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AN AI-POWERED DIAGNOSTIC TOOL FOR *PLASMODIUM* MALARIA: A CASE STUDY ON MICROSCOPIC IMAGE ANALYSIS

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ABSTRACT
Malaria is still become disease the infection that has the biggest impact to health humans all over the world. When parasites Plasmodium enter into blood can influence physiology general body host, so that can cause disruption of hematological parameters which can cause a number of manifestation clinical such as anemia and thrombocytopenia so that can make things worse Health conditions. Identification in a way accurate infection parasite plasmodium is very important for determine therapy that will given with right. Technology intelligence artificial intelligence (AI) offers solution innovative For identify parasite Plasmodium Malaria with more efficient and accurate. AI, especially that based on deep learning and computer vision, can analyze picture microscopic with high speed and accuracy so that help speed up diagnosis and treatment in Medical decision. For develop and test system based intelligence artificial that can in a way automatic classify type parasite Plasmodium Malaria based on picture microscopic. Type study This covering image data set collection parasite Plasmodium malaria from laboratory medical, data labeling, and training of deep learning models based on convolutional neural networks (CNN). This model will evaluated based on accuracy, sensitivity, and specificity in differentiate various type Plasmodium. Type study is combination between experimental, quantitative and developmental AI technology in microbiology medical. Malaria Level (Mild, Moderate, Severe) and Duration of AI Use (Sig = 0.004). While Malaria Level and Duration Inspection Microscopic Conventional show significant and relevant results, which strengthen urgency innovation AI-based. With mark significance (Sig) 0.006, AI (Artificial Intelligence) is effectively superior in the diagnosis of Severe Malaria in endemic areas.

Keywords: artificial intelligence; malaria; microscopic; parasite; plasmodium

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INTRODUCTION

Malaria is one of the world's deadliest infectious diseases, caused by the Plasmodium parasite and transmitted through the bite of the Anopheles mosquito. According to data from the World Health Organization (WHO), in 2020 there were approximately 241 million cases of malaria worldwide, with 627,000 reported deaths (WHO, 2021). Papua became province with The highest malaria problem in the country is reached 86,022 problems until when this. Proportion malaria problems that are intertwined in the province the reached 90.9% of the total. After that, followed by East Nusa Tenggara with malaria problem reached 2,393 cases (2.5%). After that there is West Papua with Malaria problems amounted to 1,841 problems (1.4%). Annisa Salsabila, CA (2021).

Based on studies study previously by Mau, RV (2018). About use microscope on staining stock blood in detect parasite state that amount malaria parasites in the blood capillary of 29.3% and in venous blood of 17.3%, from results the there is difference results inspection amount malaria parasite by 12%. Plasmodium infect erythrocytes and perform destruction of erythrocytes so that cause erythrocytes in the body become reduced and not sufficient need body, number low erythrocytes called anemia which is characterized by with decline level hemoglobin, hematocrit and count cell blood red. D impact from anemia can cause fatigue , dizziness and weakness matter This

due to disruption of the transportation process oxygen and carbon dioxide inside body, disruption of the transportation process nutrition results digestion, disturbance transportation hormone to glands and anemia can make things worse Health conditions. Suryadi, Doni., et al. al. (2021). Identification parasite Plasmodium is step important in disease diagnosis infection. This process generally done through RDT and techniques molecular like Polymerase Chain Reaction (PCR).

