Automatic White Blood Cell Detection and Segmentation in Microscopy Images of Thin Blood Smears

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INTRODUCTION

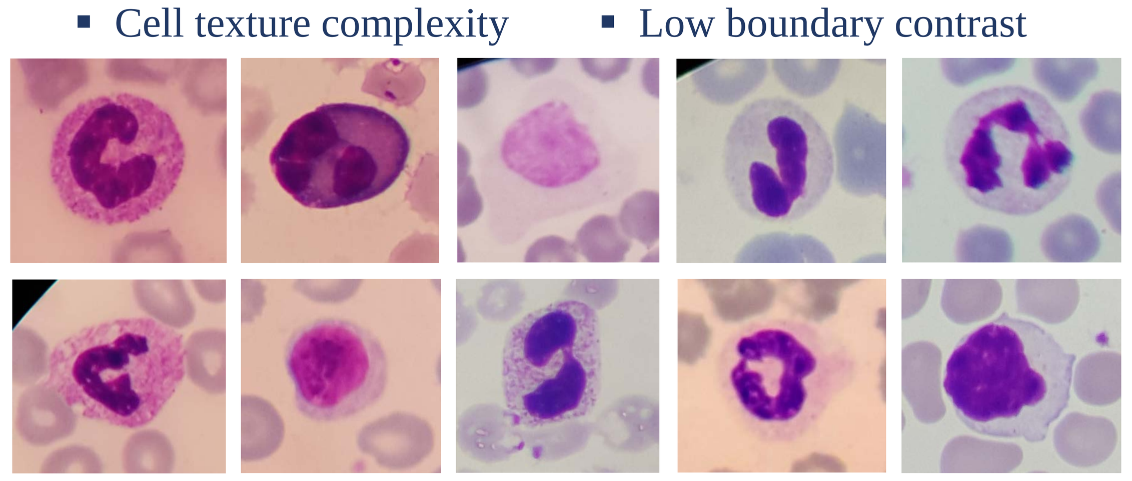
Automatic analysis of microscopic images of blood smears with parasite-infected red blood cells can assist field workers in screening and monitoring malarial infection. Millions of blood slides are manually screened for parasites every year, which is a time consuming and error-prone process. We have developed a smartphone-based software to perform this task using machine learning and image analysis methods for counting infected red blood cells automatically. The software runs on a standard Android smartphone attached to a microscope by a low-cost adapter. The smartphone's built-in camera views images of thin blood smear slides through the eyepiece of the microscope. Our method first detects and segments red blood cells in these images. However, the presence of white blood cells (WBCs) adversely affects the accuracy of red blood cell detection and segmentation since WBCs are often mistaken for red blood cells by current automatic cell detection methods. Therefore, a pre-processing step for WBC elimination is necessary, which requires WBC detection and segmentation methods. Segmentation of WBCs is a complex process due to the morphological diversity of WBCs and staining differences. We introduce an algorithm that successfully detects white blood cells in microscopic images of thin blood smears following a range filtering approach that accurately estimates the boundary of each cell using a level-set algorithm. Our method is capable of detecting different types of white blood cells with different shades of staining. We test our algorithm on more than 1300 thin blood smear images exhibiting about 1350 WBCs, which are manually annotated by a professional slide reader. For cell detection, we achieve 96.4% precision, 98.4% recall, and 97.4% F1-score. For cell segmentation, we assess the performance by a pixel-wise comparison of the manual segmentations with our machine segmentations, which has resulted in an overlap of 82% based on the Jaccard similarity index. These results are promising outcomes for automatic WBC analysis, which lead to higher accuracy in the counting of red blood cells and a concomitant improvement in screening performance.

