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RESEARCH ARTICLE

An automated malaria cells detection from thin blood smear images using deep learning

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ABSTRACT

Timely and rapid diagnosis is crucial for faster and proper malaria treatment planning. Microscopic examination is the gold standard for malaria diagnosis, where hundreds of millions of blood films are examined annually. However, this method's effectiveness depends on the trained microscopist's skills. With the increasing interest in applying deep learning in malaria diagnosis, this study aims to determine the most suitable deep-learning object detection architecture and their applicability to detect and distinguish red blood cells as either malaria-infected or non-infected cells. The object detectors Yolov4, Faster R-CNN, and SSD 300 are trained with images infected by all five malaria parasites and from four stages of infection with 80/20 train and test data partition. The performance of object detectors is evaluated, and hyperparameters are optimized to select the best-performing model. The best-performing model was also assessed with an independent dataset to verify the models' ability to generalize in different domains. The results show that upon training, the Yolov4 model achieves a precision of 83%, recall of 95%, F1-score of 89%, and mean average precision of 93.87% at a threshold of 0.5. Conclusively, Yolov4 can act as an alternative in detecting the infected cells from whole thin blood smear images. Object detectors can complement a deep learning classification model in detecting infected cells since they eliminate the need to train on single-cell images and have been demonstrated to be more feasible for a different target domain.

Keywords: Malaria; Yolov4; Faster R-CNN; SSD300; deep learning.

INTRODUCTION

Malaria is a severe and occasionally fatal disease caused by a *Plasmodium* parasite that commonly infects the *Anopheles* mosquito, which feeds on human blood. World Health Organization (WHO) has been committed to malaria eradication since 1955. However, in 2020 alone, 241 million cases and 627,000 deaths were recorded. According to the World malaria report for 2021, the number of reported malaria cases remained the same for 2000 and 2020. This demonstrates that malaria remains a serious global health issue 67 years after the eradication pledge. As one of the tropical countries, Malaysia is also affected by this disease. During the past decade, the incidence of zoonotic *P. knowlesi* cases in Southeast Asia has been increasing, with Malaysia reporting the highest number of infections (WHO, 2021a). Based on WHO (2021b) harnessing innovation and expanding research is one of the supporting elements in the fight against malaria. Substantial research and development to create new tools and strategies in medicines, diagnostics, vector control, and vaccines can contribute to malaria elimination and, eventually, its global eradication.

Microscopic examination remains the gold standard for malaria diagnosis. The results of the examination highly depend on the microscopist's interpretation. Diagnosing the disease is challenging in non-endemic countries as the disease is rarely seen, and expertise in malaria diagnosis needs to be better maintained. However, in malaria-endemic countries, a lack of resources is a significant barrier to reliable and timely diagnosis of diseases (Tangpukdee *et al*., 2009; Capela *et al*., 2019). Therefore, alternate use of artificial intelligence for decision-making can play a crucial role in facilitating the rapid detection and prompt diagnosis of diseases.

With current advances, deep learning, a subset of artificial intelligence (AI), plays a prominent role in healthcare by improving the reliability and efficiency of diagnosis and treatment across various specializations (Ahuja, 2019). In previous studies, different deep-learning methods have been applied to malaria diagnosis. A Convolutional Neural Network (CNN) is a type of artificial neural network mainly used in image recognition and processing and is famously used to detect and classify infected cells. However, one main challenge in applying deep learning in malaria diagnosis is the need for a comprehensive dataset. To learn the infected cells'

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