Cellco: Portable Device for Automated Blood Cell Count and Abnormal Cell Detection

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***Abstract*— In medical diagnosis, cell counting and cell analysis are very important to determine our health condition. The aim of this project is to automate the counting of red blood cell, white blood cell and platelets, and detect cell anomalies such as malaria using an affordable and portable device. A device called Cellco was developed based on image analysis technique due to its simplicity and portability. With the Cellco mobile application and the hardware setup, Cellco will first capture the blood sample image under microscope or microscopic camera. With image processing algorithm, Cellco performs the counting process automatically and returns the result within several seconds to the user's phone. Cellco is fast, portable and affordable, especially for hematologists and mobile doctors.**

***Index Terms*— Abnormal Cell Detection; Blood Cell Count; Image Processing; Microscope**

I. Introduction

Blood contains three major cells, namely red blood cells, white blood cells and platelets. These cells are produced in the bone marrow, which is the soft tissue inside the bone. When released to the plasma, each cell has its own role in maintaining our health. If one type of cell is diseased, it causes improper bodily functions and sickness.

Blood cell disorders can exhibit itself through various symptoms. One of the symptoms is abnormal blood cell count. Cancer patient, pregnant woman and suspected dengue or malaria patient need to check their blood cell count regularly to make sure that their cell count is within the normal range, and appropriate treatment can be administered when cell count is out of range [1].

Red blood cells contain hemoglobins that carry and transport oxygen to cells and tissues throughout our body. Red blood cell count, also known as erythrocyte count, estimates how many red blood cells a person has. Fatigue or shortness of breath can be a sign of low or high red blood cell count. Red blood cell count is affected by certain medical condition, dietary habit and medication [2].

White blood cells are one of our body defense mechanism against enzyme, bacteria or viruses that enter our body. The white blood cell count can be used to diagnose few types of infection that cannot be found or diagnosed under medical conditions. Abnormal white blood cell count alerts patients and doctors on possible sickness before it is too late. Other than that, it also helps doctor to monitor the effectiveness of chemotherapy or radiation treatment for patient with cancer [3].

Platelets are the cells associated with clotting, to stop bleeding. Low platelet count can lead to serious problem such as unstoppable bleeding or bruises and in some cases, the patient bleeds to death due to large blood loss. Platelet transfusion may be needed when platelet count is low [4].

Hence, this project primarily aimed to develop a device that could perform a complete blood count, so that the patient or even healthy people could check their blood count regularly and identify the possibility of illness before it is too late. This project includes hardware design of a portable integrated lens and software algorithm for calculating te number of cells in a blood sample and the detection of abnormal cells.

II. Methodology

The first step of this project was to understand the necessity of blood cell counting related to dengue, and the gap in automated cell counting. In addition to publication reviews, interviews and observations were carried out at local health institutions to identify the current process of blood cell counting in clinical labs and the problems that the users faced. A list of open-ended questions were designed to extract more information from interviewees regarding this project based on their experiences. The interviewees consisted of doctors, nurses, medical practitioners and bio-medical lecturers. From the interview sessions, it was found that most automated cell counting problem was for portable usage or decentralized usage. For example, mobile doctors/nurses, who had to travel to rural area, would treat many patients a day and lack the sophisticated blood analyser to help them make a diagnosis in the rural areas. There was a need for a portable system that could analyse the data on the spot. The pain point and needs of target users are summarised in Table 1.

Based on the problems identified, we proposed a portable and affordable automated cell counting device that is internet-enabled to allow fast diagnosis with server database that can work even at rural areas. This project would require both software and hardware implementation. The hardware portion included development of a portable microscope set-up using phone camera and inverse camera lens, suitable holders for lighting and glass slide and electronic circuitry for sustainable power system. The software portion included algorithms for cell calculation, malaria detection, back-end cloud storage and analysis and front-end mobile application for the user. The Internet-of-Things (IoT) features enabled users to store, retrieve and compare database images from internet [5].

