Automated Capillary Detection in Medical Capillaroscopic Images

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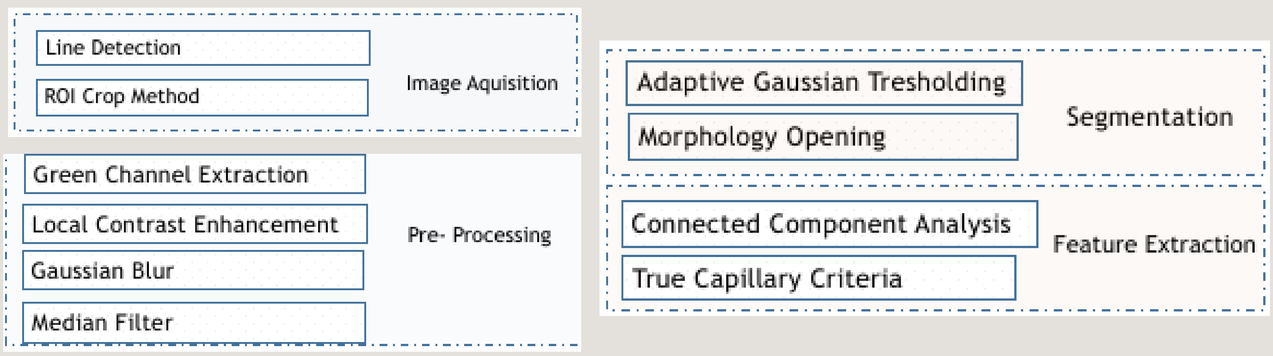
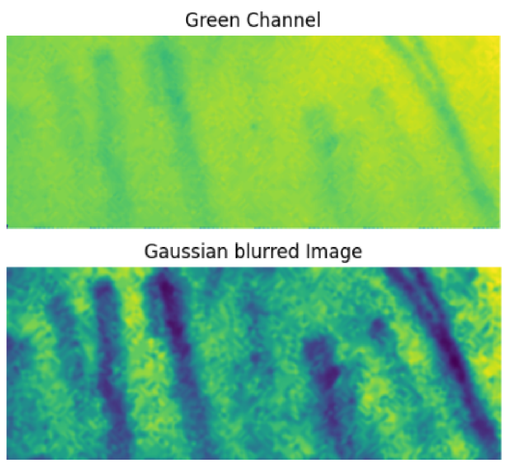
Knowing the numbers of capillaries present in a region of interest is valuable for medical diagnosis, research purposes, image analysis, treatment evaluation, monitoring disease progression and treatment response. In this work, we propose a method to detect numbers of present capillaries in a low quality ROI of Nailfold capillaroscopic images. Image processing techniques such as pre-processing, binarization, Adaptive thresholding segmentation and feature extraction are designed to obtain the number of capilllaries.
After implementation, all parameters can be measured automatically and the detection has accuracy up to 80% based on groundtruth image.

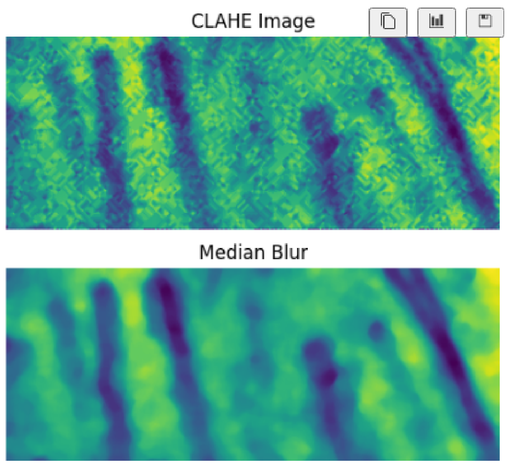
INTRODUCTION

Capillaroscopy is a non-invasive imaging technique used to visualize capillaries in the human microcirculation, aiding in the diagnosis of various medical conditions. However, the quality of capillaroscopic images can be compromised by low resolution, noise, artifacts, and poor illumination. This research focuses on developing a computer vision-based solution to accurately detect capillaries in low-quality images. we aim to create a robust algorithm for automated capillary detection. The proposed approach encompasses preprocessing, feature extraction, and model development. Experimental results and comparative analysis will showcase the algorithm's effectiveness in supporting the analysis and diagnosis of microvascular disorders, thus benefiting medical professionals.