Method conventional This own limitations in matter time and accuracy so that required innovation For increase efficiency identification parasite Plasmodium. Microscopic image is one of the method main in identification parasite Plasmodium. The emergence of Artificial Intelligence (AI) has develop rapidly in various field. With integrating AI into system health own opportunity big For change management infection parasite Plasmodium malaria. Wong, F., Cesar, et al. (2023). Increasingly many people use intelligence artificial intelligence (AI) as useful and usable tools reliable in various type application. AI has potential For allows identification disease early with based on data analysis and recognition pattern so that reduce errors and improve diagnostic accuracy as well as can ensure consistent and reliable results reliable. Kumar, W. Raj., (2024). Enabling greater efficiency Good in increase care and satisfaction patient. Rahim, Hirani., et al. (2024). With utilise machine learning and deep learning techniques, AI can identify pattern in image medical with high accuracy. Stefano, Marletta., et al. (2023). Technology This can help in increase efficiency and effectiveness from analysts, especially in identification pathogens. The use of AI in identification bacteria pathogen through image microscopic has become promising innovation. With utilizing deep learning, especially Convolutional Neural Networks (CNN), AI systems can recognize and classify parasite Plasmodium malaria with more fast and accurate. Tian, Tian., Xuan, Zhang., et al. (2024). Objective develop and test system based intelligence artificial that can in a way automatic classify type parasite Plasmodium Malaria based on picture microscopic.

