, especially the quality aspects of the captive breeding results. Superior quality is obtained from broodstock that has superior quality. This can affect the benefits obtained by breeders because if the quality is superior, the selling price of the catch is higher and balanced with the higher demand. This research implements the Simple Additive Weighting (SAW) method which is one of the methods of the decision support system. Decision Support Systems can also provide solutions in problem-solving with various conditions both structured and unstructured[5]. SAW method used to determine or select songbirds that are suitable for breeding and have superior quality. This method is done by finding the weight value on each attribute, then the ranking process is carried out to determine the optimal alternative, namely songbird broodstock that is feasible and of superior quality as a broodstock because the SAW method is widely used for deciding support system that focuses more on many criteria[6]. Not only involving criteria, the main point in determining the results in the SAW method is the existence of choices[7]. Simple Additive Weighting (SAW) method is a decision support system technique that involves summation with weights. The basic concept of this method lies in the weighted calculation of performance values for each alternative across predetermined criteria. SAW requires a calculation process to normalize the decision matrix (X) into a scale that can be compared with alternative assessment criteria. In the data processing phase, the SAW method can process all alternatives and assessment criteria, producing the best alternative among those provided in this decision support system. This process involves careful calculations to enable effective comparison among alternatives assessed based on predetermined criteria[8].

Several research results that have been conducted by previous researchers who have similar themes and fields in implementing the Simple Additive Weighting (SAW) method to provide decision recommendations with the research to be carried out. Research by Eky Khoiril Ulama[9] with the title Decision Support System for Selection of Ready-to-Sell Cattle (Lembu Jaya Lestari Central Lampung) Using the SAW Method. The research discusses the implementation of a decision support system with the Simple Additive Weighting (SAW) method for selecting cows that are ready to be sold. The input data used in this study are Weight, Health, Height, Age, and Chest Circumference. The test results conducted by this study resulted in an accuracy rate of 89.07% based on testing on 5 respondents. Research by Devi[10] with the title Best Employee Selection Application with Simple Additive Weighting Method (Case Study Citra Widya Teknik). The research implements the Simple Additive Weighting method to support the selection of the best employees with the criteria of responsibility, job knowledge, cooperation, and quality of work. The research aims to help the owner of Citra Widya Teknik choose which employee is the best of all existing employees. This research on the implementation of a decision support system with the Simple Additive Weighting (SAW) method to provide recommendations for quality bird breeders has one main goal. The goal is to help breeders choose superior quality birds to be used as brooders to produce the best quality catches possible. So that the breeder can participate in the preservation of existing songbirds and get income from breeding because it can attract more customers with superior quality breeding results. As for other goals and expectations, namely being able to help bird hobbyists in choosing birds that have superior quality to be used as pets as entertainment to relieve fatigue after doing tiring activities and can also help ordinary people who do not have experience in choosing birds that have superior quality. This system is also built as a learning medium for hobbyists and breeders to select quality birds.

2. Methods

The methodology of this research is shown in Figure 1, which describes the flow of the research. It starts with the identification of the Problem, Data Collection, Designing System, Implementation System, Testing System, and conclusion.

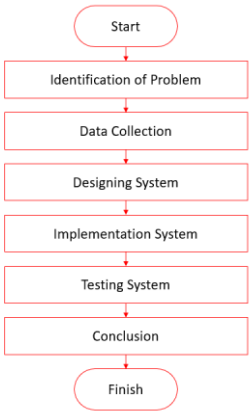


Figure 1 Research Methodology

2.1 Identification of Problem

In this state, an evaluation of the current operational system is conducted, offering streamlined solutions to enhance the efficiency of the existing processes. The analysis of the system that runs at the Mbah Kebhon Bird Farm can be seen in Figure 2. From Figure 2 it can be concluded that the steps taken by farmers are still done manually which results in frequent errors in selecting birds as broodstock. Sometimes there is also doubt in deciding which bird to choose.

Figure 2 Current System

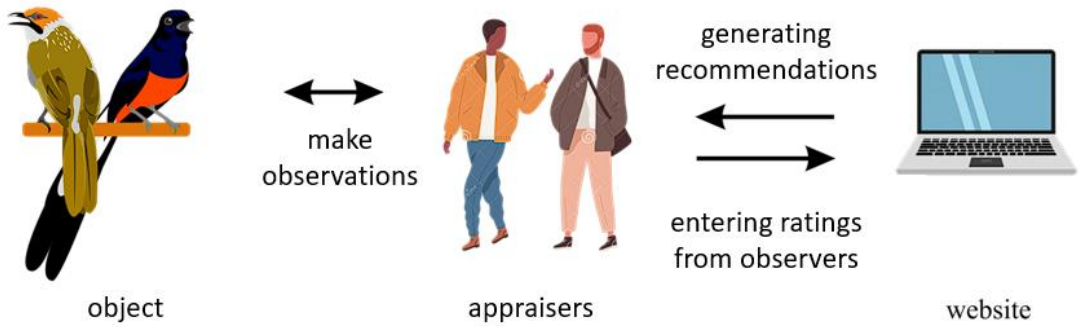


Figure 3 Proposed System

In Figure 3 is the proposed system to be created, the appraiser or in this case a breeder gets recommendations for quality songbirds to be used as broodstock. The results of the assessment are then entered into a decision support system with the SAW method for parent bird selection. Then the value is processed by the method used to produce recommendations on which songbirds have superior quality to be used as broodstock.

2.2 Data Collection

The data that will be used in the research Implementation of a Decision Support System with a Simple Additive Weighting Method for Selection of Quality Bird Breeds is obtained through interviews with breeders who breed songbirds. Interview is one of the data collection methods, especially qualitative research data by following procedures to produce maximum data results and not disappoint[11] **,** data on what criteria are usually used as reference standards in selecting birds that will be used as broodstock. They also obtained data in the form of data on the results of the assessment carried out on the available prospective brood birds. Knowledge data is obtained in the form of how the assessment is usually done by breeders and knowledge data in the form of how to breed songbirds properly and correctly. Also obtained data on how the system is desired by its users later.

The data that will be used in the research Implementation of a Decision Support System with Saw Method for Selection of Bird Breeders (Case Study: Mbah Kebhon Bird Farm), obtained directly through the owner of Mbah Kebhon Bird Farm using the interview method. In obtaining and collecting data, data collection methods are used in the form of interviews. Interviews were conducted directly with the owner of Mbah Kebhon Bird Farm, the location of this research case study. This is done to get clearer and more precise data and so that the data has high accuracy. In obtaining and collecting data, data collection methods are used in the form of interviews. The interview was conducted directly with the owner of Mbah Kebhon Bird Farm, the location of this research case study. This is done to get clearer and more precise data and so that the data has high accuracy.

2.3 System design

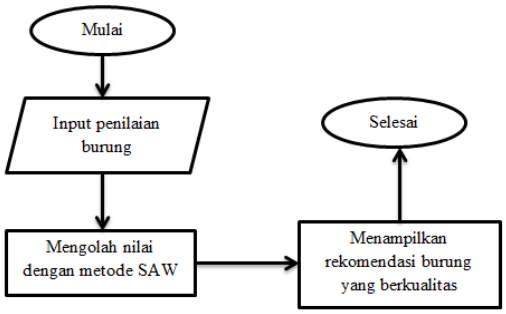


Figure 4 system workflow diagram

The design phase is employed to define the system to be constructed, encompassing the creation of workflow diagrams, activity diagrams, and feature design. In Figure 4 regarding the system workflow diagram, it can be seen the flow of the system that will be used by its users. The first flow is when the user has started entering the system, then the user can enter the results of the assessment based on observations made of prospective songbirds that will be selected as broodstock. Then the system will perform calculations with the SAW method to be able to bring up recommendations that will be displayed. then the system will display the results of songbird recommendations that have superior quality and will be used as broodstock. Then the system is finished Data Flow Diagrams, namely data or process logic, are made to describe the flow of data to and from the system where it is stored, the processes that generate data, and the interactions that occur between data and processes imposed on that model[12]

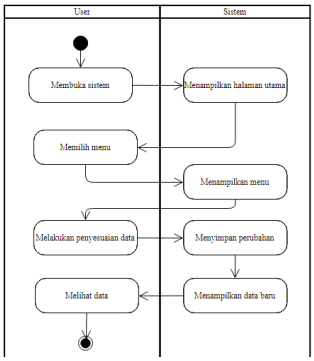


Figure 5 Activity Diagram

In Figure 3. above shows the activity diagram of the system that the user will do when the user opens the system. Activity Diagrams detail the flow of work in a system and define the order in which the system is displayed. With specialized components connected by arrows, this diagram depicts the sequence of activities from start to finish[13] . Users will first be directed to the main page which displays various features or menus available. Then after the user selects the menu that will be used, the contents of the menu page will appear. Furthermore, users can enter or adjust the data. After the user makes changes to the data, the system will save and calculate the data. Then the system will display the results of the calculation as a recommendation to the user. Next, the user sees the data from the calculation and then finishes.

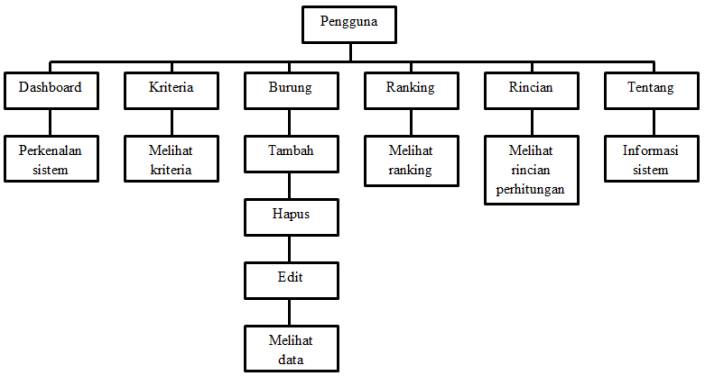


Figure 6 Feature Design.

The feature design contains all the features that can later be used by system users. The feature design is displayed in the form of a flowchart. Flowchart is a tool that shows the steps of solving a computational problem through expression in a series of special graphical symbols[14]. These features are designed according to the needs of users of this system. Because it is expected that the features created can help users appropriately. The following feature design will be built. Figure 6. shows the design of the features that will be made which will be used by users of the system. Six features that will be displayed, namely dashboard, criteria, birds, ranking, details, and about. Each feature has its uses according to the needs of its users.

2.4 Implementation Phase

This website is developed using the PHP programming language and incorporates Bootstrap to craft a user-friendly interface. Additionally, the website integrates the SAW algorithm for processing user-input data. The SAW (Simple Additive Weighting) method is employed in this research due to its relative ease of implementation,

facilitated by its straightforward concept. This simplicity enables developers to swiftly apply it in data processing. Moreover, it facilitates multi-criteria assessment, allowing each criterion to be assigned a weight based on its level of importance. So, this is a computer-based support system for decision-making management related to problems according to aspects of work. The SAW method is recommended to solve selection problems in multi-process decision-making systems. The SAW method is a method that is widely used in decision making that has many attributes. The SAW method requires a normalization process of the decision matrix (X) to a scale that can be compared with all existing alternative ratings[15]. The formula for normalizing is as follows:

$$r_{ij} = \begin{cases} \dfrac{x_{ij}}{Max\ x_{ij}} \ if\ j\ atribut\ benefit & (1) \\ \dfrac{Min\ x_{ij}}{x_{ij}} \ if\ j\ atribut\ cost & (2) \end{cases}$$

Caption:
Max Xij : The greatest value of each criterion i
Min Xij : The smallest value of each criterion i
Xij : The attribute value that each criterion has
Benefit : If the largest value is the best
Cost : If the smallest value is the best
Rij : Normalized performance rating

The convention value for each alternative (Vi) is given as:

$$Vi = \sum_{j=1}^{n} w_j r_{ij}$$

Caption:
Vi : Ranking for each alternative
Wj : Ranking weight value (of each criterion)
Rij : Normalized performance rating value

The results of the calculation of the greater Vi value indicate that alternative i is the best alternative.

3. Results and Discussion

3.1 Results

After conducting research and design, a system is produced that can support farmers in making decisions on the selection of quality bird breeds. The resulting system uses the Simple Additive Weighting (SAW) method to provide recommendations for quality birds. The system is made with a responsive website base so that it is easy to open anywhere and on any device. Providing recommendations in the form of rankings can make it easier for users to see the results of recommendations. The main page display can be seen in Figure 7 below. In the left image, the system display is shown when accessed via a PC device while on the right, the system display is shown when accessed via a smartphone or the like.

Figure 7 Main Page.

The system that has been created has several menus that are used to support the running of the system. The menu created contains things that are used in the calculation of recommendations and information about the system. The

menus contained in the system include the Dashboard menu, this menu contains an introduction to the system to its users by displaying a brief explanation of the system such as the name and use of the system. Next, there is a Criteria menu that displays the criteria of the assessment used to assess the candidate birds to be selected as broodstock, each criterion has a percentage of the level of importance of each according to the needs of the breeder. Furthermore, there is a bird menu that contains bird identity data and the results of the assessment of the assessor in this case the breeder against the candidate bird. To get a more objective recommendation, there are two assessor inputs so that later the resulting recommendation value is the average value of the two assessors. This is expected to increase the level of accuracy in providing recommendations. There is a Ranking menu that contains the results of calculations that have been carried out by the system which is a recommendation to breeders to select prospective parent birds, recommendations are displayed in the form of a ranking to make it easier to find out which birds are worthy of being used as broodstock. Next there is a details menu that displays details of the calculations carried out by the system to produce recommendations to breeders. The menu shows the calculation stages carried out from the data entered to produce a recommendation ranking. Finally, there is an About menu that describes more about the system.

3.2 Testing

The results of the system can help breeders select birds that have superior quality to be used as broodstock. Farmers will be given recommendations for birds that have superior quality to be used as broodstock in the form of rankings so that they are easy to understand. Farmers can freely add and subtract assessment data on existing birds. From the results of the system built, the results of the analysis of the application of the Simple Additive Weighting (SAW) method in selecting quality birds to be used as brooders are as follows.

Tabel 1. Criteria

Kicauan (C1)	Usia (C2)	Postur (C3)	Silsilah (C4)	Produksi (C5)
40	70	80	70	50

Table 1. is a table that contains criteria data that will be used in calculating to get recommendations for quality birds to be used as broodstock. The data was obtained from songbird breeders directly using the interview method. Table 2. contains test data from the first appraiser which will be calculated to get the recommendation value. The data used is in the form of data on the name of the bird that is a prospective broodstock, the ring number of the bird, and the values obtained from the assessment results carried out by the first assessor according to the criteria used.

Tabel 2. Data Appraisers 1

No	Nama	No.ring	C1	C2	C3	C4	C5
1	Burung5	26	25	25	30	10	20
2	Burung6	30	30	25	10	15	20
3	Burung29	1	30	20	20	20	10
4	Burung12	8	20	10	20	25	25
5	Burung41	41	15	20	30	15	20
6	Burung32	32	30	20	15	15	20
7	Burung33	33	20	20	10	40	10

Tabel 3. Data Appraisers 2

No	Nama	No.ring	C1	C2	C3	C4	C5
1	Burung29	1	15	20	20	30	15
2	Burung12	8	20	30	10	20	20
3	Burung5	26	20	20	30	10	20
4	Burung32	31	30	15	20	15	20
5	Burung33	33	20	30	30	10	10
6	Burung41	41	30	20	20	15	15
7	Burung6	30	20	10	20	20	30

Table 3. contains test data from the second assessor which will be calculated to get the recommendation value. The data used is in the form of data on the name of the bird that is a prospective broodstock, the ring number of the bird, and the values obtained from the assessment results carried out by the second assessor according to the criteria used. The use of more than one appraisal to get more accurate recommendation value results it is expected

that the resulting recommendation value is more objective because the recommendation value is generated from the average value of the two appraisers and is expected not to be influenced by the subjective matters of the appraiser..

Tabel 4. Calculation Stage 1 appraiser 1

No	Nama	No.ring	C1	C2	C3	C4	C5	Jumlah
1	Burung5	26	25	25	30	10	20	110
2	Burung6	30	30	25	10	15	20	100
3	Burung29	1	30	20	20	20	10	100
4	Burung12	8	20	10	20	25	25	100
5	Burung41	41	15	20	30	15	20	100
6	Burung32	32	30	20	15	15	20	100
7	Burung33	33	20	20	10	40	10	100

Tabel 5. Calculation Stage 2 appraiser 1

No	Nama	No.ring	C1	C2	C3	C4	C5
1	Burung5	26	0,85	1	1	0,25	0,8
2	Burung6	30	1	1	0,33	0,38	0,8
3	Burung29	1	1	0,8	0,67	0,5	0,4
4	Burung12	8	0,67	0,4	0,67	0,63	1
5	Burung41	41	0,5	0,8	1	0,38	0,8
6	Burung32	32	1	0,8	0,5	0,36	0,8
7	Burung33	33	0,67	0,8	0,33	1	0,4

Table 4. are tables that contain the first stage of mathematical calculations in getting recommendations for quality birds to be used as broodstock. In the first stage of the calculation, the value of the value obtained by each bird is summed up. A similar calculation was performed on the second appraiser. Table 5. contain the second stage calculation of the value data obtained. in this second stage, normalization is carried out using the first formula of the Simple Additive Weighting (SAW) method to obtain the normalized value of each bird according to its criteria. A similar calculation was performed on the second appraiser.

Tabel 6. Calculation Stage 3 appraiser 1

No	Nama	No.ring	Total poin	SAW	Ranking
1	Burung5	26	110	240.8333	1
2	Burung41	41	100	222.25	2
3	Burung29	1	100	204.3333	3
4	Burung6	30	100	202.9167	4
5	Burung32	32	100	202.25	5
6	Burung12	8	100	201.76	6
7	Burung33	33	100	199.3333	7

Tabel 7. Calculation Stage 3 appraiser 2

No	Nama	No.ring	Total poin	SAW	Ranking
1	Burung33	33	100	216.6667	1
2	Burung29	1	100	215	2
3	Burung5	26	100	210	3
4	Burung12	8	100	203.3333	4
5	Burung41	41	100	200	5
6	Burung6	30	100	200	6
7	Burung32	32	100	196.6667	7

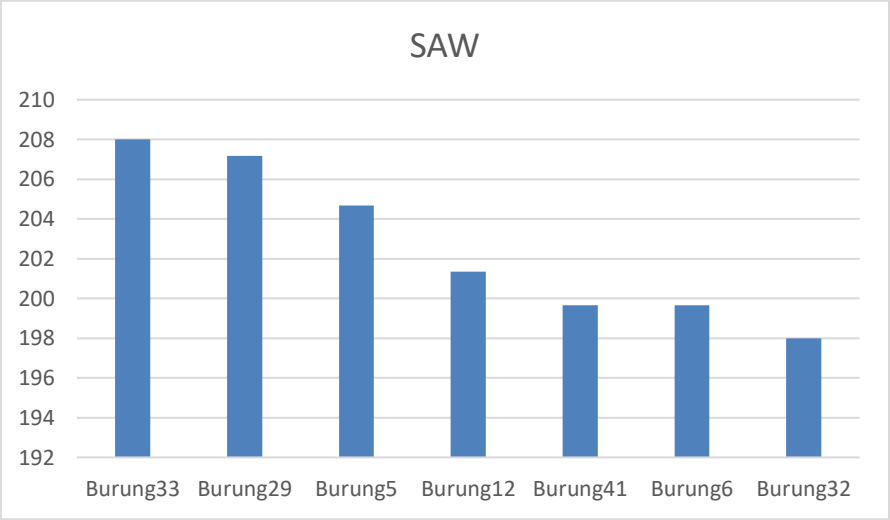
Table 6. and Table 7. contain the third stage calculations used to obtain recommendations. In the third stage, mathematical calculations are carried out with the formula of the Simple Additive Weighting (SAW) method which will get the final results of the calculation with this method.

Tabel 8. Average Value Calculation

Ranking	Nama	No.ring	Total poin	SAW
1	Burung33	33	200	208
2	Burung29	1	200	207.16665
3	Burung5	26	200	204.66665
4	Burung12	8	200	201.3333
5	Burung41	41	200	199.66665
6	Burung6	30	200	199.66665
7	Burung32	32	200	198

Table 8. contains the average results of recommendations from the two assessors. The average is done because it is to get the results of recommendations that are more objective in providing recommendations. Chart 1 represents the outcomes of the preceding calculations, indicating that Burung33 is the most suitable candidate for domestication as a breeding bird.

Figure 8. Final Result



4. Conclusions

Based on the results of the research that has been done, the implementation of a decision support system with the simple additive weighting (SAW) method to select superior quality bird breeds, it is concluded that the system can help breeders in selecting quality birds that will be used as breeds for breeding. In addition, with the continuous use of this system, breeders over time can distinguish birds that have superior quality by just looking directly without having to get help from anyone else. By using the system properly and correctly, breeders will get recommendations for birds that really have superior quality to be used as breeders or just to be used as pets.

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References

[1] D. Iswandaru, N. Novriyanti, I. S. Banuwa, and S. P. Harianto, “Distribution of bird communities in university of lampung, indonesia,” *Biodiversitas*, vol. 21, no. 6, pp. 2629–2637, Jun. 2020, doi: 10.13057/biodiv/d210634.

[2] I. Fitri Sari, A. Setiawan, D. Iswandaru, and B. Sari Dewi, “Peran Ekologi Spesies Burung pada Ekosistem Hutan Kota (Studi Kasus di Kota Metro).”
[3] Anastasia Anik Adisti and Rosa Zulfikhar, “Mengenal Berbagai Macam Burung di Indonesia,” 2021.
[4] H. Sukmantari and A. Januarsa, “Mengenalkan Keanekaragaman Burung Endemik Indonesia Melalui Perancangan Buku Ensiklopedia untuk Anak-anak.”
[5] S. Akbar, M. Indra, and G. Anugrah, “Sistem Pendukung Kepustusan Pemilihan Tempat Kos Untuk Mahasiswa Di Gresik Dengan Metode Saw,” vol. 7, no. 2, 2022.
[6] K. H. Manurung, A. E. Syaputra, and Y. S. Eirlangga, “Design the Best Student Selection Decision Support System With Simple Addictive Weighting (SAW) Method,” *INTERNATIONAL JOURNAL of DYNAMICS in ENGINEERING and SCIENCES (IJDES) LLDIKTI WILAYAH X*, vol. 7, no. 2, 2022, doi: 10.22216/jod.v7i1.1089.
[7] E. F. Wati, “Penerapan Metode SAW Dalam Menentukan Lokasi Usaha (Embun Fajar Wati) |241 Universitas Bina Sarana Informatika Jl,” 2021.
[8] U. Apsiswanto, A. Setiawan STMIK Dharma Wacana, and M. Lampung, “PENERAPAN METODE SIMPLE ADDITIVE WEIGHTING (SAW) DALAM MENENTUKAN KELUARGA MISKIN (STUDI KASUS : DESA NAMPIREJO).”
[9] E. Khoiril Ulama, A. Thyo Priandika, and F. Ariany, “SISTEM PENDUKUNG KEPUTUSAN PEMILIHAN SAPI SIAP JUAL (TERNAK SAPI LEMBU JAYA LESTARI LAMPUNG TENGAH) MENGGUNAKAN METODE SAW,” *Jurnal Informatika dan Rekayasa Perangkat Lunak (JATIKA)*, vol. 3, no. 2, pp. 138–144, 2022, [Online]. Available: http://jim.teknokrat.ac.id/index.php/informatika
[10] D. Witasari and Y. Jumaryadi, “APLIKASI PEMILIHAN KARYAWAN TERBAIK DENGAN METODE SIMPLE ADDITIVE WEIGHTING (STUDI KASUS CITRA WIDYA TEKNIK),” Teknologi Informatika dan Komputer. [Online]. Available: https://jurnal.umj.ac.id/index.php/just-it
[11] Eko Haryono, “METODOLOGI PENELITIAN KUALITATIF DI PERGURUAN TINGGI KEAGAMAAN ISLAM,” 2023.
[12] S. Silvia Infromatika, “PERANCANGAN SISTEM INFORMASI PENGARSIPAN DATA PAJAK (STUDI KASUS : PT KURNIA ABADI JAYA BANDAR LAMPUNG).”
[13] B. Simare Mare, A. A. Yana, and U. N. Mandiri, “PERANCANGAN SISTEM INFORMASI BERBASIS WEB PADA KOPERASI SIMPAN PINJAM SEJAHTERA BERSAMA,” Online.
[14] Jindra Hakim, “KLASIFIKASI TERHADAP IKLAN PROMOSI DENGAN PERHITUNGAN ALGORITMA POHON KEPUTUSAN C4.5,” 2022.
[15] Kanim, Tukiyat, and Murni Handayani, “ANALISIS PERBANDINGAN METODE TECHNIQUE FOR ORDER PREFERENCE BY SIMILARITY TO IDEAL SOLUTION, SIMPLE ADDITIVE WEIGHTING DAN WEIGHTED PRODUCT DALAM SISTEM PENDUKUNG KEPUTUSAN PEMILIHAN GURU TERBAIK,” *JSiI (Jurnal Sistem Informasi)*, vol. 10, no. 1, pp. 33–40, Mar. 2023, doi: 10.30656/jsii.v10i1.6134.

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The Effect of LAB Color Space with NASNetMobile Fine-tuning on Model Performance for Crowd Detection

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Abstract. In the COVID-19 pandemic, computer vision plays a crucial role in crowd detection, supporting crowd restriction policies to mitigate virus spread. This research focuses on analyzing the impact of using the RGB LAB color space in advance to perform NASNetMobile better. The fine-tuning process, involving freezing layers in various NASNetMobile base model variations, is considered. Results reveal that the model with LAB color space outperforms the model with RGB color space, with an average accuracy of 94.68% compared to 94.15%. From all the test iterations, it was found that the highest performance for the NASNetMobile model occurred when freezing 10% of the layers from the back for both model LAB and RGB color spaces, with the LAB color space achieving an accuracy of 95.4% and the RGB color space achieving an accuracy of 95.1%.

Keywords: Convolutional Neural Network (CNN), Fine-tuning, LAB, NASNetMobile, RGB

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1. Introduction

Computer vision, as one of the main branches of artificial intelligence, has had a significant impact on various aspects of human life [1]. With its ability to understand and process visual information, computer vision plays an important role in various social activities. One important context in computer vision applications, especially during the COVID-19 pandemic, is crowd detection. One of the most effective methods in processing visual data is Convolutional Neural Networks (CNN), which has shown its superiority in various image processing applications. In this context, CNNs are used to detect crowds of people to support crowd restriction policies so as to prevent the spread of disease outbreaks. In addition, this technology is also used in other activities, such as detecting the use of masks [2] and automatic human counts [3].

Although there has been significant progress in the application of CNNs to various social activities, research continues to be developed in search of models with better accuracy. Several CNN models, including ResNet, DenseNet, MobileNet, and NASNetMobile, have been proven to excel in solving visual detection problems. NASNetMobile has stood out as an efficient and robust model in image recognition tasks of the various existing CNN architectures.

Several studies focusing on studying popular deep learning architectures have been conducted over the past few years [4]–[6]. Some literature has discussed the CNN model, especially regarding the performance of NASNetMobile.

For example, Anwar Fuadi [4] researched the comparison of MobileNet and NASNetMobile architectures for disease classification in potato leaf images. This research aims to compare MobileNet and NASNetMobile architectures in performing disease detection on potato plant leaves. The data used in this study are divided into images of healthy potato leaves, images of potato leaves infected with Early Blight, and images of potato leaves infected with Late Blight. The research concludes that models using NASNetMobile architecture produce better model evaluation results than MobileNet with certain schemes.

Ahsan M [5] conducted research on patient symptom detection with COVID-19 using eight different models including VGG16, InceptionResNetV2, ResNet50, DenseNet201, VGG19, Mo-bilenetV2, NasNetMobile, and ResNet15V2, using two datasets namely 400 CT scans and 400 chest X-ray images. The results of this study show that the NASNetMobile model outperforms all other models.

Enkvetchakul P [6] presents a plant leaf disease recognition system using two CNN Architectures namely MobileNetV2 and NASNetMobile. The results of the study show that the architecture that has the highest accuracy for plant leaf disease recognition is the NASNetMobile architecture using transfer learning. These results are obtained when combining offline training techniques with data augmentation techniques.

In addition, the accuracy results of several CNN models, including NASNetMobile, are also affected by the selection of color features. Therefore, it is important to explore the potential of some CNN models further and understand how the use of color space can affect their performance. Several color spaces, such as RGB, LCH, LAB, and others, are often used for image processing research. Several studies have conducted discussions on the differences in these color spaces.

Thevarasa N [7] researched the classification of mosquito breeding locations using various approaches such as CNN, SVM, and FSL. The study also compared the use of datasets with RGB and LAB color spaces in training CNN. The results showed that CNN training using LAB color space produced better performance with an accuracy rate of 90%, while CNN training with RGB color space only achieved an accuracy of 84.29%. Meanwhile, SVM and FSL achieved an accuracy rate of 79% and 80%, respectively.

Gowda S [8] conducted a study that explored the effect of various color spaces on the level of accuracy in training deep learning CNN. The study tested several color spaces, such as RGB, HSV, YUV, LAB, YIQ, XYZ, YPbPr, YCbCr, HED, and LCH, using the Cifar-10 dataset. The results showed that the LAB color space achieved the highest accuracy rate than other color spaces, reaching 80.43%, with a training time of 26 seconds.

This research will focus on the application of the NASNetMobile CNN model by applying LAB color space features and fine-tuning for crowd-detection purposes. The selection of NASNetMobile as the main model is based on its proven advantages in previous studies. In contrast, the selection of LAB color space is motivated by previous studies showing its potential in improving visual detection accuracy.

This research aims to investigate the effect of LAB color space by fine-tuning NASNetMobile on the performance of crowd detection. By considering this aspect, this research is expected to provide more insight into how NASNetMobile can be optimized by considering the use of specific color spaces. This research will collect test iteration results of various freezing layer variations in two RGB and LAB color spaces on the NASNetMobile model for crowd detection. We hypothesize that the use of RGB LAB color space can affect the model's performance, and adjusting the freezing layer range will play an important role in strengthening the experimental results.

With these experiments, we expect to obtain more precise information about how color space variables might be used to optimize deep learning models, especially NASNetMobile, for crowd-detection tasks. The findings of this research significantly improve image recognition technology and enhance model performance in various application scenarios.

2. Research Methods

2.1. Research Flowchart

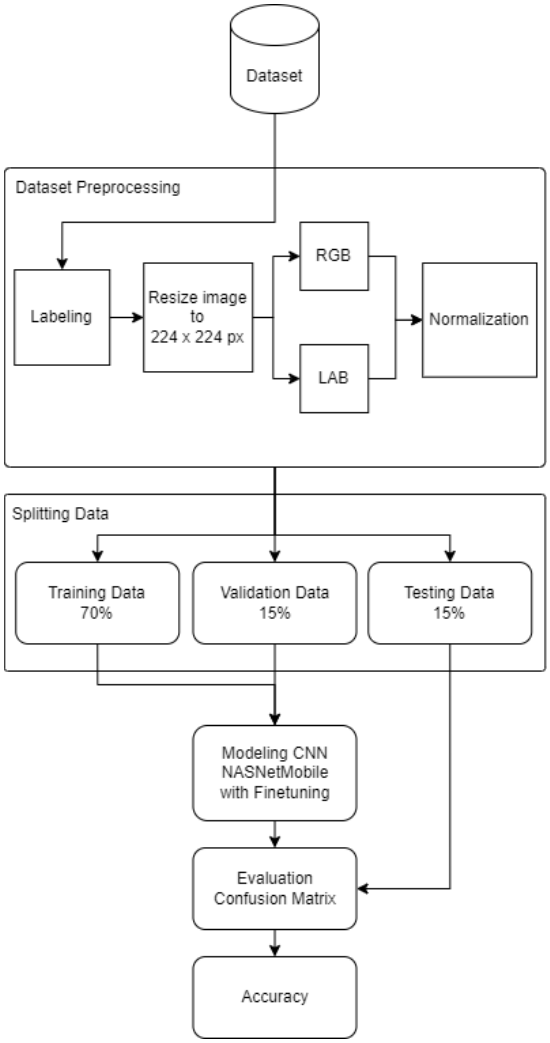

Figure 1. Research Flowchart

Figure 1 illustrates how the research begins with the initial stage of dataset preparation. The dataset will then undergo pre-processing to prepare it for model training. After that, the dataset processed in the earlier stage will be split into three sets: testing, validation, and training.

Next, the NASNetMobile CNN modeling process with fine-tuning using freezing layer. There are several freezing layer ranges used starting from overall freezing, 10% from the front, 20% from the front, 25% from the front, 30% from the front, 40% from the front, 50% from the front, 10% from the back, 20% from the back, 25% from the back, 30% from the back, 40% from the back, and 50% from the back as can be seen in Figure 3.

The model will be trained using the training data during the training phase. The confusion matrix will be used as an evaluation metric to evaluate the model's performance. This metric measure offers insight into the model's functionality, which will be utilized as evaluation material. The accuracy value serves as a standard for a number of the behaviors used in this research.

2.2. Dataset

The Crowd Human dataset, which is an open-source collection of images in a range of sizes, positions,

and backdrops, is used in this study [9], [10]. There are 15,000 images in this dataset overall. This dataset has been processed by previous research [11] to highlight the important areas of each image.

2.3. Dataset Preprocessing

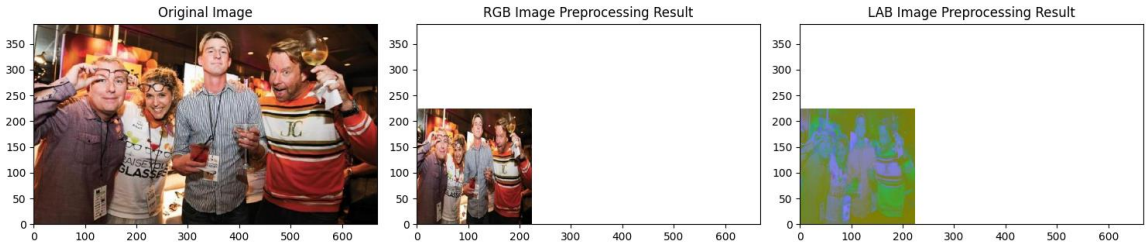

Figure 2. Dataset Preprocessing Results

Of the 15000 images in the Crowd Human collection, only 30% are used in this research, which is 5500 images. These images are going to be set up for model training. Initially, the images are divided into two classes: the crowd class and the non-crowd class. The image is then resized to 224 by 224 pixels. Since the NASNetMobile model requires a certain image size to be learned, this step is carried out to prepare the images or data for training on the model.

After that, this is where the color space distinction will be used. An additional process for the LAB color space is needed, which is converting the color space from RGB to LAB. In contrast, the RGB color space does not need to do an additional process because the original color of the dataset is RGB. An explanation of RGB and LAB color spaces can be seen in section 2.4.

Last, each image's pixel intensity is normalized, applying its value to a range from 0 to 1. This normalizing step is essential to guarantee consistency and improved performance during the model training phase. The results of pre-processing the RGB and LAB versions of the images can be seen in Figure 2.

2.4. Convert RGB color to LAB color

RGB (Red, Green, Blue) color space is one of the additive color space models in images that produce colors at each pixel. RGB color space is very common in electronic devices, such as monitor screens, televisions, and other display devices [12]. This model is relatively easy to understand and use in image processing due to its intuitive nature, but it is not fully capable of representing all colors that the human eye can see.

LAB color space is one of the color space models specifically designed to represent all colors that can be seen by the human eye [12]. Another advantage of the LAB color space is that it segmented accurate colors. By separating the color and brightness components, LAB color space can be used to identify objects based on their color difference from the background or other objects. LAB color space is invariant to lighting changes, meaning that colors in this color space are more stable to changing lighting conditions. This makes LAB color space commonly used in applications that require color accuracy, such as medical image processing and color quality in photography.

Converting RGB color to LAB color is done through two conversion stages, i.e., RGB color conversion to XYZ color and XYZ color conversion to LAB color. RGB color conversion to XYZ color can be done through equation (1).

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.607 & 0.174 & 0.200 \\ 0.299 & 0.587 & 0.114 \\ 0.00 & 0.066 & 1.116 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

The XYZ color is converted to LAB color using the following equation (2-5).

$$L^* = 116\sqrt[3]{\frac{Y}{Y_n}} - 16, \text{untuk } \frac{Y}{Y_n} > 0.008856 \quad (2)$$

$$L^* = 903.3\frac{Y}{Y_n}, \text{untuk selain } \frac{Y}{Y_n} > 0.00885 \quad (3)$$

$$a^* = 500\left(f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right) \quad (4)$$

$$b^* = 200\left(f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)\right) \quad (5)$$

Therefore, LAB color space is often used for image processing that requires high precision in color reproduction, color mapping, and color adjustment.

2.5. Splitting Data

The 5500 images will be separated into two classes: non-crowd (2250 images) and crowd (2250 images). Moreover, the dataset will be split into three sets: 70% of the images are training data (3850 images), 15% are validation data (825 images), and 15% are testing data (825 images).