Table 1
Pain Point and Needs

Process types	Pain Point	Need
Blood Count Machines	Very expensive	Affordable but functional products
	Bulky and heavy	Lightweight, compact and portable
	Requires power supply	Includes solar panel and power banks
	Difficult to operate	Easy to operate
	Only used to count blood cells	Include diseases detection
Manual Counting	Time consuming	Fast and accurate results
	Labor intensive	Automated process

In the hardware application, several designs were proposed during the entire project. The first design was the integration of 3D printing with tube microscope. The blood sample slide was placed under the microscope tube and a Cellco mobile application allowed the phone camera to capture the blood cell image through the tube microscope. The limitation of this first design was the low magnification of the tube microscope at only 40x. The accurate blood cell count will require at least 1000x magnification.

The second design was proposed using a ball lens attached to phone clip. The phone clip was used to fix the location of a ball lens to be right in the middle of the phone camera lens to transform the camera into a microscope. However, for ball lens with 1000x magnification, the field of view was too small for any useful view of the blood cell. Additionally, the diameter of the ball lens was less than 1mm, making it difficult to mount without any precision tools.

For the final hardware design, a reverse phone camera set-up was proposed to provide the magnification up to 2000x. This allowed a larger field of view of the sample slide, while maintaining the portability of the device.

III. Implementation

A. Hardware

The hardware prototype was designed using Solidworks software and printed using a 3D printer. The whole set up required power supply of only 10 volts, which can easily be supplied using a portable power bank. For sustainability, a solar panel with charging circuit was added to the design to allow the charging of the powerbank in remote areas using solar energy. This charging circuit and the power bank were detachable from the whole system, allowing independent charging away from the microscopic set-up.

A movable blood sample platform was designed to allow user to adjust the height of the glass slide for image focusing. Below the slide, there was a hollow tube with LED and above the slide, there was a phone camera lens. The blood sample slide was sandwiched in between the LED and the lens. The hollow tube allowed the LED light to hit directly on the blood sample to give a clearer image to be captured using mobile phones. The image is magnified through the inversion of the camera lens.

Figure 1: Cellco hardware with ball lens

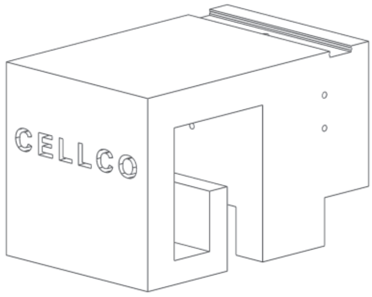

Figure 2: Cellco hardware design with inverse camera lens

B. Software Application

The software for this system comprised two main parts, the MATLAB image processing and a mobile application that was connected to the cloud. Using MATLAB, we applied image processing algorithms to detect different types of blood cells. The targeted blood cells for this project were red blood cells, white blood cells and platelets. An Android mobile application was developed as a user interface to capture an image, send image to cloud and retrieve results to be displayed to the user.

Each blood cell poses its own morphology and characteristic which can be determined with image processing techniques. For example, white blood cell contains granule inside, but red blood cell and platelet do not have any. Thus, each type of blood cell identification required their own specific algorithms and threshold values. Figure 3 shows the overall process flow for the image analysis using MATLAB.

In red blood cell count, the algorithm firstly converted the captured blood cell image into HSV color space. HSV color space contained hue, saturation and value component of an image. Then, the image is segmented by setting threshold value. Hole filling and unnecessary segment elimination was done to make the image clearer. After this filtering process, the image was then converted into binary image. Red blood cells, which are the targeted cells, will be circled based on the correct parameters and the number of circles would be automatically counted to be displayed to user. The technique involved in this step is Sobel edge detection [2].