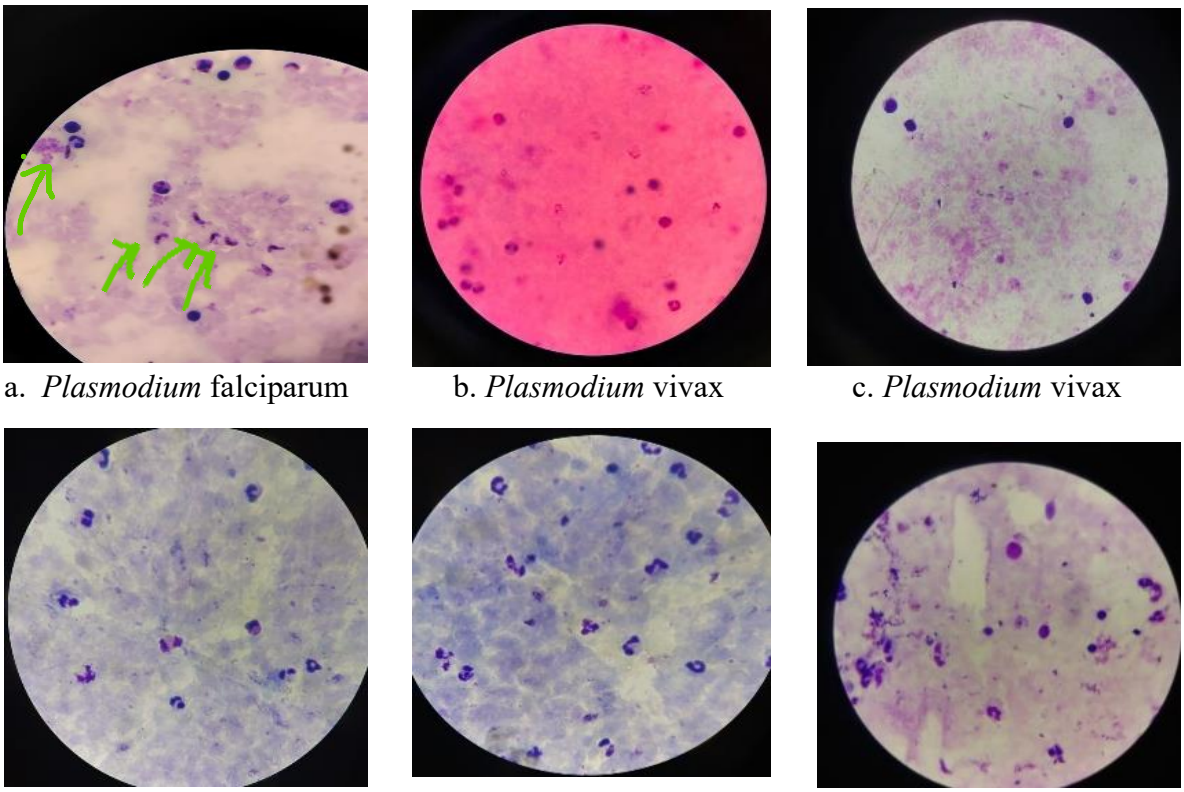
METHOD

This study was conducted using an analytical observational method involving 45 malaria respondents as research subjects and was approved by the Research Ethics Committee. This study included the collection of Plasmodium malaria parasite image datasets from medical laboratories, data labeling, and training a deep learning model based on a convolutional neural network (CNN). The study locations were three laboratories of Medical Hospitals, Community Health Centers, and Clinics in the city and district. The study took place from August to September 2025. Each respondent was interviewed to collect information on age, gender, occupation, education, and duration of malaria. Individuals who agreed to participate in the study underwent malaria examination using a rapid diagnostic test. Positive results were then followed up by taking venous blood from the antecubital fossa, which was collected in a purple EDTA tube (Cat. No. 250306, OneMed, PT. Intisumber Hasil Sempurna Global, Surabaya, East Java, Indonesia). Thick smears were prepared on a glass slide by dropping 2-3 drops of blood using a sterile pipette on the glass surface, then the blood was homogenized by moving the other end of the glass clockwise from the outside to the inside, forming a circle, and allowed to dry. After drying, the smear was immediately stained with Giemsa solution (Cat. No. HX46103004, OneMed, PT. Jayamas Medica Industri Tbk., Sidoarjo, Indonesia). The staining procedure followed the manufacturer's instructions. Next, identification of plasmodium parasites was carried out using artificial intelligence and microscopic images. The collected and examined data were then statistically analyzed using SPSS Version 26.0 (IBM Corporation, New York, United States). The Kolmogorov-Smirnov test was used to assess normally distributed quantitative data with a p value > 0.05. After that, a correlation test was performed with Spearman's rho which produced a significance mark of $p < 0.05$.

RESULT

Figure 1. This shows significant variation in cell distribution. Accurately locating and identifying parasites requires high visual acuity and considerable time for technicians. Identification of the parasite species and its developmental stage is crucial. This image demonstrates the need to clearly

differentiate between P. falciparum and P. vivax, as these two species have different therapeutic implications.



a. *Plasmodium* falciparum b. *Plasmodium* vivax c. *Plasmodium* vivax

d. *Plasmodium* falciparum e. *Plasmodium* falciparum f. *Plasmodium* vivax

Figure 1. Results of identification of *plasmodium parasites* through Artificial Intelligence and microscopic images in three laboratories in Southwest Papua Province

Table 1.
Distribution Frequency Respondents Identification of *plasmodium* parasites Use of AI and Microscopic Images in Malaria Patients (n= 45)

Variables	f	%
Age		
0-18 Years	18	40.0
19-55 years old	22	60.0
Gender		
Man	26	57.8
Woman	19	42.2
Research Location		
Hospital Lab	5	11.1
Health Center Laboratory	38	84.4
Clinical Lab	2	4.4
Education		
No school	2	4.4
Elementary School	4	8.9
Junior High School	6	13.3
Senior High School	30	66.7
High College	3	6.7
Work		
Private	8	17.8
Civil servant	2	4.4
Businessman	3	6.7
Doesn't work	32	71.2
Long Suffering		
1-4 Days	24	53.3

Variables	f	%
5-7 Days	17	37.8
>7 Days	4	8.9
Types of Plasmodium		
Falciparum	26	26
VivaxMalaria	19	19
Levels		
Heavy	30	66.7
Currently	9	20.0
Light	6	13.3
Microscopic Image Examination Time Duration		
5-15 Minutes	18	15.6
16-30 Minutes	27	35.6
AI Examination Time Duration		
1-3 Minutes	26	57.8
4-5 minutes	19	42.2