2.6. Modeling CNN NASNetMobile with Fine-tuning

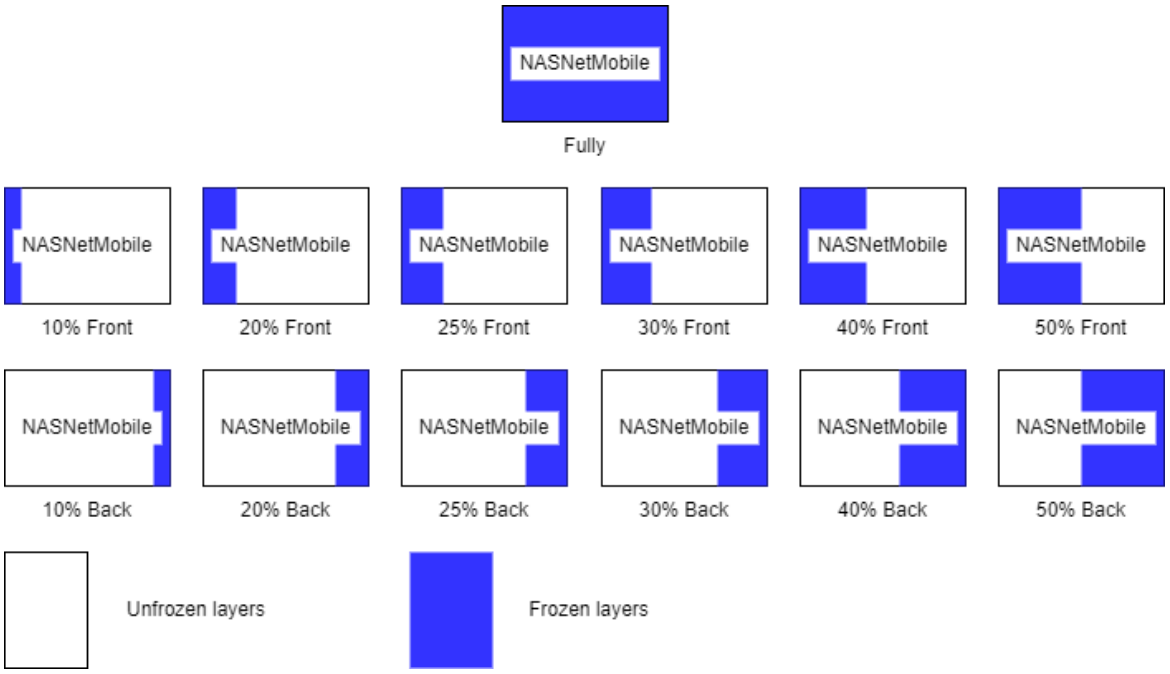

Figure 3. Freezing Layer Variations

In this research, the convolutional neural network model used is NASNetMobile. NASNetMobile has a mobile-friendly design, making it a practical choice for real-world applications requiring image classification on mobile devices. The architecture of NASNetMobile includes multiple convolutional layers designed to extract features from images, making it suitable for investigating the effect of different color spaces on image classification performance.

To sample the performance of the NASNetMobile model, the transfer learning method is carried out and then processed by fine-tuning by freezing the layer with various variations, i.e., fully freezing, 10% from the front, 20% from the front, 25% from the front, 30% from the front, 40% from the front, 50% from the front, 10% from the back, 20% from the back, 25% from the back, 30% from the back, 40% from the back, and 50% from the back as can be seen in Figure 3. The results of these various variations will be used as comparison samples to find out the effect of RGB and LAB color spaces on NASNetMobile performance.

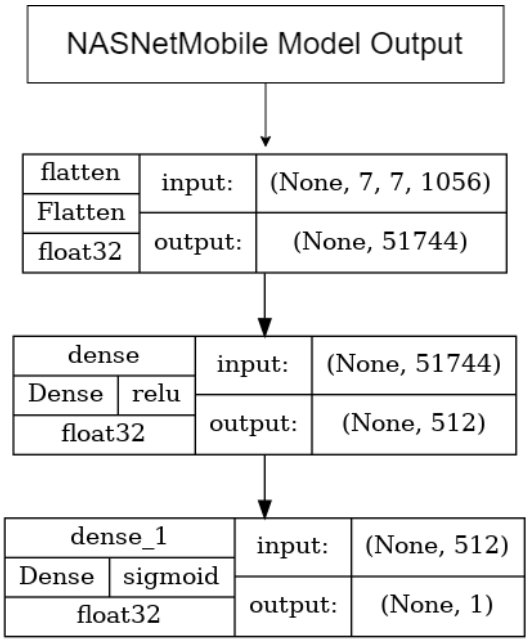

Figure 4. Modelling NASNetMobile

Additionally, three training layers are added, as shown in Figure 4: a flattened, dense, and final dense layer. From the previous output layer, which results from the transfer learning of the NASNetMobile CNN architecture, the flattened layer is utilized to create a one-dimensional vector [13], [14]. The final dense layer contains 1 neuron, while the dense layer contains 512 neurons. In the dense layer, the Rectified Linear Unit (Rectified) activation function is also utilized to resolve the gradient loss issue and enhance training effectiveness [15]. L2 kernel regulation is also used in the dense layer to prevent overfitting. The final dense layer is used to process data and analyze more complex patterns than the previous layers [16], [17]. In the last dense layer, sigmoid is also utilized. Sigmoid is an activation function that is utilized for binary classification activities. The sigmoid function's main objective is to translate the model's output into a probability value between 0 and 1 [18].

2.7. Evaluation

In this research, two color spaces, RGB and LAB, were evaluated with several samples obtained through various freezing layers. The evaluation is done by comparing the confusion matrix and classification report. The confusion matrix evaluates how well the model performs in classification. A classification report is an instrument that provides an overview of the precision and recall for each class. The comparison value used is the accuracy value in the classification report.

3. Results and Discussion

3.1. Implementation

Implementation is done by applying the NASNetMobile model with three-layer modifications. The three layers are the flattened layer, the dense layer, and the final dense layer. Implementation is done with the Crowd Human dataset. The training model employs binary cross-entropy as the loss function, learning rate 1e-4, batch size 32, and SGD optimizer. The early stop and patience techniques were applied for 10 epochs during the 100 epochs of the training phase. Each test run takes about 35 minutes. All test results also show that the learning process runs smoothly until the 100th epoch without an early stop.

3.2. Evaluation of Results

Table 1. Accuracy Test Iteration Results (%)

Model Color Space	Freezing Layer													Avg
	Fully	Front						Back						
		10%	20%	25%	30%	40%	50%	10%	20%	25%	30%	40%	50%	
RGB NASNet Mobile	93,8	93,7	93,5	94,2	94,3	93,9	94,2	95,1	94,3	94,2	94,8	93,7	94,3	94,15
LAB NASNet Mobile	94	94	94	95,2	94,9	94,8	94,4	95,4	95,1	94,8	95,2	94,5	94,6	94,68

From Table 1, we can see the results of the experimental tests that have been carried out, starting from freezing the layer entirely up to freezing the layer 50% from the back for both RGB and LAB color spaces. The results of experimental tests that have been carried out on the NASNetMobile model are to compare the performance differences between the RGB color space and the LAB color space. From 13 freezing layer experiments, all experiments show that the model's accuracy with LAB color space is higher than that of the model with RGB color space.

From all the experimental results, it is also known that the highest accuracy results for the NASNetMobile model occur when freezing the layer 10% from the back. In this case, the LAB color space still shows higher accuracy than the RGB color space, with the highest values of 95.4% and 95.1%, respectively. LAB color space clearly stands out in better pattern recognition capabilities.

The average accuracy calculation results show that the RGB color space gets an average value of 94.25% while the LAB color space gets an average value of 94.58%. This proves that the LAB color space performs better than the RGB color space, with a difference of 0.53%.

3.3. Analysis and Discussion

In the NASNetMobile model, three additional layers are added as the basic model of this research. Furthermore, the model will be trained using the Human Crowd dataset, which has been divided into two classes, such as the crowd class and the non-crowd class, which has passed the pre-processing stage according to the color space to be tested (RGB or LAB). Then the model is iterated with various freezing layer variations, including a fully freezing layer, 10% from front, 20% from front, 25% from front, 30% from front, 40% from front, 50% from front, 10% from back, 20% from back, 25% from back, 30% from back, 40% from back, and 50% from back.

All test accuracy results were stored, recorded, and compared in one table, as shown in Table 1. The table of experimental test results shows that the model with LAB color space provides consistently higher accuracy results than the model with RGB color space. This is proven by 13 freezing layer experiments; all experiments show that the model's accuracy with LAB color space is higher than the model with RGB color space.

The freezing layer, 10% from the back, has the highest accuracy compared to all freezing layer variations. This can happen because, in crowd detection, special features or patterns that detect crowds more accurately are located in the deeper layers of the network. By freezing the layer 10% of the way back, the model can maintain its ability to capture these important features. The table of experimental test results also shows that the average calculated result of the RGB color space gets an average value of 94.15%. In comparison, the LAB color space gets an average value of 94.68%. The difference

between the two average values is 0.53%. All these test results show that the LAB color space clearly stands out in better pattern recognition ability in crowd images.

4. Conclusion

Based on the evaluation results, all iterations of test results show good accuracy for crowd and non-crowd image classification, which is above 90%. The experimental test results table shows that the LAB color space performs better than the RGB color space on the performance of the NASNetMobile model for crowd detection. This is proven by all experimental results showing that the model with LAB color space provides consistently higher accuracy results than the model with RGB color space.

The average value of the two color spaces also shows that the LAB color space is higher than the RGB color space, with an average accuracy value of 94.68% and 94.15%, respectively. The difference from the average obtained is 0.53%. Although the difference in numbers looks small, it is also a good improvement, considering the accuracy results of all test iterations are already very high, above 90%.

The table of experimental test results also shows that the freezing layer 10% from the back in the NASNetMobile model is the highest accuracy result. This is because, in crowd detection, special features or patterns that can detect crowds more accurately are located in the deeper layers of the network. By freezing the back 10% layer, the model can maintain its ability to capture these important features.

NASNetMobile models with LAB color space and fully freezing layers are proven to show improvements in model performance. In addition, implementing the tuning parameter of freezing at 10% of the back improved the accuracy significantly. The findings of this research contribute to further development in image processing applications and understanding of optimal fine-tuning, i.e., freezing layer mechanisms in Deep Learning environments.

References

[1] J. Chai, H. Zeng, A. Li, and E. W. T. Ngai, "Deep learning in computer vision: A critical review of emerging techniques and application scenarios," *Machine Learning with Applications*, vol. 6, p. 100134, Dec. 2021, doi: 10.1016/j.mlwa.2021.100134.

[2] A. I. Pradana, "Deteksi Ketepatan Pengunaan Masker Wajah dengan Algoritma CNN dan Haar Cascade," *JATISI (Jurnal Teknik Informatika dan Sistem Informasi)*, vol. 9, no. 3, pp. 2305–2316, Sep. 2022, doi: 10.35957/jatisi.v9i3.2912.

[3] D. T. Laksono, I. N. Husna, M. Ulum, A. K. Saputro, M. F. Fahmi, and D. N. Purnamasari, "SISTEM DETEKSI DAN PERHITUNGAN JUMLAH MANUSIA DALAM RUANGAN MENGGUNAKAN METODE CONVOLUTIONAL NEURAL NETWORK," *Jurnal Simantec*, vol. 11, no. 1, pp. 131–138, Dec. 2022, doi: 10.21107/simantec.v11i1.19745.

[4] A. Fuadi and A. Suharso, "PERBANDINGAN ARSITEKTUR MOBILENET DAN NASNETMOBILE UNTUK KLASIFIKASI PENYAKIT PADA CITRA DAUN KENTANG," *JIPI (Jurnal Ilmiah Penelitian dan Pembelajaran Informatika)*, vol. 7, no. 3, pp. 701–710, Aug. 2022, doi: 10.29100/jipi.v7i3.3026.

[5] M. M. Ahsan, K. D. Gupta, M. M. Islam, S. Sen, Md. L. Rahman, and M. Shakhawat Hossain, "COVID-19 Symptoms Detection Based on NasNetMobile with Explainable AI Using Various Imaging Modalities," *Mach Learn Knowl Extr*, vol. 2, no. 4, pp. 490–504, Oct. 2020, doi: 10.3390/make2040027.

[6] P. Enkvetchakul and O. Surinta, "Effective Data Augmentation and Training Techniques for Improving Deep Learning in Plant Leaf Disease Recognition," *Applied Science and Engineering Progress*, Jan. 2021, doi: 10.14416/j.asep.2021.01.003.

[7] N. Thevarasa, G. Ananthajothy, R. Navaratnam, and M. B. Dissanayake, "Weighted Ensemble Algorithm for Aerial Imaging Based Mosquito Breeding Sites Classification," in *2023 IEEE 17th International Conference on Industrial and Information Systems (ICIIS)*, IEEE, Aug. 2023, pp. 347–352. doi: 10.1109/ICIIS58898.2023.10253588.

[8] S. N. Gowda and C. Yuan, “ColorNet: Investigating the Importance of Color Spaces for Image Classification,” 2019, pp. 581–596. doi: 10.1007/978-3-030-20870-7_36.
[9] X. Shao *et al.*, “Multi-Scale Feature Pyramid Network: A Heavily Occluded Pedestrian Detection Network Based on ResNet,” *Sensors*, vol. 21, no. 5, p. 1820, Mar. 2021, doi: 10.3390/s21051820.
[10] S. Shao *et al.*, “CrowdHuman: A Benchmark for Detecting Human in a Crowd,” Apr. 2018.
[11] P. Langgeng, W. E. Putra, M. Naufal, and E. Y. Hidayat, “A Comparative Study of MobileNet Architecture Optimizer for Crowd Prediction,” *Semarang 123 Jl. Imam Bonjol No*, vol. 8, no. 3, p. 50131, 2023.
[12] D. Alamsyah and D. Pratama, “Segmentasi Warna Citra Bunga Daisy dengan Algoritma K-Means pada Ruang Warna Lab,” *Jurnal Buana Informatika*, vol. 10, no. 2, Oct. 2019, doi: 10.24002/jbi.v10i2.2458.
[13] B. Kaddar, H. Fizazi, M. Hernandez-Cabronero, V. Sanchez, and J. Serra-Sagrista, “DivNet: Efficient Convolutional Neural Network via Multilevel Hierarchical Architecture Design,” *IEEE Access*, vol. 9, pp. 105892–105901, 2021, doi: 10.1109/ACCESS.2021.3099952.
[14] W. Sun, Q. Wei, L. Ren, J. Dang, and F.-F. Yin, “Adaptive respiratory signal prediction using dual multi-layer perceptron neural networks,” *Phys Med Biol*, vol. 65, no. 18, p. 185005, Sep. 2020, doi: 10.1088/1361-6560/abb170.
[15] E. Belcore and V. Di Pietra, “LAYING THE FOUNDATION FOR AN ARTIFICIAL NEURAL NETWORK FOR PHOTOGRAMMETRIC RIVERINE BATHYMETRY,” *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XLVIII-4/W1-2022, pp. 51–58, Aug. 2022, doi: 10.5194/isprs-archives-XLVIII-4-W1-2022-51-2022.
[16] A. M. Javid, S. Das, M. Skoglund, and S. Chatterjee, “A ReLU Dense Layer to Improve the Performance of Neural Networks,” in *ICASSP 2021 - 2021 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, IEEE, Jun. 2021, pp. 2810–2814. doi: 10.1109/ICASSP39728.2021.9414269.
[17] C. Fang, H. He, Q. Long, and W. J. Su, “Exploring deep neural networks via layer-peeled model: Minority collapse in imbalanced training,” *Proceedings of the National Academy of Sciences*, vol. 118, no. 43, Oct. 2021, doi: 10.1073/pnas.2103091118.
[18] X. Wang, H. Ren, and A. Wang, “Smish: A Novel Activation Function for Deep Learning Methods,” *Electronics (Basel)*, vol. 11, no. 4, p. 540, Feb. 2022, doi: 10.3390/electronics11040540.

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Comparison of Gradient Boosting and Random Forest Models in the Detection System of Rakaat during Prayer

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Abstract. Errors in the execution of prayer among Muslims can occur due to a lack of profound understanding of the prayer procedure. This research aims to compare two machine learning models, Random Forest and Gradient Boosting, in classifying prayer movements, subsequently extending to calculate the number of prayer cycles (rakaat). A total of 7220 manually gathered data based on 33 landmark coordinates using Mediapipe Pose Detection were employed. The research findings reveal that the Random Forest model with a 70:30 ratio achieves 99.9% accuracy, precision, and recall, with the fastest training time being 3.8 seconds. Both models exhibit testing results close to 100%, but the Gradient Boosting model faces challenges in classifying specific movements. On the other hand, Random Forest successfully overcomes these challenges, enabling accurate prayer cycle calculations. The findings can contribute to the development of tools supporting Muslims in correct prayer execution, positively impacting religious and well-being aspects.

Keywords: Classification, Machine Learning, Mediapipe, Random Forest, Gradient Boosting

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1. Introduction

Prayer is one of the pillars of Islam that plays a crucial role for Muslims [1]. Although prayer has clear procedures and pillars, common mistakes often occur during its execution. These mistakes can happen due to a lack of deep understanding, negligence, or misunderstanding of the correct procedures for prayer. One example of a mistake in prayer is an excess or deficiency in the number of prayer cycles (rakaat). This lack of understanding can have a negative impact on the quality of a person's prayer performance, as prayer plays a crucial role as one of the pillars of Islam. Therefore, the development of this prayer movement detection system is essential to improve the quality of prayer execution, serve as an educational tool, and contribute to future technological advancements.

In recent years, the field of artificial intelligence (AI) has experienced tremendous advancements [2], Opening up new potential for innovation and solutions across various sectors of human life, the field of AI has witnessed remarkable progress in recent years. One of the most prominent aspects of AI advancement is the utilization of machine learning (ML), which serves as the backbone for processing vast amounts of data and involves systems learning from the provided data. By employing

ML, computers can perform pattern recognition, make predictions, and make decisions. [3]. Therefore, the application of ML is highly relevant for use in classification, where systems can learn to categorize data into specific categories or classes.

By integrating ML with Computer Vision (CV), computers can understand, analyze, and interpret visual data from the real world. With this capability, it becomes possible to perform human body detection. One way to implement pose detection is by utilizing the framework provided by MediaPipe. [4]. By using the framework provided by MediaPipe, it allows for the implementation of pose detection without the need for programming from scratch. Thus, integrating ML with CV and leveraging frameworks like MediaPipe provides an effective and efficient solution for automatically detecting and analyzing human body poses.

There are several algorithms suitable for classification, and some examples include Gradient Boosting [5] and Random Forest [6]. Gradient Boosting, with its incremental learning approach [7], capable of building a highly adaptive and accurate model by focusing on correcting the prediction errors of the previous model [8]. Its main strength lies in its ability to handle complex and irregular data, as well as its robustness in dealing with overfitting. Meanwhile, Random Forest stands out due to its ensemble nature, harnessing the power of multiple Decision Trees. [9]. By building a large number of trees independently and combining their prediction results [10], Random Forest can provide stable predictions and avoid overfitting, which is commonly observed in a single Decision Tree [11].

To evaluate the trained model, a Confusion Matrix can be used [12]. The use of model evaluation using a confusion matrix reflects the importance of understanding the performance of a classification model. In the context of machine learning model development, especially in classification tasks, accurate and informative evaluation is key to measuring how well a model can classify data correctly. The confusion matrix is an evaluation tool that provides in-depth insights into the model's performance. It depicts the classification results of the model by dividing predictions into four matrices. With the confusion matrix, various evaluation metrics such as accuracy, precision, and recall can be calculated [13], provides a more comprehensive understanding of the model's performance.

The main objective of this research is to develop a prayer posture detection system using AI and CV technology. This system is designed to recognize movements and body positions during prayer with the primary goal of improving accuracy and precision in determining the number of prayer cycles (rakaat). The system is expected to contribute positively to enhancing the implementation of prayers for Muslims.

2. Methods

2.1. Data Acquisition

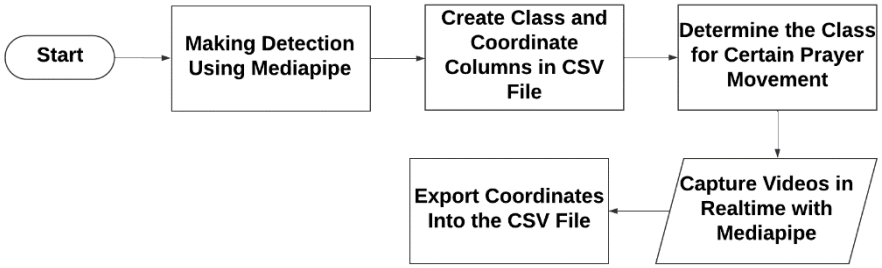


Figure 1. Sequence of Data Acquisition

In this Data Acquisition process, the dataset to be used is manually created with the assistance of Mediapipe Pose Detection. Based on Figure 1, the initial stage involves ensuring that the detection using Mediapipe Pose Detection can work optimally and accurately detect the body parts of the object. Following this, columns are created for the Class of each prayer movement and the Coordinates of each movement. The Class of prayer movements consists of Takbiratul Ihram, Bersedekap, Rukuk, Rukuk (Hadap Depan), Itidal, Sujud, Duduk Iftirosy, Duduk Ifirasy (Hadap Depan), Duduk Tawaruk, Duduk

Tawaruk (Hadap Depan), Salam. As for the coordinate columns, since Mediapipe Pose Detection has a total of 33 Landmarks as shown in Figure 2, and each Landmark has 4 variables within it, namely x, y, z, and v (visibility) [14]. Therefore, in the coordinate column, there are a total of 132 columns starting from x1, y1, z1, v1 up to x33, y33, z33, v33.

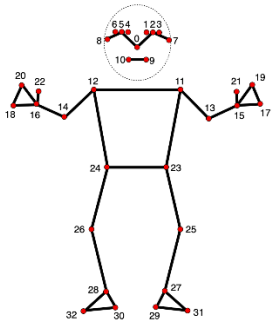


Figure 2. Mediapipe Pose Detection Landmarks

After creating the class and coordinate columns in the CSV file, the next step is to determine which movement or class's coordinates will be captured in real-time. Then, capture the video of that movement in real-time. Automatically, Mediapipe Pose Detection will generate values for each landmark coordinate. These values are then exported to the previously created CSV file. This process is repeated, from determining the movement to exporting landmark values for each prayer movement or class.

2.2. Modeling

At this stage, experiments are conducted on the separation of training and testing data with several ratios, 70:30, 80:20, and 90:10. This separation is done to determine at which ratio the model can achieve its best performance. The main reason for using Random Forest and Gradient Boosting models is that both are Ensemble learning techniques capable of overcoming overfitting and handling complex data. Gradient Boosting works in a unique way to iteratively build a strong model. The process starts with the creation of a basic model, often a weak Decision Tree. The first model provides initial predictions, and subsequently, each iteration focuses on minimizing the loss function as indicated in formula (1). At each step, a new model is added by assigning weights to their prediction results. This creates a series of models that are increasingly complex and adaptive, capable of capturing finer and more intricate structures in the data.

$$-log\ L_1 = -\sum_{i=1}^{N}(y_i \log(odds) + \log(1 + e^{\log(odds)})) \quad (1)$$

Random Forest employs an ensemble learning approach by constructing a large number of Decision Trees independently. In each tree, a small portion of the data and a random subset of features are used to avoid high correlation among the trees. The prediction results from each tree are combined through voting or averaging to create a stable prediction. By leveraging the strength of many trees operating independently, Random Forest demonstrates resilience to overfitting and can handle various types of data.

The determination of the root node can use metrics like Entropy and Information Gain or Gini Index and Gini Split. Random Forest begins by specifying the number of decision trees to be created. It performs bagging by sampling from features and rows, creating multiple decision trees. Afterward, formulas for Entropy and Information Gain or Gini Index (2) and Gini Split (3) are applied to build the tree and determine the majority prediction.

$$Gini(S) = 1 - \sum_{i=1}^{C}(P_i)^2 \quad (2)$$

$$Gini_{split} = \sum_{i=1}^{n} \frac{|S_i|}{|S|} \times Gini(S_i) \quad (3)$$

2.3. Evaluation

Confusion Matrix is a crucial evaluation tool in measuring the performance of a classification model by providing a detailed overview of prediction outcomes. By breaking down predictions into four main groups, namely True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN), the Confusion Matrix helps identify how well the model can correctly classify instances. The representation of the matrix with these four cells forms the basis for calculating several highly informative evaluation metrics.

Accuracy, shown in formula 4, provides the percentage of total instances correctly classified by the model. Although accuracy gives a general picture of performance, it does not accommodate class imbalances that may exist in the dataset. Precision, shown in formula 5, evaluates how well the model can accurately identify the positive class. Precision is particularly useful when the focus is on reducing false positives to avoid undesired identification errors. Recall (Sensitivity or True Positive Rate), shown in formula 6, measures how well the model can detect all positive instances that should be detected. Recall focuses on reducing false negatives and is useful in situations where false positives are more critical.

$$Accuracy = \frac{\text{TP} + \text{TN}}{\text{TP} + \text{FP} + \text{FN} + \text{TN}} \quad (4)$$

$$Precision = \frac{\text{TP x } 100\%}{\text{FP} + \text{TP}} \quad (5)$$

$$Recall = \frac{\text{TP x } 100\%}{\text{FN} + \text{TP}} \quad (6)$$

3. Results and Discussion

3.1. Data Acquisition

Data used in this research was obtained by recording each prayer movement based on the source from the Ministry of Religious Affairs of West Java, downloaded on October 1, 2023. During the data collection using Mediapipe Pose Detection, there were several conditions, including:

1. Distance between the object and the camera is approximately 2.5 meters.
2. Only one type of object is used.
3. The camera is positioned below, facing the front part of the object in the classes Takbiratul Ihram, Bersedekap, Rukuk (Hadap Depan), Itidal, Sujud, Duduk Ifirasy (Hadap Depan), Duduk Tawaruk (Hadap Depan), Salam.
4. The camera is positioned below, facing the left side of the object in the class Rukuk.
5. The camera is positioned below, facing the back part of the object in the classes Duduk Ifirasy and Duduk Tawaruk.
6. Adequate room lighting, and the background remains constant.
7. Real-time video capture is performed for approximately 2 minutes for each movement or class.

The variation in video capture positions is due to certain movements being more effective for analysis from the front, side, and back, as suggested by Dr. ZAENUDIN, M.Ag. The data obtained for each class is approximately 656 rows, and the total data obtained overall is 7220 rows, comprising 11 classes. The results of the data can be seen in Table 1.

Table 1. Dataset Result

No	Class	Total

1	Takbiratul Ihram	645
2	Bersedekap	641
3	Rukuk	693
4	Rukuk (Hadap Depan)	645
5	Itidal	654
6	Sujud	674
7	Duduk Iftirasy	662
8	Duduk Iftirasy (Hadap Depan)	648
9	Duduk Tawaruk	717
10	Duduk Tawaruk(Hadap Depan)	615
11	Salam	626

3.2. Modeling

In this stage, the data previously obtained is initially separated into training data and test data [14]. Training data is used to train the model, allowing the model to adapt its rules based on patterns and relationships in the data. On the other hand, test data is not used during training and serves as the final evaluation to measure the model's performance. Data separation ensures that the model's performance evaluation is based on data that has never been used before, providing a realistic overview of how well the model will perform in real-world situations. In this study, several ratios of data separation between training and test data are used, namely 70:30, 80:20, and 90:10. The results of the separation for these three ratios can be seen in Table 2 below.

Table 2. Splitting Training and Testing Data

Data Separation	Training Data Quantity	Testing Data Quantity
70:30	5054	2166
80:20	5776	1444
90:10	6498	722

3.3. Evaluation

In this study, the performance of the classification model is evaluated using the Confusion Matrix, which is a fundamental evaluation tool in classification tasks. The Confusion Matrix enables in-depth analysis of the model's prediction quality by presenting information about the number of correct and incorrect classification results, allowing researchers to identify accuracy, precision, and recall levels. Thus, the evaluation results provide comprehensive insights into the ability and reliability of the classification model in handling the data used in this study. The accuracy, precision, and recall results for the Gradient Boosting model can be seen in Table 3, while the accuracy, precision, and recall results for the Random Forest model can be seen in Table 4.

Table 3. Accuracy, Precision, Recall results for the Gradient Boosting Model.

Data Separation	Accuracy	Precision	Recall
70:30	0.997	0.997	0.997
80:20	0.996	0.996	0.996
90:10	0.995	0.995	0.995

Table 4. Accuracy, Precision, Recall results for the Random Forest Model

Data Separation	Accuracy	Precision	Recall
70:30	0.999	0.999	0.999
80:20	0.997	0.997	0.997

90:10	0.998	0.998	0.998

Table 5. Model Training Time

Data Separation	Gradient Boosting	Random Forest
70:30	313.3s	3.8s
80:20	356.1s	4.0s
90:10	405.7s	4.7s

However, the use of accuracy, precision, and recall does not determine whether the model can work optimally; testing is necessary. In Figure 3, testing is shown using the Gradient Boosting model with a ratio of 70:30. During testing, it was found that some movements were misclassified. This could be due to the limited diversity of the dataset and the need for parameter tuning. Figure 4 shows testing with the Random Forest model with a ratio of 70:30. In the test, almost all movements could be classified correctly.

Figure 3. Gradient Boosting Model Testing

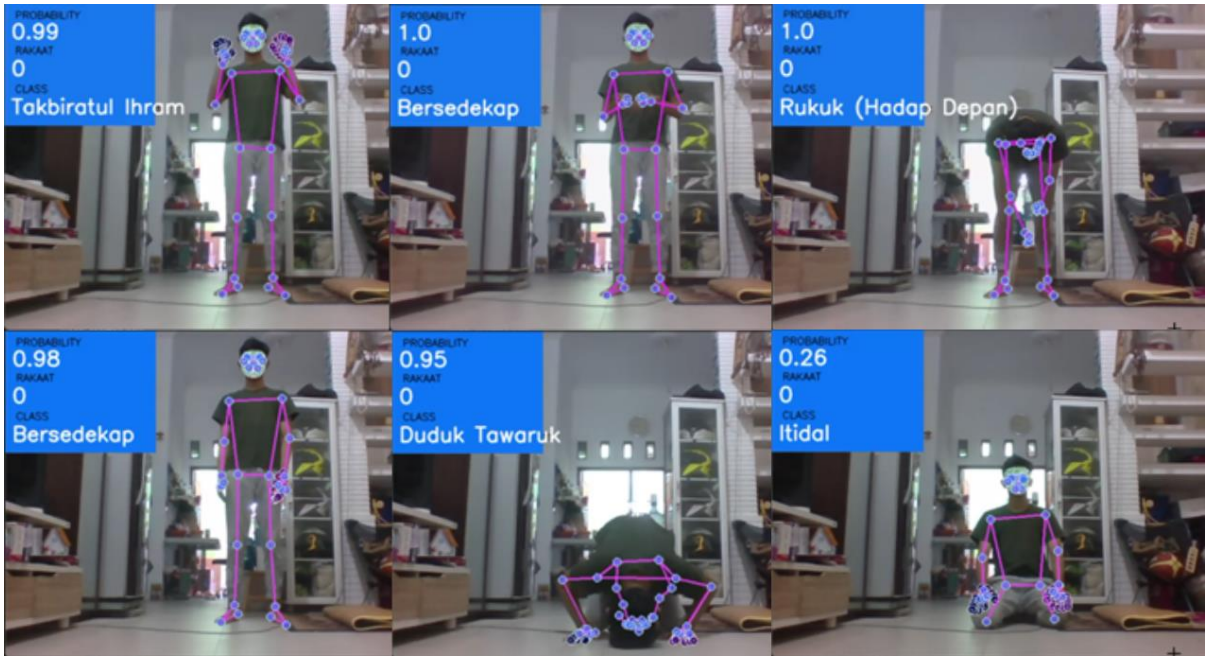
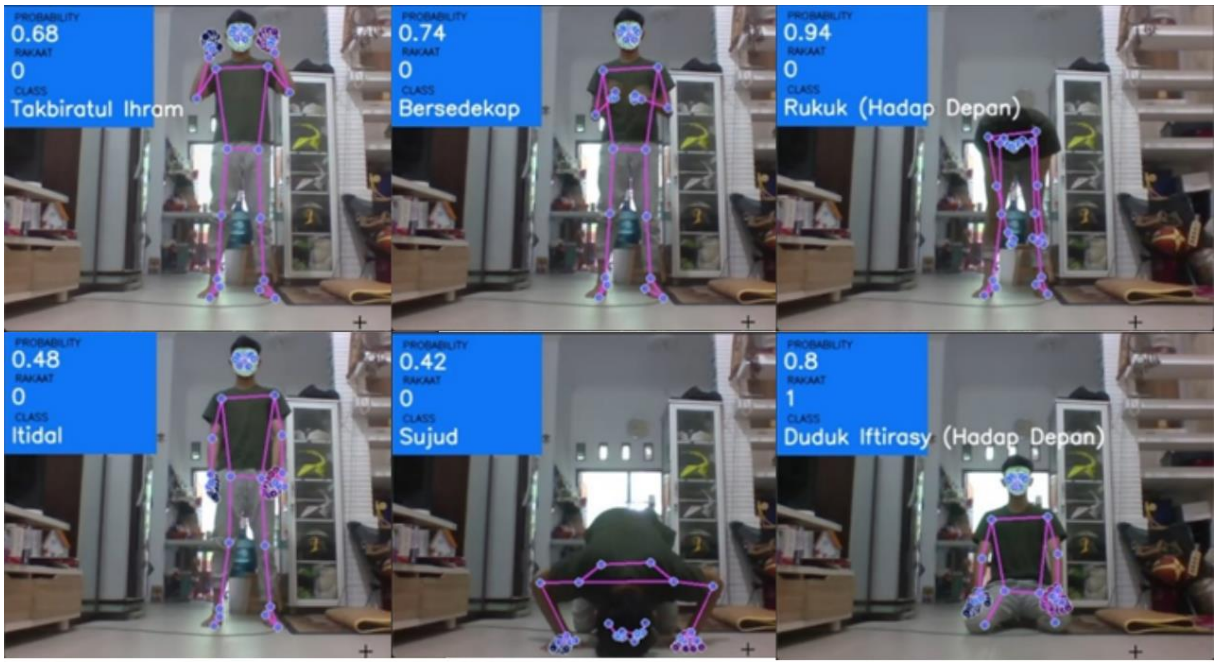


Figure 4. Random Forest Model Testing



4. Conclusion

Errors during prayer execution arise from a lack of profound understanding or misunderstandings regarding the correct prayer procedure. One common example of such errors is the miscalculation of prayer cycles. With 2770 data points collected using Mediapipe Pose Detection and classified using Random Forest and Gradient Boosting models, the Random Forest model with a 70:30 ratio achieved an accuracy, precision, and recall of 99.9%, along with the fastest training time of 3.8 seconds. Overall, this indicates that both models achieved testing results close to 100% in the three separation ratio comparisons, but Random Forest demonstrated faster training times compared to Gradient Boosting [15]. On the other hand, the more the number of training data, the longer the training time for the model based on Table 5.

However, during the classification testing, the Gradient Boosting model could only correctly classify a few movements, thus unable to count prayer cycles. In the Random Forest model, only one movement, Salam, proved challenging to detect, while others could be accurately classified, enabling the counting of prayer units. This can occur due to various factors such as dataset limitations, conditions during data acquisition, and the need for tuning in both models used. These factors significantly impact the models' ability to recognize and classify prayer movements accurately. Understanding factors like dataset limitations and conditions during data acquisition, as well as the need for tuning in both models, future research efforts can focus on improving model performance through dataset expansion, enhancing data quality, and adjusting model parameters.

References

[1] A. Nurhuda, I. H. Ansori, and Ts. E. S. B. E. Ab Rahman, "THE URGENCY OF PRAYER IN LIFE BASED ON THE AL-QUR'AN PERSPECTIVE," *LISAN AL-HAL: Jurnal Pengembangan Pemikiran dan Kebudayaan*, vol. 17, no. 1, pp. 52–61, Jun. 2023, doi: 10.35316/lisanalhal.v17i1.52-61.

[2] I. E. Samara, "Intelligent systems and AI techniques: Recent advances and Future directions," *International Journal of Advances in Applied Computational Intelligence*, vol. 1, no. 2, pp. 30–45, 2022, doi: 10.54216/IJAACI.010202.

[3] I. Manan, F. Rehman, H. Sharif, N. Riaz, M. Atif, and M. Aqeel, "Quantum Computing and Machine Learning Algorithms - A Review," in *2022 3rd International Conference on Innovations in Computer Science & Software Engineering (ICONICS)*, IEEE, Dec. 2022, pp. 1–6. doi: 10.1109/ICONICS56716.2022.10100452.
[4] B. C. Santoso, H. Santoso, and J. Sandjaya, "Development of Independent Taekwondo Training Machine Learning with 3D Pose Model Mediapipe," *Sinkron*, vol. 8, no. 3, pp. 1427–1434, Jul. 2023, doi: 10.33395/sinkron.v8i3.12571.
[5] K. Yongcharoenchaiyasit, S. Arwatchananukul, P. Temdee, and R. Prasad, "Gradient Boosting Based Model for Elderly Heart Failure, Aortic Stenosis, and Dementia Classification," *IEEE Access*, vol. 11, pp. 48677–48696, 2023, doi: 10.1109/ACCESS.2023.3276468.
[6] Y. Ren, X. Zhu, K. Bai, and R. Zhang, "A New Random Forest Ensemble of Intuitionistic Fuzzy Decision Trees," *IEEE Transactions on Fuzzy Systems*, vol. 31, no. 5, pp. 1729–1741, May 2023, doi: 10.1109/TFUZZ.2022.3215725.
[7] C. Bentéjac, A. Csörgő, and G. Martínez-Muñoz, "A comparative analysis of gradient boosting algorithms," *Artif Intell Rev*, vol. 54, no. 3, pp. 1937–1967, Mar. 2021, doi: 10.1007/s10462-020-09896-5.
[8] X. Ju and M. Salibián-Barrera, "Robust boosting for regression problems," *Comput Stat Data Anal*, vol. 153, p. 107065, Jan. 2021, doi: 10.1016/j.csda.2020.107065.
[9] Y. Ren, X. Zhu, K. Bai, and R. Zhang, "A New Random Forest Ensemble of Intuitionistic Fuzzy Decision Trees," *IEEE Transactions on Fuzzy Systems*, vol. 31, no. 5, pp. 1729–1741, May 2023, doi: 10.1109/TFUZZ.2022.3215725.
[10] J.-M. Nguyen *et al.*, "Random forest of perfect trees: concept, performance, applications and perspectives," *Bioinformatics*, vol. 37, no. 15, pp. 2165–2174, Aug. 2021, doi: 10.1093/bioinformatics/btab074.
[11] K. Dedja, F. K. Nakano, K. Pliakos, and C. Vens, "BELLATREX: Building Explanations Through a LocaLly AccuraTe Rule EXtractor," *IEEE Access*, vol. 11, pp. 41348–41367, 2023, doi: 10.1109/ACCESS.2023.3268866.
[12] M. Fahmy Amin, "Confusion Matrix in Binary Classification Problems: A Step-by-Step Tutorial," *Journal of Engineering Research*, vol. 6, no. 5, pp. 0–0, Dec. 2022, doi: 10.21608/erjeng.2022.274526.
[13] S. Riyanto, I. S. Sitanggang, T. Djatna, and T. D. Atikah, "Comparative Analysis using Various Performance Metrics in Imbalanced Data for Multi-class Text Classification," *International Journal of Advanced Computer Science and Applications*, vol. 14, no. 6, 2023, doi: 10.14569/IJACSA.2023.01406116.
[14] N. M. Kebonye, "Exploring the novel support points-based split method on a soil dataset," *Measurement*, vol. 186, p. 110131, Dec. 2021, doi: 10.1016/j.measurement.2021.110131.
[15] M. T. Anwar, "Automatic Complaints Categorization Using Random Forest and Gradient Boosting," *Advance Sustainable Science, Engineering and Technology*, vol. 3, no. 1, p. 0210106, Apr. 2021, doi: 10.26877/asset.v3i1.8460.

