Mobile Microscope supported by whirling Centrifuge for the effective detection of Pathogenic cells

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Abstract— One of the most basic and powerful tools in all of science and medicine is the light microscope, the fundamental device for laboratory as well as research purposes. With the improving technology, the need for portable, economic and user-friendly instruments is on high demand. The light microscope though an effective device, fails to live up to the emerging trend. And adequate access to healthcare, is not widely available, especially in developing countries. The most basic step towards the curing of a malady is the diagnosis of the disease itself. This challenge is solved with the most common device, Cell Phones, which prove to be the immediate solution for most of the modern day needs with the development of wireless infrastructure allowing us to compute and communicate on the move. This opened up the opportunity to develop novel imaging, sensing, and diagnostics platforms using mobile phones as an underlying platform to address the global demand for accurate, sensitive, cost-effective, and field-portable measurement devices for use in remote and resource-limited settings around the world. A new approach is proposed wherein the camera of a mobile phone would be sufficient to study the blood samples and check for the presence of malarial parasites.

Keywords – *Malarial parasites; microscope; cellular; hand-held*

INTRODUCTION

The developments in the application of information technology have completely changed the world. The obvious reason for the introduction of computer systems is: reliability, accuracy, simplicity and ease of use. Besides, the customization and optimization features of a computer system stand among the major driving forces in adopting and subsequently strengthening the computer aided systems[1]. Mobile phones are becoming an important part of everyday lives, so extending their purpose to healthcare systems, with the use of mobile phone cameras to capture clinically relevant images growing rapidly in recent years. For instance, doctors have demonstrated new ways to interact with and record medical image data in various medical arenas that specializes in dermatology and neurosurgery. Also mobile phones have a wider reach and audience compared to the testing laboratories. There are many research based projects emerging in the recent years to diagnose diseases in the fastest means possible. Many important medical decisions are still based on opinion of a lab expert or technician [7]. This can reduce the number of people to doctor ratio. Since prevention is better than cure it is preferred to give the patient diagnosis kit [8] Replacing some of these costly laboratory-based instruments with cheaper, portable devices that can achieve similar performance will see for the option of reducing the cost and infrastructure burdens that quality health care situations in the society.

ANALYSIS AND PROPOSAL

To address healthcare needs in low-resource regions, research has also shown that mobile phones can bring traditional diagnostic assays to inadequately served populations. Microscopic imaging, holographic imaging, label-free spectroscopy, and image-based quantification of diagnostic tests.

The Mobscope is based on a cost effective camera system. With these cameras, imaging parameters can be carefully chosen and maintained so that clinicians can obtain accurate and repeatable information needed for diagnostic decision making. For example, diagnosis of malaria species from images of blood smears requires micron-scale resolution of parasite shape, while the speed of diagnosing malignancy on breast biopsy slides has been shown to improve with consistent colour information[2].

Mobile phone cameras, on the other hand, permit limited control of camera parameters and often allow no control over post-processing done on the image before viewing or transmission. Exposure time and electronic gain are automatically adjusted on most phones to prevent over or under-exposure, but this can cause variations in brightness and colour response within or between specimens, making comparisons across images by human viewers or by automated analysis software difficult. In this work, we systematically characterize the image quality achieved by mobile phone cameras when used as part of a mobile phone microscope. The effect of iPhone and Android phones released within a given period on the spatial resolution of images taken with a custom mobile microscope, known as Mobscope, outfitted with an adaptor is suitable for use with multiple phone types. Also additional characteristics of the mobile phone microscopy system including brightness uniformity across the field of view, degree of image distortion, and nonlinear encoding of pixel intensity, which can be corrected through a gamma transformation is examined. Barriers to the use of mobile phones for quantitative imaging caused by the automatic camera parameter adjustments implemented by most phones is analysed. Artefacts that result in nonlinear response to input signals, variation in spectral sensitivity, and changes in effective magnification – all of which can compromise diagnostic imaging is demonstrated– and outline approaches to achieve more reproducible and consistent imaging is outlined. The results of our study indicate that mobile phone microscopes can indeed provide reliable and repeatable images suitable for diagnostic use.