WHITE BLOOD CELLS

- Also known as "Leukocytes"
- Nucleated cells in the blood that protect the body against infectious disease
- Five main types:

Neutrophils Eosinophils Basophils Lymphocytes Monocytes

- Segmentation challenges in blood smear images:
  - Cell staining differences
  - Shape diversities
  - Uneven illumination
  - Size variation
  - Cell texture complexity
  - Low boundary contrast



ACKNOWLEDGMENT

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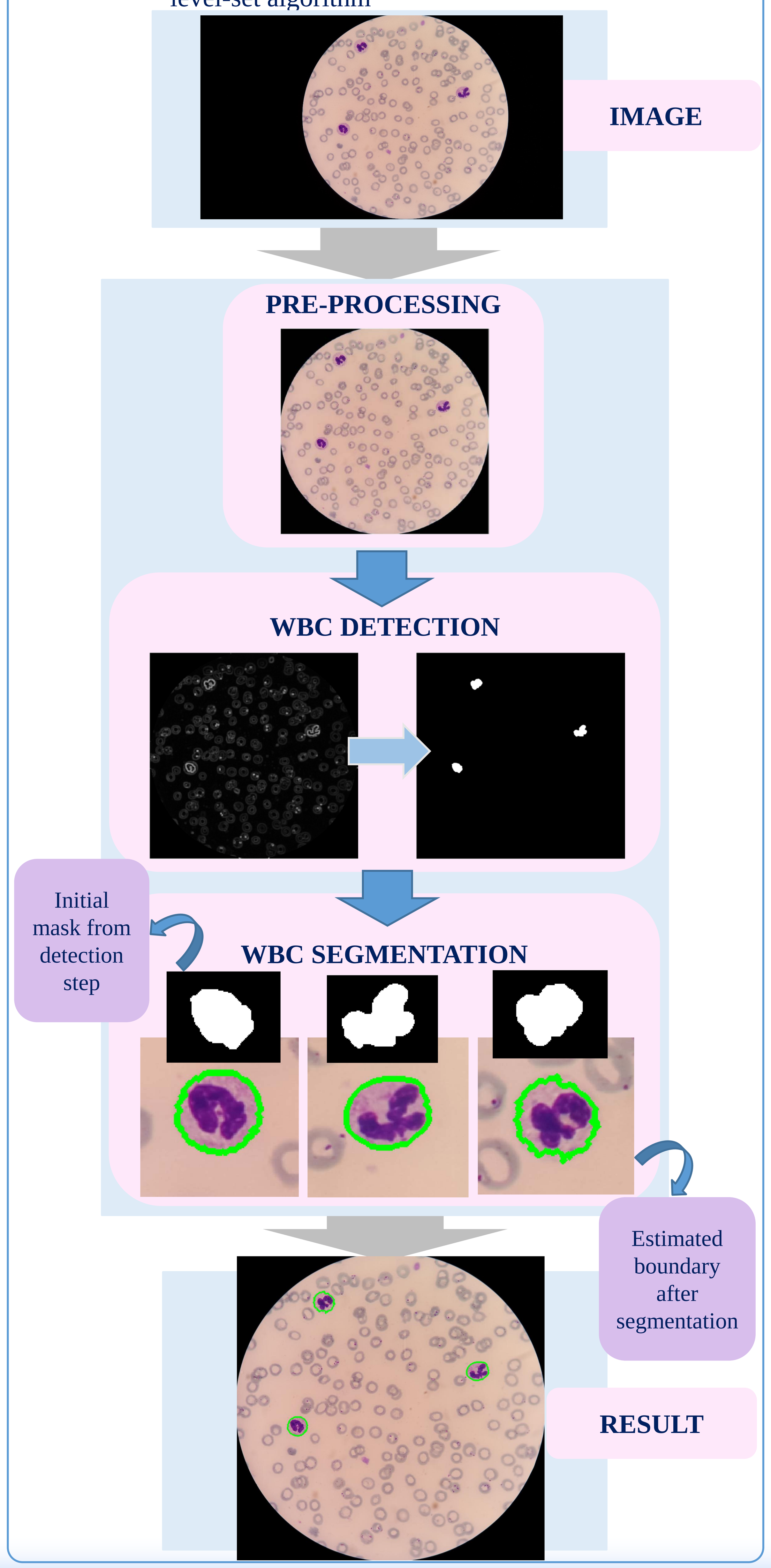
METHOD