METHOD







Preprocessing:
Green Channel Extraction possesses the highest degree of contrast between background and capillaries

Contrast Limited Adaptive Histogram Equalization (CLAHE, 15, 5x5): to enhance local contrast and improve isibility of details in uneven lighting conditions or low contrast. clipLimit=15, tileGridSize=(5, 5)

Gaussian blur for reducing noise and smoothing image details. kernel size (9x9) and standard deviation control blurring to preserve important image features.

$$g(m,n) = G_\sigma(m,n) * f(m,n), \text{where } G_\sigma = \frac{1}{\sqrt{2\pi\sigma^2}}\exp\left(\frac{-m^2+n^2}{2\sigma^2}\right)$$

Median filter (7x7) after applying Gaussian blur, preserves edges by replacing each pixel with the median value of its neighboring pixels

SEGMENTATION

Adaptive Gausian thresholding (15, 2) calculates the threshold value based on the local characteristics of the image, accommodating variations in lighting and contrast.

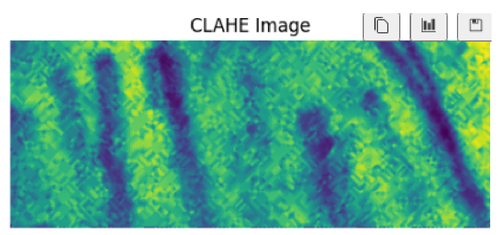
$$T(x, y) = \mu(x, y) - k * \sigma(x, y)$$

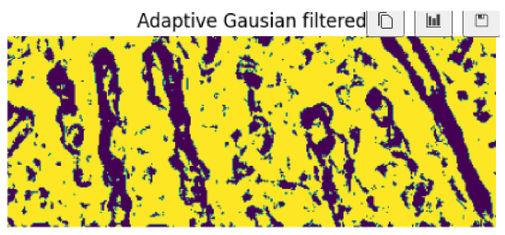
B(X, Y) = NEIGHBORHOOD BLOCK AROUND PIXEL (X, Y)
M(X, Y) = LOCAL GAUSSIAN-WEIGHTED AVERAGE OF B(X, Y).
Σ(X, Y) = LOCAL STANDARD DEVIATION WITHIN BLOCK B(X, Y).
K = CONSTANT VALUE OR OFFSET.

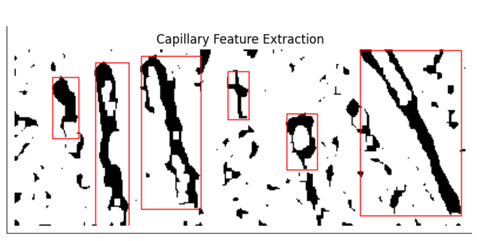
Morphological opening then combines erosion (3x3) then dilation (6x5) to remove small noise or unwanted details while preserving the overall shape and structure of the capillary regions.

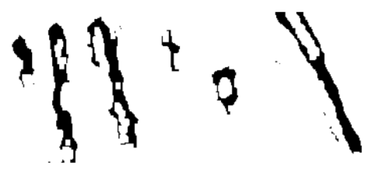
capillary feature extraction (200l) to define criteria eg length, width, tortuosityetc using connected components analysis to helps identify and label true distinct capillary structures.

RESULTS









CONCLUSION

The preprocessing stage enhances image quality, reducing noise and artifacts. The adaptive Gaussian thresholding accurately segments capillary structures by adapting to local image characteristics.

Finally, the feature extraction step captures relevant capillary characteristics, enabling quantitative analysis and aiding in the diagnosis of microvascular disorders.

Overall, our approach works but deep learning for robust feature extraction mothod should provide effective quantitative analysis

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