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GOMS-based User Experience for Cultural Tourism Application in Indonesia

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Abstract. Indonesia's diverse cultural heritage presents an opportunity for tourism, yet traditional approaches and insufficient technology utilization hinder its full potential. We propose the development of a Cultural Tourism Application, specifically targeting the rich cultural attractions of Yogyakarta, Indonesia. The research develop the GOMS (Goals, Operators, Methods, and Selection Rules) model to design user-friendly interfaces for discovering cultural attractions, providing detailed information, searching, and exploring historical timelines and helped us understand the steps and knowledge required for users to achieve their goals within the app This model allows for a systematic understanding of user interactions and cognitive processes within the context of the Cultural Tourism Application. A User Acceptance Testing (UAT) survey reveals a high level of acceptance 91.2% for the Cultural Tourism Application, signifying its effectiveness in enhancing learnability, efficiency, memorability, safety, and overall user satisfaction.

Keywords: Cultural Tourism, Tourism Application, User Acceptance Testing, GOMS Model.

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1. Introduction

Indonesia is an a country that is has the potential in tourism [1]. With possession of 17,508 islands, therefore, Indonesia is one of the richest culture country that has its own uniqueness [2]. Indonesia is a country with a multitude of distinct cultures due to its broad cultural background, which makes it imperative to maintain Indonesian culture [3].

This diverse cultural fabric not only shapes Indonesia's character, but also has a major impact on the Indonesia tourism industry. Tourism is a very important sector in both developed and developing countries [4]. Furthermore, traveling is becoming more and more popular in the digital age [5]. The Indonesian government is facing multiple challenges concerning the advancement of tourism areas, encompassing both domestic and international aspects [6]. The issue of Indonesia's tourism development lies in the insufficient utilization of technology to enhance cultural experiences for both tourists and locals, persisting with traditional approaches. There are research by [7] about Application of QR codes as a new communication technology and interactive tourist guide in Jaboi, Sabang, an economical solution from the side of technology. However, it should be noted that this research has not yet

demonstrated a significant improvement in the tourism sector in terms of providing a seamless digital experience.

Despite this, the integration of digital technologies in the tourism industry has the potential to revolutionize how tourists access information about destinations in Indonesia. Tourism businesses are going digital, which will make it easier for travelers to find information about places and improve their overall experience [8]. According to [9] many companies and organizations are leveraging mobile devices as an online platform for promotional purposes, capitalizing on the rapidly increasing number of smartphone users. In the tourism industry, mobile applications are regarded as highly efficient tools for advertising. There is an application by [9] about Development of Interactive Mobile Application with Augmented Reality for Tourism Sites in Batam. But, this research only focused in tourism in general, not cultural tourism. There are research by [10] about Design and Development of Tourism Geographical Information System of Semarang City Based on Android Mobile. But, this research only focused in tourism in Geographical, not based on User Experience cultural tourism.

Our research is the first to develop Cultural Tourism Application. Tourism that provides living culture, cultural heritage, and physical and intangible cultural attractions is known as Cultural Tourism. One of the cultural tourism icon with the largest tourism potential in Indonesia is Yogyakarta. Information about Indonesian cultural tourism applications is still lacking, and Yogyakarta is no exception.. Yogyakarta Special Region has a lot of tourism potential, both natural and cultural. The region's abundance of tourist attractions makes it one of Indonesia's most popular tourist destinations [11]. Moreover, there are many cultural heritage from Hindu, Buddhist, Islamic, and Dutch colonial periods [12].

We aim to develop a cultural tourism application, which is a software program or mobile app designed to enhance the experience of travelers and tourists interested in exploring and learning about the cultural aspects of a particular destination. There are research by [13] about ICONS: a Mobile Application for Introduction Culture of North Sulawesi which is expected to be a medium of information and knowledge for users. However, the current focus of the ICONS on serving as a medium for information and knowledge dissemination may not fully address the broader needs of cultural tourism. To enhance its effectiveness, the application should consider incorporating interactive features, guided tours, and real-time updates on cultural events and experiences, thereby transforming it into a more engaging and comprehensive resource for tourists seeking an immersive cultural experience.

This research develop an app on an iOS smartphone for Cultural Tourism in Indonesia using MapKit to find the user point. The main feature is historical information, addresses and navigation, photo galleries, types of cultural tourism, updated information, specific recommended times so user could utilize their time in Yogyakarta effectively. This paper develop a model based on GOMS (Goals, Operators, Methods, and Selection rules) to achieve a deeper understanding of user interaction and cognitive processes within the context of a Cultural Tourism Application. GOMS (Goals, Operators, Methods, and Selection Rules) is a method for analyzing tasks based on user cognition, known for its high reliability and efficiency [14]. Goal signifies the task to be accomplished and the final outcome expected from the user, Operator is a series of actions involving perception, movement, or cognitive processes. Method pertains to the organized structure of goals and actions. Selection rules are employed to decide the most suitable method of operation based on the specific context of use.

Furthermore, this research stems from the notable absence of previous studies utilizing this methodology in the realm of cultural tourism applications. In essence, this research represents a pioneering contribution to the domain of cultural tourism technology and user experience design, as we use the GOMS method to develop a Cultural Tourism Application that redefine the way travelers engage with and appreciate the cultural heritage of Yogyakarta, Indonesia.

2. Methods

In this study, we applied the research methodology with a focus on the Agile development cycle illustrated in Figure 1. The design and development of KulturHub was determined to be best served by

the Agile paradigm. A mobile application that is high-quality, dependable, and long-lasting will be produced if it is developed using the Agile methodology. Agile contributes to the system's enhanced functionality and performance. By means of continuous testing and issue resolution, it also aids in the elimination of system failure [15] .

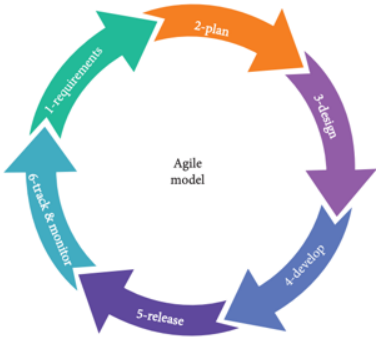


Figure 1. Agile Model

This Agile development cycle, adopted after the implementation of our proposed system, consists of six primary phases, as elucidated by [15] : (1) requirements, (2) planning, (3) design, (4) development, (5) release, and (6) evaluation. Requirements, researcher focuses on develop an app on an iOS smartphone for Cultural Tourism in Indonesia named KulturHub that can seamlessly accommodate evolving user needs on features encompassing historical information, addresses and navigation, photo galleries, various types of cultural tourism, updated content, and specific recommendations. Planning, the planning phase of our app development project strategically decided to harness the power of Swift as Programming Language, SwiftUI as Framework, and MapKit as our core technologies, aiming to create a seamless and engaging user experience. This choice aimed to ensure a seamless and engaging user experience. Design, in the design phase, the application of the GOMS method provided a structured approach to dissecting user tasks into discrete Goals, Operators, Methods, and Selection Rules, enabling us to systematically refine the app's user interface and interaction design. Developmen, the next phase is development, in this phase researcher actively translated design specifications into code, leveraging Swift, SwiftUI, and MapKit as the core technologies. This phase was implemented the planned features and functionalities, adhering to agile methodologies to ensure iterative progress and continuous integration of user feedback. Release, in the release phase, researchers remained vigilant for post-launch issues, swiftly addressing any user-reported bugs or concerns, and planning for subsequent updates and enhancements based on real-world user interactions. Evaluation, the evaluation phase within this Agile framework corresponds to the User Acceptance Testing (UAT). This phase involves the assessment of research outcomes, the drawing of conclusions, and the evaluation of the extent to which research goals were achieved, akin to the UAT evaluation's role in ensuring software meets end-user requirements and expectations.

Figure 2 shows the components of the User Acceptance Test (UAT) approach include learnability, efficiency, memorability, safety to use or low error rates, and a high level of satisfaction [16]. Learnability, the research will assess the learnability of the system by measuring how quickly new users, can grasp its functionalities and navigate through it without encountering significant barriers. Efficiency, this study aims to evaluate the efficiency of the software in terms of task completion time and resource utilization, ensuring that users can achieve their objectives swiftly and with minimal effort. Memorability, the research will investigate the memorability of the user interface, examining how well users can recall and utilize the system's features after a period of non-use, thereby reducing the need for retraining. Safety to Use or Low Error Rates, this research will focus on assessing the safety of the product, aiming for a low error rate during usage to ensure that users can interact with the system confidently without encountering adverse consequences. High Level of Satisfaction, the study will

gauge user satisfaction levels to determine the overall user experience, with the objective of promoting user adoption, positive feedback, and long-term user loyalty to the product.

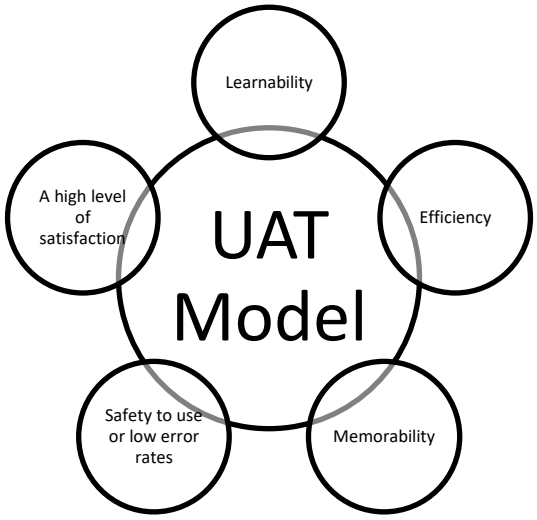


Figure 2. User Acceptance Testing Model

2.1. GOMS Model

In this research, we applied the GOMS Model to design a user-friendly cultural tourism application. The GOMS Model helped us understand the steps and knowledge required for users to achieve their goals within the app. We outlined GOMS Models for key activities: Discover, Detail, Search, and Timeline feature. These models ensure that the application is intuitive and meets user needs, enhancing the cultural exploration experience for users exploring Indonesian attractions.

GOMS is one of the methods used to examine a task [17]. A GOMS model serves as a depiction of the essential user knowledge needed to perform tasks within a device or system. It embodies the instructional information detailing the steps on how to accomplish the desired tasks, which the system relies upon for execution[18]. In this cultural tourism application, users will have several goals.

The rationale behind using GOMS as a framework is to create a valuable model specifically tailored for developing GOMS models solely focused on interface design, without the need for prior prototyping or user testing [18].

2.2. User Acceptance Testing (UAT)

User acceptance testing (UAT) is a test that is intended outside the system, namely the user. Testing is aimed at users related to face-to-face tutorial activities then the purpose of user acceptance testing is to determine the feasibility of the software. In User acceptance testing (UAT), it is carried out using a survey method, namely by distributing questionnaires to users who have previously been given tutorials on using the application.

3. Results and Discussion

3.1. Implementation in the Application

The GOMS Model can be implemented in a user interface such as figure 3(a), figure 3(b), figure 3(c) and figure 3(d).

In figure 3(a), the main menu Discover is shown. The main aim of the Discover feature is to allow users to explore a list of cultural attractions in Indonesia. To achieve this goal, users should click the Discover button on the home screen. Once they do so, the method employed is to display a list of cultural attractions accompanied by thumbnails and titles. Users can easily scroll through this list to discover more options. When a user selects a specific attraction from the list, the system will provide detailed

information about that cultural attraction. In the end, the selection process is straightforward, as users simply choose one from the list of cultural attractions they wish to explore.

In figure 3(b), the primary purpose of the Detail feature is to furnish users with comprehensive information about a selected cultural attraction. To access this wealth of information, users initiate the process by clicking on one of the cultural attractions from the list provided in the Discover screen. Once selected, the Detail feature employs the method of displaying an exhaustive range of details related to the cultural attraction. This information encompasses a descriptive overview, an assortment of photographs, precise location data, and other pertinent particulars. This feature serves to enhance the user's understanding and appreciation of the chosen cultural attraction by offering a deep dive into its characteristics and significance.

In figure 3(c), the principal aim of the Search feature is to grant users the ability to search for cultural attractions based on specific keywords or geographical locations. Users initiate this search process by clicking on the Search button available on the home screen. Subsequently, the feature employs the method of presenting a user-friendly search box. Within this box, users are encouraged to input relevant keywords or specify their desired location for the search. After entering this information, the application retrieves and displays search results that align with the provided keywords or location.

Users are then afforded the opportunity to select one of the results from the displayed list, enabling them to further explore the chosen cultural attraction. Essentially, the Search feature offers users a tailored approach to discovering cultural attractions based on their specific interests and criteria.

Moreover, when users discover cultural attractions through the Search feature and wish to learn more about a particular attraction, they can seamlessly transition to the Detail feature. This allows for a deeper exploration of the selected attraction, providing users with comprehensive information to enhance their understanding and appreciation of the cultural site. In this way, the Search and Detail features work in tandem to offer users a versatile and informative cultural exploration experience.

In figure 3(d), the primary purpose of the Timeline Feature is to enable users to explore the history of historical buildings in Indonesia. This is achieved through users clicking the Timeline button on the home screen. The method involves presenting a historical timeline that combines text, and important dates to convey information about these historical buildings. Users can actively engage with the content by scrolling through the historical timeline, allowing them to select and view different historical periods of the buildings.

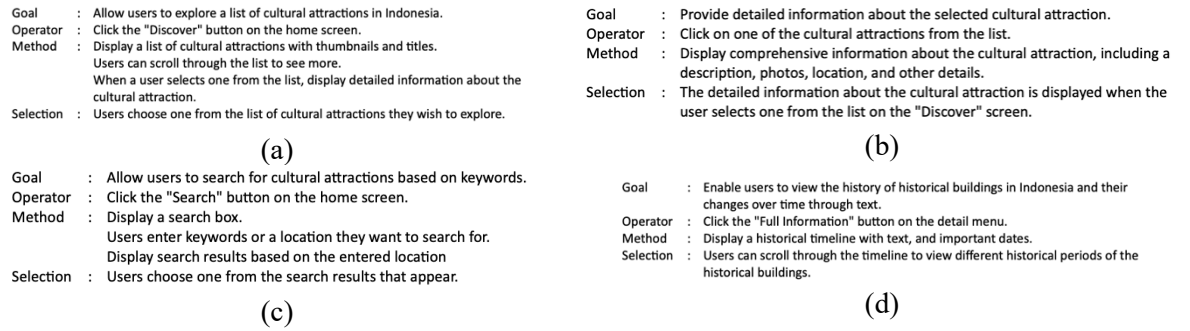
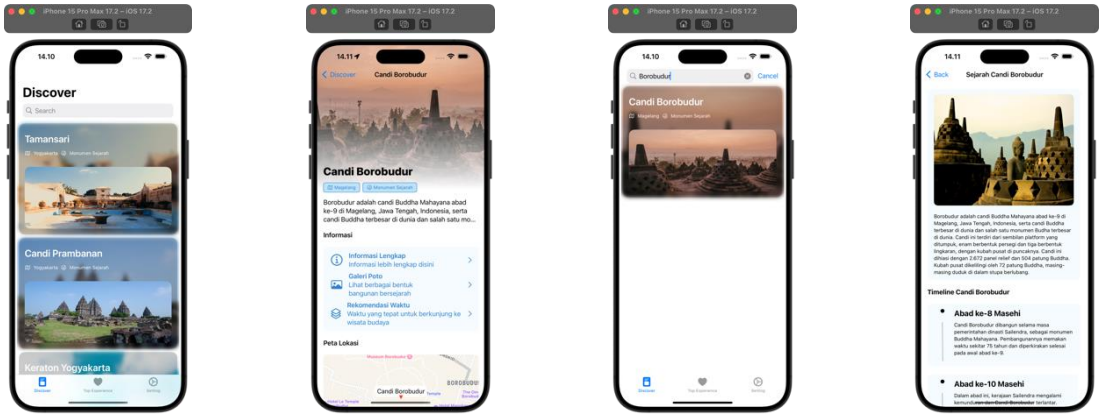


Figure 3. (a) GOMS Model on Discover Activities. (b) GOMS Model on Detail Activities. (c) GOMS on Search Activities. (d) GOMS Model on Timeline Feature

The GOMS Model can be implemented in a user interface such as figure 4(a), figure 4(b), figure 4(c) and figure 4(d). In figure 4(a), the main menu Discover is shown. The main aim of the Discover feature is to allow users to explore a list of cultural attractions in Indonesia. Figure 4(b) is detail menu, the main aim of the Detail Menu feature is to provide detailed information about the selected cultural attraction. Figure 4(c) is search menu, the main aim of the Search Menu feature is to allow users to search for cultural attractions based on keywords. Figure 4(d) is timeline feature, the primary objective behind the

Timeline Feature is to empower users with the ability to explore the historical evolution of buildings in Indonesia along with their transformations over time, all through textual information.



(a) (b) (c) (d)

Figure 4. (a) User Interface on Discover. (b) User Interface on Detail. (c) User Interface on Seacrh. (d) User Interface on Timeline

3.2. Result of Analysis User Acceptance Testing (UAT)

The purpose of the outcome is to ascertain the degree of support and acceptance that the system may receive from prospective users. A Likert scale was used to measure the usefulness of the system being constructed in terms of accessibility, navigation, and content for 20 potential system users. [19]. Table 1 shows the questionnaire used in measuring user acceptance of the developed cultural tourism application.

Table 1. Quistionnaire Using A Likert Scale

No	Question	SD	D	N	A	SA
1	I can easily understand how to use this cultural tourism application.					
2	I can easily understand how to use this cultural tourism application.					
3	The interface of this culturalctourism application is easy to remember.					
4	I feel safe and helped when using this cultural tourism application.					
5	Overall, to what extent are you satisfied with this cultural tourism application?					

The test results demonstrate that the developed application satisfies the functional specifications. Nonetheless, errors are still possible in the process. What has been built is a system that can produce the necessary outcomes. It is possible to determine the percentage of each response using the information from the questionnaire results. The following formulas are utilized in the computation of the assessment results.

1. Maximum score: 20 x 5 = 100 (number of respondents x highest Likert score)
2. Minimum score: 20 x 1 = 20 (number of respondents x lowest Likert score)
3. Index (%): (Total Score / Maximum Score) x 100

Provide interval value on index (%)

1. Index 0% - 20% : Strongly Disagree
2. Index 20% - 40% : Disagree
3. Index 40% - 60% : Neutral
4. Index 60% - 80% : Agree
5. Index 80% - 100% : Strongly Agree

Based on the formulas, the calculated results are presented in a table. Table 2 shows the results of the computations based on the formulas.

Table 2. Questionnaire Result

Responden	Question				
	Question 1	**Question 2**	**Question 3**	**Question 4**	**Question 5**
Responden 1	5	4	4	4	5
Responden 2	5	5	5	5	5
Responden 3	5	4	4	5	5
Responden 4	5	4	5	4	5
Responden 5	5	5	5	5	5
Responden 6	5	5	5	5	5
Responden 7	4	4	4	4	4
Responden 8	5	5	4	5	5
Responden 9	4	4	4	5	4
Responden 10	4	4	4	4	4
Responden 11	5	4	4	4	5
Responden 12	4	5	4	4	5
Responden 13	4	5	4	5	5
Responden 14	5	5	5	5	5
Responden 15	5	4	5	4	5
Responden 16	4	5	4	5	4
Responden 17	5	5	5	5	5
Responden 18	5	5	5	5	5
Responden 19	4	3	3	2	4
Responden 20	5	5	5	5	5
Total Score	**93**	**90**	**88**	**90**	**95**
Index %	**93**	**90**	**88**	**90**	**95**

Meanwhile, the following calculation formulas are used to determine the level of user approval of the system:

1. Mean score user acceptance:
   = (Total Score1 + Total Score2 + ... + Total Score 5) / 5
2. User acceptance index (%):
   = (Average Score / Maximum Value) X 100%

The user acceptability interval of the system is calculated as follows:

1. Index 0% - 20% : Very Unacceptable
2. Index 20% - 40% : Not Accepted
3. Index 40% - 60% : Neutral
4. Index 60% - 80% : Accepted
5. Index 80% - 100% : Very Accepted

Calculation of the mean score user acceptance:
= (93 + 90 + 88 + 90 + 95) / 5 = 91,2
The formula for calculating the Acceptance Index is:
= (91,2 / 100) x 100%= 91,2 %

The acceptance test findings show that the level of acceptance of the respondents to the application system that was built was 91,2%, indicating that the respondents rated the application as extremely accepting.

4. Conclusion

Based on the findings of User Acceptance Testing (UAT), it is clear that the Cultural Tourism Application we developed has garnered significant acceptance and favorable feedback from users, achieving an impressive 91.2% on the acceptance index. This outcome underscores the application's

effectiveness in delivering an intuitive and enjoyable cultural exploration experience, improving aspects such as learnability, efficiency, memorability, safety, and overall user satisfaction. In essence, this research represents a pioneering contribution to the domain of cultural tourism technology and user experience design, as we use the GOMS method to develop a Cultural Tourism Application that redefine the way travelers engage with and appreciate the cultural heritage of Yogyakarta, Indonesia. In the context of future prospects, the application holds the potential to transform into an essential tool for both domestic and international tourists intrigued by Indonesia's diverse cultural heritage.

References

[1] D. Luthfiya, E. Susanto, and T. Andrianto, "Applying the Technology Acceptance Model to Design Wellness Tourism E-Guidebook," *J. Tour. Sustain.*, vol. 1, pp. 82–94, Dec. 2021, doi: 10.35313/jtos.v1i2.16.

[2] S. Seff, D. O. Susanti, and M. Nawwawi, "EXPLORING THE DIVERSITY OF LOCAL TRADITIONS OF INDONESIAN SOCIETY IN THE ISLAMIC LAW PERPECTIVE," *Multicult. Educ.*, vol. 8, no. 01, Art. no. 01, Mar. 2022.

[3] A. Y. Manueke, I. N. Nurjaya, R. Safa'at, and R. Sulistyorini, "The Meaning of Legal Protection of Ancestral Graves as a Cultural Reserve in the National Culture System in Indonesia," *Int. J. Soc. Sci. Res. Rev.*, vol. 6, no. 6, Art. no. 6, Jun. 2023, doi: 10.47814/ijssrr.v6i6.1210.

[4] S. P. E. Pertama, I. P. Astawa, and I. G. Mudana, "The Implementation of Environmental Management Accounting and Sustainable Tourism in Tourism Villages in Bali," *Int. J. Glocal Tour.*, vol. 3, no. 1, pp. 28–37, Mar. 2022, doi: 10.58982/injogt.v3i1.172.

[5] F. Nofiyanti, D. Zulyanti Nasution, D. Octarina, and R. M. W. Agie Pradhipta, "Local Wisdom for Sustainable Rural Tourism: The Case Study of North Tugu Village, West Java Indonesia," *E3S Web Conf.*, vol. 232, p. 02031, 2021, doi: 10.1051/e3sconf/202123202031.

[6] A. Andiyan and T. Cardiah, "Application of Contemporary Architecture in the Transfer Hub High Land Borobudur Building," *Civ. Eng. Archit.*, vol. 9, no. 7, pp. 2353–2361, Dec. 2021, doi: 10.13189/cea.2021.090722.

[7] Marwan, M. Yanis, Muzakir, and G. S. Nugraha, "Application of QR codes as a new communication technology and interactive tourist guide in Jaboi, Sabang," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 796, no. 1, p. 012025, Mar. 2020, doi: 10.1088/1757-899X/796/1/012025.

[8] Hungarian University of Agriculture and Life Sciences (MATE), Hungary and STIE Pariwisata API, Jl. Glendongan, Yogyakarta, Indonesia, S. Priatmoko, L. D. David, and Hungarian University of Agriculture and Life Sciences (MATE), Hungary, "WINNING TOURISM DIGITALIZATION OPPORTUNITY IN THE INDONESIA CBT BUSINESS," *Geoj. Tour. Geosites*, vol. 37, no. 3, pp. 800–806, Sep. 2021, doi: 10.30892/gtg.37309-711.

[9] R. E. Saragih and Suyoto, "Development of Interactive Mobile Application with Augmented Reality for Tourism Sites in Batam," in *2020 Fourth World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4)*, London, United Kingdom: IEEE, Jul. 2020, pp. 512–517. doi: 10.1109/WorldS450073.2020.9210300.

[10] A. Shobirin, G. Aryotejo, and D. Danang, "Design and Development of Tourism Geographical Information System of Semarang City Based On Android Mobile," *Adv. Sustain. Sci. Eng. Technol.*, vol. 2, no. 1, May 2020, doi: 10.26877/asset.v2i1.6018.

[11] R. R. Aji, "Tourism social entrepreneurship in community-based tourism: A case study of Pentingsari tourism village," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 447, no. 1, p. 012009, Feb. 2020, doi: 10.1088/1755-1315/447/1/012009.

[12] A. Wijayanti and J. Damanik, "Analysis of the tourist experience of management of a heritage tourism product: case study of the Sultan Palace of Yogyakarta, Indonesia," *J. Herit. Tour.*, vol. 14, no. 2, pp. 166–177, Mar. 2019, doi: 10.1080/1743873X.2018.1494182.

[13] S. Joshua, "ICONS: a Mobile Application for Introduction Culture of North Sulawesi," *Int. J. Innov. Technol. Explor. Eng.*, vol. 9, Nov. 2019, doi: 10.35940/ijitee.A4438.119119.

[14] X. Zhou, F. Teng, X. Du, J. Li, M. Jin, and C. Xue, "H-GOMS: a model for evaluating a virtual-hand interaction system in virtual environments," *Virtual Real.*, vol. 27, no. 2, pp. 497–522, Jun. 2023, doi: 10.1007/s10055-022-00674-y.
[15] M. Elkhateeb, A. Shehab, and H. El-bakry, "Mobile Learning System for Egyptian Higher Education Using Agile-Based Approach," *Educ. Res. Int.*, vol. 2019, pp. 1–13, Mar. 2019, doi: 10.1155/2019/7531980.
[16] J. Rahmadoni, R. Akbar, and R. Ulya, "Analysis of Nagari Management Information System Evaluation (SIMNAG) Using PIECES and UAT Methods," *J. Appl. Eng. Technol. Sci. JAETS*, vol. 4, no. 1, Art. no. 1, Dec. 2022, doi: 10.37385/jaets.v4i1.1326.
[17] F. Sujito, R. Arifudin, and F. Y. Arini, "An Analysis of User Interface and User Experience Using System Usability Scale and GOMS Method," *J. Adv. Inf. Syst. Technol.*, vol. 1, no. 1, Art. no. 1, Oct. 2019, doi: 10.15294/jaist.v1i1.36503.
[18] U. Rosyidah, H. Haryanto, and A. Kardianawati, "Usability Evaluation Using GOMS Model for Education Game 'Play and Learn English,'" in *2019 International Seminar on Application for Technology of Information and Communication (iSemantic)*, Semarang, Indonesia: IEEE, Sep. 2019, pp. 1–5. doi: 10.1109/ISEMANTIC.2019.8884268.
[19] E. Arif and I. P. Soko, "The Evaluation of web-based and android face-to-face tutorial applications quality using the user acceptance testing (UAT) method," *J. World Sci.*, vol. 1, no. 8, pp. 590–595, Aug. 2022, doi: 10.58344/jws.v1i8.76.

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Developing Decentralized Data Storage Network Using Blockchain Technology to Prevent Data Alteration

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Abstract. In the face of escalating global data exchange, the pronounced vulnerability of traditional centralized storage networks to manipulation and attacks poses a pressing challenge. Digital service providers, entrusted with vast datasets, grapple with the formidable task of ensuring the security, integrity, and continuous availability of their stored information. This paper tackles these multifaceted issues by proposing a decentralized data storage network empowered by blockchain technology. This approach systematically mitigates the inherent susceptibilities of centralized systems, thereby providing heightened resilience against unauthorized alterations and malicious attacks that compromise digital information integrity. Moreover, the decentralized model holds significant promise for securing public data. By leveraging the transparency and immutability of blockchain ledgers, this approach not only safeguards against unauthorized access but also actively fosters transparency and accountability in data management. This makes it particularly well-suited for ensuring the security and integrity of public data, addressing concerns related to trust and reliability in the ever-evolving landscape of information exchange.

Keywords: Blockchain, Decentralization, Data Storage, Data Security

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1. Introduction

The exchange of data has experienced a significant global increase compared to the last few decades. The management of data in the digital realm has become an integral part of various industrial sectors. The rise in volume and complexity of data generated by various digital service providers poses challenges in ensuring the security, integrity, and availability of data. The conventional approach of storing data in centralized networks poses significant obstacles in terms of security, integrity, and accessibility. One critical challenge that has garnered attention is the vulnerability of centralized systems to data manipulation and alteration. The inherent centralization makes these systems susceptible to unauthorized access and malicious activities, leading to potential compromises in data integrity. Decentralized platform systematically mitigates these issues by encrypts and distributes data across a decentralized network, with the use of blockchain technology as a distributed ledger to verify and

authenticated every transcation in the network using public-key encryption and consensus protocol [1-3].

Blockchain is a technology that amalgamates various disciplines, including computer science, mathematics, and cryptography. Blockchain technology enables the formation of a decentralized data storage network resistant to changes, manipulation, or network-based attacks [4-6]. Blockchain technology is characterized by trustlessness, eliminating dependence on centralized storage providers through the implementation of a transparent and decentralized system. The decentralized system does not involve third parties or intermediaries; instead, it utilizes a peer-to-peer (P2P) method allowing direct communication between nodes, and with the consensus protocol that eliminates the potential for data fraud in the network [7], [8].

This research aims to develop a decentralized data storage network infrastructure by implementing blockchain technology to prevent data manipulation by centralized data storage. The findings of this research are expected to contribute insights into the development of blockchain as a decentralized data storage solution.

2. Methods

2.1. Type of Research

This research employs an exploratory research type and qualitative method. Exploratory research examines existing knowledge on a particular topic and other relevant information. The aim of this research is to provide fundamental knowledge on a topic as an introduction for further studies. And by employing qualitative methods, this research seeks to offer in-depth explorations that serve as an insightful introduction, laying the groundwork for subsequent studies [9].

2.2. System Development

The system development is carried out using the prototype method. The programming language used is Go for the blockchain nodes, and Typescript with the NestJS framework for the API Gateway. Badger DB is utilized as persistent and fast key-value database on each node in the blockchain network. Inter-node communication in the blockchain network is facilitated through the gRPC protocol, while REST API is employed in the API Gateway. Containerization is achieved using Docker to simplify system deployment and configuration [10]. The use of the prototype method allows developers to design a running prototype as a sample of the developed system.

3. Results and Discussion

3.1. Planning

The planning phase begins with identifying issues and conducting a literature review on both centralized data storage systems and decentralized systems as a solution to the identified problems. The exploratory research method is then determined by implementing fundamental aspects of decentralized blockchain systems based on related studies.

3.2. Analysis

During this phase, it was found that the decentralized nature not only mitigates the risk of a single point of failure but also ensures data immutability through cryptographic mechanisms. Additionally, the increased transparency and trust derived from blockchain technology contribute significantly to the reliability of data transactions. Despite the promising benefits, the analysis reveals noteworthy challenges in the development and maintenance of decentralized data storage with blockchain. The intricate nature of blockchain technology demands specialized expertise, making system development more resource-intensive. Interoperability issues and scalability concerns also emerge as potential challenges, requiring careful consideration to ensure seamless integration and sustained performance.

3.3. System Design

The system network infrastructure can be seen in the Figure 1, consists of multiple nodes to handle blockchain transcations built based on microservice architecture, with each node run within an internal network. These nodes can later be configured and added to scale the network [11]. Inter-node communication is facilitated using the gRPC protocol, which is an RPC (Remote Procedure Call) protocol developed by Google. gRPC utilizes Protocol Buffers (protobuf) as the Interface Definition Language (IDL), and it operates over HTTP/2, making inter-node communication faster and more efficient [12]. Clients make HTTP calls to an API Gateway, which then forwards the requests to be processed by the blockchain network through NGINX as a load balancer [13], [14].

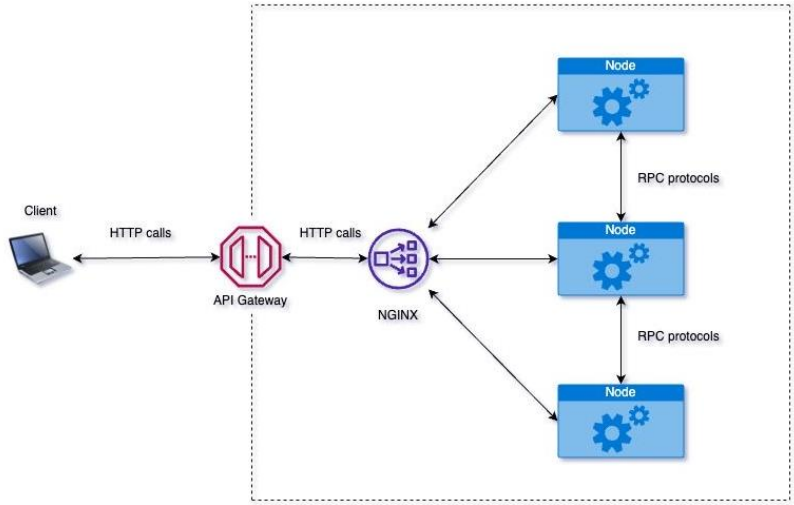

Figure 1. Blockchain Data Storage Network System

3.4. Prototype

The prototype utilizes a blockchain node capable of receiving, hashing, and storing data in JSON format. This prototype features the primary function of blockchain storage in the system under development.

3.5. Implementation

The system development is divided into two components: the blockchain node where data is stored as blocks in the blockchain network, and the API Gateway that connects applications to the blockchain network. The hashing algorithm used in blockchain storage employs the SHA256 algorithm with the Proof of Work (POW) consensus algorithm. In the Proof of Work (POW) consensus algorithm, nodes in the network must use a significant amount of computing resources to add a block to the blockchain. This computation involves a hashing process that combines the hash of the previous data, current data and a random value. As shown in Figure 2 the new block depends on the previous block hash, this hashing process ensures that any changes to the data will result in a different hash outcome [15-18].

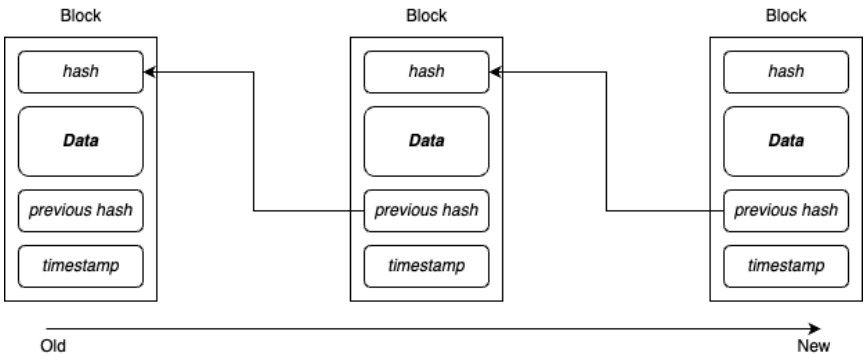

Figure 2. Block Data Structure

Each node in the blockchain network receives data in JSON format from NGINX as a load balancer. The node receiving the data executes the consensus algorithm and adds the data as a block in the blockchain, then sends the data to other nodes using gRPC to be stored in their respective blockchains. The communication mechanism employed is the Gossip Protocol, allowing each node in the blockchain network to receive data received from the API, additionally the system will check the previous hash wether it matchs or not [19], [20]. If previoush hash didn't match with the hash that stored in the node, it will then retrieve the full copy of blockchain from other nodes to repair itself, this aims to prevent data manipulation that purposely change the data block in the blockchain. During the development phase, docker compose were utlize to run multiple service in the blockchain network inside Docker container, while also simulate the full function of the system networks, the example of configurations can be seen on Figure 3.

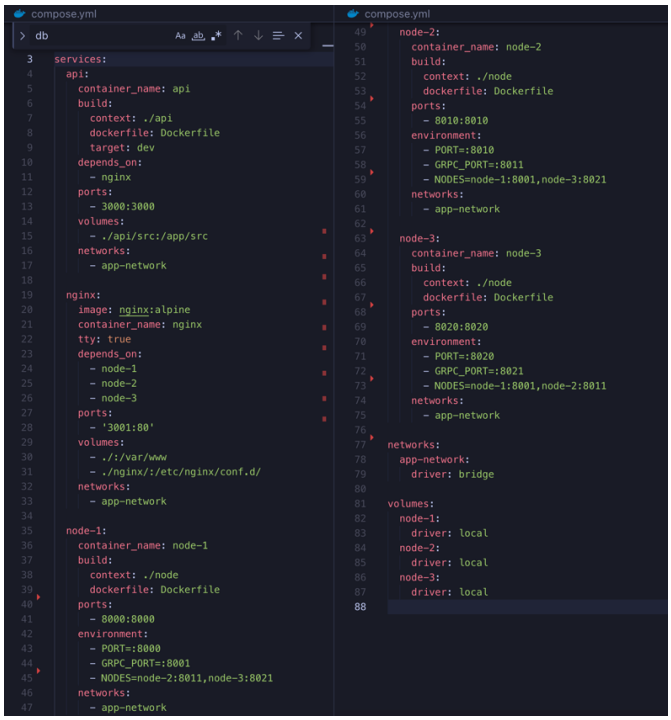

Figure 3. Docker Compose Configuration

The creation of the API Gateway serves as a bridge between applications and the blockchain network as a decentralized data storage, using NodeJS with the NestJS framework. The API Gateway forwards

HTTP requests to NGINX as a load balancer, which is subsequently processed by nodes in the blockchain network. There are three endpoints for data transactions in the blockchain network through the API Gateway, including adding and retrieving data from blocks in the blockchain network, as well as retrieving the full copy of blockchain. Data payload can be any type as long it is a valid JSON object.