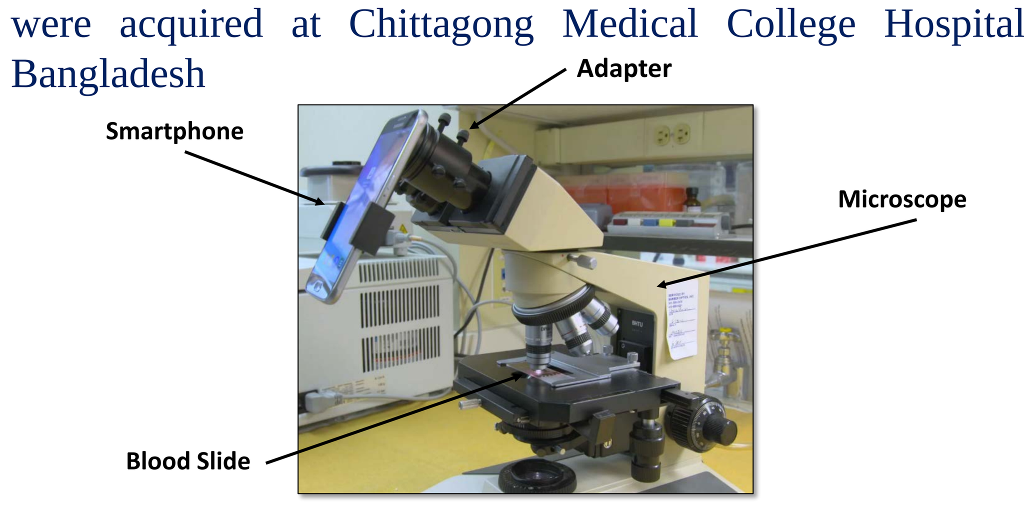
The proposed algorithm includes **three** main steps

- Pre-processing
  - To extract regions of interest (ROI) and perform illumination correction and color enhancement
- White Blood Cell Detection
  - To specify the location of any white blood cell present in an image using a range filtered version of the image
- White Blood Cell Segmentation
  - To segment the detected cells employing an accurate level-set algorithm

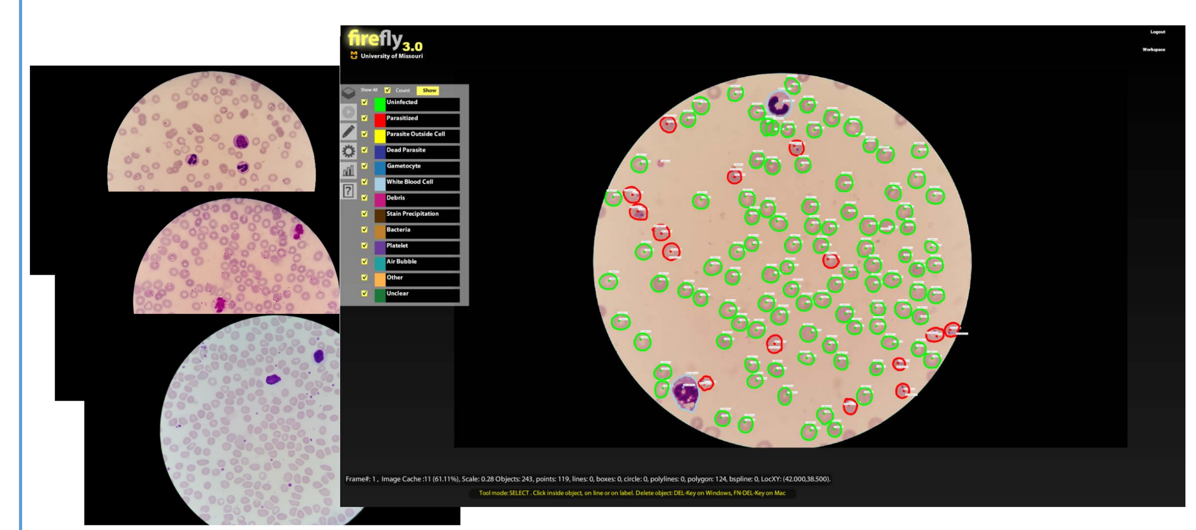


DATASET & ANNOTATION

- More than 1300 slide images containing about 1350 WBCs were acquired at Chittagong Medical College Hospital in Bangladesh