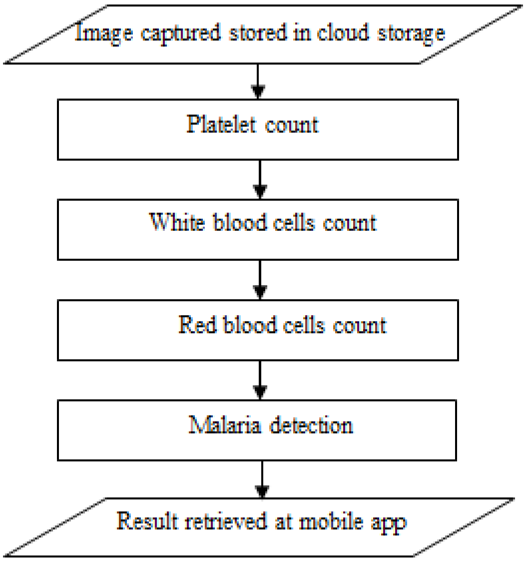

Figure 3: Flow chart of MATLAB algorithm

For white blood cell count, a different procedure was used. First, a disc shape structuring element was created. The structuring element was used to erode the captured blood sample image. The isolated pixels were removed morphologically. After that, the algorithm converted the filtered image into black and white. Eclipse detection algorithm, which used modified differential evolution was applied. The algorithm would only circle the cells with the dark content inside, which were the granules of the white blood cell. User verification could be requested for white blood cell detection to prevent wrong detection [3].

The third type of targeted blood cell in this project was platelet, which had the smallest radius among all types of blood cell [6]. Firstly, the algorithm adjusts the intensity of captured image by converting the true color to grayscale. The grayscale image was then converted to black and white color. Edge detection technique using Sobel algorithm was used to filter the salt noise of the image. By setting the appropriate threshold values, the radius beyond platelet range is eliminated. The targeted cells are circled and the number of circles was counted by the algorithm automatically [6].

Besides the counting of each type of blood cells, one more important feature was added in Cellco, which was the detection of malaria parasite in cell. Red blood cell infected with malaria parasite would have its morphology altered and presented an irregular shape [1]. The algorithm in malaria detection was quite similar to the algorithm used in red blood cell counting. The procedures were the same until the elimination of unwanted segment in the filtered image. After the blood sample image was filtered, the image was converted into binary image. The result of 'yes' or 'no' would be displayed on screen to indicate the presence of malaria disease based on the number of the eclipse detected by the algorithm. If the number of eclipse obtained was different with the red blood cell count, the blood sample was suspected to contain malaria parasite.

A graphical user interface (GUI) was created using MATLAB to link all the functions for counting different types of blood cells. This GUI would be linked with the Cellco mobile application to analyze blood cell sample. For red blood cell count, white blood cell count and platelet count, the result of the algorithm will be displayed in numerical form. The presence of malaria will be shown as a Yes/No indication. Users can obtain the results from their mobile phone after submitting an image.

Cellco mobile application was used as an interaction platform for users to turn a sample image data into understandable results. The user only needed to capture an image, send the image to a specific cloud database and wait for results to be displayed. At the backend, the analysis will be completed using MATLAB algorithm and returned to the user via mobile application display. Figure 4 shows the process flow of the mobile application.

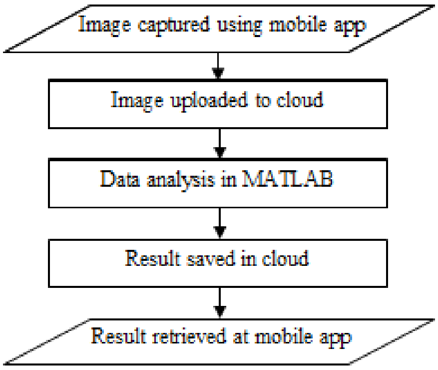

Figure 4: Flow chart of mobile application algorithm

IV. Results and Discussion

In this project, 23 sample images, with different types of blood cells, different magnifications and different blood sample preparation techniques, were tested. Figures 5-9 below shows the results of image analysis using the Cellco application. The results of the analysis would be shown in a graphical user interface (GUI) of Cellco application with the raw image, as shown in Figure 10. The summary of the results would also be sent to the mobile application to notify the user. The results of the automated blood count was compared with manual count.