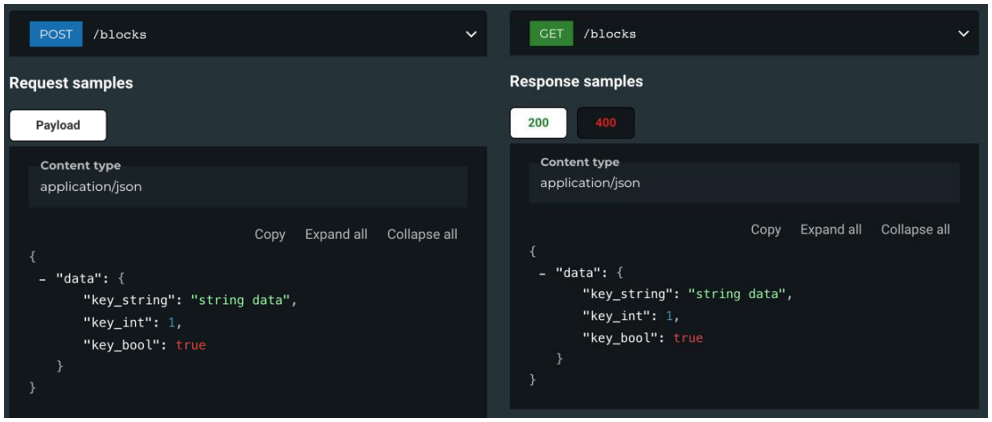

Figure 4. Send Block and Get Latest Block Request

Figure 4 and 5 show the example of API Request and Response on the API Gateway, the API will accept any kind of data structure as long as it was sends in JSON format, this will enable client to be flexible for storing their data. The "/blocks" endpoint is utilized to add data using the POST method, meanwhile, the GET method returns the latest block from the blockchain network. Additionally, the "/blockchains" endpoint returns the full copy of blockchain, containing the history from the first or genesis block to the latest block in the blockchain.

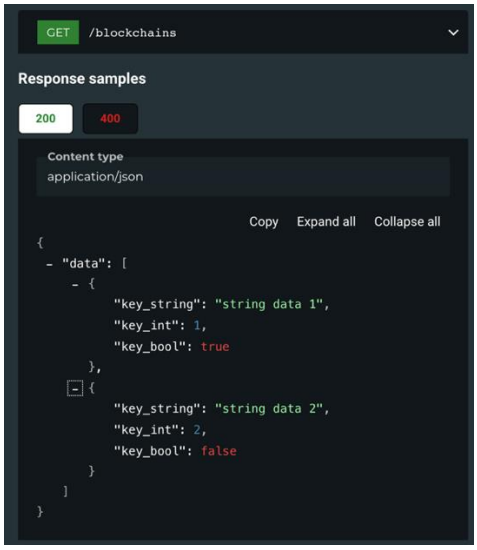

Figure 5. Retrieve The Full Copy of Blockchain

3.6. System Testing

Testing conducted using black box testing method to ensure the developed system meet the specified decentralized data storage system requirements. The system will be tested by matching the expected output and the result by each API endpoints. Testing will also include the data manipulation simulation in a blockchain node, to verified the system capability to endure data manipulation.

Table 1. System Testing Results

Test Case	Description	Result
Add data to system	Send HTTP POST request with JSON data payload that will then addeds data in blockchain network	Success
Retrieve latest data	Send HTTP GET request that will return latest data from blockchain network	Success
Retrieve full copy of blockchain	Send HTTP GET request that will return full copy of blockchain that contain data from genesis block to the latest	Success
Alter data from blockchain	Manually modify the data from the blockchain and then run the system to allow nodes to repair themselves when consensus fails during a transaction by downloading a valid copy of the blockchain from the nearest configured blockchain node	Success
Alter data from the middle of blockchain nodes (change data history)	Manually change data from the middle block on the blockchain then run the system to allow node to repair itself when consensus is failing since the hash and previous hash block didn't match	Success

4. Conclusion

Based on the system testing results and observation, this research successfully developed a decentralized data storage network by implementing blockchain technology to prevent data alteration. The adoption of a transparent and decentralized system, with the use of blockchain technology as a distributed ledger, effectively addresses the inherent challenges posed by centralized data storage systems. This approach not only enhances the security, integrity, and availability of data but also presents a viable solution to the limitations associated with traditional systems. The results of the system testing unveil the prowess of the decentralized data storage system in navigating diverse scenarios, ranging from seamless addition and retrieval of data to the efficient acquisition of the latest block and retrieval of the complete blockchain. Notably, the system's adeptness in repairing an invalid node through the Gossip Protocol stands as a testament to its resilience and commitment to maintaining the integrity of data within the blockchain network.

Future research endeavors may chart a course toward scalability enhancements, optimization of consensus algorithms, and strategic considerations for network scaling and deployments. By delving deeper into these avenues, the research community can continue to advance the frontiers of decentralized data storage, ushering in an era of heightened data security, efficiency, and adaptability. In essence, this research not only contributes to the current understanding of decentralized systems but also paves the way for transformative innovations in the broader realm of data storage and management.

References

[1] Yoon-Jin Han, Geun-Hyung Kim, *"A Comparative Study on Decentralized Storage Platforms for Self-sovereign Data", doi: 10.21742/apjcri.2020.05.01, 2020.*

[2] Mohammed Ali Berawi, Mustika Sari, Fikroh Amalia Fahmi Addiani, Nunik Madyaningrum, *"Developing a Blockchain-based Data Storage System Model to Improve Government Agencies' Organizational Performance"*, Vol 12 No.5, doi: 10.14716/ijtech.v12i5.5237, 2021.

[3] Henderi, I Ketut Gunawan, Husni Teja Sukmana, Agung Yudo Ardianto, *"Blockhain Technology As A Me For Sharing Information That Generates User Access Rights and Incentives"*, Vol. 1 No. 1, doi: 10.34306/bfront.v1i01.2, 2021.

[4] Lu Meng, Bin Sun, *"Research on Decentralized Storage Based on a Blockchain"*, doi: 10.3390/su142013060, 2022.

[5] Wang Changjing, Jiang Huiwen, Zeng Jingshan, Yu Min, Huang Qing, Zuo Zhengkang, *"A Review of Blockchain Layered Architecture and Technology Application Research",* Vol.26 No.5, 415-428, doi: 10.19823/j.cnki.1007 1202.2021.0052, 2021.

[6] Kriti Bhalibar, Abhay Singh, Himani Sharma, Ashish Uphadyay, Himanshu Gupta, *"Centralize Storage System with Encryption vs Decentralize Storage System Using Blockchain"*, doi: 10.2139/ssrn.4119952, 2022.

[7] Mónica Martínez-Castañeda, Claudio Feijoo, *"Use of blockchain in the agri-food value chain: State of the art in Spain and some lessons from the perspective of public support"*, Vol.47. doi: 10.1016/j.telpol.2023.102574, 2023.

[8] E. Karaarslan, E.Konacaklı, *"Data Storage in the Decentralized World: Blockchain and Derivatives"*, doi: 10.26650/B/ET06.2020.011.03, 2020.

[9] Pranas Žukauskas, Jolita Vveinhardt and Regina Andriukaitienė, *"Exploratory Research"*, doi: 10.5772/intechopen.70631, 2018.

[10] Rama Aria Megantara, Farrikh Alzami, Ricardus Anggi Pramunendar, Dwi Puji Prabowo, *"Pengembangan dan Implementasi Docker Untuk Memaksimalkan Utilitas Server Universitas pada Masa Covid-19",* doi: 10.14710/transmisi.24.2.48-54, 2022.

[11] Fachru Dahri, Andi Marwan El Hanafi, Divi Handoko, Nur Wulan, *"Implementation of Microservices Architecture in Learning Management System E-Course Using Web Service Method"*, doi: 10.33395/sinkron.v7i1.11229, 2022.

[12] Eko Rudiawan Jamzuri, Hanjaya Mandala, Riska Analia, Susanto Susanto, *"Cloud-Based Architecture for YOLOv3 Object Detector using gRPC and Protobuf"*, doi: 10.15294/jte.v14i1.36537, 2022.

[13] J T Zhao, S Y Jing, L Z Jiang, *"Management of API Gateway Based on Micro-service Architecture"*, doi: 10.1088/1742-6596/1087/3/032032, 2018.

[14] Muhamad Rafli, *"Journal Web Server Load Balancing Performance Testing using Nginx Riverse Proxy Based on Centos 7 OS"*, Vol.9 No.3, doi: 10.35957/jatisi.v9i3.2185, 2022.

[15] Yan Zhu, Chunli Lv, Zichuan Zeng, Jingfu Wang, Bei Pei, *"Blockchain-based Decentralized Storage Scheme"*, doi: 10.1088/1742-6596/1237/4/042008, 2019.

[16] Santi Sulastri, Riana Defi Mahadji Putri, *"Implementasi Enkripsi Data Secure Hash Algorithm (SHA-256) dan Message Digest Algorithm (MD5) pada Proses Pengamanan Kata Sandi Sistem Penjadwalan Karyawan"*, doi: 10.15294/jte.v10i2.18628, 2018.

[17] Fariha Jahan, Mayel Mostafa, Shahrin Chowdhury, *"SHA-256 in Parallel Blockchain Technology: Storing Land Related Documents"*, doi: 10.5120/ijca2020920911, 2020.

[18] Untung Rahardja, Achmad Nizar Hidayanto, Ninda Lutfiani, Dyah Ayu Febiani, Qurotul Aini, *"Immutability of Distributed Hash Model on Blockchain Node Storage"*, doi: 10.15294/sji.v8i1.29444, 2021.

[19] A.S. Shaleva, V.V. Korkhov, *"Efficient Gosip-Based Protocol in The Neo Blockchain Network"*, 2021.

[20] Shadab Alam, *"T he Current State of Blockchain Consensus Mechanism: Issues and Future Works", doi: 10.14569/IJACSA.2023.0140810, 2023.*

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The Implementation and Analysis of The Proof of Work Consensus in Blockchain

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Abstract. Communication in peer-to-peer (P2P) networks presents challenges in maintaining security, data integrity, and decentralization. Consensus mechanisms play a crucial role in addressing these challenges by validating data and ensuring that each entity has synchronized data without intermediaries. This research focuses on the implementation and analysis of the Proof of Work (PoW) consensus mechanism, widely used in blockchain, to enhance understanding of its functions, benefits, and workings or flow. This research, conducted using the Go programming language, successfully implements Proof of Work (PoW) as a security measure, ensuring data integrity, and preventing manipulation. Through black-box testing, this research confirms the functionality and reliability of the implemented Proof of Work (PoW) consensus. These findings contribute to a deeper understanding of consensus mechanisms, offering insights to optimize blockchain protocols and foster trust among entities. This research highlights the relevance of sustainable Proof of Work (PoW) in blockchain technology, emphasizing its role in enhancing security and ensuring data integrity in decentralized networks.

Keywords: Blockchain, Consensus, Proof of Work, Security, Decentralized

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1. Introduction

The development of blockchain usage in recent years has experienced a very significant increase across various fields. This significant increase is because blockchain offers several advantages and solutions to some problems in different sectors. Blockchain is a distributed database technology that operates through a peer-to-peer (P2P) network, meaning the database is distributed among all entities in the network, and communication between entities occurs directly without intermediaries [1], [2].

Communication through peer-to-peer (P2P) networks poses significant challenges in maintaining security, data integrity, consistency, and decentralization. A mechanism is needed to validate and prevent data falsification and manipulation, ensuring that each entity has identical and synchronized copies of the database without intermediaries [3]–[6]. This mechanism is called consensus.

Consensus is a key in blockchain that operates on each entity within the network. Consensus functions to validate data before it is added as a new block to the blockchain, ensuring that each entity

has synchronized data and without intermediaries [7]–[10]. Consensus is a solution to existing challenges of maintaining security, data integrity, consistency, and decentralization in the blockchain. Proof of Work (PoW) is one of the most widely used consensus today and is also known as the first consensus applied in blockchain. One example of the use of Proof of Work (PoW) is in the Bitcoin network, which aims to verify and secure transactions and create new blocks in the blockchain by harnessing computational power.

This research aims to implement and analyze Proof of Work (PoW) consensus on blockchain. The results of this research are expected to increase knowledge and insight about consensus, especially about proof of work and its implementation in blockchain.

To guide readers through the content of this paper, the following is the structure that will be followed. The next section will delve into the Methods, discussing the research type employed and the system development undertaken. Subsequently, the paper will move on to the Results and Discussion section, covering planning, analysis, system design, prototype, implementation, and system testing. The paper will conclude with a summary and suggestive recommendations for future developments in this field.

2. Methods

2.1. Research Type

This research employs exploratory research. Exploratory research is a type of scientific investigation conducted to explore a topic without specific hypotheses. This research aims to broaden insights and gain a deeper understanding of a topic that is not well explored, thus providing a foundation for future research [11].

2.2. System Development

The system development is carried out using the prototype method. This method is chosen because it allows for easy changes and adjustments during the development process, making it flexible and providing a visual or interactive representation of the system's flow before development begins. This representation enables developers to see and understand the system's requirements better throughout the design process and allows for development adjustments [12].

The main technology used in developing the system is the Go programming language. The Go programming language creates the blockchain and Proof of Work (PoW) consensus due to several advantages that support blockchain, such as fast performance, parallelism, clean and easily understandable syntax, efficiency in resource usage, and more [16]. Supporting technologies include BadgerDB, gRPC, and Docker. BadgerDB is a key-value database for each blockchain entity because it is designed with high performance, storage efficiency, and other features. gRPC for communication between blockchain entities due to its advantages that align with communication needs in blockchain, including efficiency, lightweight, strong security and authentication, using Protocol Buffers (Probuf), asynchronous communication, and more. Docker to run multiple services in the blockchain network, simplifying the configuration process.

3. Results and Discussion

3.1. Planning

At this stage, the process begins with identifying issues and conducting a literature review on security and decentralization systems within the blockchain. This leads to the consensus mechanisms as a solution to these problems. Based on these issues, the researcher aims to implement and analyze the Proof of Work (PoW) consensus within the blockchain to gain a deeper understanding and further insights into consensus, especially Proof of Work (PoW), within the blockchain.

3.2. Analysis

At this stage, the process involves analyzing aspects related to consensus. The main focus is on the functions and benefits of consensus in blockchain, the workings or flow of Proof of Work (PoW), and the strengths and weaknesses of Proof of Work (PoW). Based on the analysis conducted, consensus in blockchain functions as a fundamental mechanism to achieve agreement among distributed entities, ensuring the validity and consistency of transactions. It prevents data tampering and secures the integrity of decentralized data. Proof of Work (PoW) is a consensus algorithm in which entities solve complex mathematical puzzles, validate transactions, and add blocks to the blockchain. Its strength lies in providing robust security, decentralization, and a proven track record in networks. However, the energy-intensive computations of Proof of Work (PoW) raise environmental concerns. Despite these weaknesses, Proof of Work (PoW) remains a reliable and secure consensus mechanism.

3.3. System Design

During this stage, the implementation of the Proof of Work (PoW) consensus in blockchain is designed. The system design starts when an entity receives data to be added as a new block. This data, along with the prev hash, nonce, and difficulty, undergoes hashing using the SHA256 algorithm. Prev hash is the hash of the previous block. Nonce is a value that can be changed by the entity to achieve the desired hash value. Difficulty is the level of difficulty that an entity must overcome to add a new block to the blockchain. Subsequently, validation occurs by checking if the resulting hash of the block is less than the target value. If true, a new block is added and disseminated to other entities in the blockchain network. If false, the process iterates by incrementing the nonce and repeating the hashing and validation steps until a valid node is found [13]–[15]. The system design can be seen in Figure 1.

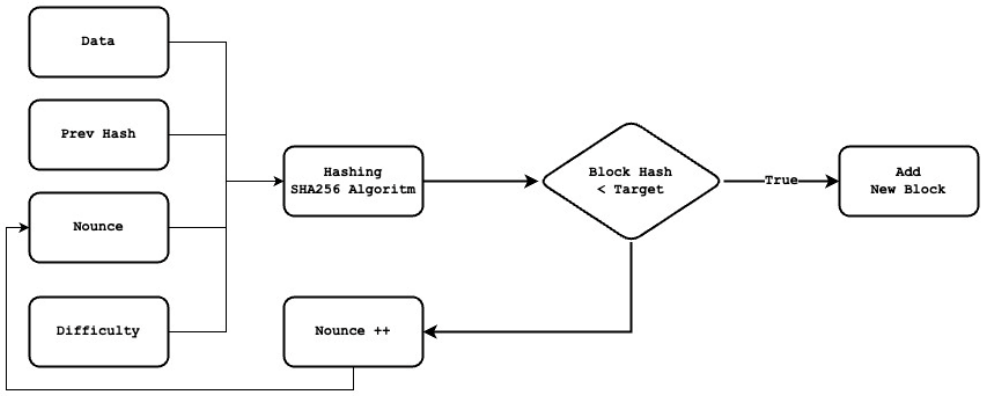

Figure 1. Design System

3.4. Prototype

This stage aims to implement the proof of work consensus flow, which involves hashing and validation to add a new block to the blockchain through prototype design, enhancing the understanding of system requirements.

3.5. Implementation

In this stage, the system design is implemented in the form of code using the Go programming language. Go is a programming language developed by Google, commonly used on the server side, and possesses several advantages such as simple syntax, fast compilation, automatic memory management, and more [16].

NewBlock function is responsible for adding a new block to the blockchain. Within this function, an instance of the Block struct is created, the NewProof function is called to determine the target, the Run method of the instance is used to perform hashing and validate the new block, and the instance of the block is returned. The NewBlock function can be seen in Figure 2.

Figure 2. NewBlock Function

NewProof is a constructor method to create a consensus instance, in this case is the main logic of the ProofOfWork consensus algorithm. The purpose is to determine the target, which is the value that entities must achieve to validate a block, typically in binary units [17], [18]. In this function, an instance of the target is created using the big.Int data type, the Lsh method is employed to shift bits from the specified value, an instance of pow is created from the ProofOfWork struct, and the pow instance is returned. The NewProof Function can be seen in Figure 3.

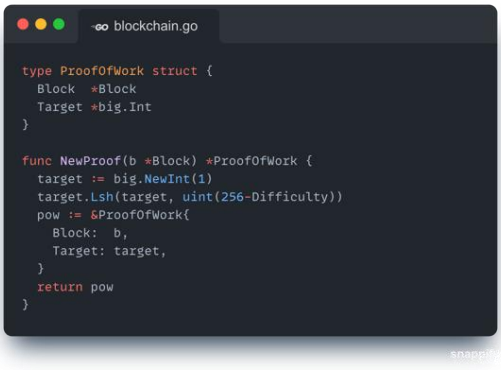

Figure 3. NewProof Function

initData method of the pow instance is aims to concatenate several byte slices, namely PrevHash and Data from the pow instance, along with nonce and Difficulty, into a single byte slice without any separator characters. Nonce is a value that entities can modify to achieve the desired hash value; generally, the nonce is less than the target. Meanwhile, Difficulty represents the level of difficulty that entities must overcome to add a new block to the blockchain. The greater the difficulty value, the higher the difficulty level, and vice versa [19]–[21]. The InitData method can be seen in Figure 4.

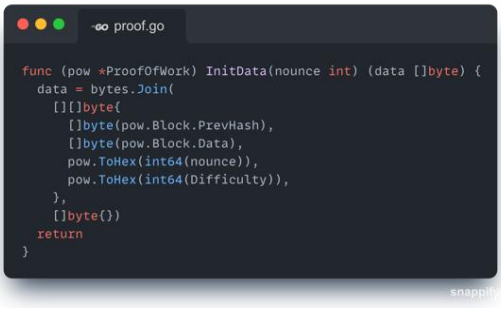

Figure 4. InitData Method

Run method of the pow instance serves to hash the byte slice data that has been combined through the initData method of the pow instance and validate whether the hash of the new block is less than the target. If true, it is considered valid; otherwise, if false, it means it is not valid. In such cases, the nonce is incremented, and the process repeats with hashing and validation until a valid node is found. The Run method can be seen in Figure 5.

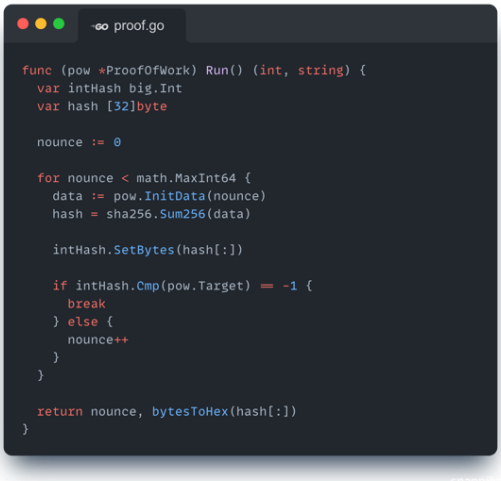

Figure 5. Run Method

3.6. System Testing

This stage is crucial for testing the created system to determine if it operates effectively and to identify and reduce potential errors. System testing employs the black box method, a software testing approach that focuses on the functionality of the system [22]. The challenge faced during system testing using black box testing is the limitation of computational resources for testing Proof of Work (PoW) consensus with high difficulty because if the difficulty increases, the computational energy required for the computation also increases. The System Testing Results can be seen in Table 1.

Table 1. System Testing Results

Test Case	Description	Result
Hash Algoritm	Hash a slice of bytes with the SHA256 Algorithm.	Success

Validate New Block	Validation of the block hash is less than the target. If the validation is successful, it will be added to the blockchain. However, if the validation fails, the nonce will be incremented, followed by hashing and validation again.	Success
Add New Block	If the block validation is successful, the block will be added to the blockchain and disseminated to other entities in the blockchain network.	Success
Edit Block	If there is a change in data within the blockchain, the validation in the consensus will become invalid, and the blockchain of the entity will self-correct by copying the blockchain from other entities.	Success
Delete Block	If there is a deletion in data within the blockchain, the validation in the consensus will become invalid, and the blockchain of the entity will self-correct by copying the blockchain from other entities.	Success

4. Conclusion

Based on the results of the system testing, this research successfully implemented the proof of work consensus in the blockchain using the go programming language. In this system, the consensus functions as a security measure and ensures data integrity by operating on every entity in the blockchain network to validate each transaction. This prevents manipulation and forgery of data and assists each entity in having accurate data through distribution without intermediaries or third parties, thus maintaining a decentralized system. System testing conducted through black box testing confirms the functionality and reliability of the implemented proof of work consensus.

This research contributes to a deeper understanding of the functions and benefits of the proof of work consensus in the blockchain. By delving into the nuanced dynamics of this consensus mechanism, the study offers perspectives for optimizing blockchain protocols and fostering trust among network participants These findings underscore the continued relevance of proof of work in the evolving landscape of blockchain technology and its potential implications for future advancements in distributed ledger systems and emphasize the role of this consensus mechanism in enhancing security and ensuring data integrity in the blockchain network.

For future research, it is recommended to explore alternative consensus mechanisms and their implications for blockchain systems. Additionally, investigating scalability issues and energy efficiency related to proof of work could provide valuable insights for the development and improvement of blockchain technology. A highly suggested area for potential exploration is to investigate the development and implications of alternative consensus mechanisms, such as Proof of Stake (PoS), Delegated Proof of Stake (DPoS), or other new protocols. This exploration can offer valuable insights into enhancing the sustainability and efficiency of blockchain systems. Moreover, researching scalability challenges and proposing innovative solutions to address them will be crucial to accommodate the growing demands of blockchain networks. Overall, this research lays the foundation for further exploration and refinement of consensus mechanisms in the dynamic field of blockchain.

References

[1] S. S. Sarmah, "Understanding Blockchain Technology," Computer Science and Engineering, vol. 8, no. 2, pp. 23–29, 2018, doi: 10.5923/j.computer.20180802.02.

[2] H. Sheth, J. D.-A. J. F. C. I. Technology, and undefined 2019, "Overview of blockchain technology," asianssr.org, vol. V Issue I, Accessed: Nov. 21, 2023. [Online]. Available: http://asianssr.org/index.php/ajct/article/view/728

[3] A. Haleem, M. Javaid, R. P. Singh, R. Suman, and S. Rab, "Blockchain technology applications in healthcare: An overview," International Journal of Intelligent Networks, vol. 2, pp. 130–139, Jan. 2021, doi: 10.1016/J.IJIN.2021.09.005.

[4] H. Guo and X. Yu, "A survey on blockchain technology and its security," Blockchain: Research and Applications, vol. 3, no. 2, p. 100067, Jun. 2022, doi: 10.1016/J.BCRA.2022.100067.

[5] C. C. Agbo, Q. H. Mahmoud, and J. M. Eklund, "Blockchain Technology in Healthcare: A Systematic Review," Healthcare 2019, Vol. 7, Page 56, vol. 7, no. 2, p. 56, Apr. 2019, doi: 10.3390/HEALTHCARE7020056.

[6] H. Xiong, T. Dalhaus, P. Wang, and J. Huang, "Blockchain Technology for Agriculture: Applications and Rationale," Frontiers in Blockchain, vol. 3, p. 462928, Feb. 2020, doi: 10.3389/FBLOC.2020.00007/BIBTEX.

[7] J. Michael, A. Cohn, J. B.-T. Journal, and undefined 2018, "Blockchain technology," steptoe.com, 2018, Accessed: Nov. 16, 2023. [Online]. Available: https://www.steptoe.com/a/web/171269/3ZEKzc/lit-febmar18-feature-blockchain.pdf

[8] D. Yaga, P. Mell, N. Roby, K. S. preprint arXiv:1906.11078, and undefined 2019, "Blockchain technology overview," arxiv.org, Accessed: Nov. 23, 2023. [Online]. Available: https://arxiv.org/abs/1906.11078

[9] E. Tijan, S. Aksentijević, K. Ivanić, and M. Jardas, "Blockchain Technology Implementation in Logistics," Sustainability 2019, Vol. 11, Page 1185, vol. 11, no. 4, p. 1185, Feb. 2019, doi: 10.3390/SU11041185.

[10] D. P. Oyinloye, J. Sen Teh, N. Jamil, and M. Alawida, "Blockchain Consensus: An Overview of Alternative Protocols," Symmetry 2021, Vol. 13, Page 1363, vol. 13, no. 8, p. 1363, Jul. 2021, doi: 10.3390/SYM13081363.

[11] M. Casula, N. Rangarajan, and P. Shields, "The potential of working hypotheses for deductive exploratory research," Qual Quant, vol. 55, no. 5, pp. 1703–1725, Oct. 2021, doi: 10.1007/S11135-020-01072-9/TABLES/4.

[12] E. Fridayanthie, … H. H.-J. K., and undefined 2021, "Penerapan Metode Prototype Pada Perancangan Sistem Informasi Penggajian Karyawan (Persis Gawan) Berbasis Web," simlitabmas.umkendari.ac.id, vol. 23, no. 2, 2021, doi: 10.31294/p.v23i2.10998.

[13] B. Sriman, S. Ganesh Kumar, and P. Shamili, "Blockchain Technology: Consensus Protocol Proof of Work and Proof of Stake," Advances in Intelligent Systems and Computing, vol. 1172, pp. 395–406, 2021, doi: 10.1007/978-981-15-5566-4_34.

[14] N. Sapra, I. Shaikh, and A. Dash, "Impact of Proof of Work (PoW)-Based Blockchain Applications on the Environment: A Systematic Review and Research Agenda," Journal of Risk and Financial Management 2023, Vol. 16, Page 218, vol. 16, no. 4, p. 218, Mar. 2023, doi: 10.3390/JRFM16040218.

[15] S. K. Zakarneh, Z. Qaroush, and A. Dawabsheh, "Cryptocurrencies Advantages and Disadvantages: A Review," International Journal of Applied Sciences and Smart Technologies, vol. 4, no. 1, pp. 1–20, Jun. 2022, doi: 10.24071/IJASST.V4I1.4610.

[16] N. Kadek et al., "Implementation of Golang and ReactJS in the COVID-19 Vaccination Reservation System," ADI Journal on Recent Innovation, vol. 5, no. 1, pp. 1–12, Feb. 2023, doi: 10.34306/AJRI.V5I1.877.

[17] S. Joshi et al., "Adoption of Blockchain Technology for Privacy and Security in the Context of Industry 4.0," Wirel Commun Mob Comput, vol. 2022, 2022, doi: 10.1155/2022/4079781.

[18] S. Noda, K. Okumura, and Y. Hashimoto, "An Economic Analysis of Difficulty Adjustment

Algorithms in Proof-of-Work Blockchain Systems," SSRN Electronic Journal, Jun. 2019, doi: 10.2139/SSRN.3410460.
[19] H. Xiong, M. Chen, C. Wu, Y. Zhao, and W. Yi, "Research on Progress of Blockchain Consensus Algorithm: A Review on Recent Progress of Blockchain Consensus Algorithms," Future Internet 2022, Vol. 14, Page 47, vol. 14, no. 2, p. 47, Jan. 2022, doi: 10.3390/FI14020047.
[20] H. Zhu et al., "Blockchain Technology, Its Applications and Open Research Challenges," J Phys Conf Ser, vol. 1950, no. 1, p. 012030, Aug. 2021, doi: 10.1088/1742-6596/1950/1/012030.
[21] Q. Liu, Y. Xu, B. Cao, L. Zhang, and M. Peng, "Unintentional forking analysis in wireless blockchain networks," Digital Communications and Networks, vol. 7, no. 3, pp. 335–341, Aug. 2021, doi: 10.1016/J.DCAN.2020.12.005.
[22] N. Rahadi, C. V.-J. Infotekmesin, and undefined 2020, "Pengujian Software Aplikasi Perawatan Barang Miliki Negara Menggunakan Metode Black Box Testing Equivalence Partitions," pdfs.semanticscholar.org, vol. 11, no. 01, 2020, doi: 10.35970/infotekmesin.v11i1.124.

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Implementation Open Artificial Intelligence ChattGPT Integrated With Whatsapp Bot

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Abstract. The rapid development of internet technology has led to changes in human habits in terms of seeking information. Now humans have a tendency to use smartphones to find information, especially by using the WhatsApp application. According to data compiled by creative agency we are social in 2023. Whatsapp is in the top position of the most used application, reaching 92%. Artificial intelligence is used as a tool to create remote services to customers because there are no restrictions on working time and can only be accessed using a smartphone. GPT (Generative Pre-training Transformer) chat technology has the ability to answer questions, as well as understand the context of the conversation and generate meaningful text like a remote conversation with humans. ChattGPT can provide information to users with these capabilities, especially in terms of health. In the research there is an integration process between Chattgpt and Whattsapp, by entering the API (Application Programming Interface) key Chattgpt into Whattsapp with the help of javascript programming language. So that the artificial intelligence system using ChattGPT can be implemented on whattapp.

Keywords: ChattGPT, Integrated, API (Application Programming Interface) key, Artificial intelligence

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1. Introduction

In this digital era, technological advancements have opened the door for major transformations in various sectors, including in healthcare. One innovation that has attracted attention is the implementation of ChatGPT on instant messaging platforms such as WhatsApp in the context of healthcare. ChatGPT, developed by OpenAI, is an artificial intelligence model capable of understanding and generating text in a human-like manner. Utilizing ChatGPT in healthcare, especially through WhatsApp, can provide a number of significant benefits [1]. In the initial approach, ChatGPT can serve as a virtual assistant that provides health information, gives simple treatment suggestions, and answers general health questions to WhatsApp users. The first benefit of this implementation is the availability of fast and accurate health information. Users can easily access health information, disease symptoms, and health tips without having to search through various sources. ChatGPT can provide more personalized and reliable answers, helping people improve their health literacy[2]. In addition, the use of ChatGPT on WhatsApp can streamline the initial medical consultation process. Patients can ask

questions regarding their symptoms or health conditions, and ChatGPT can provide initial guidance or direct them to seek further treatment. This can help in early detection of health issues and increase public awareness of preventive measures[3]. By combining artificial intelligence and easy access through WhatsApp, the implementation of ChatGPT in healthcare can be a step towards providing more affordable, fast and efficient healthcare services. As such, this technology can act as a catalyst to achieve the global goal of improving overall public health.

Telemedicine is a concept that allows interaction between patients and healthcare professionals without physical presence in the same location. The utilization of telecommunication technology in telemedicine has opened the door for globally accessible healthcare. A chatbot, as an artificial intelligence that can communicate in real-time, provides an interactive and user-friendly interface. In the context of telemedicine, a chatbot can be a virtual assistant that assists patients in undergoing medical consultations, providing health information, and even guiding patients in the monitoring of certain health conditions. Chatbots enable better accessibility for medical consultations, especially for those who live in remote areas or are hard to reach by traditional healthcare facilities. Patients can easily communicate with the chatbot through an online platform, reducing geographical barriers. Chatbots can help in continuous health monitoring. Patients who have chronic conditions can use chatbots to record symptoms, undergo regular monitoring, and receive treatment-related advice based on the data collected.

2. Methods

This research uses the Software Development Life Cycle (SLDC) methodology[4]. Software Development Life Cycle (SLDC) is a work stage used to determine software makers to determine the steps that must be taken to process the development of a software. The stages used are requirements analysis, design, system, implementation, verification and maintenance. The design used in this method is a waterfall model where this model requires users to create software in a coherent manner according to the sequence in the Software Development Life Cycle (SLDC)[5].

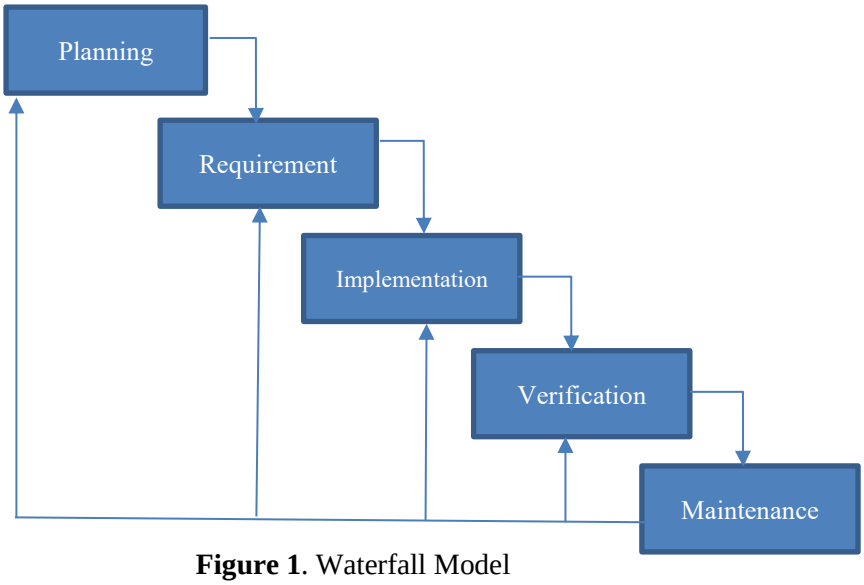

Figure 1. Waterfall Model

2.1 Project planning

Define the specific needs and objectives of implementing ChatGPT on WhatsApp in a healthcare context. Create an account on ChatOpenAI, to obtain the API key of chattGPT. After that, prepare an adequate program with javascript and C++ programming languages. Prepare a whatsapp account to link with the program that will be created.

2.2. Requirement

The API key that has been obtained from ChatOpenAI is a way to create artificial intelligence in a system, so that the API key is likened to a robot that will produce an answer to the question. after that it is integrated into WhatsApp so that it can answer questions created by humans. as depicted in Figure 2.

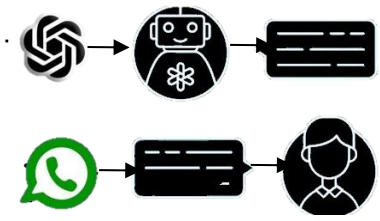

Figure 2. requirement API key for whatsapp

2.3 Implementation

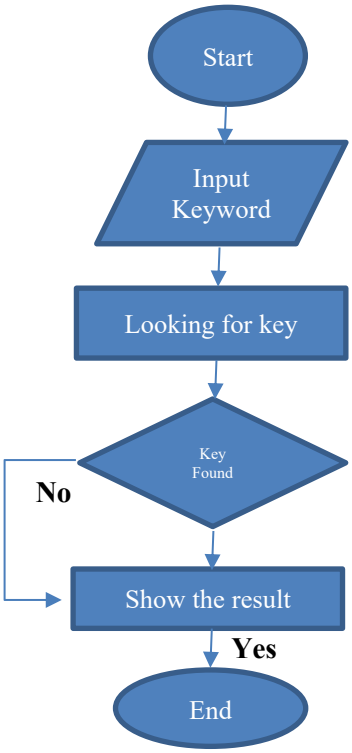

Figure 3. Whatsapp Bot Flowchart

Computer The framework of this research is a series of systematic steps to solve the problem, including the following process for creating a whatsaap bot [2]. Figure 3 shows a Whatsapp bot created

with @botfather and provides access to the creation process. This is done by signing up to @botfather. When you find a parent bot, the bot command is created in /ai. You will receive an automated bot response asking for your bot name. The bot searches the OpenAI ChatGPT database for related keywords. A keyword search will display results if the keyword you entered is present. Conversely, if the keyword you entered is missing, other answers will be displayed and the search will be completed. This subsection explains the steps to integrate and implement ChatGPT with WhatsApp bots.

