IMPROVING POINT-OF-CARE DIAGNOSTICS OF LATERAL FLOW IMMUNOASSAYS USING COMPUTER VISION

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INTRODUCTION

Cardiovascular disease (CVD) is considered one of the biggest current global health threats. People with chronic heart disease are living longer, increasing the need to deliver affordable, portable and high-quality Point-of-Care (POC) diagnostic devices that are readily available and user accessible.

POC devices provide low cost, rapid PoC diagnostic testing, facilitating better disease diagnosis (Vashist et al. 2017). A popular approach to POC diagnostics is the use of Lateral Flow Immunoassays (LFA). LFA are a diagnostic device used to confirm the presence or absence of a target substance within a sample. The result is obtained after a few minutes and enables the rapid diagnosis of various diseases or the detection of certain physiological conditions (such as HCG levels for pregnancy or NT-proBNP for heart failure).

One of the challenges presented is in the low sensitivity of LFA (Bishop et al. 2019), which limits their ability to detect sensitive medical biomarkers such as C-Reactive Protein (CRP), normally found in low concentrations in blood. Another issue is in the interpretation of results – most commonly completed visually by humans, the results vary based on human error, lighting and environmental conditions, leaving the method prone to inaccuracies. Advancements in areas such as image processing and computer vision have enabled us to obtain highly accurate results and use machine learning, alongside the use of smartphone technology to enable the automatic detection and analysis of test results (Carrio et al. 2015), reducing the workload of healthcare staff.

MATERIALS AND METHODS

Using image processing techniques, the work focused on aiming to improve the accuracy of region of interest (ROI) detection of LFA – in this case the ROI were the presence of the control and test lines within the strips. Working upon a small dataset (30 images), using the OpenCV watershed image segmentation (OpenCV 2020), RGB to grayscale conversion and pixel thresholding were used to enable the automatic detection of the control and test lines.

The images were taken using a complementary metal-oxide-semiconductor (CMOS) camera and converted to single channel grayscale. But due to the low image resolution, shadowing on the test strips affected the results obtained using the segmentation method. The watershed algorithm was able to identify the test and control line ROI for samples as low as 19 ng/ml. The test samples ranged from 0 ng/ml to 2500 ng/ml. Using this technique, by adjusting the thresholds and adding contour highlighting via Python, boundary boxes were drawn to highlight the ROI. Figure 1 shows the pixel intensity values as a graph, with its corresponding LFA strip and ROI detected with 2500 ng/ml. The graph clearly shows the presence of the test line and control line as intensity drops compared to the rest of the lateral flow.

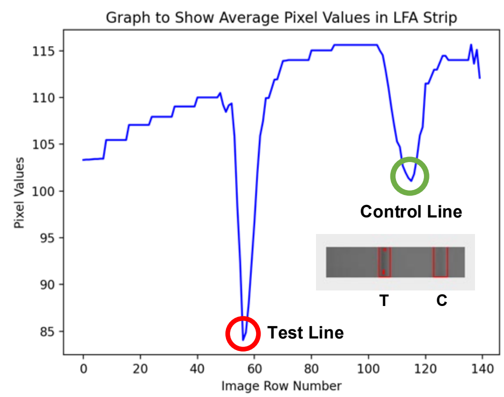

Figure 1 Graph showing the increase in pixel intensity values (where 0 = black and 255 = white) of a LFA strip with 2500 ng/ml, used to determine the presence of the lines.

RESULTS & DISCUSSION

Using image processing techniques such a segmentation and pixel thresholding, we were able to automate the process of detecting the ROI and use that to produce quick quantification and visualisation of test results.

The low resolution of the images greatly impacted the results and even with adjustments to the thresholding, some of the test lines with 'low positive' results were not correctly identified. The issues of shadowing around the edges of the strips could be eliminated with further work surrounding the method of image capture and the analysis of data collected. Future work will focus on the use of smartphone technology to capture the strip images and machine learning for the detection of ROI. In particular, we plan to look at the use of Convolutional Neural Networks (CNNs) to enable image segmentation and ROI detection of LFA. Using a CNN will enable both the automation of image classification of strip results and ROI detection, either on the client side (smartphone) or processed later at the server side.

REFERENCES

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