ABSTRACT

Tuberculosis (TB) remains a global health concern that requires fast and accurate diagnosis. One of the common diagnostic methods is microscopic examination using Ziehl-Neelsen (ZN) staining on sputum samples. However, suboptimal staining quality such as *Over Staining* or *Less Staining* can affect the accuracy of microscopic readings and potentially lead to diagnostic errors. The main problem addressed in this study is the lack of an automated, machine learning–based system capable of classifying ZN staining quality and counting TB bacteria efficiently in environments without internet access.

To address this issue, this study developed a standalone application based on machine learning, capable of classifying ZN staining quality and automatically detecting TB bacteria. The system was designed to operate fully offline and integrates a CNN-based classification model with a YOLOv11-based bacterial detection model. The application includes automatic image preprocessing, input validation features, and notification alerts for invalid images. All classification results are stored locally using encrypted storage to ensure data security and maintain operational efficiency in laboratory environments.

Based on the test results on the test dataset, the classification system with the CNN model achieved 100% accuracy, precision, sensitivity, specificity, and F1-score for each class (Good Staining, Less Staining, Over Staining). In the bacterial detection stage, the YOLOv11 model demonstrated evaluation performance with mAP, precision, recall, and F1-score ≥ 80%. The average image processing time on 30 different laptops was recorded at ≤ 3 seconds per image. These results indicate that the developed system has high performance, flexibility, and is ready to be implemented on a laboratory operational scale or in areas with network limitations.

Keywords: image classification, machine learning, standalone application, tuberculosis, Ziehl-Neelsen