In table 1. Shows that respondents involved in study this, some big sample patient is at in group Age 19-55 Years (60.0%). Group age productive this is very important Because own mobility high, which has the potential become spreader, so that the diagnosis is fast become priority main. Based on type gender, data shows that 57.8% of respondents is men, while the remaining 42.2% is women, which reflects sufficient distribution balanced, even though there is A little domination men. This location especially conducted in the laboratory health center, with participation of 84.4% of respondents. This important remember community health center is the vanguard in provision service health, especially in Southwest Papua, where the implementation of innovation intelligence Artificial Intelligence (AI) is very relevant. In terms of education, the majority respondents (66.7%) had a high school education, while only 6.7% are educated high. Research This show the need AI devices designed to be easy used by users from various level education. In general clinical, analysis show that species *Plasmodium* detected in study This is *Plasmodium* falciparum (57.8%) and *Plasmodium* vivax (42.3%). More further, severe malaria cases dominate, reaching 66.7%, Research This indicates that AI is capable detect malaria cases even at the stage initial (light), which is very important For initiation treatment early detection and prevention complications, time required For the examination also showed significant differences; manual inspection requires time between 16 and 30 minutes, which was done by 35.6% of respondents, while with use of AI, the majority respondents only need time between 1 and 3 minutes, which also reached 57.8%.

Table 2.

Results of identification of *plasmodium* parasites with malaria levels using AI in Malaria Patients

Malaria levels	Identify AI Uses					
	1-3 Minutes		4-5 minutes		Total	
	F	%	F	%	F	%
Heavy	13	50.0	17	89.5	30	66.7
Currently	7	26.9	2	10.5	9	20.0
Light	6	23.2	0	0.0	6	13.3
Total	26	100	19	100	45	100
α=0.05					*Sig* = 0.004	

Table 2 shows the analysis of Malaria Level (Mild, Moderate, Severe) and Duration of AI Use (Sig = 0.004). This indicates that the relationship is not a coincidence. This relationship is categorized as moderate with a negative correlation coefficient of r = −0.431, which indicates that the shorter the AI time (1–3 minutes), the higher the level of malaria identified. Conversely, AI tends to take longer (4–5 minutes) to diagnose more complex or severe malaria cases, as more in-depth image processing is required to achieve optimal confirmation. Specifically, the 4–5 minute group shows a very high percentage of Severe cases (89.5%).

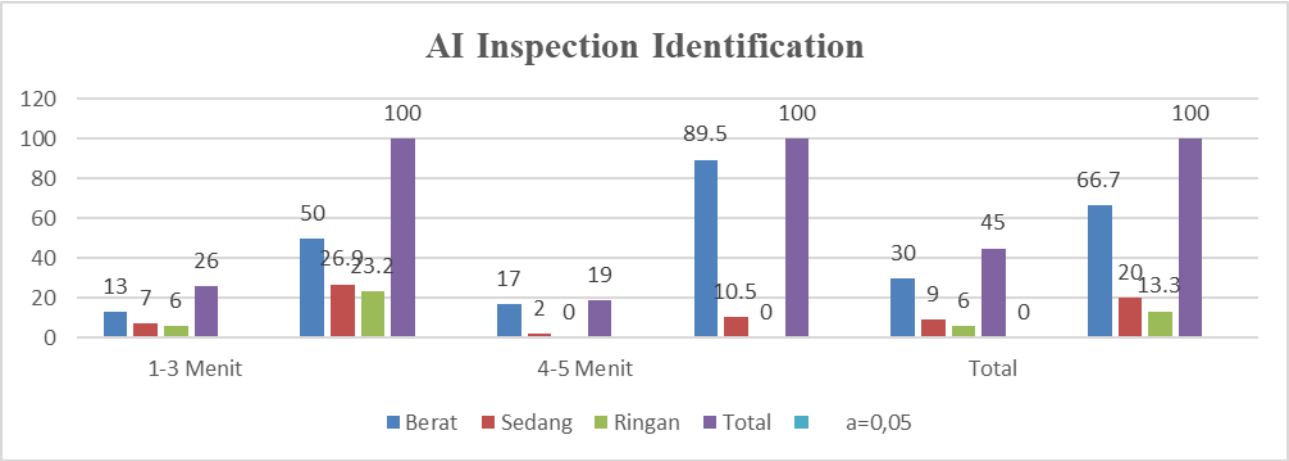


Chart 1. Identification of *plasmodium* parasites with malaria levels using A I in Malaria Patients