- Annotated manually by an experienced professional slide reader using the Firefly annotation tool (firefly.cs.missouri.edu)



RESULTS

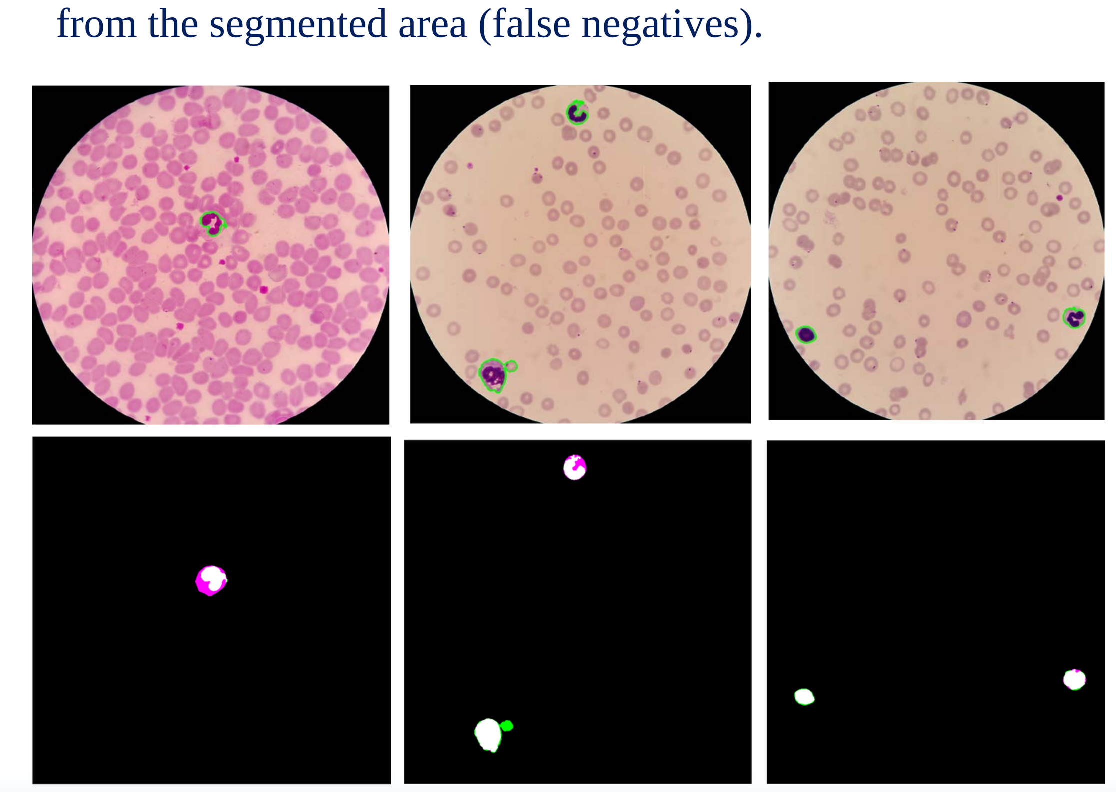
- We evaluate the two processing steps of our algorithm, cell detection and cell segmentation, separately:
  - WBC Detection Step