2.4 Verification.

Test the chatbot functionality to ensure correct responses to queries. Conduct performance testing to ensure the chatbot can handle the expected volume of users and respond quickly. Questions that have been asked to the chatbot will be verified by asking the same thing to people or systems that are experts in their fields. for example in Figure 5 the questions given are verified by someone who is an expert in their field. the verification is like in Figure 7, we asked the doctor with the same question.

2.5 Maintenance

Implement monitoring tools to track chatbot performance and identify potential issues quickly. Continuously update and improve the ChatGPT model based on the latest trends and user response. Performance monitoring on the chattbot is done once every 10 minutes. If more than 10 minutes then the npm start command will be called to start the chattbot again. Further research would be better done to provide different questions, especially in the world of health. whether the answer will be validated valid or not by the expert.

3. Results and discussion:

Creating a chatbot with WhatsappBot using ChatGPT makes it easier to search for information. Among them are diagnosing diseases based on disease symptoms and determining the output of a C++ program. The experimental results are displayed in written format [6]. Testing is carried out by checking the application repeatedly and thoroughly to ensure that the system is free from bugs and errors. As part of the first stage, Figure 4 is the first experimental illustration, namely calling the npm start command meaning the bot is started [7]. At this stage the chatbot is expected to be able to provide a response as a guide, and the results are as expected (an example is shown in Figure 5). The desired output format is shown in Figure 5. This shows that the chat starts with a dialogue .ai question and then the Bot can respond according to the expected instructions. In the next stage, the chatbot needs to provide the correct answer in the programming language and the results are as expected, as seen in Figure 5. The integration of AI and ChattGPT has worked as expected. Nearly all experiments were run multiple times without any errors in the system or response [8]. This is an advantage that is present in the OpenAI ChatGPT system which is integrated into the WhatsApp bot.

Figure 4. Views on MINGW.

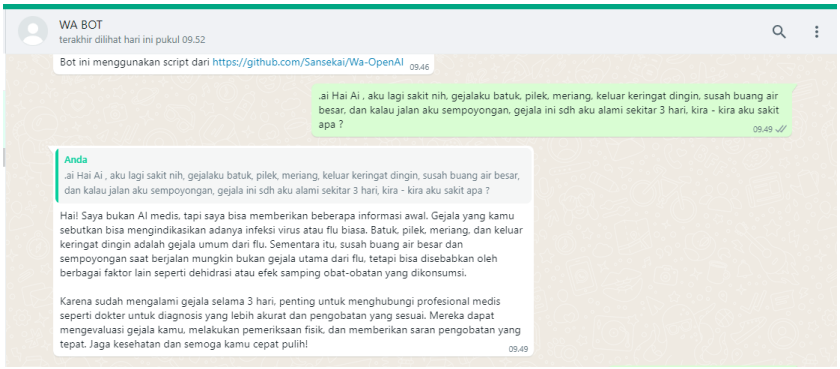

Figure 5. Disease diagnostic test

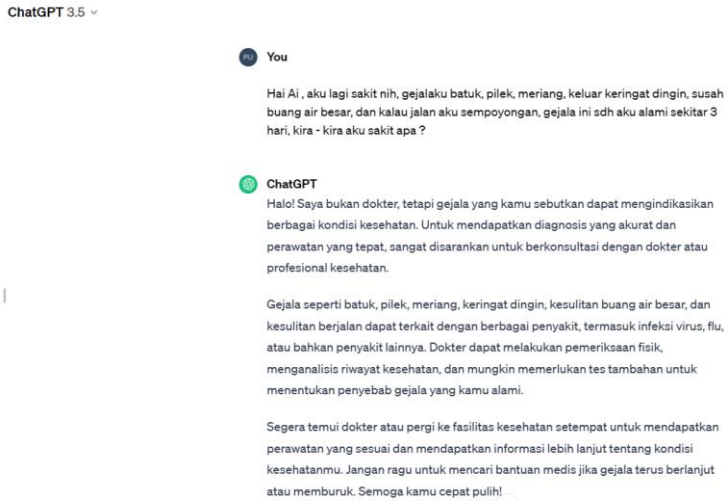

Figure 6. Diseases Diagnostic Test Using Open AI Website.

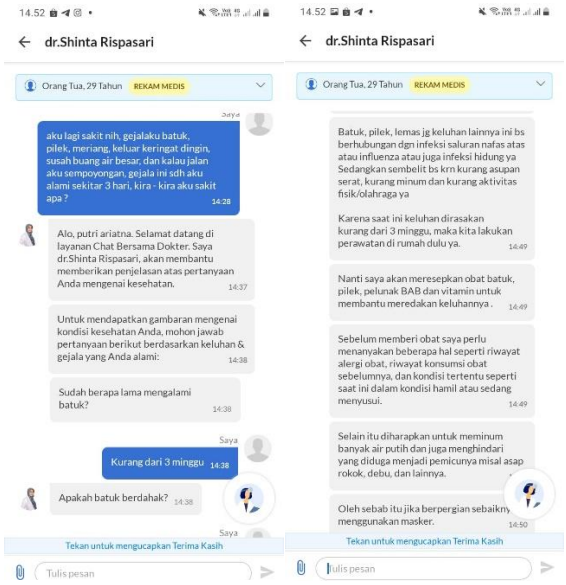

Figure 7. Diseases Diagnostic Test With dr.Shinta Rispasari From Alodoc.com

Whatsapp makes it easy for users to find the information they want. For example, if someone experiences symptoms of a disease while the health facility is far from home, then first aid can determine

the diagnosis of the disease through artificial intelligence, in this case AI has been implemented into Whatsapp, making it easier for users [9]. This has been proven in Figure 5, the response from artificial intelligence answers the diagnosis of the disease, so this technology has been proven to help someone experiencing symptoms of disease and treat it early. From figure 7 was confirmed by Dr. Shinta Rispasari from Alodoc.com. So that for the need to find information remotely it is more efficient to use this technology. However, further research needs to be done whether this technology is appropriate for diagnosing all disease symptoms. Searching for answers to the same questions on the implementation of chattgpt on whatsapp and the chattgpt website is because artificial intelligence works based on many keywords so that if done at different times it will produce different answers, and the size of the data sent in the form of questions will affect the length of the answer, so that the answer on the chattgpt website in Figure 6 is longer than the answer on whattsapp bot in Figure 5.

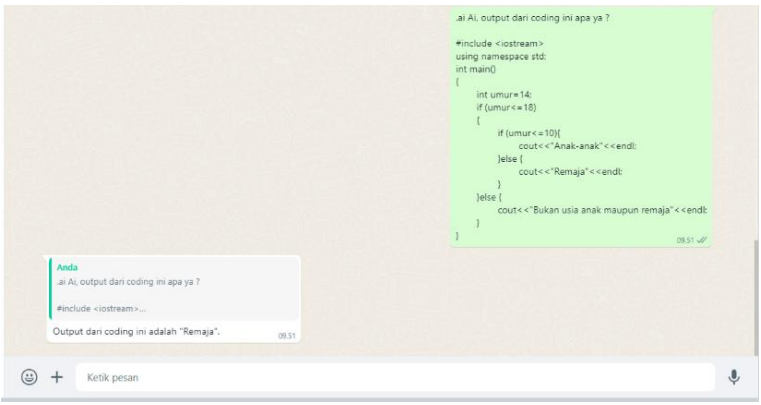

Figure 8. Test the Output a Program from implementation chattGPT at whatsapp.

Figure 9. Test the Output a Program from compiler C++ .

The next implementation in Figure 7 is the implementation of artificial intelligence used to search for answers in the c++ program. and the results show correct. The comparison is done by searching for answers on the c++ compiler platform and the implementation of artificial intelligence on WhatsApp. And it can be proven that it produces the same answer in Figures 7 and 8. So that in terms of finding answers the c++ chattgpt program is proven valid.

4. Conclusions:

The integration between open AI and WhatsApp is an innovation to make it easier for humans to do many things, in this research making it easier to find information. The implementation of Chattgpt into Whatsapp can make it easier for users to find information, especially information about health and education. The information provided by the WA chatbot is given in detail and systematically so that it is considered more efficient because users do not need to go to the hospital to diagnose the disease.

Chatbot, as an artificial intelligence that can communicate in real-time, provides an interactive and user-friendly interface. In the context of telemedicine, a chatbot can be a virtual assistant that assists patients in undergoing medical consultations and providing health information. However, to validate the chattbot's answers from all the symptoms of the disease, further research is still needed.

Acknowledgments
We would like to thank the support from LPPM Anwar Medika University for supporting our research.

References

[1] A. Suparno and S. Yos Sudarso Purwokerto, "Chat Bot sebagai implementasi Pemanfaatan Teknologi Artificial Intelligence dengan Channel Telegram," vol. 12, p. 2020, doi: 10.33488/1.ma.2.1.275.

[2] G. Fontanesi *et al.*, "Artificial Intelligence for Satellite Communication and Non-Terrestrial Networks: A Survey," Apr. 2023, Accessed: Dec. 19, 2023. [Online]. Available: http://arxiv.org/abs/2304.13008

[3] "View of Optimasi Business Process Improvement Berbantuan Metode FLASH dengan Integrasi API Trello." Accessed: Dec. 19, 2023. [Online]. Available: https://jurnal.iaii.or.id/index.php/RESTI/article/view/2824/404

[4] "View of Sistem Tutorial Berbasis Kecerdasan Buatan Pada Proses Pengambilan Keputusan Perawatan dan Perbaikan Gitar." Accessed: Dec. 19, 2023. [Online]. Available: https://jurnal.iaii.or.id/index.php/RESTI/article/view/842/127

[5] "View of Implementasi Chatbot sebagai Virtual Assistant Penerimaan Mahasiswa Baru pada Universitas Bumigora." Accessed: Dec. 19, 2023. [Online]. Available: https://journal.universitasbumigora.ac.id/index.php/bite/article/view/1664/987

[6] "View of Application of Capital Market Investment Planning Expert System Using Website-Based Forward Chaining Method." Accessed: Dec. 19, 2023. [Online]. Available: https://pels.umsida.ac.id/index.php/PELS/article/view/1318/917

[7] O. Morin *et al.*, "An artificial intelligence framework integrating longitudinal electronic health records with real-world data enables continuous pan-cancer prognostication," *Nature Cancer 2021 2:7*, vol. 2, no. 7, pp. 709–722, Jul. 2021, doi: 10.1038/s43018-021-00236-2.

[8] "View of Open Artificial Intelligence Analysis using ChatGPT Integrated with Telegram Bot." Accessed: Dec. 19, 2023. [Online]. Available: https://eltikom.poliban.ac.id/index.php/eltikom/article/view/724/110

[9] J. Chatterjee and N. Dethlefs, "Scientometric review of artificial intelligence for operations & maintenance of wind turbines: The past, present and future," *Renewable and Sustainable Energy Reviews*, vol. 144, p. 111051, Jul. 2021, doi: 10.1016/J.RSER.2021.111051.

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Yogyakarta Batik Image Classification Based on Convolutional Neural Network

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Abstract. This paper studies the efficiency of identifying motifs and patterns in Yogyakarta batik using the Convolutional Neural Network (CNN) algorithm. This research uses the AlexNet architecture on CNN to increase the accuracy of batik image classification. Apart from that, it also involves the use of Canny edge detection techniques and feature extraction using the Gray Level Co-occurrence Matrix (GLCM) to improve the feature extraction process in batik images. There are 6 folders representing 6 types of motifs containing -+20 to 25 data that have been prepared for the training session. Next, the data is processed with 20% of the data used for training and 80% for testing. The accuracy of this research using the SGDM optimizer reached 100%. The evaluation results provide insight into the extent to which edge emphasis can improve the model's ability to recognize and classify batik patterns. It also presents classification test results and evaluation metrics such as precision, recall, and F1 score.

Keywords: Batik Yogyakarta, Classification, CNN Algorithm, SGDM Optimizer

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1. Introduction

Batik is a traditional Indonesian cloth painting art that has special characteristics. As a testament to Indonesia's rich heritage, Yogyakarta Batik not only showcases artistic beauty but also conveys profound cultural meanings, weaving a tapestry that reflects the nation's artistic depth and historical richness[1]. Batik making involves using a canting or other tool to apply wax to the fabric. Batik has various types, motifs and meanings[2][3]. Batik motifs can vary, from traditional motifs to modern motifs adapted to the times.

Yogyakarta Batik is a type of batik that has a special history and characteristics. This batik is characterized by dominant earth colors in its pattern [3]. There are many types of Yogyakarta Batik patterns, but generally there are 6 types that are the most famous. These are the Kawung Batik, Parang Batik, Satrio Manah Batik, Sekar Jagad Batik, Sido Mukti Batik, and Truntum Batik. Yogyakarta Batik has high artistic and cultural value. The motifs often depict elements of Javanese culture and history, such as wayang, gardens, and images inspired by the surrounding environment. Yogyakarta Batik is an important part of Javanese culture and has beauty and deep meaning in each motif. Edge detection in digital image processing is an important technique for finding edges or boundaries between objects and

backgrounds in images [4][5]. Some commonly used edge detection techniques include the first gradient operators, such as Sobel, Canny, Prewitt, and Roberts, which calculate changes in image intensity in the vertical and horizontal directions [6]. The main goal of edge detection is to highlight significant changes in the image, enabling further analysis such as object segmentation and pattern recognition. This edge-detection technique has an important role in various applications, including computer vision, medical image processing, and object detection.

The AlexNet architecture is one of the important milestones in the development of deep learning and Convolutional Neural Networks (CNN). Created by Alex Krizhevsky, AlexNet won the ImageNet Large Scale Visual Recognition Challenge (ILSVRC) competition in 2012, which was the starting point for the great popularity of CNNs in image processing. AlexNet also introduced the use of ReLU (Rectified Linear Unit) as an activation, which helps overcome the problem of model training deep [7]. In addition, AlexNet uses a dropout technique to reduce overfitting, which at that time was a significant innovation in deep learning[8]. The AlexNet architecture proves that deep learning models can achieve excellent levels of accuracy in image classification, inspiring further developments in the fields of image recognition and visualization[9]. The success of AlexNet laid the foundation for many more sophisticated and complex CNN architectures used in applications such as object detection, segmentation, and medical image analysis.

Research on image classification of Yogyakarta Batik Cloth with edge detection using the Canny method and measurements with Convolutional Neural Network (CNN) based on the AlexNet architecture is an important effort in identifying motifs and patterns on batik efficiently [10]. By applying this technology, batik images can be processed with high accuracy, enabling better motif recognition and reducing errors in the classification process. CNN-AlexNet, with its powerful feature extraction capabilities[9], plays a crucial role in improving the accuracy of batik image classification, supporting the preservation of Yogyakarta batik culture through sophisticated digital analysis.

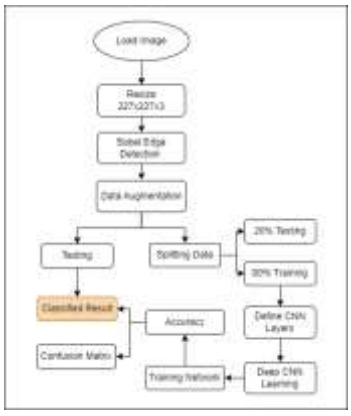
Identifying motifs and patterns in Yogyakarta batik is crucial for preserving and understanding Indonesia's cultural legacy. Research in this realm not only safeguards traditional craftsmanship but also fosters cultural appreciation, enabling applications in heritage conservation, educational programs, and even inspiring contemporary art and fashion that respectfully incorporates these timeless motifs into the global discourse of design and creativity. In the context of batik motifs, where details and textures are very important, CNN can automatically identify complex patterns and features that may be difficult to extract by traditional methods.

2. Methods

Figure 1 shows a flowchart diagram that explains the process of image classification using deep learning. The diagram consists of 12 boxes with arrows connecting them, representing the steps in the process. The diagram shows the different layers and steps involved in the process, including resizing the image, converting it to grayscale, augmenting the data, splitting the data into training and testing sets, defining the CNN layers, training the network, and finally evaluating the accuracy of the classified result using a confusion matrix. The input image is loaded into the system, and then it is preprocessed by resizing it and converting it to grayscale. The data is then augmented to increase the size of the dataset, and then it is split into training and testing sets. The CNN layers are defined, and the network is trained using the training set. Finally, the accuracy of the classified result is evaluated using a confusion matrix[11][12].

The CNN algorithm is widely used in image recognition, object detection, and segmentation tasks

Figure 1. *Proposed Method*



The flowchart you sent outlines the steps involved in processing an image through a Convolutional Neural Network (CNN). Each layer in the CNN architecture has a specific role, as follows:

1. Load Image: This is the initial step where an image is loaded into the system for processing.
2. Resize: The image is resized to a specific dimension (227x227x3 in this case) to ensure consistency in input data size.
3. Sobel Edge Detection: This process identifies edges within the image, helping in feature extraction.
4. Data Augmentation: Enhancing the dataset by creating modified versions of images, increasing dataset size and diversity.
5. Splitting Data: The dataset is divided into testing and training sets. Here, 20% is used for testing and 80% for training.
6. Testing: Evaluating the model's performance using the test data set.
7. Classified Result: The outcome after testing, indicating how well the model classified images.
8. Confusion Matrix: A table used to evaluate performance of classification algorithm, showing actual vs predicted classifications.
9. Training Network: Process of adjusting weights and biases using training data to minimize error and improve accuracy.
10. Define CNN Layers: Establishing layers like convolutional, pooling etc., that make up neural network architecture.
11. Deep CNN Learning : Refers to training deep Convolutional Neural Networks with multiple layers.

2.1. Dataset

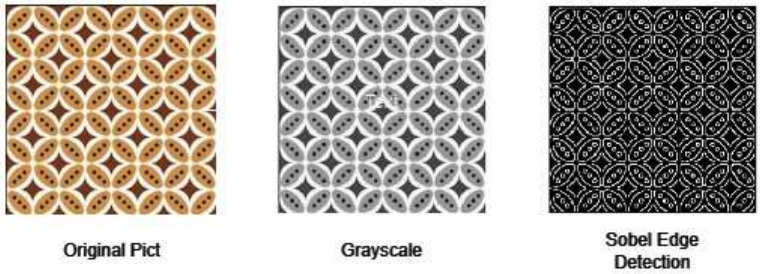
Datasets in research play an important role to classify images. A dataset is a curated collection of digital images along with associated labels that define an image's class or category[11]. Success in image classification using the CNN algorithm is highly dependent on the quality, diversity and size of the data set used for training. Therefore, the dataset taken is open source with a file with an image extension (.jpg) as in the Figure 3. To perform pattern tracking, Edge detection is first performed on the dataset at the edges of the image. And to expand the variety of existing training data, the dataset is further processed by applying augmentation.

Figure 2. *Batik Dataset*

Image augmentation is a technique used to increase the amount of training data in machine learning tasks, especially in image processing tasks. The use of Augmentation in this research includes random horizontal reflections in the image with a 50% probability of occurrence, random rotation of the image in the range of -10 to 10 degrees, shifting the image randomly horizontally in the range of -10 to 10 pixels, and shifting the image randomly in the vertical direction in the range -10 to 10 pixels.

After that, the Dataset is being processed to the classification stage with the first process of grouping data based on species type. There are 6 folders containing -+20 to 25 data that have been prepared for the training session. Next, the data is processed with 20% of the data used for training and 80% for testing.

Figure 3*. Sobel Edge Detection*



The picture above illustrates the preprocessing process, which involves resizing the data to a size of 227x227x3. Subsequently, in the application of Sobel Edge Detection, the data must undergo the grayscale process first, or in other words, it is converted into a gray image to facilitate and enhance the accuracy of Sobel Edge Detection.

2.2. CNN

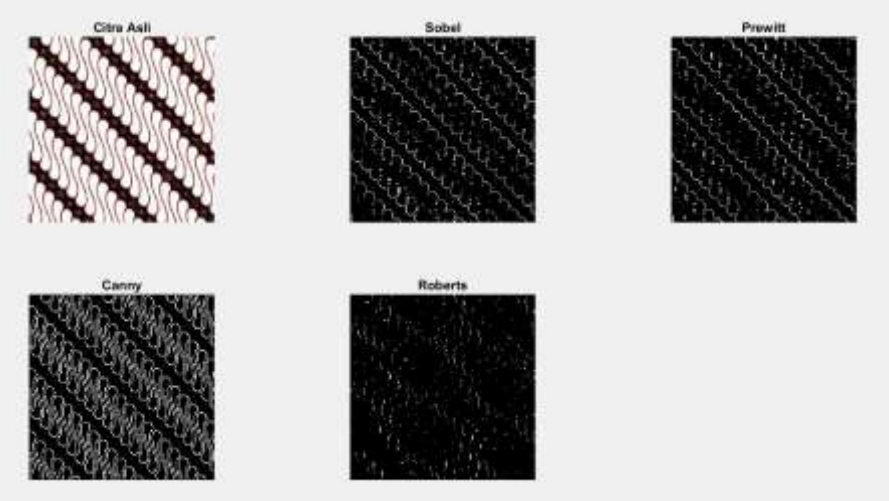
Convolutional Neural Network (CNN) is a special type of neural network architecture used primarily for image processing and computer vision tasks[13]. It is designed to automatically learn and extract features from images using convolutional layers, pooling layers, and fully connected layers. CNN is widely used in various applications such as image classification, object detection, and image segmentation[11]. CNN has several advantages over traditional machine learning algorithms, including the ability to learn and extract features automatically, handle large datasets, and achieve high accuracy in image recognition tasks[14]. When compared with the latest models such as Resnet or GoogLeNet, Alexnet is a model that is not more deeper outperformer. But the plus side of this model is cheap computing than other[15].

We know that, the flowchart of the Convolutional Neural Network (CNN) process, which is a deep learning algorithm used for image processing and analysis. The flowchart is a vertical list of steps that starts with the input layer at the top and ends with the output layer at the bottom. The steps in the flowchart are connected by blue lines with circles at each end and are labeled with text in black font. The flowchart shows the different layers and steps involved in the process, including Conv1, Pool1, Conv2, Pool2, Conv3, Pool3, Conv4, Pool4, Conv5, Pool5, FC1, FC2, and Output. The input layer receives the image data, and the output layer produces the final classification result. The intermediate layers perform various operations such as convolution, pooling, and fully connected layers to extract features from the input image[12].

2.3. Canny Edge Detection

Testing some of edge detection algorithms on batik datasets is an essential step in evaluating the impact of this technique on image classification[16]. In this process, the batik dataset is carefully prepared, covering various types and design variations to represent the diversity of batik.

***Figure 4**. Comparation some of Edge Detection Algorithms*



The Canny algorithm is considered superior in edge detection due to its combination of comprehensive and effective approaches. First, Canny smoothes the image using the Gaussian operator to reduce noise[17]. Then, gradient detection is performed to find significant intensity changes. The next step is to reduce the edges using the non-maximum suppression method, which produces thin and accurate edges. Finally, Canny uses hysteresis thresholding to identify and connect significant edges[18]. This combination of steps provides advantages in handling noise, producing sharp edges, and providing good parameter control, making it the algorithm of choice for edge detection in a wide range of imaging conditions[16][6].

The use of Canny edge detection in processing batik datasets is important because this technique can improve the feature extraction process in images. By highlighting edges and sharp changes in images, edge detection helps Convolutional Neural Network (CNN) algorithms to understand structures and patterns that may be difficult to identify without special emphasis[19]. Edge detection images tend to focus more on features that have semantic meaning, such as design details on batik, which is an important criterion in image classification. Another advantage is the improved generalization power, ensuring that the model is more robust to lighting and contrast variations. By emphasizing the main characteristics in a batik image, this technique helps overcome the challenge of variability in batik designs and patterns that may vary.

2.4. Confusion Matrix

Confusion matrix is a performance evaluation tool commonly used in classification and pattern recognition[20][21]. The confusion matrix provides a detailed picture of how well a model can differentiate between different classes. It is usually used in the context of classification tasks, where a model tries to predict the class of a sample.

The confusion matrix consists of four main parts:

1. True Positive (TP):

Representation of the number of samples that actually belong to the positive class and were predicted correctly by the model.

2. True Negative (TN):

Representation of the number of samples that actually belong to the negative class and were predicted correctly by the model.

3. False Positive (FP):

Representation of the number of samples that are actually included in the negative class, but predicted as positive class by the model.

4. False Negative (FN):

Representation of the number of samples that are actually included in the positive class, but predicted as negative class by the model.

The confusion matrix is usually presented in a tabular form like this:

3. Result and Discussion

In this research, the CNN model was developed using an architecture that includes several layers, such as convolutional, pooling, and fully connected layers. Yogyakarta batik image data was used to train the model, and the resulting model was validated and tested on test data. It is hoped that the results of this research will increase understanding in identifying and categorizing Yogyakarta batik based on visual features and develop an efficient and accurate learning system for various applications in the field of batik design and production.

Table 1. *Training Run Result*

No	Optimizer	1st Trainig	2nd Training	3rd Training	Average
1	Adam	90%	70%	80%	80%
2	SGDM	70%	90%	100%	86.66%
3	RMSProp	80%	80%	80%	80%

In the training process, there are three optimizers used being Adam, SGDM (Stochastic Gradient Descent with Momentum), and RMSProp (Root Mean Square Propagation). It uses momentum from SGD and scaling from RMSProp, making it computationally efficient and requiring only a little memory. SGDM is one of the most popular optimization algorithms in deep learning and is used even more than SGD. In this research, SGDM optimizer is considered to work well even with small resources thus considered effective and can replace traditional stochastic gradient algorithm. Based on the three optimizers compared with a minimum of three training runs to find the best optimizer to use, it is concluded that we will use SDGM as the optimizer with 86.66% percentage of the accuracy.

In the context of CNN Batik image classification, the performance of three general optimizers in Neural Networks Model training, namely Adam, Stochastic Gradient Descent with Momentum (SGDM), and RMSPROP, has been reviewed. There are various factors that can affect the performance differences between the optimizers. The characteristics of the dataset can be a key factor, with specific patterns that may be more compatible with certain optimization methods[22]. Additionally, the convergence of the model can be affected by the size of the batch, which can also play a role in performance differences. Critical factors that can affect the performance of the optimizers include learning rate parameters, model structure, and weight initialization. Ultimately, the difference in performance between the optimizers can be caused by a unique combination of these factors, and empirical experiments are often necessary to find the optimizers that best suit the image classification task in the CNN algorithm.

Table 2. *Sample Result of Classification of Batik Yogyakarta*

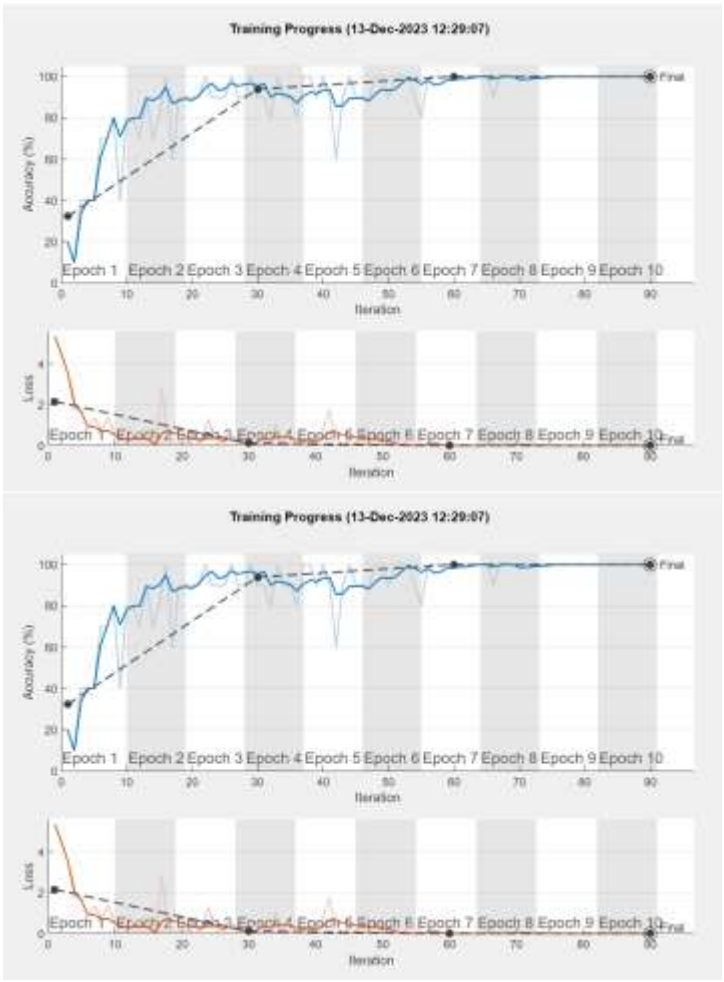
Image Name	Real Name	Folder Name	True / False
1	Batik Kawung	Batik Kawung	T
7	Batik Kawung	Batik Kawung	T
3	Batik Parang	Batik Parang	T
10	Batik Parang	Batik Parang	T
5	Batik Satrio Manah	Batik Satrio Manah	T
6	Batik Satrio Manah	Batik Satrio Manah	T
5	Batik Sekar Jagad	Batik Sekar Jagad	T

8	Batik Sekar Jagad	Batik Sekar Jagad	T
11	Batik Sido Mukti	Batik Sido Mukti	T
10	Batik Sido Mukti	Batik Sido Mukti	T
12	Batik Truntum	Batik Truntum	T
2	Batik Truntum	Batik Truntum	T

Based on the classification tests conducted 12 times, the results show that the model demonstrates 100% true. This finding is further supported by accuracy tests, which report accuracy levels ranging from 70% to 100%. This proves that the application of CNN uses the SGDM optimizer with 436 total datasets that are owned and divided into 6 classes.

Table 3. *Result of Confusion Matrix*

	Precision	**Recall**	**F1-Score**
Test 1	1	1	1
Test 2	0.66	1	0,80
Test 3	0.50	1	0.66
Test 4	0.80	1	0.80
Test 5	1	1	1



The aim of researching and classifying Yogyakarta batik using the CNN algorithm and ADAM optimizer is to develop a model that can be efficient and accurate in identifying and categorizing Yogyakarta batik

based on visual features, such as motifs, colors and designs. In this research, CNN is used because it has the ability to identify local features in image data by utilizing convolution, pooling, and fully connected layers. The ADAM optimizer is used to produce a model that can converge quickly and stably, which is important for achieving optimal solutions within limited learning time.

4. Conclution

The research paper effectively summarizes the key findings and their implications, highlighting the successful implementation of the Convolutional Neural Network (CNN) algorithm and Canny edge detection techniques to achieve 100% accuracy in identifying motifs and patterns in Yogyakarta batik images. The study emphasizes the cultural significance of Yogyakarta batik and the importance of preserving Indonesia's cultural legacy through advanced image processing techniques.

Future research could explore the application of other edge detection algorithms in conjunction with CNN to further enhance feature extraction in batik images. Additionally, investigating the use of larger and more diverse datasets could provide a more comprehensive understanding of Yogyakarta batik patterns and motifs, leading to improved classification accuracy.

The research underscores the ethical considerations related to cultural representation and biases in the dataset. It is essential for future studies to ensure the respectful and accurate representation of Indonesia's cultural heritage in image classification research. Additionally, efforts should be made to address any potential biases in the dataset to ensure fair and unbiased classification of Yogyakarta batik patterns.

References

[1] L. A. Ana, "Aplikasi Penerapan Motif Batik Kawung Pada Sepatu Kulit Boot," pp. 72–88.

[2] C. J. PRABOWO, "Studi Visual Dan Karakteristik Batik Glugu Di Ampel–Boyolali," 2019.

[3] D. Gede, T. Meranggi, N. Yudistira, and Y. A. Sari, "Batik Classification Using Convolutional Neural Network with Data Improvements," *JOIV Int. J. Informatics Vis.*, vol. 6, no. March, pp. 6–11, 2022.

[4] C. U. Khasanah, E. Utami, and S. Raharjo, "Implementation of Data Augmentation Using Convolutional Neural Network for Batik Classification," *2020 8th Int. Conf. Cyber IT Serv. Manag. CITSM 2020*, pp. 20–24, 2020, doi: 10.1109/CITSM50537.2020.9268890.

[5] I. A. Dly, S. Sanjaya, L. Handayani, and F. Yanto, "Klasifikasi Citra Daging Sapi dan Babi Menggunakan CNN Alexnet dan Augmentasi Data," vol. 4, no. 4, pp. 1176–1185, 2023, doi: 10.47065/josh.v4i4.3702.

[6] V. No, K. Panggalih, W. Kurniawan, and W. Gata, "Implementasi Perbandingan Deteksi Tepi Pada Citra Digital Menggunakan Metode Roberst , Sobel , Prewitt dan Canny.," vol. 5, no. 2, pp. 337–347, 2022.

[7] A. Satyo, B. Karno, W. Hastomo, Y. Efendi, D. Diyah, and R. Irawati, "Arsitektur Alexnet Convolution Neural Network (CNN) Untuk Mendeteksi Covid-19 Image Chest-Xray," *Konf. Nas. Ilmu Komput.*, vol. 5, no. 1, pp. 482–485, 2021.

[8] D. Riana, D. Uki Eka Saputri, and S. Hadianti, "Klasifikasi Alexnet dan Deteksi Tepi Canny untuk Identifikasi Citra Repomedunm," *J. Inf. dan Teknol.*, vol. 5, no. 1, pp. 191–198, 2023, doi: 10.37034/jidt.v5i1.295.

[9] M. A. Rasyidi and T. Bariyah, "Batik Pattern Recognition Using Convolutional Neural Network (CNN)," *Bull. Electr. Eng. Informatics*, vol. 9, no. 4, pp. 1430–1437, 2020, doi: 10.11591/eei.v9i4.2385.

[10] B. Falakhi, E. F. Achmal, M. Rizaldi, R. R. R. Athallah, and N. Yudistira, "Perbandingan Model AlexNet dan ResNet dalam Klasifikasi Citra Bunga Memanfaatkan Transfer Learning," *J. Ilmu Komput. dan Agri-Informatika*, vol. 9, no. 1, pp. 70–78, 2022, doi: 10.29244/jika.9.1.70-78.

[11] A. G. S. Auni, C. A. Sari, E. H. Rachmawanto, and M. Doheir, "Lovebird Image Classification Based on Convolutional Neural Network," *Lect. Notes Data Eng. Commun. Technol.*, vol. 93, no. 02, pp. 833–842, 2023, doi: 10.36055/tjst.v19i2.21946.

[12] E. A. Nabila, C. A. Sari, E. H. Rachmawanto, and M. Doheir, "A Good Performance of

Convolutional Neural Network Based on AlexNet in Domestic Indonesian Car Types Classification," *Adv. Sustain. Sci. Eng. Technol.*, vol. 5, no. 3, p. 0230302, 2023, doi: 10.26877/asset.v5i3.16854.

[13] A. S. Dharma, M. Kom, S. Tambunan, and P. K. Naibaho, "Deteksi Objek Aksara Batak Toba Menggunakan Faster R-CNN dan YoloV3," 2022, [Online]. Available: https://www.academia.edu/68753590/Deteksi_Objek_Aksara_Batak_Toba_Menggunakan_Faster_R_CNN_dan_YoloV3

[14] D. Bhatt *et al.*, "Cnn variants for computer vision: History, architecture, application, challenges and future scope," *Electron.*, vol. 10, no. 20, pp. 1–28, 2021, doi: 10.3390/electronics10202470.

[15] E. G. Mohamed, R. P. D. Redondo, A. Koura, M. S. EL-Mofty, and M. Kayed, "Dental Age Estimation Using Deep Learning: A Comparative Survey," *Computation*, vol. 11, no. 2, pp. 1–22, 2023, doi: 10.3390/computation11020018.

[16] S. Rahmawati, R. Devita, R. H. Zain, E. Rianti, N. Lubis, and A. Wanto, "Prewitt and Canny Methods on Inversion Image Edge Detection: An Evaluation," *J. Phys. Conf. Ser.*, vol. 1933, no. 1, 2021, doi: 10.1088/1742-6596/1933/1/012039.

[17] Z. Stosic, "An Improved Canny Edge Detection Algorithm for Detecting Brain Tumors in MRI Images," vol. 3, 2018.

[18] L. C. Ngugi, M. Abelwahab, and M. Abo-Zahhad, "Tomato leaf segmentation algorithms for mobile phone applications using deep learning," *Comput. Electron. Agric.*, vol. 178, no. August, p. 105788, 2020, doi: 10.1016/j.compag.2020.105788.

[19] E. A. Sekehravani, E. Babulak, and M. Masoodi, "Implementing canny edge detection algorithm for noisy image," vol. 9, no. 4, pp. 1404–1410, 2020, doi: 10.11591/eei.v9i4.1837.

[20] I. P. Kamila, C. A. Sari, E. H. Rachmawanto, and N. R. Dwi, "A Good Evaluation Based on Confusion Matrix for Lung Diseases Classification using Convolutional Neural Networks," vol. 6, no. 1, pp. 1–8, 2024.

[21] S. Juliansyah and A. D. Laksito, "Klasifikasi Citra Buah Pir Menggunakan Convolutional Neural Networks," *J. Telekomun. dan Komput.*, vol. 11, no. 1, p. 65, 2021, doi: 10.22441/incomtech.v11i1.10185.

[22] E. Hassan, M. Y. Shams, N. A. Hikal, and S. Elmougy, *The effect of choosing optimizer algorithms to improve computer vision tasks: a comparative study*, vol. 82, no. 11. Multimedia Tools and Applications, 2023. doi: 10.1007/s11042-022-13820-0.