Graph 1. Shows the results of Plasmodium Parasite Identification using AI Testing, demonstrating significant time efficiency and intelligent time allocation based on disease severity. The analysis results show a Sig value of 0.004, indicating a strong relationship between Malaria Level (Severe, Moderate, Mild) and AI Testing Time Duration (1–3 Minutes and 4–5 Minutes). The AI system successfully completed 45 diagnoses in a maximum of 5 minutes.

Table 3 .

Results of *plasmodium* parasites with malaria levels using microscopic images in malaria patients

Malaria levels	Identification of Microscopic Image Use					
	5-15 Minutes		16-30 Minutes		Total	
	f	%	f	%	f	%
Heavy	8	44.4	22	81.5	30	66.7
Currently	5	27.8	4	14.8	9	20.0
Light	5	27.8	1	3.7	6	13.3
Total	18	100	27	100	45	100
α=0.05					*Sig* = 0.006	

Table 3. Shows Analysis of Malaria Levels and Duration Inspection Microscopic Conventional show significant and relevant results, which strengthen urgency innovation AI -based. With mark significance (Sig) 0.006, which is more low from threshold of 0.05, there is significant relationship in a way statistics between level severity of the patient's malaria (mild, moderate, severe) and the time required technician For diagnose use method imaging microscopic conventional (5–15 minutes and 16–30 minutes). Relationship This indicated by the coefficient correlation moderate negative (r=−0.417, although should referring to the analysis r=−0.431 and Sig=0.004), which is implicit show that the more critical malaria conditions, increasingly rapid diagnosis is a must enforced.

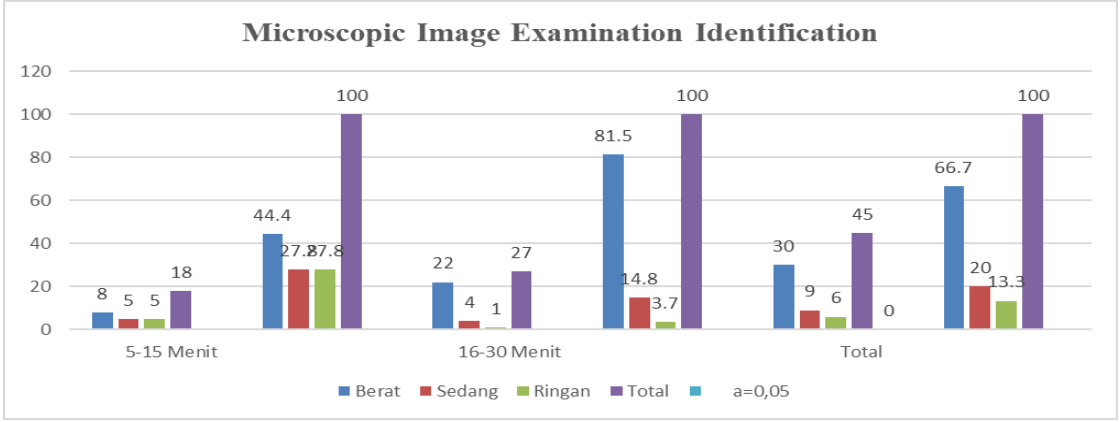


Chart 2. Identification of *plasmodium* parasites with malaria levels using microscopic images in Malaria Patients

Graph 2. The *Plasmodium parasite display* using a conventional microscope shows a Sig value of 0.006, indicating a statistically significant relationship related to the inefficiency of diagnosing severe cases. This value, which is below 0.05, indicates a correlation between malaria severity (Severe, Moderate, Mild) and diagnosis time (5–15 minutes and 16–30 minutes). This pattern has negative clinical implications. Frequency analysis shows that the majority of severe malaria cases (30 cases or 66.7%) were diagnosed in the longest time category (16–30 minutes), with 81.5% of these being severe malaria.