Measure	Value
Precision	96.37
Recall	98.37
F1 Score	97.36

  - WBC Segmentation Step

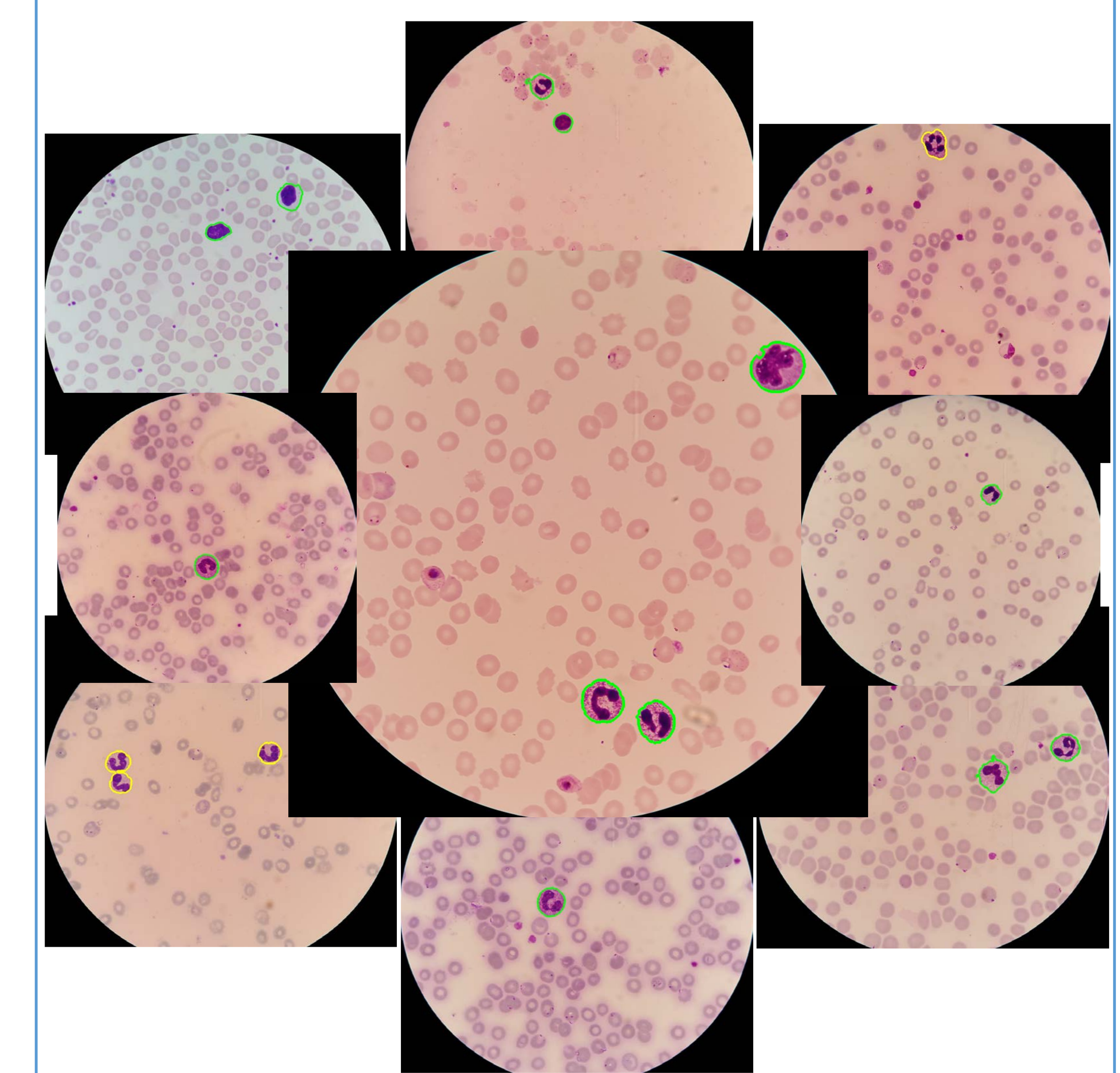
Measure	Value
Jaccard Index	82.28
Dice Index	78.33

- Illustrated, the output segmentation mask and ground truth mask are compared for three sample images. The green pixels represent the pixels falsely included in the segmented area (false positives) and the pink pixels show those falsely excluded from the segmented area (false negatives).



RESULTS (cont.)

- The outcome of the proposed method for sample images from our dataset is demonstrated below.



CONCLUSIONS

We introduced an algorithm that successfully detects white blood cells in microscopic images of thin blood smears following a range filtering approach. This method is capable of detecting different types of white blood cells with different shades of staining. The proposed algorithm accurately estimates the boundary of each cell, using a level-set algorithm. The results demonstrate that our algorithm provides promising segmentation outcomes. In future work, we will add this algorithm to our current smartphone application for malaria cell counting.

REFFERENCES

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