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Optimizing Biomass Pre-Treatment Technologies for BBJP Plants in Indonesia: A Multi-Criteria Decision Making Approach

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Abstract. The challenges of energy consumption and environmental sustainability are pronounced in the dynamic landscape of contemporary industries driven by Industry 4.0 technologies. Indonesia, heavily reliant on fossil fuels, charts a course toward a clean energy future with a National Energy Transition Roadmap for Net Zero Emission by 2060. This transition involves innovative strategies such as biomass co-firing and waste utilization in Solid Recovered Fuel (SRF) plants, known as Bahan Bakar Jumputan Padat (BBJP) plants. To optimize these BBJP plants, this study employs Multi-Criteria Decision Making (MCDM) methodologies, specifically the Analytical Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), to evaluate and select pre-treatment technologies. Criteria include capacity, conversion process, waste type, electricity consumption, operational ease, land requirement, and investment cost. Comparing bio-drying, thermal drying, and mechanical drying, AHP ensures consistent criterion weights, with TOPSIS ranking bio-drying as the most favorable, followed by thermal and mechanical drying. The study acknowledges global waste management challenges and introduces a mobile-modular containerized BBJP/SRF plant model, addressing installation, maintenance, scalability, and adaptability issues. While recognizing challenges, especially in pre-treatment processes, the research emphasizes the need for efficient and cost-effective solutions. Practical implications include enhanced decision-making in biomass drying, identification of technology advantages and disadvantages, and a commitment to address challenges for sustainable implementation. The study contributes to Indonesia's energy transition discourse, advocating the pivotal role of BBJP plants in balancing Industry 4.0 demands and environmental protection, providing insights for stakeholders and decision-makers in advancing sustainable waste-to-energy initiatives.

Keywords: Industry 4.0, Bahan Bakar Jumputan Padat (BBJP), Multi-Criteria Decision Making (MCDM), Analytical Hierarchy Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Bio Drying, Thermal Drying, Mechanical Drying.

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1. Introduction

In the era of Industry 4.0, characterized by the integration of intelligent sensors, Internet of Things (IoT), artificial intelligence (AI)/machine learning (ML), cloud computing, big data and analytics, virtual reality (VR)/augmented reality (AR), intelligent robotics, 5G communications, and 3D printing, the industrial sector has witnessed a significant evolution. While these technological advances have substantially improved production processes, addressing challenges in energy consumption and environmental sustainability has become paramount [1]. The escalating demand for electrical energy, driven by the reliance on data centers, cloud computing, and web servers, poses a critical issue globally. This demand is further intensified by the simultaneous growth in the global population and shifts in lifestyle. Nations, including Indonesia, are thus forced to reassess their energy landscapes to balance Industry 4.0 demands with environmental preservation. Indonesia, like many other parts of the world, relies heavily on fossil fuels coal, gas, and oil for electrical energy production. Coal dominates the energy mix, constituting 50-65% of Indonesia's power plant performance [2]. This reliance contributes significantly to greenhouse gas emissions and environmental challenges. In response to global commitments, Indonesia aligns itself with the principles of the 2015 Paris Agreement. The challenge lies in achieving a global temperature reduction of no more than 2°C while balancing national energy sources, budget constraints, and the Trilemma Energy index (security, equity, and sustainability) [3]. To realize clean and sustainable energy, Indonesia crafted the National Energy Transition Roadmap targeting Net Zero Emission (NZE) by 2060. This roadmap emphasizes renewable energy-based power plants and innovative approaches, including biomass co-firing in existing coal-fired power plants. This co-firing method faced initial opposition due to environmental concerns but gained support through proposals like the energy plantation forest (EPF) program[4].

Waste management emerges as a global challenge, leading to the deployment of *Bahan Bakar Jumputan Padat* (BBJP) for sustainable waste-to-energy conversion. Operational BBJP plants, located strategically, are modest in number but demonstrate potential for expansion. A paradigm shift is underway with the introduction of a mobile-modular containerized BBJP/SRF plant model. This innovation streamlines waste-to-energy conversion, offering advantages like ease of installation, maintenance flexibility, scalability, and adaptability to diverse land configurations. The modular BBJP plant comes in scalable capacities (10, 20, 50, and 100 Tons Per Day), offering a dynamic solution. Containerized modules, transportable via trailer trucks, enhancing mobility, enabling deployment in remote waste source locations and minimizing the need for extensive waste mobilization to centralized facilities. However, challenges, such as the pre-treatment process, must be addressed to optimize BBJP. Transitioning from fixed-conventional BBJP plants to the mobile-modular containerized model signifies a significant leap in sustainable waste-to-energy efforts [5]. .

The study highlights challenges in BBJP plant pre-treatment, emphasizing the urgent need for a cost-effective solution. Current conditions lack efficiency, prompting a search for an affordable and efficient treatment model. This acknowledgment underscores the commitment to enhancing waste-to-energy sustainability. The optimization process for co-firing programs involves meticulous selection of pre-treatment technology, considering factors like capacity, conversion processes, waste types, electricity consumption, operational ease, land requirements, and investment costs. Implementing the Multi-Criteria Decision Making (MCDM) method is crucial for determining the optimal alternative based on predefined criteria weights.

2. Methods

In this comprehensive section, we expound upon the meticulous methodology employed to determine the optimal pre-treatment technology for BBJP (Solid Recovered Fuel) plants, utilizing the sophisticated Multi-Criteria Decision Making (MCDM) approach. The criteria guiding this decision-making process are thoughtfully curated from pertinent literature studies, ensuring relevance to the case at hand.

2.1. Identification of Criteria

The criteria enlisted in the decision-making process encompass a diverse set of parameters crucial for evaluating pre-treatment technologies. These criteria, along with their detailed descriptions, provide

a holistic framework for assessing the technologies. The table below encapsulates this identification process:

Table 1. Identification of Criteria for Determining Pre-Treatment Technology for BBJP Plants [6]

No.	Criteria	Description
1	Capacity	Describes the production capacity of the considered pre-treatment technology, with options: small, large, or very large.
2	Conversion Process	Describes the type of solid recovered fuel (RDF/SRF) conversion process used by the pre-treatment technology, with options: biological (slow), thermal (fast), or mechanical (fast).
3	Type of Waste	Describes the type of waste that can be processed by the pre-treatment technology, with options: organic, organic and non-organic, or organic only.
4	Electricity Consumption	Describes the level of electricity consumption required by the pre-treatment technology, with options: small, large, or medium.
5	Operational Ease	Describes the level of operational ease of the pre-treatment technology, with options: easy, easy with specialized expertise, or easy but requires specialized expertise.
6	Land Requirement	Describes the type of land utilization needed by the pre-treatment technology, with options: distributed, centralized, or centralized with a larger size.
7	Investment Cost	Describes the level of investment cost required by the pre-treatment technology, with options: low, high, or very high.

The criteria for selecting pre-treatment technology for BBJP Plants (Solid Recovered Fuel from waste biomass) are strategically chosen to facilitate a thorough and effective evaluation process. Capacity is crucial, directly influencing production scale and aligning with energy efficiency goals. Conversion Process choice—biological, thermal, or mechanical—affects fuel quality and overall energy conversion efficiency. The Type of Waste criterion recognizes diverse waste compositions, ensuring technology optimization for specific types and maximizing efficiency. Electricity Consumption considerations aim for sustainability, favoring lower consumption to reduce operational costs and support sustainable energy goals. Operational Ease's impact on practical implementation and long-term success emphasizes user-friendliness and adoption feasibility. Land Requirement addresses spatial needs, aiding in system planning and adaptation to diverse settings. Lastly, Investment Cost balances economic viability, ensuring technology aligns with financial parameters and BBJP Plants' long-term objectives. This comprehensive evaluation framework, encompassing technical, economic, and operational aspects, guarantees the selected pre-treatment technology effectively meets the specific needs and goals of BBJP Plants in utilizing waste biomass for energy production.

2.2. Technology Ranking

By adhering to this rigorous methodology, the article aims to present a nuanced and data-driven perspective on the pre-treatment technology selection for BBJP plants. The inclusion of criteria weights, normalization processes, and comprehensive ranking ensures a robust foundation for decision-making, emphasizing the multi-faceted nature of technology evaluation. It is crucial to acknowledge that while these methodologies offer valuable insights, other external factors like environmental considerations, sustainability metrics, and regulatory compliance must also be factored into the final decision-making process.

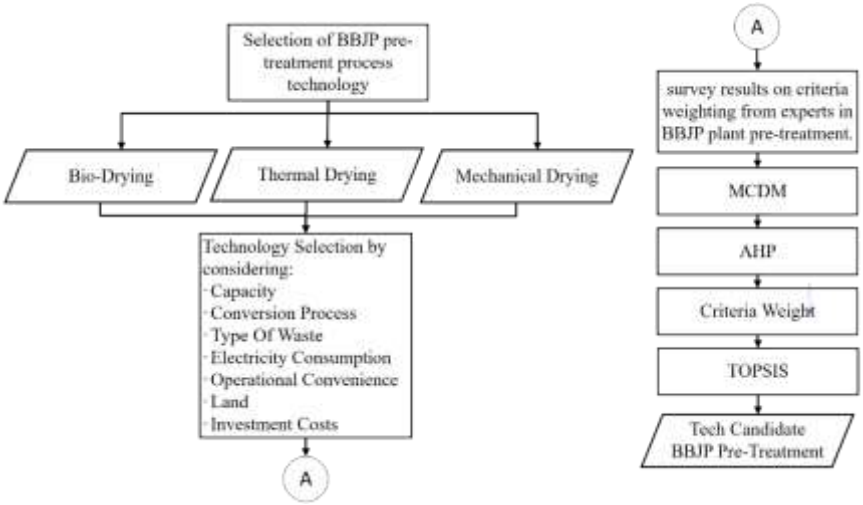

Figure 1. Research Methodology

2.3. Biomass Pre-Treatment Technologies

The selection of pre-treatment technology for biomass drying is a nuanced process, contingent upon the type of biomass utilized, desired outcomes, and available resources. Each technology presents its own set of advantages and drawbacks, necessitating a comprehensive evaluation of these factors to determine the most suitable choice.

1) Bio-drying stands out as a pre-processing technology for biomass drying, leveraging microorganisms in a bio-activator to degrade organic matter within the biomass. This process unfolds within a closed-box reactor, maintaining controlled temperature and humidity. Microorganisms consume organic matter in the biomass, generating heat and water vapor that effectively dries the biomass. The resulting product boasts biological stability, requiring minimal preparation [7].
2) Thermal drying represents another pre-processing technology for biomass drying, relying on heat to evaporate moisture within the biomass. Executed in dryers, which can take the form of rotary drums, fluidized beds, or belt conveyors, heat sources may include burning fossil fuels, biomass, or utilizing residual heat from other processes. This process enhances heating value and combustion efficiency of biomass, concurrently reducing required capacity [8].
3) Mechanical drying is a pre-processing technology for biomass drying that employs mechanical methods such as centrifugation or pressing to eliminate moisture from the biomass. Implemented in mechanical dryers, including screw presses, belt presses, or centrifuges, this process is particularly suitable for biomass with high moisture content, such as sludge or fertilizer [9].

In the quest for an optimal pre-treatment technology, the selection among these methods requires careful consideration of specific project requirements, resource availability, and the nature of the biomass in question. Each technology offers a distinctive approach to biomass drying, and the choice should align with the overarching goals of the biomass utilization project. The following sections delve deeper into the evaluation and comparison of these technologies based on key criteria, providing insights into their respective strengths and areas of application.

2.4. Advantages and Disadvantages of Pre-Treatment Technologies

This section delves into a comprehensive analysis of the strengths and weaknesses inherent in various pre-treatment technologies utilized for biomass drying, namely Bio-Drying, Thermal Drying, and Mechanical Drying. The detailed breakdown is presented in **Table 2.**

Table 2. Comparative Analysis of Pre-Treatment Technologies for Biomass Waste [6, 7 & 8]

Pre-Treatment Technology	Advantages	Disadvantages
Bio-Drying	a. Low energy consumption b. Low capital cost c. Low operational cost d. Produces biologically stable products	a. Prolonged drying time b. Limited to specific biomass types c. Requires enclosed container with controlled temperature and humidity
Thermal Drying	a. High drying rate b. Suitable for various biomass types c. Can recover residual heat d. Enhances heating value and biomass combustion efficiency	a. High energy consumption b. High capital cost c. High operational cost d. Greenhouse gas emissions
Mechanical Drying	a. High drying rate b. Suitable for high moisture content biomass c. Low energy consumption	a. High capital cost b. High operational cost c. Limited to specific biomass types

The table meticulously outlines the advantages and disadvantages associated with each pre-treatment technology for biomass drying. The positive aspects encompass factors such as low energy consumption, low capital and operational costs, high drying rates, suitability for various biomass types, and more. Conversely, the drawbacks include prolonged drying times, limitations to specific biomass types, the need for enclosed containers with controlled conditions, high energy consumption, high capital and operational costs, and greenhouse gas emissions. The selection of the most suitable pre-treatment technology necessitates a thorough consideration of the merits and demerits associated with each technology. It also requires a nuanced understanding of specific processing conditions and needs in biomass treatment. This comprehensive evaluation ensures an informed decision-making process that aligns with both efficiency and sustainability goals in biomass processing.

2.5. Multi-Criteria Decision Making (MCDM)

Michael Scoot Morton initially introduced the concept of Multi-Criteria Decision Making (MCDM) or Decision Support Systems (DSS) in 1971. MCDM is an information system designed to assist management in deciding semi-structured issues. The goal of MCDM is to generate various alternatives that users can interactively use in the decision-making process [8]. MCDM is a procedure used to find the best alternative from a set of feasible options [9]. MCDM with an optimization approach is highly useful in ranking, especially when complex criteria need to be considered simultaneously [10]. Decision Support Systems consist of building global preference relationships for a group of evaluated alternatives. The evaluation uses several selection criteria, where each option is assessed against these criteria, including measures that may conflict. Using MCDM or DSS, management can optimize decision-making by considering various relevant factors and criteria. This approach helps in complex situations where many alternatives and measures must be evaluated holistically. Thus, MCDM or DSS can be an effective tool in making better and data-driven decisions[11]. Some characteristics of MCDM that need to be considered include:

1. Consists of several criteria or attributes used as a selection basis.
2. These criteria often have conflicts with each other.
3. There is uncertainty in the decision-making process, such as subjective assessments, uncertain data, and incomplete information.
4. Sometimes, the final result of the MCDM process does not provide a clear conclusion or a single alternative as the best.
5. The considered alternatives are different objects with equal opportunities to be chosen by decision-makers.

6. Decision matrices are often used to visualize the relationship between alternatives and criteria in MCDM. The decision matrix M is m x n, where m represents the number of other options, and n represents the number of evaluated criteria.

In Multi-Criteria Decision Making (MCDM) for Bahan Bakar Jumputan Padat (BBJP) or Solid Recovered Fuel (SRF) plants, criteria identification and evaluation are meticulous processes. Factors like production capacity and investment costs are curated based on literature studies, with weights assigned through methodologies such as the Analytical Hierarchy Process (AHP) or stakeholder consensus [12]. Data normalization maintains parameter consistency, and weight calculation leads to comprehensive evaluations. The Technique for Order of Preference by Similarity to the Ideal Solution (TOPSIS) refines decision-making, evaluating alternatives based on proximity to the ideal solution [13]. TOPSIS involves matrix normalization, weighted normalization, identifying perfect and non-ideal solutions, calculating separation measures, and determining scores. The integrated AHP and TOPSIS methodology quantitatively ranks pre-treatment technologies for BBJP or SRF plants, emphasizing the multi-faceted nature of technology evaluation and ensuring a robust foundation for sustainable energy decision-making [14]. This approach acknowledges external factors like environmental considerations and regulatory compliance, providing a comprehensive and data-driven perspective on technology selection. The final ranking based on TOPSIS scores determines the most favorable and preferred pre-treatment technology for the envisioned project.

3. Results and Discussion

This chapter provides detailed guidelines for composing the full text, encompassing the article section, the systematic chapter, and their respective contents. These explicit instructions serve as a comprehensive framework, directing the entirety of the editorial process for the article, as illustrated in Figure 1. Authors are expected to adhere closely to these guidelines to ensure the coherence and quality of the written content throughout the publication process.

3.1. Analytical Hierarchy Process (AHP)

This research utilizes the Analytical Hierarchy Process (AHP) method to prioritize criteria in selecting RDF/SRF waste treatment technologies [16]. The pairwise criteria matrix weights are determined based on a questionnaire provided to experts and practitioners directly involved in the BBJP Plant execution at TPSA Begedung.

1) Step 1: Pairwise Criteria Matrix

   In this step, researchers embark on the formation of a pairwise comparison matrix as a method to evaluate the relative significance among criteria. The essence of this comparison is encapsulated by the term a_{ij}, signifying the degree of importance attributed to criterion i in relation to criterion j. This matrix serves as a fundamental tool, providing a structured approach for researchers to systematically analyze and quantify the hierarchical relationships existing among the diverse set of criteria under consideration.

Table 3. Pairwise Comparison Matrix

Criteria	Capacity	Conversion Process	Type of Waste	Electricity Consumption	Operational Convenience	Land	Investment Cost
Capacity	1	5	7	3	6	4	1/2
Conversion Process	1/5	1	3	1	4	2	1/3
Type of Waste	1/7	1/3	1	1/4	1/2	1/3	1/4
Electricity Consumption	1/3	1	4	1	3	2	1/2

Operational Convenience	1/6	1/4	2	1/3	1	1/3	1/2
Land	1/4	1/2	3	1/2	3	1	1/3
Investment Cost	2	3	4	2	2	3	1
Total	4	11	24	8	19 1/2	12 2/3	3 2/5

2) **S**tep 2: Normalization of Pairwise Criteria Matrix

The pairwise comparison matrix (A) undergoes a normalization process to yield the Relative Weight Matrix (W), which signifies the relative importance of each criterion on a scale ranging from 0 to 1. This normalization is achieved by dividing each element a_{ij} by the total of the corresponding column. The resulting Relative Weight Matrix provides a nuanced understanding of the influence of individual criteria in the decision-making process. This method ensures that each criterion's contribution is appropriately scaled, facilitating a more accurate representation of their relative significance in the overall evaluation.

Table 4. Normalized Pairwise Comparison Matrix

Criteria	Capacity	Conversion Process	Type of Waste	Electricity Consumption	Operational Convenience	Land	Investment Cost
Capacity	0,2443	0,4511	0,2917	0,3711	0,3077	0,3158	0,1463
Conversion Process	0,0489	**0,0902**	0,1250	0,1237	0,2051	0,1579	0,0976
Type of Waste	0,0349	0,0301	0,0417	0,0309	0,0256	0,0263	0,0732
Electricity Consumption	0,0814	0,0902	0,1667	0,1237	0,1538	0,1579	0,1463
Operational Convenience	0,0407	0,0226	0,0833	0,0412	0,0513	0,0263	0,1463
Land	0,0611	0,0451	0,1250	0,0619	0,1538	0,0789	0,0976
Investment Cost	0,4887	0,2707	0,1667	0,2474	0,1026	0,2368	0,2927
Total	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000

The normalized value w_{12} is calculated by dividing the corresponding element a_{12} by the total of the second column in matrix A.

$$w_{12} = \frac{a_{12}}{\sum_{i=1}^{n} a_{i2}} \text{ For the given values in } A:$$

$$w_{12} = \frac{1}{5 + 1 + 1/3 + 1 + 1/4 + 1/2 + 3}$$

$$w_{12} = \frac{1/5}{11.75} \approx 0.0902$$

So, the value of 0.0902 in the normalized matrix W for w_{12} is obtained by normalizing the comparison value a_{12} in A based on the total of the second column. This process is repeated for each element in the matrix to obtain the complete normalized matrix W.

3) Step 3: Consistency Analysis of Weighting

After obtaining the Relative Weight Matrix (W), a consistency analysis of the weighting is performed to ensure the reliability of these weights. In this step, the Weight Vector (W^*) and Consistency Index (CI) are calculated to evaluate the consistency among criterion preferences.

Table 5. Consistency Analysis of Weighting

Criteria	Capacity	Conversion Process	Type of Waste	Electricity Consumption	Operational Convenience	Land	Investment Cost	Weighted sum value	Criteria weight	Consistency measure
Capacity	**0,2443**	0,4511	0,2917	0,3711	0,3077	0,3158	0,1463	2,1281	0,2443	8,7099
Conversion Process	0,0489	**0,0902**	0,1250	0,1237	0,2051	0,1579	0,0976	0,8484	0,0902	9,4029
Type of Waste	0,0349	0,0301	**0,0417**	0,0309	0,0256	0,0263	0,0732	0,2627	0,0417	6,3048
Electricity Consumption	0,0814	0,0902	0,1667	**0,1237**	0,1538	0,1579	0,1463	0,9201	0,1237	7,4377

Operational Convenience	0,0407	0,0226	0,0833	0,0412	**0,0513**	0,0263	0,1463	0,4118	0,0513	8,0299
Land	0,0611	0,0451	0,1250	0,0619	0,1538	**0,0789**	0,0976	0,6234	0,0789	7,8965
Investment Cost	0,4887	0,2707	0,1667	0,2474	0,1026	0,2368	**0,2927**	1,8055	0,2927	6,1688

λmax	7,7072
CI	0,1179
CR	**0,0893**

Example Consistency Calculation:

1. Calculation of Weight Vector (W^*) : $w_{ij} = \frac{a_{jl}}{\sum_{i=1}^{n} a_{0j}}$, For example, $w_{11} = \frac{1}{4}, w_{32} = \frac{1/4}{3/4} = \frac{1}{3}$.
2. Calculation of Weight Vector (W^*) : $W^* = \frac{1}{n}\sum_{j=1}^{n} w_{ij}$, With $n = 7, W^*$ represents the average of each column in the W matrix
3. Calculation of Consistency Index (CI) : $CI = \frac{\lambda_{\max} - n}{n-1}$, Where $\lambda_{\max}$ is the maximum eigenvalue
4. Calculation of Consistency Ratio (CR) : $CR = \frac{CI}{RI}$, With RI being a pre-determined consistency index
5. $CI = \frac{\lambda_{\max} - 7}{7-1}$, $\lambda_{\max}$ is computed from eigenvalue calculations and can be set at 7.7072.
   $CI = \frac{7.70\pi 2 - 7}{6}, CI \approx 0.1179$
6. $CI = \frac{\lambda_{\max} - 7}{7-1}$, $CR = \frac{CI}{RI}$ (With $RI = 1.32$)
   $CR \approx \frac{0.1179}{1.32} = CR \approx 0.0893$

In this example, CI is approximately 0.1179, and CR is 0.0893, which is below the consistency threshold (typically 0.1). This indicates that the generated criterion weights can be considered consistent.

3.2. TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)

TOPSIS is a decision-making method employed to evaluate and select alternatives based on the Euclidean distance between each alternative and the ideal best and worst solutions [17]. In the context of the provided decision matrix, here is a detailed description of each step in the TOPSIS process

1) Step 1: Entering Matrix Values and Calculating Total Column Squares

In this step, the decision matrix values are entered, and the total sum of squares per column is calculated. This process is undertaken to normalize the matrix values in the subsequent step.

Table 6. Matrix Values and Calculating Total Column Squares

Criteria		Capacity	Conversion Process	Type of Waste	Electricity Consumption	Operational Convenience	Land	Investment Cost
Bio-Drying	**Field Report**	Small	Slow	Organic	Small	Easy	Distributed	Small
	Score (1-5)	1	1	1	3	3	3	3
Thermal Drying	**Field Report**	Large	Fast	Organic and Non-Organic	Large	Easy and requires expertise	Centralized	Large
	Score (1-5)	3	3	3	1	2	3	1
Mechanical Drying	**Field Report**	Large	Fast	Organic and Non-Organic	Moderate	Easy and requires expertise	Centralized	Large
	Score (1-5)	3	3	3	2	2	3	1
Total Squares		**19**	**19**	**19**	**14**	**17**	**27**	**1**

2) Step 2: Normalizing the Decision Matrix with Total Column Squares

After calculating the total sum of squares per column, the decision matrix is normalized by dividing each matrix element by the corresponding total sum of column squares. This is done to standardize the scale of values for each criterion.

Table 7. Matrix Values and Calculating Total Column Squares

Criteria	Capacity	Conversion Process	Type of Waste	Electricity Consumption	Operational Convenience	Land	Investment Cost
Bio-Drying	0,229415734	0,22941573	0,229415734	0,801783726	0,727606875	0,577350269	0,904534034
Thermal Drying	0,688247202	0,6882472	0,688247202	0,267261242	0,48507125	0,577350269	0,301511345
Mechanical Drying	0,688247202	0,6882472	0,688247202	0,534522484	0,48507125	0,577350269	0,301511345

3) Step 3: Assigning Weights to the Normalized Decision Matrix

In this step, weights are assigned to the normalized decision matrix. These weights reflect the importance of each criterion in the decision-making process. Each value in the normalized decision matrix is multiplied by the corresponding weight.

Table 8. Weighted Decision Matrix

Criteria	Capacity	Conversion Process	Type of Waste	Electricity Consumption	Operational Convenience	Land	Investment Cost
Weighted	0,244328098	0,84838644	0,26270125	0,920128624	0,411787492	0,623404974	1,805511369
Bio-Drying	0,05605271	0,1946332	0,0602678	0,737744156	0,29961941	0,35992303	1,633146481
Thermal Drying	0,16815813	0,58389959	0,1808034	0,245914719	0,199746273	0,35992303	0,54438216
Mechanical Drying	0,16815813	0,58389959	0,1808034	0,491829438	0,199746273	0,35992303	0,54438216

4) Step 4: Determining Ideal Best and Ideal Worst

Ideal Best (V+) and Ideal Worst (V-) are solutions that have the highest and lowest values for each criterion. In this context, V+ and V- values have been identified for each criterion.

Table 9. Ideal Best (V+) and Ideal Worst (V-) Values

Criteria	Capacity	Conversion Process	Type of Waste	Electricity Consumption	Operational Convenience	Land	Investment Cost
V+	0,16815813	0,58389959	0,1808034	0,737744156	0,29961941	0,35992303	1,633146481
V-	0,05605271	0,1946332	0,0602678	0,245914719	0,199746273	0,35992303	0,54438216

5) Step 5: Calculating Euclidean Distance and Criterion Scores

Table 10. Euclidean Distance, Criterion Scores, and Ranking for Biomass Waste Pre-Treatment Technologies

Criteria	Ed+	Ed-	Psi	Rank
Bio-Drying	0,4226	1,1989	0,739	1
Thermal Drying	1,1989	0,4226	0,261	2
Mechanical Drying	1,1207	0,4890	0,304	3

In the final step, Euclidean Distance (Ed+) and (Ed-) are calculated for each alternative. Euclidean Distance represents the distance between each alternative and the ideal best solution (Ed+) and the ideal worst solution (Ed-). Criterion scores (Psi) are also computed as the ratio of Ed- to (Ed+ + Ed-). Alternatives are ranked based on the criterion scores generated. The rankings are determined based on the Criterion Scores (Psi), where a lower score indicates better performance. According to the TOPSIS analysis, Bio-Drying emerges as the most favorable pre-treatment technology for biomass drying, securing the top rank with a Psi score of 0.739. Thermal Drying follows closely behind with a Psi score of 0.261, while Mechanical Drying takes the third position with a Psi score of 0.304. These results offer valuable insights into the relative performance of each pre-treatment technology, aiding decision-makers in selecting the most suitable alternative for biomass drying applications.

3.3. Comparative Analysis of Pre-Processing Technologies: Strengths and Weaknesses

In delving into the specifics of the Analytical Hierarchy Process (AHP) employed for prioritizing criteria in the selection of RDF/SRF waste treatment technologies, a nuanced examination of its strengths and weaknesses is essential. AHP offers a systematic and structured approach, presenting a comprehensive

decision-making framework. The method's incorporation of experts directly involved in the execution of the BBJP Plant at TPSA Begedung ensures a realistic and industry-specific viewpoint. The use of paired comparisons, however, introduces subjectivity into the process, potentially influencing the final weightings assigned to criteria. The complexity of these paired comparisons might also pose challenges, requiring careful attention to maintain accuracy in the evaluation process. The normalization step in AHP, transforming the pairwise criteria matrix into a Relative Weight Matrix (W), is a pivotal aspect. It provides a valuable insight into the relative importance of each criterion, offering a quantitative basis for decision-making. Nevertheless, the normalization process may face limitations in capturing dynamic changes in the needs and goals of the BBJP Plant over time. The industrial landscape is inherently dynamic, and the relevance of criteria may evolve, necessitating periodic reassessment. The consistency analysis of weighting, involving the calculation of the Weight Vector (W^*) and Consistency Index (CI), contributes to the reliability of the results. It ensures that the generated criterion weights align coherently with the decision-making process. However, the effectiveness of this analysis may be influenced by the evolving nature of industrial requirements. Regular reassessment and adjustment of weights might be crucial to maintaining the consistency and relevance of the decision-making framework.

3.4. Contextual Relevance to BBJP Plant in Indonesia:

In the specific context of the BBJP Plant in Indonesia, the strengths of the AHP approach become more apparent. Its systematic nature aligns with the industrial processes of the plant, providing a structured methodology for evaluating and prioritizing pre-processing technologies. The involvement of experts from the field ensures that the criteria selected, such as capacity, Conversion Process, type of waste, electricity consumption, operational convenience, land, and investment cost, are directly relevant to the plant's operations. However, the potential limitation of AHP in capturing dynamic changes becomes more critical in an industry where technological advancements and operational requirements evolve rapidly. The criteria and their respective weights might need periodic adjustments to reflect the evolving landscape of the BBJP Plant [18].

4. Conclusion

In summary, the thorough analysis of biomass drying pre-treatment technologies within BBJP (Solid Recovered Fuel) plants offers valuable insights for the transition to sustainable energy. The MCDM approach, integrating AHP and TOPSIS, proves robust for evaluating technologies through paired comparisons. Criteria, from production capacity to investment costs, are meticulously weighed and normalized, ensuring a nuanced assessment. AHP ensures consistent criterion weights, reflecting accurate relative importance. TOPSIS ranks technologies, with Bio-Drying as the preferred method, followed by Thermal Drying and Mechanical Drying. These rankings guide decision-makers toward sustainable energy alternatives. However, external factors like environmental considerations and regulatory compliance must also influence decisions. Balancing technical feasibility with environmental and societal impacts is crucial for a clean energy future. Integrating innovative technologies like Bio-Drying in Indonesia's energy transition showcases the nation's commitment to sustainability. This research contributes to Indonesia's energy discourse, emphasizing the role of BBJP plants in balancing Industry 4.0 demands with environmental protection. Future research should advance biomass drying pre-treatment technologies, exploring AI integration and intelligent monitoring for enhanced efficiency and sustainability. Real-world application requires systematic testing through pilot projects and large-scale implementations. Collaboration between academia, industry, and policymakers is essential for translating research into practical solutions, shaping Indonesia's evolving sustainable energy landscape.

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References

[1] Bongomin, O., Gilibrays Ocen, G., Nganyi, E.O., Musinguzi, A., and Omara, T. (2020). Exponential Disruptive Technologies and the Required Skills of Industry 4.0. Journal of Engineering Volume 2020, Article ID 4280156, 17 pages https://doi.org/10.1155/2020/4280156

[2] PLN (2022), PLN Annual Report 2022. Leading the Way to Empower Nation.

[3] World Energy Trilemma Index | 2022. (n.d.). World Energy Council. https://www.worldenergy.org/publications/entry/world-energy-trilemma-index-2022

[4] Prasodjo, Darmawan (2022), Decarbonizing Energy Sector for Net Zero-Achievement, Progress and Challenge, UNFCC COP27, Sharm El Sheik, Egypt. https://www.youtube.com/watch?v=MJGczFzZu8Q

[5] PLN Indonesia Power (2023), Materi Presentasi Optimisasi Operasi BBJP Plant, TPSA Bagendung, Cilegon.

[6] Jakpro. (Tahun). Kajian Awal Pengelolaan dan Pemanfaatan Sampah Organik. Jakarta Provincial Government.

[7] Mohammed, M., Ozbay, I., Karademir, A., & Isleyen, M. (2017). Pre-treatment and utilization of food waste as energy source by bio-drying process. Energy Procedia, 128, 100–107.

[8] Leon, M. A., & Kumar, S. (2008). Design and Performance Evaluation of a Solar-Assisted Biomass Drying System with Thermal Storage. Drying Technology, 26(7), 936–947.

[9] Abdullah, A., Al-Sood, M. A., Omara, Z., Bek, M. A., & Kabeel, A. (2018). Performance evaluation of a new counter flow double pass solar air heater with turbulators. Solar Energy, 173, 398–406. https://doi.org/10.1016/j.solener.2018.07.073

[10] Defit, D. N. D. S. (2017). Multi Criteria Decision Making (MCDM) pada Sistem Pendukung Keputusan. Deepublish

[11] Shyur, H., & Shih, H. (2006). A hybrid MCDM model for strategic vendor selection. Mathematical and Computer Modelling, 44(7–8), 749–761. https://doi.org/10.1016/j.mcm.2005.04.018

[12] Díaz-Cuevas, P., Domínguez-Bravo, J., & Campos, A. P. (2019). Integrating MCDM and GIS for renewable energy spatial models: assessing the individual and combined potential for wind, solar and biomass energy in Southern Spain. Clean Technologies and Environmental Policy, 21(9), 1855–1869.

[13] Wu, Y., & Geng, S. (2014). Multi-Criteria Decision Making on Selection of Solar–Wind Hybrid Power Station Location: A Case of China. Energy Conversion and Management 81 , 527-533.

[14] Multi-criteria decision analysis for supporting the selection of engineering materials in product design / Ali Jahan ; Kevin L. Edwards, editor-in chief. (2013). Universitas Indonesia Library.

[15] Multi-criteria decision analysis for supporting the selection of engineering materials in product design / Ali Jahan ; Kevin L. Edwards, editor-in chief. (2013). Universitas Indonesia Library.

[16] Saaty, T. L. (2001). Fundamentals of the analytic hierarchy Process. In *Managing forest ecosystems* (pp. 15–35). https://doi.org/10.1007/978-94-015-9799-9_2

[17] Opricović, S., & Tzeng, G. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. European Journal of Operational Research, 156(2), 445–455.

[18] Ansari, I. (2020). Posdaya berbasis seni rakyat bagi masyarakat Desa Gedegan, Kecamatan Tlogomulyo, Kabupaten Temanggung. Abdi Seni: Jurnal Pengabdian Kepada Masyarakat, 10(1), 22–33.

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Development of Microwave Maceration Method for the Extraction of Organic Constituents of Buton Bajakah (Kakatola) Root and Test of its Activity as an Antioxidant

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Abstract. The extraction of organic constituents, antioxidant activity test, and toxicity test of Bajakah Buton (Kakatola) root extract were conducted. Bajakah Buton roots were extracted using the microwave-assisted maceration method, followed by extraction using ethyl acetate solvent. The resulting yield reached 40,827% b/v. The analysis identified the presence of flavonoids, glycosides, phenols, terpenoids, and tannins. Antioxidant activity testing using the DPPH method showed IC_{50} values of ethyl acetate extract and vitamin C of 100.317 ppm and 13,797 ppm, respectively, indicating strong antioxidant properties. Toxicity tests using the BSLT method showed that the ethyl acetate extract of Bajakah Buton roots had a toxic activity with an LC_{50} value of 11,232 ppm. The results of this study will continue to be developed, so it is expected to be an important breakthrough in the field of cancer treatment.

Keywords: Antioxidants, Bajakah Buton, Maceration, Toxicity

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1. Introduction

Traditional medicine, which has been applied since ancient times, is a common practice in society. Hereditary experience recommends these methods for prevention, treatment and immune enhancement. Various degenerative diseases have emerged in the context of the development of science and technology. The focus on free radicals and antioxidants suggests that many degenerative diseases stem from the body's oxidation reactions. However, the body's antioxidant system plays a role in inhibiting free radical reactivity [1]. As a producer of medicinal plants, Indonesia has the Bajakah Buton (Kakatola) plant, which has potential as a medicine for degenerative diseases. Laboratory test results show that Bajakah has a high antioxidant content and 40 substances that have the potential to kill cancer cells, such as

saponins, phenolics, steroids, terpenoids, tannins, alkaloids, and terpenoids [2].

The maceration method is a technique for separating organic compounds in plants using organic solvents. In this study, water solvent was chosen as an alternative. This is based on the solubility of water by the extracted compounds, as well as consideration of the availability of water that is easily available [3]. The extraction method of Bajakah Buton (Kakatola) roots used is the microwave-assisted maceration method. Microwave-based extraction utilizes microwave heating in the extraction system, which has the advantage of obtaining extraction levels quickly. The maceration technique chosen involves soaking the powdered simplisia in an aqueous solution for several days at room temperature [4].

The 1-diphenyl-2-picrylhydrazyl (DPPH) assay method was used to assess the antioxidant activity of various samples, including compounds found in the Bajakah Buton (Kakatola) plant. This method provides information on the antioxidant capacity of the sample against DPPH, measured as the percentage of DPPH captured by the sample [5]. The higher the capture percentage, the stronger the antioxidant capacity of the sample. Compounds suspected of having anticancer activity are first tested on experimental animals using the Brine Shrimp Lethality Test (BSLT) method. BSLT testing is based on active compounds from plants that are toxic and able to kill Artemia salina shrimp larvae as test animals [6]. The results of toxicity tests with this method correlate with the cytotoxic power of anticancer compounds. Cytotoxic properties can be identified based on the number of larval deaths at a certain concentration [7].