DISCUSSION

Innovation in the application of Artificial Intelligence (AI) to identify malaria-causing *Plasmodium parasites* should be based on model performance metrics: Accuracy, Sensitivity, and Specificity, which are key indicators for determining diagnostic quality in Southwest Papua. In some cases, they even surpass the performance of manual microscopy performed by experts. In general, recent studies report that the accuracy of AI systems in diagnosing malaria ranges from 95% to over 99%. Tavares, V., et al. al. (2024)., Cakir, A., et al. (2023), which showed significant improvements compared to conventional methods that are susceptible to factors such as technician fatigue and subjectivity. The high sensitivity achieved by AI models, which in some studies even exceeds 99%. Lee, TS, et al. (2023). AI has the ability to detect the presence of parasites even at low parasitemia levels a situation often missed by human techniciansa fact that is particularly relevant given this study's ability to detect mild cases of malaria. The model's high specificity (often above 99%) indicates that AI can accurately confirm uninfected blood cells as negative, thereby reducing the likelihood of false positives and preventing unnecessary treatment. The accuracy and sensitivity of this microscopic method are highly dependent on the skill of the technician performing the examination and the parasite density (parasitemia) present in the blood. Tjahjono, B., et al. al. (2016)., Wowor, MF, et (2019), In the field, this can lead to decreased sensitivity, especially in cases of mixed infections or very low parasite levels. Frequency data obtained from a study in Southwest Papua clearly demonstrate the negative impact of this inefficiency, with the majority of severe malaria cases (81.5%) being detected over a long period of time, between 16 and 30 minutes, when using conventional methods. This time far exceeds the recommended time limit for critical case management. Berzosa , P., et et al. (2018),

Another study in line with that conducted by He, K., et al. (2020), that the AI system is able to diagnose faster (1–5 minutes) and shows an efficient correlation with the severity of malaria ($r=-0.417$, Sig. $=0.004$) which is strongly supported by other studies as well. Zubair, M., et al. (2023), regarding *Deep applications Learning* (DL). Research using *Convolutional Neural Network* (CNN) architectures consistently demonstrates superiority in diagnostic metrics, where DL systems have achieved Accuracy >95%, even several studies conducted by Malik, J., et al. al. (2023) successfully achieved 99.68% accuracy in classifying malaria-infected and uninfected blood cells from blood smear images. This high accuracy advantage overcomes the variability and accuracy limitations often encountered by human technicians whose skills are affected by fatigue, low parasite density, or smear staining quality. In addition to accuracy, speed is a key advantage relevant to the study by Hariyani, YS, et al. al. (2024). while conventional microscopic diagnostics can take 30 to 60 minutes per sample, in another study by Alhumyani, H., et (2024), a risky delay in severe cases, the DL model was able to process and provide diagnostic results in an average of only 4 seconds per image, drastically reducing waiting times and accelerating clinical intervention. Thus, these studies reinforce the justification that AI innovations not only match but surpass manual diagnostic capabilities in terms of efficiency and reliability, making it a crucial tool for malaria management, especially in resource-limited health facilities such as Community Health Centers.

CONCLUSION

The conclusion of this study shows that AI (Artificial Intelligence) is effectively superior in the diagnosis of Severe Malaria in endemic areas. Statistically significant results (Sig = 0.004 for AI) indicate that the diagnosis can be completed in a maximum of 5 minutes. This is in stark contrast to

the Conventional Microscopic method, where 81.5% of Severe Malaria cases experienced delays, diagnosed within 16–30 minutes. Thus, AI innovation not only improves speed but also efficiency, with a focus on higher processing time (4–5 minutes) for 89.5% of Severe cases, thus becoming a crucial solution to reduce the risk of delays in clinical care.

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