**Report**

**Motivation:**

With millions of cases and hundreds of fatalities recorded each year, malaria continues to pose a danger to world health. Microscopy analysis of stained blood smears, the gold standard for diagnosing malaria, has drawbacks, such as laborious procedures and the requirement for specialized parasitologists. Inappropriate therapies, such as the needless use of antibiotics or antimalarial medications, might result from incorrect diagnosis. Using cellphones, this research proposes a novel approach for automated identification of malaria parasites in thick blood smears, addressing issues of diagnostic accuracy and expert availability in resource-constrained settings.

**Problem Statement:**

Various approaches have been proposed for malaria detection, but the focus here is on thick blood smear detection.Traditional techniques involve thresholding and morphological operations, but their accuracy is limited.Feature-based methods extract attributes and use machine learning, achieving better detection rates but often on patch-level evaluation.Deep learning methods, a relatively recent trend, have shown promise in achieving high accuracy and have been applied to thick blood smear analysis, and its ability to work with large data sets.

**Objectives:**

Develop a deep learning-based application for smartphones.

Provide an overview of the background, challenges, and existing approaches.

Showcase the advantages and potential of deep learning in malaria parasite detection.

Present our methodology and results.

Discuss the implications and future directions.

**Contributions:**

1. Smartphone-Based Parasite Detection: Developed a smartphone-based system for the automated detection of malaria parasites in thick blood smears. This system is built on our proposed intensity-based Iterative Global Minimum Screening (IGMS) method for rapid preselection of parasite candidates and a customized Convolutional Neural Network (CNN) model for classifying these candidates as parasites or background. This marks the first attempt to employ deep learning methods for malaria parasite detection in the context of smartphone applications.

2. Efficiency: The system stands out for its efficiency. It can detect parasites in a 3024 x 4032 image in just about 10 seconds when executed on a standard Android smartphone.

3. Large Dataset Testing: Unlike some previous works that used smaller datasets, experiments conducted on a significantly larger image set acquired from 150 patients. This extensive dataset includes 1819 thick smear images and a total of 84,961 annotated parasites. Importantly, this dataset is publicly available, which serves as a valuable resource for further research in the field.

**Methodology:**

Parasite Candidate Screening:

The initial screening involves WBC detection and IGMS-based parasite preselection.

IGMS identifies potential parasite candidates by localizing minimum intensity values in the grayscale image.

Parasite Classification:

A customized CNN model is used for parasite classification.The CNN model structure includes seven convolutional layers, three max-pooling layers, and three fully connected layers.The methodology can be integrated into a smartphone application for user-friendly diagnosis.

**Data Preparation and Experimental Results:**

A dataset containing Giemsa-stained thick blood smear images from 150 P. falciparum infected patients was utilized, totaling 1819 images with 84,961 annotated parasites. Notably, the parasites displayed varying radii, averaging 22 pixels per parasite, with each image containing an average of 47 parasites. The dataset was divided into two sets, Set A and Set B, for training and evaluation. The preselection phase achieved high sensitivity, especially in Set B. The customized CNN model displayed robust performance, with an impressive average AUC score of 98.39% in five-fold cross-evaluation. Evaluation on patch, image, and patient levels consistently demonstrated accuracy and strong correlations. Importantly, the customized CNN model outperformed pre-trained networks, such as AlexNet, VGG19, and ResNet50, in terms of accuracy and F-scores.

**Critical Analysis:**

1. Method Effectiveness: The methodology achieves high sensitivity, specificity, and accuracy due to the effectiveness of preselection through IGMS and classification using the customized CNN model.

2. Handling False Positives: The methodology generates false positives (negative patches) that resemble parasites to improve the CNN model's performance, which is an innovative approach.

3. Optimization of Patch Size: Experimentation with patch sizes indicates the importance of selecting an optimal size to avoid false positives and background noise.

4. Comparison with Traditional Methods: A comparison with traditional methods and pre-trained networks demonstrates the superiority of the customized CNN model.

5. Object Detection Networks: Object detection networks like faster-RCNN and YOLO did not perform well for detecting small objects like malaria parasites.

**Conclusion**

In conclusion, the integration of deep learning with smartphone technology presents a groundbreaking advancement in malaria parasite detection. This approach offers several significant benefits:

Accessibility: By leveraging the widespread availability of smartphones, this method democratizes access to malaria detection, especially in remote and resource-limited regions.

Accuracy: Deep learning algorithms have demonstrated high accuracy in identifying malaria parasites, potentially surpassing traditional methods and reducing human error.

Efficiency: The automated nature of deep learning models enables rapid analysis of blood samples, facilitating timely diagnosis and treatment.

Cost-effectiveness: Utilizing smartphones for detection minimizes the need for expensive laboratory equipment and specialized personnel, making the process more affordable.

By combining the power of artificial intelligence with the ubiquity of smartphones, this approach has the potential to revolutionize the fight against malaria, ultimately saving lives and contributing to global health improvement. Future research and development in this field should focus on enhancing model robustness, expanding datasets, and ensuring the technology's adaptability across different environments and conditions