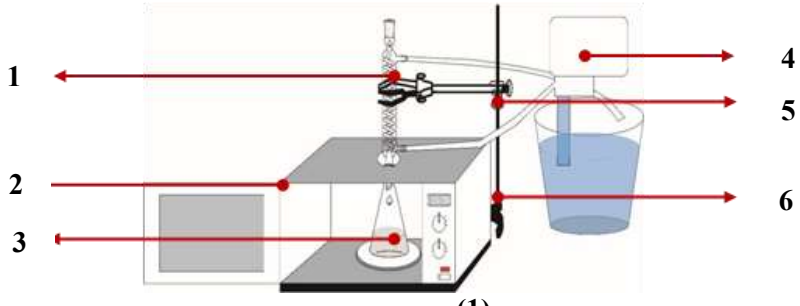
2. Methods

2.1. *Tools and Materials*

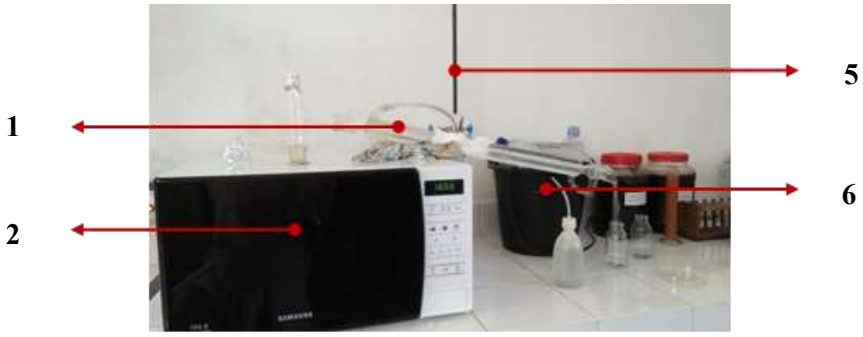
The tools used in this study are a microwave (Samsung), UV-Vis spectrophotometer (Jasco V-360) to measure the concentration of antioxidant compounds in a solution., blender (Panasonic), water pump, condenser, Erlenmeyer (pyrex), measuring cup (Pyrex), beaker, stirring rod, analytical balance (Explorer Ohaus), suction rubber (filler), volume pipette, capillary pipette, spray bottle, stopwatch, measuring pipette, volumetric flask (pyrex), drop pipette, funnel, stative, clamp, aluminium foil, scissors, knife, cloth, gloves, glass bottle, container bottle, vial bottle, ultraviolet lamp, bucket, sieve and petri dish. The materials used in this study are Bajakah Buton (Kakatola) root, Whatman filter paper, distilled water, technical n-hexane (C_6H_{14}), ethyl acetate ($CH_3CH_2OC(O)CH_3$), distilled water (H_2O), KLT plate, 5% hydrochloric acid (HCl), ascorbic acid ($C_6H_8O_6$), 2,2-diphenyl-1-picrylhydrazyl (DPPH) reagent 0,4%, Dragendroff reagent, Mayer reagent, acetone P, acetic acid P, sulfuric acid, sodium hydroxide, 10 mL ether P, 10% iron (III) chloride solution, chloroform and Artemia salina shrimp larvae.

2.2. Microwave Appliance Set

The microwave equipment consists of a microwave, sample container (Erlenmeyer), water pump, stative condenser, and clamps. The microwave is a Panasonic NN-ST342M type with a maximum power source of 800 W. The circuit of the microwave extraction apparatus is presented in Figure 1.



(1)



(2)

Descriptions:

1. Condenser
2. Microwave
3. Sample container (erlenmeyer)
4. Water Pump
5. Clamps
6. Stative

Figure 1. (1) Destruction Devices (2) Distillation Devices

2.3. *Maceration and Microwave Process*

Bajakah Buton (Kakatola) root powder (200 grams) was macerated with distilled water (3800 mL) for seven days. The extract was filtered to obtain a non-viscous maceration liquid. Next, Bajakah Buton (Kakatola) roots were re-extracted with 300 mL of water in an Erlenmeyer using a microwave (600 watts, 100 minutes) at 110 ^{0}C. The extracted macerate was stored and evaporated using microwave distillation to obtain a viscous macerate.

2.4. *Bajakah Buton (Kakatola) Root Water Macerate Extraction*

Bajakah Buton (Kakatola) root macerate was extracted using a separatory funnel, where each 50 mL of macerate was mixed with 50 mL of distilled solution with different polarities. After the separation of the two layers, the remaining maserat was mixed again with the distiller solution and repeated until clear. N-hexane and ethyl acetate distillation solutions were used to obtain extracts from the macerate. The extracts were evaporated with a rotary evaporator, and the yield was measured as the dry weight of Bajakah Buton (Kakatola) root extract.

2.5. *Qualitative analysis by KLT method*

A portion of the sample from each dilution was taken and blotted on a KLT plate with an n-hexane ethyl acetate mobile phase. After elution, it was dried, and the separation pattern was observed under UV light (254 nm - 366 nm). The Rf price was calculated and recorded at UV detection with the equation formula.

$$Rf = \frac{Distance\ travelled\ by\ solute}{Distance\ travelled\ by\ mobile\ phase}$$

2.6. Phytochemical screenings

Alkaloid Screening

The test solution was evaporated to form a residue. The residue was dissolved in 2 N HCl and divided into three tubes. Tube 1 was given dilute acid as a blank, tube 2 with Dragendorff reagent, and tube 3 with Mayer reagent. The formation of orange precipitate (tube 2) and yellow precipitate (tube 3) indicates the presence of alkaloids.

Flavonoid screening

The test solution was moistened with acetone, boric acid fine powder, and oxalic acid, which were added and heated in a water bath. The residue was mixed with ether and observed under UV light 366 nm. Yellow luminescence indicates the presence of flavonoids.

Saponin Screening

The test tube solution was shaken vertically for 10 seconds. The formation of 1-10 cm high foam that is stable for 10 minutes indicates the presence of saponins.

Tannin and polyphenol Screening

The test solution is divided into tube A (as blank), and tube B. Tube B reacts with 10% iron (III) chloride solution; dark blue or greenish black indicates tannins and polyphenols.

Glycoside Screening

The simplicia powder is dissolved in ethyl acetate and evaporated over a water bath, and the remainder is dissolved in anhydrous acetic acid with the addition of sulfuric acid. A blue or green colour indicates the presence of glycosides.

Steroid and triterpenoid Screening

The test solution was evaporated, and the residue was dissolved in chloroform. Anhydrous acetic acid and concentrated sulfuric acid were added to the solution. The formation of brownish or purple rings indicates the presence of triterpenoids, while blue-green rings indicate the presence of steroids.

2.7. Antioxidant Activity Test

The antioxidant test was conducted by incubating DPPH solution (blank), test solution + DPPH, and ascorbic acid + DPPH solution at 37°C for 30 minutes. The absorbance was measured at a wavelength of 517 nm with a UV-Vis spectrophotometer to obtain the inhibition value calculated with the following percentage equation.

$$\%\ resistance = \frac{Blank\ absorption - Sample\ absorption}{Blank\ absorption}\ x\ 100\%$$

2.8. Toxicity Test with the Brine Shrimp Lethality Test (BSLT) Method

Tests were conducted by injecting 100 µL of a solution containing 10-15 A. Salina Leach larvae into each well of the microplate, resulting in a variation of sample concentration. A no-sample control was also performed. Microplates were incubated for 24 hours at 22-29^{O}C. After that, the number of dead larvae was counted by looking at the wells using a flashlight, followed by the addition of 100 µL of methanol into the wells and left for 15 minutes. The LC_{50} value was obtained by calculating the percentage of death of test animals after 24 hours.

$$\%\ larvae = \frac{number\ of\ dead\ larvae}{number\ of\ test\ larvae}\ x\ 100\%$$

The next process involves finding the probit number through the probit table. A graph is created with the log of concentration on the x-axis and the percentage mortality in probit units on the y-axis. The LC50, which is the concentration that causes 50% mortality of the test animals, is calculated using the linear regression equation y = a + bx.

3. Results and Discussion

3.1. *Preparation and Extraction of Bajakah Buton (Kakatola) Root using microwave-assisted extraction (MAE)*

In this study, the roots of the Bajakah Buton (Kakatola) plant were washed and dried in the sun to reduce moisture content and prevent enzymatic reactions. The roots were pulverized into simplicia powder with a blender. The extraction process begins by wetting the powdered simplisia using an aqueous solvent to facilitate the penetration of the liquid into the pores of the simplisia. After maceration, the macerate is filtered to produce a liquid macerate, which is extracted using a microwave in a transparent glass reactor. Microwaves cause collision of water molecules, generate energy, and increase the temperature during irradiation [5]. After extraction, the simplicia are separated from the filtrate with filter paper. The blackish-brown filtrate contains water and bioactive compounds. A microwave was used to evaporate the solvent from the macerate, with the temperature maintained to keep the bioactive compounds functioning as antioxidants, resulting in a dark brown viscous macerate [8].

3.2. Liquid-Liquid Multistage Extraction

The yield of the macerate obtained was 6,725% (180 g thick extract from 200 g simplicia). Based on these results, the macerate was selected for liquid-liquid multistage extraction, resulting in two extract components. The extraction results show that the most Bajakah Buton (Kakatola) root extract is ethyl acetate extract (42.784% b/v), while the extract with n-hexane does not contain any compounds (0% b/v) (Table 1).

Table 1. Yield results of n-hexane and ethyl acetate extracts.

No.	Nama Ekstrak	% yield (% b/v)
1.	n-hexane	0
2.	Ethyl acetate	42,784

3.3. Qualitative analysis by KLT method

Thin Layer Chromatography (KLT) analysis on the extract was carried out using KLT plates eluted using a mixture of ethyl acetate and n-hexane in a ratio of 7:3. In the results of the analysis under UV light 254 nm, two stains were seen with Rf values of 0.1 and 0.46 respectively, as illustrated in Figure 2. The Rf value reflects the extent to which a compound moves on a KLT plate relative to its solvent. Compounds with smaller Rf values tend to be more retained by the solvent or migrate less over the KLT plate, while compounds with larger Rf values migrate more easily. Fluorescence under 254 nm UV light indicates there are at least two conjugated double bonds, while fluorescence under 365 nm UV light indicates the presence of longer conjugated double bonds called chromophores, with autochrome groups in the compound structure.

Figure 2. KLT profile of ethyl acetate extract of Bajakah Buton (Kakatola) root. A) under UV light 254 nm; B) under UV light 365 nm

3.4. Phytochemical Screening

Phytochemical screening was conducted on Bajakah Buton (Kakatola) root extract to identify secondary metabolites with potential antioxidant and anticancer activities as part of the toxicity test. The results of the phytochemical screening are documented in the table.

Table 2. Phytochemical screening results of ethyl acetate extract of Bajakah Buton (Kakatola) root

Phytochemical Test	**Positive Results According to Literature**	**Results**
	Formed orange precipitate (Dragendorff reagent)	
Alkaloid	Formed white precipitate (Mayer Reagent)	-
	Formed yellow precipitate (Wagner Reagent)	
Flavonoid	Discoloration of the control tube	++
Saponin	There is a foam that lasts ±10 minutes with a height of 10 cm.	-
Terpenoid	Brownish or violet rings	+

Tannin	A dark blue or greenish-black colour is formed.	++
Glycoside	The dark blue or green colour formed.	+
Polyphenol	A dark blue or greenish-black colour is formed.	++
Steroid	Formation of a blue-green ring	-

Description:

1. ++ sign: contained more compounds/concentrated colour
2. + sign: contained compounds/light colour
3. sign -: not contained compounds / no colour formed

Phytochemical screening of ethyl acetate extract of Bajakah Buton (Kakatola) roots identified secondary metabolite compounds such as flavonoids, glycosides, phenols, and tannins. In general, the secondary metabolites found were polar and soluble in the polar solvents used, namely water and ethyl acetate. Phytochemical screening of ethanol extract of Bajakah Tampala stem by maceration method showed the presence of flavonoids, saponins, terpenoids, tannins, phenols, and steroids without alkaloids [3]. In contrast, a study by Jabbar [8] stated that the ethanol extract of Bajakah Tampala from maceration contained alkaloids, flavonoids, and steroids. Susanto and Zayani's study [9] showed that Bajakah Tampala extract from maceration with methanol contained alkaloids, flavonoids, terpenoids, and phenolics. In conclusion, in general, Bajakah Buton (Kakatola) and Bajakah Tampala extracts have similar compounds.

3.5. Antioxidant Activity Test

Testing the activity of the Bajakah Buton (Kakatola) root extract was carried out by measuring the absorbance of each test solution using a UV-Vis Spectrophotometer at the maximum wavelength. Based on the research that has been done, the results of antioxidant activity testing of ascorbic acid standard solution are shown in Table 3.

Table 3. Antioxidant Activity Test Results of Ascorbic Acid

Concentration (ppm)	Average absorbance	Inhibition (%)	IC_{50} ppm
20	0,336	54,042	
40	0,288	60,657	
60	0,209	71,396	
			13,797
80	0,132	82,003	
100	0,071	90,283	
Blanko	0,731		

Based on the research that has been done, the results of antioxidant activity testing of Bajakah Buton (Kakatola) root extract are shown in Table 4.

Table 4. Antioxidant Activity Test Results of ethyl acetate root extract of Bajakah Buton (Kakatola)

Concentration (ppm)	Average absorbance	Inhibition (%)	IC_{50} ppm
20	0,604	17,381	
40	0,585	19,913	
60	0,499	31,775	100,317
80	0,436	40,397	
100	0,355	51,369	
Blanko	0,731		

Antioxidant activity testing on Bajakah Buton (Kakatola) root extract using ethyl acetate solvent and ascorbic acid standard solution was carried out with various concentrations whose absorbance was measured using a UV-Vis spectrophotometer at a wavelength of 517 nm. Based on the research that has been done, the relationship between variations in the concentration of standard solution and % inhibition can be seen in Figure 3.

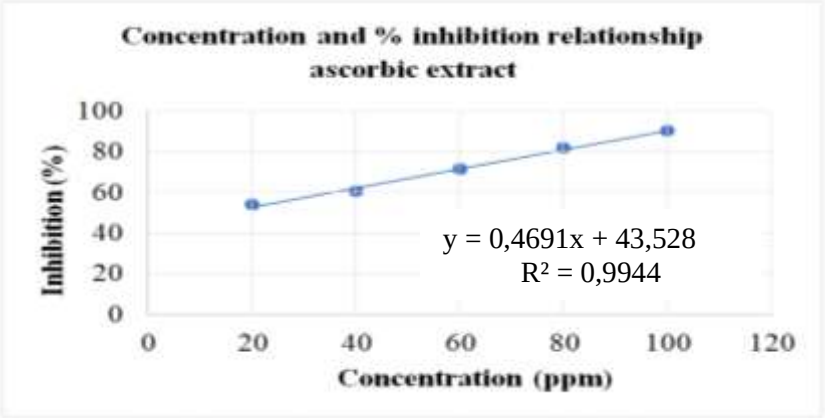


Figure 3: Graph of concentration relationship and % inhibition of ascorbic acid solution

Figure 3 shows the relationship curve between the concentration of ascorbic acid standard solution and antioxidant activity. The higher the concentration of ascorbic acid, the higher its silencing activity against free radicals. This is due to the increase in hydrogen atoms from the hydroxy group, which aids in the reduction of DPPH radicals to DPPH-H. Ascorbic acid, with two hydroxy groups, is more effective in donating hydrogen atoms. Based on the linear regression equation y = ax + b, the IC_{50} value for an ascorbic acid solution was 13,797 ppm. The relationship between concentration and % inhibition of Bajakah Buton (Kakatola) root extract can be seen in Figure 4.

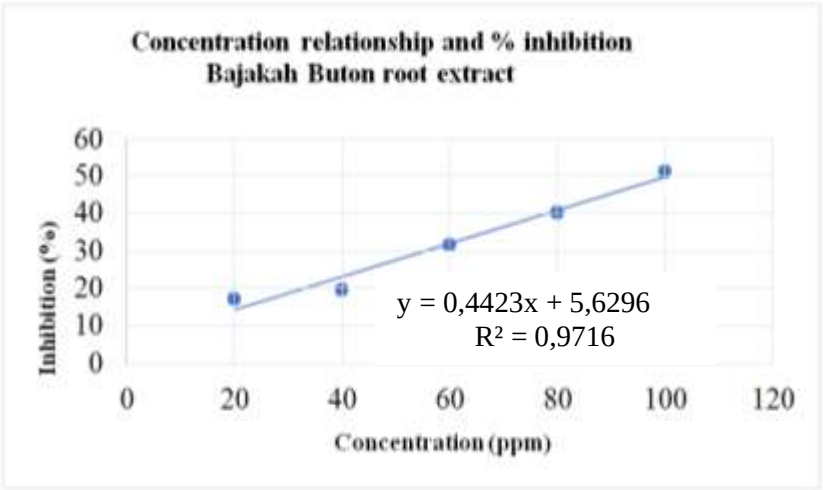


Figure 4. Concentration relationship curve and % inhibition of Bajakah Buton (Kakatola) root extract

Figure 4 displays the concentration curve of Bajakah Buton (Kakatola) root extract against antioxidant activity. The highest activity was at a concentration of 100 ppm, the lowest at 20 ppm. Increasing extract concentration increases secondary metabolite compounds, donating H atoms to DPPH radicals and forming stabilized DPPH-H. The more stabilized DPPH compounds, the colour intensity decreases the low absorbance value, increasing the percentage of antioxidant activity. The linear regression equation y = ax + b shows the IC_{50} of Bajakah Buton (Kakatola) root extract is 100,317 ppm, indicating high antioxidant power. This value indicates the concentration at which the antioxidant activity reaches 50%, and the result of the equation shows that the antioxidant power of the extract is rated as high. Therefore, Bajakah Buton (Kakatola) root extract has a fairly strong antioxidant power, which could have positive implications for the protection of cells from oxidative damage. According to Arysanti et al. [10], the IC_{50} value of a compound determines its antioxidant strength. $IC_{50} \leq 50$ ppm is considered very strong, 50-100 ppm as strong, 101-150 ppm as moderate, and > 151 ppm as weak. Based on the IC_{50} value, ascorbic acid is very strong because it is ≤ 50 ppm, purer and has two hydroxyl groups. Bajakah Buton (Kakatola) root extract is also strong with IC_{50} values between 0-100 ppm [11].

3.6. Acute Toxicity Test

The acute toxicity test in this study used the BSLT (Brine Shrimp Lethality Test) method with A. salina Leach shrimp larvae in a 96-well microplate. The number of samples used was minimal (0.6 mg) [12]. The A. salina larvae tested were 48 hours after hatching because, at the age of 24 hours, the mouth and digestive tract were not fully formed. Larvae aged 48 hours have a perfect mouth and digestive tract, as well as increased endurance [13]. Bajakah Buton root extract was prepared in seven concentration variations as the mother solution. A control without a sample was also prepared [14]. Larvae mortality data were processed using Excel analysis based on the Finney formula to determine the LC_{50} value with a confidence level of up to 95%. The results of the toxicity test of the Bajakah Buton (Kakatola) root extract can be found in Table 5.

Table 5. Results of BSLT Toxicity Test of Bajakah Buton (Kakatola) Root Extract

Concentration (ppm)	**Log C**	**Number of Live Larvae (Initial)**			**Total Dead Larvae**	**Larval Mortality (%)**	**LC_{50}**
X		1	2	3			
0 (Control)		10	10	10	0		
7,8125	0,89	10	10	10	5	16,7	
15,625	1,19	10	10	10	15	50	11,232 ppm (<1000 ppmor toxic)
31,25	1,49	10	10	10	30	100	
62,5	1,8	10	10	10	30	100	
125	2,1	10	10	10	30	100	
250	2,4	10	10	10	30	100	
500	2,7	10	10	10	30	100	

Figure 5 shows that the concentration of the extract affects the mortality rate of the test larvae, especially at a concentration of 500-31,25 µg/mL with the highest mortality rate. In the Brine Shrimp Lethality Test (BSLT), the level of toxicity is determined by the LC_{50} value, which is the concentration causing 50% mortality [15]. Compounds are considered active if they cause high mortality, with smaller LC_{50} values indicating greater mortality. The extract against A. salina Leach larvae is toxic if $LC_{50} \leq$ 1000 µg/mL, not toxic if $LC_{50} \geq 1000$ µg/mL. Toxicity is categorized as LC_{50} value ≥ 200 µg/mL and highly toxic if $LC_{50} \leq 30$ µg/mL [7].

The toxicity test of Bajakah Buton (Kakatola) root extract showed an LC_{50} of 11,232 ppm, indicating potential acute toxicity based on the BSLT method. This LC_{50} indicates that the concentration can cause 50% mortality of A. salina Leach larvae. In the context of potential use as an anticancer agent, a relatively high LC_{50} value indicates a low level of toxicity to the test organism. These findings support the potential of Bajakah Buton (Kakatola) root extract as an anticancer agent and motivate further research.

Tests were conducted on 48-hour-old A. salina Leach larvae when sensitivity to the test compounds reached maximum levels. Toxic compounds entering through oral and dermal routes cause changes in concentration gradients inside and outside the cell. Once absorbed into body tissues, the compounds invade cells, causing functional and metabolic damage to the larvae. The mechanism of larval mortality

is thought to involve these compounds, such as stomach toxins or gastric toxins, causing fatal damage to A. salina Leach cells.

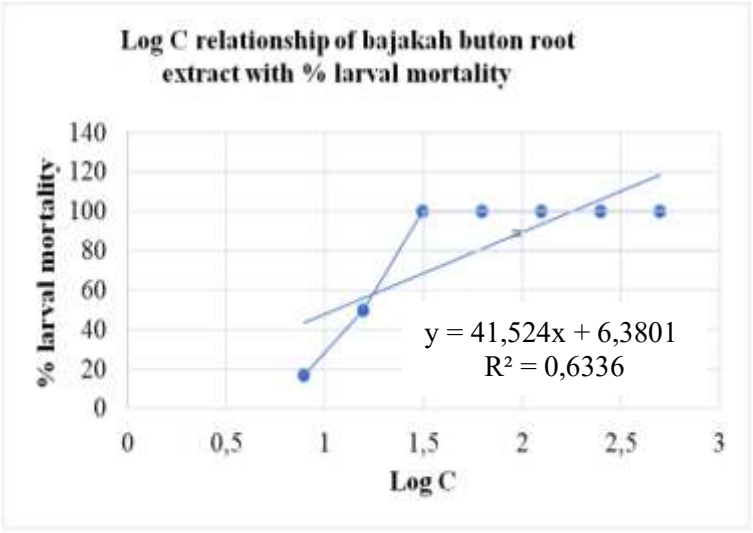


Figure 5: Log concentration curve of Bajakah Buton (Kakatola) root extract with % larval mortality

4. Conclusion

Phytochemical screening of ethyl acetate extract of Bajakah Buton (Kakatola) root identified flavonoids, saponins, glycosides, phenols, and tannins. DPPH antioxidant testing showed the IC_{50} values of the extract and vitamin C control were 100,317 ppm and 13,797 ppm, respectively, categorized as strong antioxidants (IC_{50} 0-100 ppm). An acute toxicity test using the BSLT method showed toxic activity (LC < 1000 ppm) with LC_{50} 11,232 ppm. This research will continue to be developed, so it is expected to be an important breakthrough in the field of cancer treatment [16].

References

[1] D. W. Rousdy, E. Rusmiyanto, P. Wardoyo, and S. Ifadatin, "Anti-inflammatory Activity of Bajakah Stem (Spatholobus littoralis Hassk.) Ethanolic Extract in Carrageenan-Induced Paw Edema Mice," vol. 7, no. May, pp. 66–74, 2022, doi: 10.15575/biodjati.v7i1.14126.

[2] M. I. Arsul, N. Syamsi, N. Putri, N. Afiah, and A. Nur, "Current Research on Biosciences and Total phenolic , flavonoid , and antioxidant capacity of bajakah (Spatholobus littoralis Hassk)," vol. 4, no. 1, pp. 2020–2023, 2022, doi: 10.5614/crbb.2022.4.1/VRJ3X4LF.

[3] N. Hidayah and G. I. Dalimunthe, "Evaluation of the Antihyperuricemia Activity of Bajakah Tampala Stem Ethanol Extract (Spatholobus littoralis Hassk.) in Male White Mice (Mus musculus)," vol. 01, no. 01, pp. 80–89, 2022.

[4] R. G. Mahardika, O. Roanisca, and U. B. Belitung, "Microwave-Assisted Extraction of Polyphenol Content from Leaves of Tristaniopsis merguensis," vol. 19, no. 2, pp. 110–119, 2019, doi: 10.22146/ajche.50448.

[5] S. R. Pratiwi and O. Roanisca, "Stannum : Jurnal Sains dan Terapan Kimia Total Phenolic and Flavonoid Test of Gleichenia linearis Leaf Extract as Antioxidant Using Microwave Assisted Extraction Uji Total Fenolik dan Flavonoid Ekstrak Daun Resam (Gleichenia linearis) Sebagai Antioksida," vol. 5, no. 2, pp. 75–82, 2023, doi: 10.33019/jstk.v5i2.4318.

[6] A. Rizqiana, J. Kimia, F. Matematika, P. Alam, and U. N. Semarang, "Indonesian Journal of Chemical Science Analysis of Antioxidant Activity on the Ethanol Extract of Indonesian Tropical Forest Plants," vol. 12, no. 1, pp. 47–57, 2023.

[7] I. Firman, B. Yuliana, and C. A. E-mail, "Acute Oral Toxicity Evaluation (Spatholobus littoralis Hassk) in Mice of Extract Bajakah," no. Na CMC, pp. 1–5, 2023.

[8] A. Jabbar, "EFFICACY OF BAJAKAH TAMPALA ETHANOL EXTRACT , A TYPICAL

PLANT OF KALIMANTAN ISLAND (BORNEO), AGAINST CANDIDA," 2022.
[9] B. Novita, A. Susanto, and N. Zayani, "THE EFFECT OF BAJAKAH (SPATHOLOBUS LITTORALIS HASSK) STEM EXTRACT ON CALCULATION OF LEUKOCYTE IN MICE (MUS MUSCULUS)," pp. 1100–1106, 2021.
[10] R. D. Arysanti, B. Wirjatmadi, D. Winarni, and U. Airlangga, "Jurnal Kesehatan Prima," vol. 16, no. August, pp. 143–148, 2022.
[11] W. Wuryanti and I. Setiawan, "A Model for Improving Human Resource Performance in the Context of Knowledge Donating," *J. Din. Manaj.*, vol. 8, no. 2, pp. 208–215, 2017, doi: 10.15294/jdm.v8i2.12761.
[12] M. A. Ghifari, E. Fachriyah, K. Anam, and D. Nopitasari, "Identification of Alkaloid Compounds from Cytotoxic Active Fraction in Peperomia pellucida," vol. 5, no. January, pp. 208–213, 2021, doi: 10.35472/jsat.v5i1.394.
[13] M. Latief, M. Muhaimin, and H. Amanda, "Isolation of alkaloids compound of ethanol extract of mangrove perepat (S. alba) root and its antibacterial activity Isolasi senyawa alkaloid dari ekstrak etanol akar mangrove perepat (S . alba) dan aktivitas antibakterinya," vol. 17, no. 1, pp. 9–18, 2021.
[14] K. C. Dewi, T. Y. Hendrawati, W. D. Rusanti, and F. Sari, "Determination of Used Cooking Oil ' s Toxicity Level by Adding Nutmeg Leaves (Myristica Fragrans Houtt) Extract," no. November, pp. 1–6, 2021.
[15] C. Biochemistry, L. Ambarsari, W. Nurcholis, and L. K. Darusman, "Characterization and Toxicity of Temulawak Curcuminoid Nanoparticles," vol. 3, no. 1, pp. 43–53, 2016.
[16] A. Yudistira and F. Wehantow, "ACUTE TOXICITY TEST OF ETANOL EXTRACT FROM MANGOSTEEN PERICARP (Garcinia mangostana L.) AGAINST ARTEMIA SALINA LEACH LARVAE USING BRINE SHRIMP LETHALITY TEST (BST)," vol. 2, no. 01, pp. 97–101, 2013.

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Hardness and Microstructural Characterization of Pack Carburizing AISI 1020 Low-Carbon Steel by Temperature and Holding Time Variations

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Abstract. Recently, low-carbon steel is often used as a basic material for automotive spare parts on the market. This study aims to improve the quality of carbon steel which is not inferior to that made by manufacturers where the price is relatively affordable by carrying out pack carburizing. This study used the pack carburizing method, AISI 1020 low-carbon steel as a starting material and used fine coconut shell charcoal powder as a carbon source mixed with Na_2CO_3 as an energizer. Pack carburizing uses temperature variations of 850ºC, 875ºC and 900ºC, aims to find out how the results of hardness and microstructure values for variations of temperature and holding time. And also use SAE 20w-40 oil as a quenching medium. The highest hardness results were obtained on specimens with a heating temperature of 900ºC with a holding time of 60 minutes, with an average hardness value of 54.21 HRC. Accompanied by the phase formed, namely 61% pearlite 39% ferrite.

Keywords: heat treatment, pack carburizing, AISI 1020, hardness, microstructural

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1. Introduction

The need for metal materials in the industry is currently increasing. The metal material must have good mechanical and physical properties. However, metal materials that exist today do not fully have the desired properties and characteristics. The industrial sector is highly dependent on the use of steel, for example, the use of steel in machines and construction components. This proves that steel currently plays an important role in technological progress and human life. A treatment process is needed for steel to obtain changes in the mechanical properties and physical properties of steel so that it can be used as needed [1], and [2].

Steel is a Fe–C alloy which may contain other alloying elements, according to the application. Even low variations in composition can lead to large differences in mechanical properties, as the final structure may change according to the manufacturing process and heat treatment cycle applied [3]. Therefore, carbon steel is required to be modified or improved in properties such as hardness on the surface and

wear resistance to friction.
AISI 1020 steel is included in the low carbon steel class which is soft and weak in strength but has very good ductility and toughness. AISI 1020 steel is commonly used in gears, shafts, and bolts because of its ease of machining and ductility [4]. The chemical composition of AISI 1020 steel is shown in the table 1.

Table 1. Chemical composition of AISI 1020 steel [4]

Fe	C	Mn	Si	P	S	Ni	Cu
Balance	0.20	0.32	0.21	0.009	0.042	0.15	0.15

In many usage applications, ductility or toughness is often needed, in addition to its wear resistance properties. In this case, it is necessary to adjust the hardening process through heat treatment of the steel to obtain increased hardness in certain areas, wear resistance, and a ductile and tough core area [5]. Heat treatment is a process to change the metal structure by heating the specimen in an electric muffle furnace at the recrystallization temperature for a certain period and then cooling it in a cooling medium such as air, water, brine, oil, and diesel fuel, each of which has a different cooling density. One way to increase the surface hardness of steel is through the process of adding carbon elements which are heated to a temperature and held at that temperature for a certain time, which is known as the pack carburizing process [6].

Research related to pack carburizing of metals has been carried out by previous researchers, Sundari et al. [7] analyzed the effect of pack carburizing on the mechanical properties of motorcycle sprockets with a catalyst using gelam wood charcoal and mussel shell powder. Pack carburizing is carried out at temperatures of 850°C and 900°C with cooling media in the form of water, used oil, silicon oil, and air. Based on the research results, it was found that the increase in the optimum hardness value of the imitation sprocket with the carburizing process at a temperature of 900 °C with a holding time of 1 hour with a water cooling, the hardness increased by 43.07% compared to the imitation sprocket without the carburizing process, and 13.94% higher above the hardness value of the original sprocket.
Research on ST41 steel was treated with pack carburizing with temperature variations (700°C, 750°C, and 800°C) and holding time for 30 minutes in reference [5]. This study analyzes the effect of temperature in the pack carburizing process on hardness and impact strength. Based on the research results, it was found that the highest hardness value was obtained in samples with a heating temperature of 800 °C, which was 32 HRC and had an impact strength value of 1.993 J/mm^2. When compared to the sample before the pack carburizing process, there was an almost double increase in hardness while the impact strength value also increased by 10%. Based on the results of these previous studies, temperature and holding time have an impact on the mechanical properties and microstructure of steel that is given heat treatment in the form of pack carburizing. Therefore, in this paper research is carried out on the effect of temperature and holding time on the hardness and microstructure of low-carbon steel AISI 1020 by providing heat treatment in the form of pack carburizing.

The purpose of this study was to analyze the hardness and microstructure of low carbon steel AISI 1020 after heat treatment in the form of pack carburizing with temperature variations of 850°C, 875°C, and 900°C as well as variations in holding time 40, 50, and 60 minutes.

2. Methods

2.1. Materials

Materials in this study is used AISI 1020 carbon steel purchased from SeAH Besteel Corporation with a chemical composition as shown in table 1, charcoal powder from refined coconut shells as a carbon source mixed with Na_2CO_3 from EMSURE® ISO MERCK as an energizer and oil SAE 20w-40 as a cooling media in the pack carburizing process.

2.2. Specimen Preparation

The pack carburizing process was carried out at varying temperatures of 850^0C, 875^0C and 900^0C with varying holding times of 40, 50 and 60 minutes. AISI 1020 steel is cut to a diameter of 25,4 mm and thickness of 30 mm as shown in Figure 1.a. The preparation of the specimen as shown in Figure 1 was carried out carefully and measured using a screw micrometer to ensure that the specimen dimensions were uniform. The vessel for the pack carburizing process is made of low carbon steel with a thickness of 10 mm with a length of 500 mm, a width of 100 mm and a height of 100 mm as shown in Figure 1.b. Later, the AISI 1020 steel specimen is inserted into the vessel and then subjected to a heat treatment process using a muffle furnace with control of temperature in 850^0C, 875^0C and 900^0C. 30 specimens were prepared, 3 specimens of AISI 1020 steel without pack carburizing (raw material) and 27 specimens for the pack carburizing process with temperature and holding time shown in table 2. Specimen for hardness test using ASTM E18-15 [8] standard for Rockwell hardness testing.

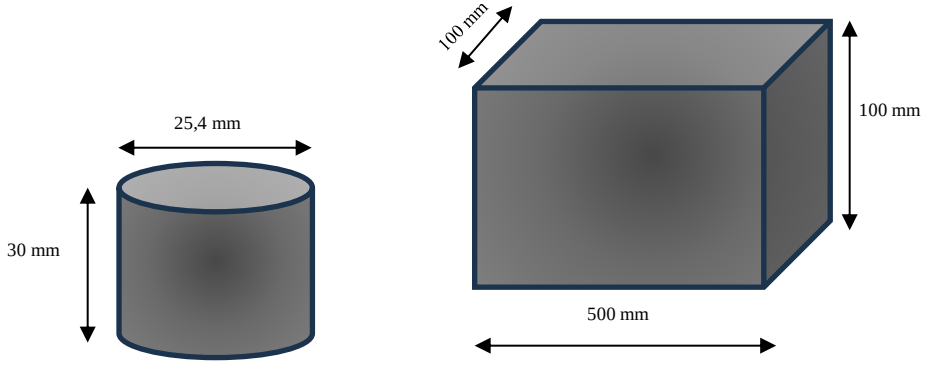


Figure 1. (a) specimen of pack carburizing; (b) vessel for pack carburizing process

Table 2. Specimens test

No	Temperature (ºC)	Holding Time (minute)	Specimens test
1	850	40	3
	850	50	3
	850	60	3
2	875	40	3
	875	50	3
	875	60	3
3	900	40	3
	900	50	3
	900	60	3

2.3. Pack Carburizing Process

Pack carburizing process begins with charcoal powder from refined coconut shells as a carbon source mixed with Na_2CO_3 as an energizer. addition of Na_2CO_3 which functions as an activator to speed up the pack carburizing process. The activator used is 20% of the total carbon weight. The prepared activated carbon is carried out mixing with the specimen in a previously made vessel. The pack carburizing process is carried out at temperatures of 850^0C, 875^0C and 900^0C with and holding times of 40, 50 and 60 minutes in a heating furnace. Then the specimen was cooled quickly in SAE 20w-40 oil media and the surface of the specimen was smoothed using a grinding machine. Then the specimen is ready to be tested for hardness and characterization of its microstructure.

2.4. Hardness and Microstructural Characterization

In this research, hardness testing used a Bowers Rockwell Hardness Tester EW-200 hardness testing machine. Hardness testing uses the Rockwell method with an illustration of the testing process as shown in Figure 2. Microstructural characterization was carried out by taking pictures using an optical microscope with 500x magnification, then the optical microscope images were analyzed regarding the microstructure using ImageJ.

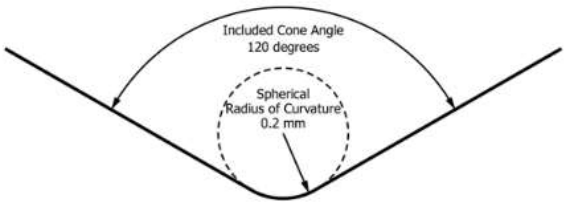


Figure 2. Illustration of Rockwell hardness test [9]

3. Results and Discussion

3.1. Hardness Characterization

Characterization of hardness values uses Rockwell hardness testing regarding ASTM E18-15 standards. The results of the hardness testing are then presented in Figure 1 for a temperature of 850°C, Figure 2 for a temperature of 875°C, and Figure 3 for a temperature of 900°C.

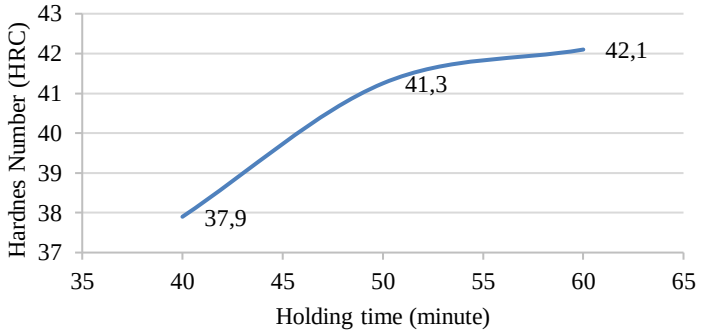


Figure 3. Hardness number (HRC) vs Holding time at 850°C pack carburizing temperature

AISI 1020 steel is given pack carburizing heat treatment with heating at 850°C with varying holding times of 40, 50, and 60 minutes respectively as shown in Figure 3. It can be seen from Figure 3 that a holding time of 40 minutes has a hardness value of 37.9 HRC, 50 minutes has a hardness value of 41.3 HRC and 60 minutes has a hardness value of 42.1 HRC. It can be concluded that the highest hardness value obtained in the pack carburizing process with a temperature of 850°C was at a holding time of 60 minutes of 42.1 HRC. Research related to the pack carburizing process on AISI 1020 steel at a temperature of 850 C was also carried out by Joni [10], the pack carburizing process was carried out with a holding time of 3 hours then quenching was carried out at a temperature of 840 C. The hardness value was obtained at 49 HRC. The higher hardness value obtained is possible due to the quenching process and longer holding time.