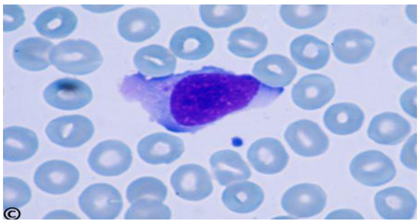

Figure 5: Raw image of blood sample image

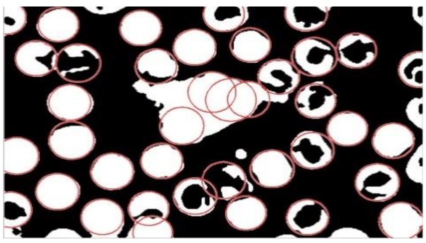

Figure 6: Detection of red blood cells

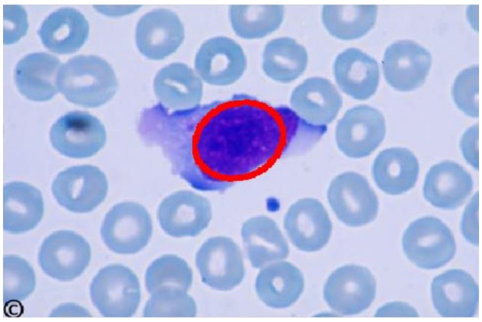

Figure 7: Detection of white blood cells

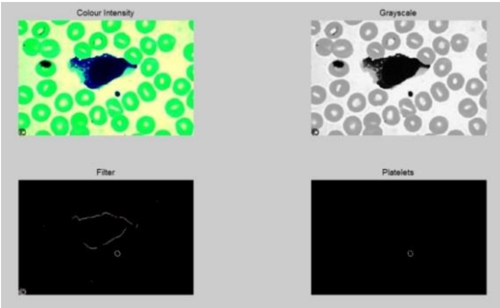

Figure 8: Detection of platelets

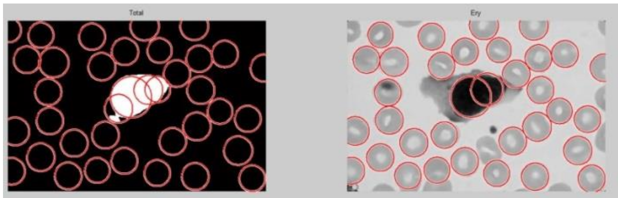

Figure 9: Detection of malaria parasites

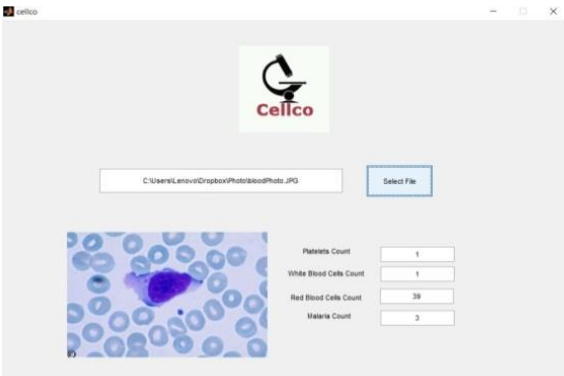

Figure 10: Graphic user interface of Cellco application

V. CONCLUSION

A current blood analyser system for cell counting used in hospitals are large and costly (in terms of purchase price and maintenance), making it impossible for mobile doctors and smaller clinics to afford the system. Thus, proper diagnosis could not be carried out in rural areas due to the lack of medical equipment. Cellco is designed as an affordable and portable system to perform automated blood cell counting using sustainable energy and IoT features. Cellco worked with a portable 10 volts power bank and a mobile phone application captured blood sample images using the camera lens and inversion lens. The Cellco algorithm could identify and count red blood cells, white blood cells and platelets, as well as detecting the presence of cells infected with malaria parasites. With the cloud database, images can be stored for further research and any outbreak could be detected and contained much earlier. The current work focused on implementing a workable solution, but more refinement has to be carried out to fine-tune the threshold values for cell detection in each category. Additionally, a systematic test has to be carried out with more images to quantify the accuracy and performance of the system.

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