Pack carburizing process by heating 875°C with holding time variations of 40, 50 and 60 minutes respectively as shown in Figure 4. It can be seen from Figure 4, a holding time of 40 minutes has a hardness value of 42.6 HRC, 50 minutes has a hardness value of 43.4 HRC and 60 minutes has a hardness value of 43.8 HRC. It can be concluded that the highest hardness value obtained in the pack carburizing process with a temperature of 875°C was at a holding time of 60 minutes of 43.8 HRC. Research related to the pack carburizing process on AISI 1020 steel at a temperature of 875 C was also carried out by Fikri, et al [11]. The pack carburizing process is carried out with a holding time of 120

minutes. The hardness value was 43 HRC. The lower hardness value obtained is possible because the cassava peel waste activator used did not work optimally when compared with the activator in this study. With the same temperature, namely 875 C with a shorter holding time, the hardness value obtained in this study was higher.

Pack carburizing process by heating 900ºC with holding time variations of 40, 50 and 60 minutes respectively as shown in Figure 5. It can be seen from Figure 5, a holding time of 40 minutes has a hardness value of 53.6 HRC, 50 minutes has a hardness value of 53.7 HRC and 60 minutes has a hardness value of 54.2 HRC. It can be concluded that the highest hardness value obtained in the pack carburizing process with a temperature of 900ºC was at a holding time of 60 minutes of 54.2 HRC. Research related to the pack carburizing process on AISI 1020 steel at a temperature of 900 C was also carried out by several researchers including Fikri, et al[11]. Obtained a hardness value of 48.2 HRC, Joni [10] with a hardness value of 56 HRC, Nasution, et al[12]. Obtained a hardness value of 55 HRC, Rizky, et al[13]. Obtained a hardness value of 48.2 HRC and Setiawan, et al[14]. The hardness value was 58 HRC. The differences in hardness values obtained by several researchers are due to the use of activators and the presence or absence of a quenching process in the pack carburizing process.

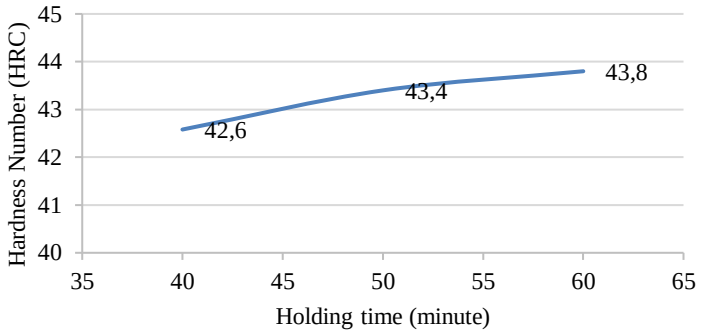


Figure 4. Hardness number (HRC) vs Holding time at 875ºC pack carburizing temperature

Based on temperature variations in the pack carburizing process of 850ºC, 875ºC, and 900ºC which are shown in Figures 3 to Figure 5, the hardness values are different. Of the three temperature variations of 850ºC, 875ºC, and 900ºC, each has the best hardness value at a holding time of 60 minutes of 42.1 HRC, 43.8 HRC, and 54.2 HRC. It can be concluded that the temperature and holding time in the pack carburizing heat treatment process on AISI 1020 steel has an influence on the hardness value of AISI 1020 steel. This is in line with research conducted by several researchers that temperature and holding time can influence the increase in the hardness value of AISI 1020 steel in the pack carburizing process. [10-14].

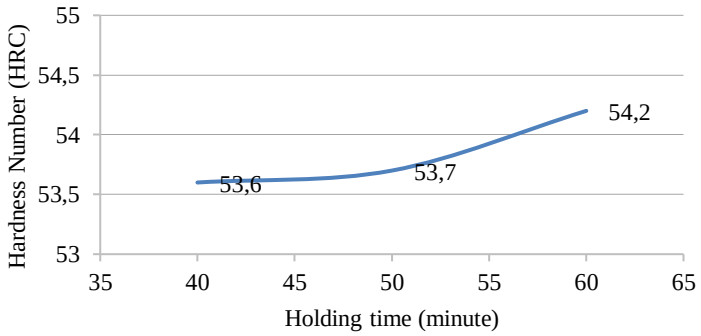


Figure 5. Hardness number (HRC) vs Holding time at 900ºC pack carburizing temperature

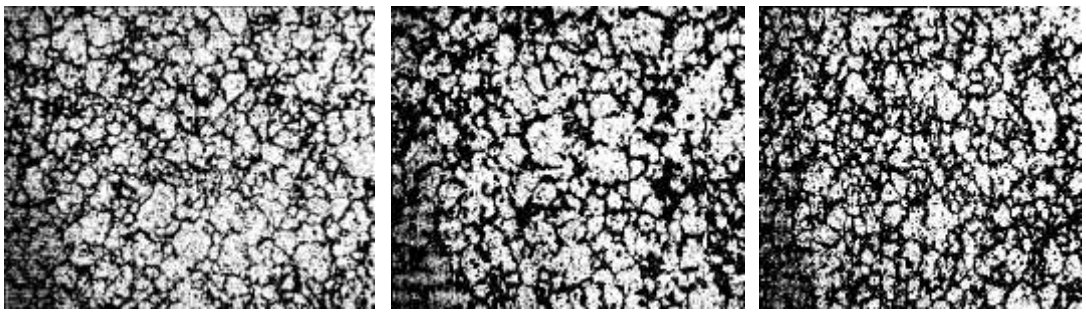
Taking a hardness testing point located on the surface of the specimen, the higher the hardness value obtained, but the deeper it is from the surface, the smaller the hardness value obtained. If we look at the microstructure image, this can happen because the concentration of carbon diffusion tends to be more

concentrated in the surface area and the deeper the penetration, the lower the concentration of carbon addition to the metal. So the hardness value tends to be higher in the surface area even in areas that are equally affected by the addition of carbon in the Pack Carburizing process [15].

Use of Na_2CO_3 mixed into solid carbon. Where from this mixture the reaction occurs during heating as follows: Na_2CO_3 + Heat splits into Na_2O + CO_2 then CO_2 will separate itself from Na_2O, then CO_2 will meet charcoal which is carbon (C) and the CO_2 + C reaction will occur then 2CO in the environment The heat will tend to change back into CO_2 and release the C element. If this reaction is within the steel structure, the C will be left behind. C left by CO_2 gas will be captured by Fe [16]. This event is referred to as element C dissolving in steel. The reaction that occurs is 2CO + Heat becomes CO_2 + C (dissolves in steel). The important role of sodium carbonate when mixed with charcoal is as a provider of CO_2 gas [17].

3.2. Microstructural Characterization

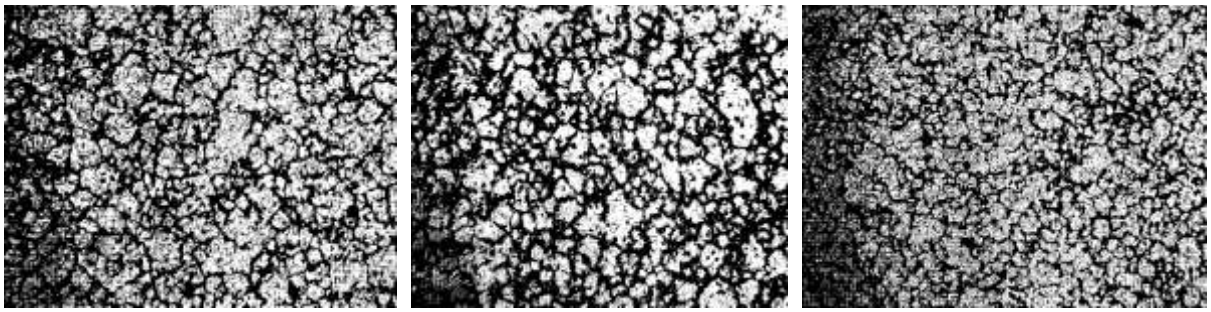
In this research, metallographic testing was carried out on pack carburizing specimens with a mixture of 80% activated carbon in the form of coconut shell charcoal powder and 20% energizer mixture in the form of Na_2CO_3 and this research focused on changes in the microstructure in parts that were not affected by the case of depth. Images were taken using an optical microscope with 500x magnification, then the images were investigated using ImageJ software to determine the ferrite and pearlite content of AISI 1020 steel after the pack carburizing heat treatment process. This is also done by several researchers in identifying microstructures resulting from microscope images [18], [19], and [20].



(a) (b) (c)

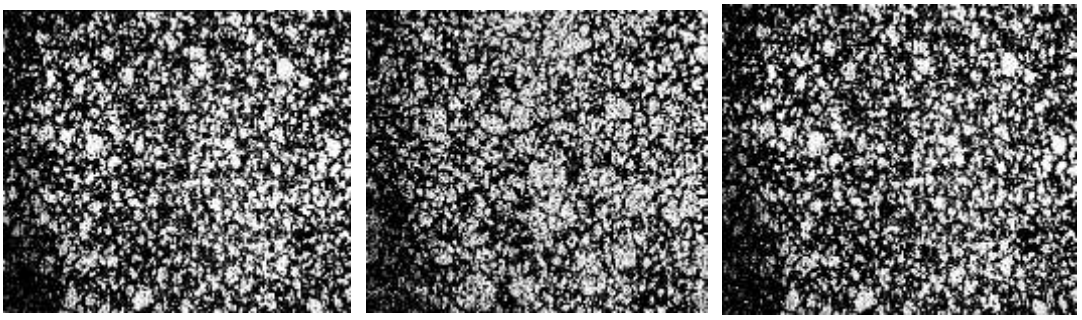
Figure 6. Microstructure image of AISI 1020 steel after pack carburizing 850^{o}C; (a) 40 minute; (b) 50 minute; (c) 60 minute

Figure 6 shows the Microstructure image of AISI 1020 steel after pack carburizing 850^{o}C, Figure 6.a shows a holding time of 40 minutes producing 46% Pearlite 54% Ferrite, Figure 6.b shows a holding time of 50 minutes producing 51% Pearlite and 59% Ferrite, and Figure 6.c shows a holding time of 60 minutes produces 54% Pearlite and 46% Ferrite.



(a) (b) (c)

Figure 7. Microstructure image of AISI 1020 steel after pack carburizing 875^{o}C; (a) 40 minute; (b) 50 minute; (c) 60 minute



(a) (b) (c)

Figure 8. Microstructure image of AISI 1020 steel after pack carburizing 900°C; (a) 40 minute; (b) 50 minute; (c) 60 minute

Figure 7 shows the Microstructure image of AISI 1020 steel after pack carburizing 875°C, Figure 7.a shows a holding time of 40 minutes producing 52% Pearlite and 48% Ferrite, Figure 7.b shows a holding time of 50 minutes producing 54% Pearlite and 46% Ferrite, and Figure 7.c shows a holding time of 60 minutes produces 54% Pearlite and 46% Ferrite.

Figure 8 shows the Microstructure image of AISI 1020 steel after pack carburizing 900°C, Figure 8.a shows a holding time of 40 minutes producing 61% Pearlite and 39% Ferrite, Figure 8.b shows a holding time of 50 minutes producing 60% Pearlite and 40% Ferrite, and Figure 8.c shows a holding time of 60 minutes produces 61% Pearlite and 39% Ferrite.

Based on the explanation in Figures 6 to Figure 8, it can be seen that the pearlite content increases along with increasing temperature and holding time in the pack carburizing process. The highest pearlite content was obtained in the pack carburizing process at a temperature of 900°C with a holding time of 40 and 60 minutes.

4. Conclusion

Based on the analysis of the results and discussions that have been carried out, it can be concluded that temperature and holding time have an influence on the hardness and microstructure values of AISI 1020 steel. As the temperature and holding time increase in the pack carburizing process, the hardness and microstructure values in the form of pearlite also increase and the highest hardness value was obtained at a temperature of 900°C with a holding time of 60 minutes of 54.2 HRC, while the highest pearlite content was obtained at 900°C with a holding time of 40 and 60 minutes of 61% of pearlite.

References

[1] A. Nurharyanto, D. A. Halim, and E. Surojo, "Perbandingan Nilai Kekerasan Baja Karbon Rendah pada Proses Pack Carburizing dengan Media Arang Sekam Padi dan Arang Tempurung Kelapa," *Tek. J. Sains dan Teknol.*, vol. 15, no. 1, p. 39, 2019.

[2] R. R. Sakura and D. D. Iskandar, "Pengaruh Variasi Karbon Aktif dan Waktu Tahan Terhadap Kekerasan Material JIS G-3123 Menggunakan Metode Pack Carburizing," vol. 2, no. 1, pp. 31–35, 2017.

[3] A. Azwinur, M. Yudi, and Z. Zulkifli, "Pengaruh media pendingin terhadap kekerasan dan ketangguhan hasil pengelasan material AISI 1050 pada proses las MAG," *J. POLIMESIN*, vol. 18, pp. 124–130, 2020.

[4] N. Maharjan, W. Zhou, and N. Wu, "Direct laser hardening of AISI 1020 steel under controlled gas atmosphere," *Surf. Coatings Technol.*, vol. 385, no. January, p. 125399, 2020.

[5] R. Ramlan, "Efek Variasi Suhu Pack Carburizing Baja St 41 terhadap Kekerasan dan Kekuatan Impak," *Pist. J. Tech. Eng.*, vol. 4, no. 1, pp. 34–37, 2020.

[6] M. M. A. Bepari, *Carburizing: A Method of Case Hardening of Steel*, vol. 2–3. Elsevier Ltd., 2017.

[7] E. Sundari, R. Fahlevi, and B. Besar, "Mekanis Sprocket Imitasi Sepeda Motor Menggunakan

Katalisator," *J. Austenit*, vol. 10, no. 2, pp. 72–78, 2018.
[8] N. Nurlina, R. M. Bisono, and D. Irawan, "Carburizing Menggunakan Media Arang Serbuk Gergaji Kayu Untuk Material Pisau," vol. 8, no. 2, pp. 129–134, 2020.
[9] American System for Testing Materials. "Standard Test Method for Rockwell Hardness of Metallic Material". *ASTM EE18-15,* Oktober, 2020.
[10] Joni, "Proses Pack Carburizing Menggunakan Arang Tempurung Kelapa," *F.SAINTEK. UNIRA Malang,* vol. 05, no. 1, pp. 402–408, 2021.
[11] A. Fikri, A. Rahman, R. Putra, and M. Habibi, "Carburizing Menggunakan Limbah Kulit Singkong Terhadap Sifat Fisik Dan Mekanik Baja 1020," vol. 7, no. 2, pp. 110–114, 2023.
[12] M. N. Nasution, "Analisak Ekerasan Dan Struktur Mikro Baja Aisi1020 Terhadap Perlakuan Carburizing Dengan Arang Batok Kelapa," *Bul. Utama Tek.*, vol. 15, no. 2, p. 165, 2020.
[13] M. A. Rizki *et al.*, "Pengaruh Proses Pack Carburizing Dengan Variasi Temparatur Dan Karbon Aktif Terhadap Kekerasan Permukaan Baja Aisi 1020," vol. 6, no. 2, pp. 63–67, 2022.
[14] T. A. Sutrisno and K. Malang, "KARAKTERISASI PROSES KARBURISASI BAJA AISI 1020 PADA TEMPERATUR 900^{o}c MENGGUNAKAN LIMBAH SERBUK FOTOKOPI," vol. 7, 2023.
[15] A. Shaifudin, H. Istiasih, and A. Mufarrih, "Optimalisasi difusi karbon dengan metode pack carburizing pada baja ST 42," vol. 1, no. 1, pp. 27–34, 2018.
[16] N. López Perrusquia, M. A. Doñu Ruiz, E. D. García Bustos, M. lores Martínez, G. M. Urriolagoitia Calderón, and C. R. Torres San Miguel, "Duplex surface treatment on microalloy steels by dehydrated paste pack boriding and pack carburizing," *Mater. Lett.*, vol. 280, 2020.
[17] D. Prayitno and S. B. Hengki, "Pengaruh Proses Pack Carburizing – Quenching Pada Kekerasan Baja Aisi 1020," *J. Penelit. Dan Karya Ilm. Lemb. Penelit. Univ. Trisakti*, vol. 7, no. 1, pp. 45–52, 2022.
[18] I. Azmy, D. Masruri, R. Rahardyanto, and Suyitno, "Pengaruh Proses Pack Carburizing Baja AISI 4340 Terhadap Peningkatan Kekerasan dan Ketahanan Aus," *J. Rekayasa Mater. Manufaktur dan Energi*, vol. 5, no. 2, pp. 102–107, 2022.
[19] D. Satria *et al.*, "Pengaruh Waktu Tahan Proses Pack Carburizing Baja AISI 3115 dengan Menggunakan Calcium Carbonat dan Batubara Sub Bituminous dan Mendapatkan Perlakuan Panas Quenching Media Pendingin Air," *Rotasi*, vol. 21, no. 2, p. 88, 2019.
[20] D. P. Nurdin, "Analisis Sifat Kekerasan Dan Metalografi Pada Baja Aisi 1020, Aisi 1037 Dan Aisi 1040 Untuk Poros (Shaft) Dengan Menggunakan Proses Heat Treatmen," *Suara Tek. J. Ilm.*, vol. 13, no. 2, p. 13, 2022.

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Automated Maintenance System For Freshwater Aquascape Based On The Internet Of Things (Iot)

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Abstract. Aquascaping is a hobby that has gained considerable popularity across different age groups, from young to old. Aquascaping itself is the art of arranging plants, water, rocks, coral, wood and other natural elements in glass or acrylic containers. One of the main obstacles in the world of aquascaping is consistency, which is often difficult to achieve when the owner has a busy schedule or limited time. Without the implementation of Internet of Things (IoT) technology and microcontrollers connected to mobile applications, this drawback is even more pronounced. The inability to maintain consistency in maintenance can lead to a decline in aquascape quality, both in terms of aesthetics and ecosystem health. Therefore, an innovative system using IoT is expected to provide a smart solution to overcome the major shortcomings of aquascape maintenance and enhance the experience of this hobby for its enthusiasts..

Keywords: Microcontroller, Monitoring, Internet of Things(IoT), Android

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1. Introduction

Aquascape is the art of organising aquatic plants, rocks, and wood with the aim of creating a look like gardening in water, enriched by the presence of fish as a companion to maintain the balance of the ecosystem.[1]. In Aquascape, the temperature factor must be a concern because it affects the balance of the ecosystem.[2]. With the development of the times, IoT or Internet of Things began to be integrated in terms of supervision and monitoring. [3]. IoT in its application can also function as a controller rather than just a supervisor [3].[4]. IoT is also popularly chosen because of the flexibility in the scale of its needs[5].

Android is also one of the results of the development of the times that has been widely used and developed[6]. The use of smartphones and android as a monitor device is increasingly popular[7]. Using a smartphone as a monitor device is also a practical choice in its use[8]. With the implementation of an IoT-based monitor system[9], aquascape ecosystem maintenance can be controlled easily and accurately without being hindered by distance or time and can be automated in its use.[10]The use of the IoT monitoring system in addition to maintaining the stability of the ecosystem, things such as replacement and detection of water quality can also be done automatically.[11]. Based on the advantages of the application of the IoT system in several fields including in the field of aquascape maintenance, this

aquascape maintenance automation system was made. And based on some research that has been done before, here are the references used as a reference for this research:

a. In the research conducted by Moch Haidar Rafi and Bambang Santoso with the title "Design of Automatic Aquascape Liquid Fertiliser Giving Tool Using NodeMCU Based on Internet Of Things (IoT)". The results obtained are, the tool that has been designed has worked as expected and successfully integrated into the Blynk control application which allows the tool to be controlled and can be monitored parameters through the Blynk website or in the Blynk application.[12].
b. Another research conducted by Piter Wijaya and Theophilus Wellem with the title "Design and Implementation of Temperature and Water Level Monitoring Systems in IoT-based Ornamental Fish Aquariums", this research produces tools that can detect and manipulate temperature, water level, and can regulate light control that has been integrated via Telegram using Bot in the Telegram application.[13].
c. Another research conducted by Nurul Fahmi and Shellya Natalia with the title "Water Quality Monitoring System for Catfish Cultivation Using IoT Technology", this research successfully integrates water temperature and pH monitoring devices in catfish ponds with android-based applications using IoT telnology that can monitor and control tools through android applications.[14].
d. Research on the application of IoT in terms of Care and Monitoring conducted by Allieffa Salsabilla Pradisthi and Joko Aryanto entitled "Monitoring and Automation System for Bird Feeding and Drinking Based on Internet of Things Using ESP32", this study successfully implemented an IoT-based care and monitoring system in bird care and cages that are able to control the Interval of bird feed and drink monitored by the system using IoT.[15]

Based on the research references cited above, the use of IoT as an aquarium or aquascape maintenance system can improve the quality of the ecosystem being maintained [16]. However, the main drawback of aquascapes is the difficulty in achieving consistency of care, including consistent light and feed schedules. Without the help of IoT technology, aquascape owners may struggle to maintain ecosystem optimality, which could lead to a decline in ecosystem aesthetics and health.

This research demonstrates that maintenance tools have limitations in managing light and feed schedules, as well as regulating water levels in aquascapes. In this context, IoT system solutions are highly relevant and can overcome these weaknesses.

By implementing IoT tools, aquascape owners can easily set feeding intervals and lighting schedules automatically. This system facilitates maintenance without the physical presence of the owner and provides the flexibility of remote monitoring and control, improving maintenance efficiency without compromising the quality of the ecosystem.

Additional benefits of the system include remote monitoring via website or Android phone, automatic setting and monitoring of water levels, and scheduled automatic feeding. By automatically scheduling lights, the system creates an optimal environment for plant growth and fish health, while maintaining the beauty of the aquascape. The implementation of IoT in aquascape maintenance ensures the sustainability of the ecosystem and provides convenience and better control for the owner. This device will also be integrated with a website that uses Firebase as storage.[17]The device will also be integrated with a website that uses Firebase as its storage [17], using a website that can be easily opened on mobile and desktop devices[18]. The website used uses the PHP programming language as its basis[19] and uses Firebase type Realtime as a place to store data[20].

2. Methods

In this study, the research process is divided into several phases, including problem identification, literature review, system design, device assembly, testing, and conclusion.

2.1. Block System Diagram

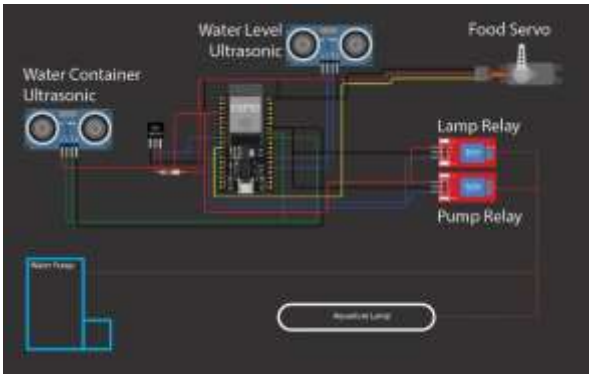

Figure 1 System Diagram

Based on Figure 1 above, ESP 32 which functions as the main control to process and process data taken from sensors and other modules which will later forward data to the Web. Water level sensor will detect the water level, then ESP 32 will process the data and if it has passed a certain limit, it will turn on the relay connected to the water pump to add water to the Aquascape. Water container Sensor on the other hand will detect the amount of water remaining in the water reservoir to fill the Aquarium, if less ESP will send the data to the Web. Food servo will open the food storage hatch every time that has been set by the web, while the Lamp Relay will turn on the lights according to the schedule hours that have been determined on the Web. The DS18B2 sensor will detect the water temperature which will be forwarded by the ESP to the Web.

2.2. Flowchart

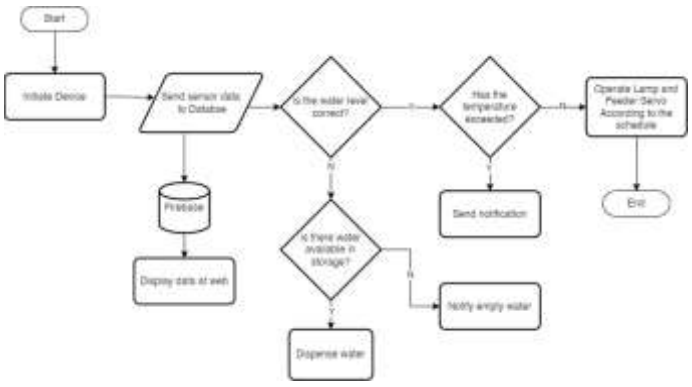

Figure 2 Device Flowchart

Based on Figure 2 above, it can be explained the workflow of the device starting from the initiation of the device followed by sending all the data detected by the sensor to the Database which will later be displayed on the Website. After that the device will process data from the water level detection sensor in the Aquascape then the reservoir sensor will detect whether water is still available in the reservoir or not, if there is still water in the reservoir, the pump relay will turn on the water pump in the water reservoir. If the water reservoir is empty, the device will send a notification. After that the device will detect the temperature in the Aquascape, if the temperature exceeds the limit then the device will send a notification. Finally, the device will turn on the lights and turn them off according to the hour, then the device also sets the servo to open the food storage hatch according to a predetermined schedule.

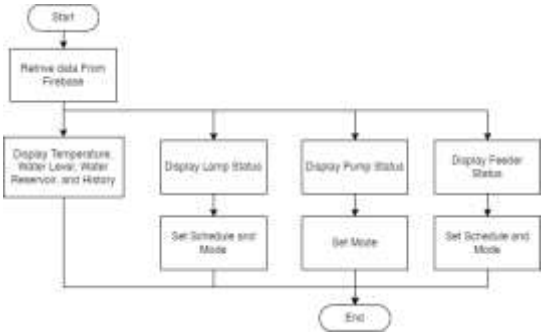

Figure 3 Website Flowchart

From the Flowchart Figure 3 above, the flow of the website can be explained as follows. First, the website will retrieve all data from Firebase to be displayed on the website, then through the website users can set schedules for lights and feed. Users can also set the mode used to manage pumps, feeders, and lights.

3. Results and Discussion

3.1. Result

The result of this system design is a tool that has been assembled and a website to monitor and control IoT tools for Aquascape. The tool can help maintain Aquascape Aquarium without the need for a lot of human intervention and with the help of a Website that can be opened through various devices, it is possible to control the tool without worrying about distance.

Figure 4 Device Set

Figure 4 above is the result of the application of the device that has been installed in an Aquarium with a size of 20cm x 15cm x 15cm. ESP 32 is used as a Microcontroller which will be connected to the Internet Network using WiFi so that it allows the device to be controlled remotely via a website.

Figure 5. Website

Figure 5 above is the result of the controller website to monitor, schedule, and view the status of sensors such as temperature, water level and water reservoir status.

3.2. Device Equipment Testing

The following is a table of device testing data that includes feeders, lights, and pumps and water levels. Testing is done to see if the device is successfully applied to real cases.

3.2.1 Feeder Testing

Table 1. Feeder Testing Result

No	Day	Time	Servo Status	Delay
1	Sunday	10.00 AM	ON	0s
2	Monday	10.00 AM	ON	0s
3	Tuesday	10.00 AM	ON	0s
4	Wednesday	10.00 AM	ON	0s
5	Thursday	10.00 AM	ON	0s
6	Friday	01.00 PM	ON	2s
7	Saturday	01.00 PM	ON	0s
8	Sunday	01.00 PM	ON	0s
9	Monday	01.00 PM	ON	0s
10	Tuesday	06.30 PM	ON	0s
11	Wednesday	06.30 PM	ON	0s
12	Thursday	06.30 PM	ON	1s
13	Friday	06.30 PM	ON	0s
14	Saturday	06.30 PM	ON	0s
15	Sunday	06.30 PM	ON	0s

During the first five days of the feeding trial, the ESP32 microcontroller functioned effectively and accepted the schedule settings at 10 am. However, when the setting time was changed, the feeding system continued to operate well despite slight delays caused by interruptions in the connection.

The ESP32 microcontroller can efficiently manage the feeding schedule under optimal conditions. However, it may experience a slight delay in situations where the connection is disrupted. Therefore, it is crucial to prioritize schedule management and maintain a stable connection to ensure optimal performance of the feeding system.

3.2.2 Lamp Testing

Table 2. Lamp Testing Result

No	Day	Time	Relay Stat	Delay	Time	Relay Stat	Delay
1	Sunday	08.00 AM	ON	1s	02.00 PM	OFF	3s
2	Monday	08.00 AM	ON	0s	02.00 PM	OFF	0s
3	Tuesday	08.00 AM	ON	0s	02.00 PM	OFF	0s
4	Wednesday	08.00 AM	ON	0s	02.00 PM	OFF	0s
5	Thursday	08.00 AM	ON	3s	02.00 PM	OFF	3s
6	Friday	08.00 AM	ON	0s	02.00 PM	OFF	0s
7	Saturday	08.00 AM	ON	0s	02.00 PM	OFF	0s
8	Sunday	08.00 AM	ON	0s	02.00 PM	OFF	0s
9	Monday	08.00 AM	ON	0s	02.00 PM	OFF	0s
10	Tuesday	08.00 AM	ON	2s	02.00 PM	OFF	0s
11	Wednesday	08.00 AM	ON	0s	02.00 PM	OFF	2s

12	Thursday	08.00 AM	ON	2s	02.00 PM	OFF	0s
13	Friday	08.00 AM	ON	0s	02.00 PM	OFF	1s
14	Saturday	08.00 AM	ON	0s	02.00 PM	OFF	1s
15	Sunday	08.00 AM	ON	0s	02.00 PM	OFF	0s

The test results indicate that the automatic light system was scheduled to turn on for 6 hours per day, in accordance with the specifications of the aquascape and its ecosystem. However, the recorded data shows delays in the relay function, which may have been caused by interruptions in the connection or potential interruptions in the Relay module used.

Overall, the testing of the lighting system went well, with no significant delays. The ESP32 microcontroller effectively received the light schedule, improving the system's operational reliability. Although some delays may have occurred, the automated lighting system's overall performance remained optimal, providing suitable lighting for the aquascape's needs.

3.2.3 Water pump and water level Testing

Table 3. Water level and container

No	Day	Interval	Delay	Capacity	Distance	Pump Relay Status
1	Sunday	1	1s	Available	1 cm	On
2	Monday	0	0s	Available	1 cm	Off
3	Tuesday	0	0s	Available	1 cm	Off
4	Wednesday	0	0s	Available	2 cm	Off
5	Thursday	0	0s	Available	2 cm	Off
6	Friday	0	1s	Available	3 cm	Off
7	Saturday	1	0s	Available	1 cm	On
8	Sunday	1	0s	Available	2 cm	On
9	Monday	1	0s	Empty	2 cm	On
10	Tuesday	0	0s	Available	1 cm	Off
11	Wednesday	0	0s	Available	1 cm	Off
12	Thursday	0	1s	Available	1 cm	Off
13	Friday	1	0s	Available	1 cm	On
14	Saturday	0	0s	Available	2 cm	Off
15	Sunday	1	0s	Available	1 cm	On

The data table attached records the results of testing the water level system on the Aquascape. The sensor was set at a distance of 1 cm from the water surface, resulting in satisfactory performance. The delays identified are believed to be due to connectivity constraints between the microcontroller and the server.

It is important to note that on the 9th day of testing, the water reservoir became empty. The system sent an automatic notification that the water reservoir was empty and required manual filling. After manual filling, the system activated the pump to replenish the water to a predetermined height.

Testing the water level system went smoothly overall, although filling the water reservoir still required manual intervention. However, this evaluation presents a favorable outlook on the system's ability to detect and respond to water levels, as well as its capacity to overcome connection constraints. Additional evaluation may be necessary to enhance the automation of water filling.

4. Conclusion

Based Previous research suggests that the success of the Aquascape system is largely dependent on the implementation of the Internet of Things (IoT) as a key infrastructure. The presence of the Website, ESP32 Microcontroller, WiFi connection, and Firebase as a Database in Aquascape maintenance

highlights the shortcomings that IoT can overcome. Without IoT, Aquascape maintenance requires repetitive manual actions, such as manually setting lights. The major concerns are the risk of user forgetfulness and the potential for exceeding the recommended light limit for Aquascape. IoT offers solutions by enabling more efficient monitoring and management. For future development, focus should be on battery solutions as backup in the event of a power outage and system functionality under offline conditions. Improved connectivity is also a priority to overcome possible delays that may arise. Considering the drawbacks of Aquascape without IoT support, the development of this technology is expected to overcome these barriers and improve the overall effectiveness of the system.

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References

[1] B. Santoso and A. D. Arfianto, "Sistem Pengganti Air Berdasarkan Kekeruhan Danpemberi Pakan Ikan Pada Akuarium Air Tawar Secara Otomatis," vol. 8, no. 2, pp. 33–48, 2017.

[2] A. Razo and H. Aprilianto, "Alat Penyiram Tanaman Aquascape Otomatis Berbasis Arduino Uno Dan Monitoring Berbasis Mobile," *Progresif J. Ilm. Komput.*, vol. 15, no. 2, pp. 83–88, 2019.

[3] D. Setiadi, "PENERAPAN INTERNET OF THINGS (IoT) PADA SISTEM MONITORING IRIGASI (SMART IRIGASI)," *Infotronik J. Teknol. Inf. dan Elektron.*, vol. 3, no. 2, pp. 95–102, 2018, doi: 10.32897/infotronik.2018.3.2.5.

[4] W. Wajiran, S. D. Riskiono, P. Prasetyawan, and M. Iqbal, "Desain Iot Untuk Smart Kumbung Dengan Thinkspeak Dan Nodemcu," *POSITIF J. Sist. dan Teknol. Inf.*, vol. 6, no. 2, p. 97, 2020, doi: 10.31961/positif.v6i2.949.

[5] V. Rahmadhani and Widya Arum, "Literature Review Internet of Think (Iot): Sensor, Konektifitas Dan Qr Code," *J. Manaj. Pendidik. Dan Ilmu Sos.*, vol. 3, no. 2, pp. 573–582, 2022, doi: 10.38035/jmpis.v3i2.1120.

[6] M. Troulis, "叶青松 1, 2, 3 1.," *Jorn. Científica Farmacol. y Salud I LAS*, vol. 28, no. 1, pp. 1–11, 2020.

[7] Y. Triawan and J. Sardi, "Perancangan Sistem Otomatisasi Pada Aquascape Berbasis Mikrokontroller Arduino Nano," *JTEIN J. Tek. Elektro Indones.*, vol. 1, no. 2, pp. 76–83, 2020, doi: 10.24036/jtein.v1i2.30.

[8] R. W. Qalbi and S. Derta, "Perancangan Aplikasi Monitoring Ibadah Harian Siswa Berbasis Android di SMAN 2 Tilatang Kamang," *Inform. J. Ilmu Komput.*, vol. 16, no. 3, p. 128, 2020, doi: 10.52958/iftk.v16i3.1900.

[9] J. S. Saputra and S. Siswanto, "Prototype Sistem Monitoring Suhu Dan Kelembaban Pada Kandang Ayam Broiler Berbasis Internet of Things," *PROSISKO J. Pengemb. Ris. dan Obs. Sist. Komput.*, vol. 7, no. 1, 2020, doi: 10.30656/prosisko.v7i1.2132.

[10] B. I. Koromari and F. David, "Perancangan Dan Implementasi Sistem Pakan Otomatis Dan Monitoring Tds Pada Akuarium Ikan Hias Berbasis Iot," *J. Penerapan Teknol. Inf. dan Komun.*, vol. 02, p. 155, 2023.

[11] A. N. Salim and A. Rahman, "Implementasi Fuzzy-Mamdani untuk Pengendalian Suhu dan Kekeruhan Air Aquascape Berbasis IoT," *J. Algoritm.*, vol. 2, no. 2, pp. 159–169, 2022.

[12] E. Sumiati and B. Santoso, "Perancangan Alat Penyiraman Tanaman Krisan Otomatis Menggunakan Nodemcu Berbasis Internet of Things (IOT)," *J. Ilmu Komput. dan Sci.*, vol. 2, no. 2, pp. 513–519, 2023.

[13] P. Wijaya and T. Wellem, "Perancangan dan Implementasi Sistem Pemantauan Suhu dan Ketinggian Air pada Akuarium Ikan Hias berbasis IoT," *J. Sist. Komput. dan Inform.*, vol. 4, no. 1, p. 225, 2022, doi: 10.30865/json.v4i1.4539.

[14] N. Fahmi and S. Natalia, "Sistem pemantauan kualitas air budidaya ikan lele menggunakan teknologi IoT," *J. Media Inform. Budidarma*, vol. 4, no. 4, pp. 1243–1248, 2020, doi:

10.30865/mib.v4i4.2486.
[15] A. S. Pradisthi and J. Aryanto, “Monitoring and Automation System for Bird Feeding and Drinking Based on Internet of Things Using ESP32,” *Adv. Sustain. Sci. Eng. Technol.*, vol. 5, no. 3, p. 0230308, 2023, doi: 10.26877/asset.v5i3.17182.
[16] R. K. Putra Asmara, “Rancang Bangun Alat Monitoring Dan Penanganan Kualitas Ait Pada Akuarium Ikan Hias Berbasis Internet Of Things (IOT),” *J. Tek. Elektro dan Komput. TRIAC*, vol. 7, no. 2, pp. 69–74, 2020, doi: 10.21107/triac.v7i2.8148.
[17] M. Mungkin, H. Satria, J. Yanti, G. B. A. Turnip, and S. Suwarno, “Perancangan Sistem Pemantauan Panel Surya Pollycristalline Menggunakan Teknologi Web Firebase Berbasis IoT,” *INTECOMS J. Inf. Technol. Comput. Sci.*, vol. 3, no. 2, pp. 319–327, 2020, doi: 10.31539/intecoms.v3i2.1861.
[18] F. Wardana, “PENGGUNAAN INTERNET OF THING (IOT) ARDUINO UNO PADA,” vol. 5, no. 2, 2023.
[19] A. Hendra, “APA ITU PHP ?, PENGERTIAN, SEJARAH, DAN BAGAIMANA CARA KERJANYA,” *Universitas Pasundan*, 2020. https://if.unpas.ac.id/berita/apa-itu-php-pengertian-sejarah-dan-bagaimana-cara-kerjanya/ (accessed Oct. 12, 2023).
[20] Dicoding Intern, “Apa itu Firebase? Pengertian, Jenis-Jenis, dan Fungsi Kegunaannya,” *Dicoding*, 2020. https://www.dicoding.com/blog/apa-itu-firebase-pengertian-jenis-jenis-dan-fungsi-kegunaannya/ (accessed Oct. 12, 2023).

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