Mobile Based Images

The use of low-quality, low-cost components makes sense in the context of visual pathologic inspection. In this application, trained professionals manually examine samples to observe tissue- and cellular-level disorders, often with the aid of optical dyes. In fact, the fundamental basis of pathologic diagnosis has remained essentially unchanged for more than 100 years, following the standardization of staining procedures such as hematoxylin and eosin (H & E) for tissue sections and Wright-Giemsa staining for blood samples. In this paper, these issues are addressed by combining structural images into a multimodality tissue profile, which paves the way for classifying healthy and pathogenic cells, followed by a categorization of the cells into more specific classes of Normal Blood Cells (NBC's), White Blood cells (WBC's), platelets, Pathogenic cells (PC's).

The contributions of this work are: 1) creation of a multi-modality profile by integration images with conventional structural images, using cellular data from several patients using the centrifuge; 2) investigation of the potential of this multi-level classification in differentiating healthy from the pathogens. Accurate and consistent cellular level classification results for several patients to illustrate the robustness of our framework, and suggest potential applications in assessing growth and in computer-guided surgery.

Performance Test

The performance of the model is based on the magnifying property of the lens which is used to distinguish the property of the cells based on the image being processed in the mobile application. Thus it is necessary for the device to be compatible with the growing population and be answerable to the needs of the society. The representative model from which profile is developed is shown in Fig.1.

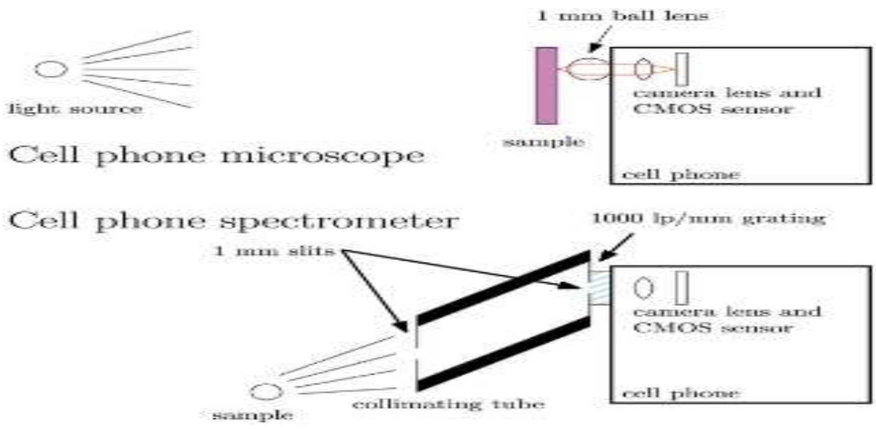

FIGURE 1. A representative model from which the profile is developed.

MODELLING

Cells in the human body number in the trillions and come in all shapes and sizes. These tiny structures are the basic unit of living organisms. Cells comprise tissues, tissues comprise organs, organs form organ systems, and organ systems work together in an organism. Cells of the digestive system, for instance, are different in structure and function from cells of the skeletal system. No matter the differences, cells of the body depend on one another, either directly or indirectly, to keep the body functioning as one unit.[3]

Centrifuge and Lens

An ultra-low-cost, human-powered centrifuge is created that separates blood into its individual components in only 1.5 minutes. Built from 20 cents of paper, twine and plastic, a "paperfuge" can spin at speeds of 125,000 rpm and exert centrifugal forces of 30,000 Gs[4]. A centrifuge is critical for detecting diseases such as malaria, African sleeping sickness, HIV and tuberculosis. This low-cost version will enable precise diagnosis and treatment in the poor, off-the-grid regions where these diseases are most prevalent. When used for disease testing, a centrifuge separates blood components and makes pathogens easier to detect. A typical centrifuge spins fluid samples inside an electric-powered, rotating drum. As the drum spins, centrifugal forces separate fluids by density into layers within a sample tube. In the case of blood, heavy red cells collect at the bottom of the tube, watery plasma floats to the top, and parasites, like those that cause malaria, settle in the middle.Fig. 2 and Fig. 3 shows the centrifuge and the lens picture. The basic principle of using a small spherical lens held close to the eye of the camera lens of the mobile phone. The proposed model uses a 140X magnification lens. The proposed model uses a 140x magnification lens placed the customised module and can be adjusted for perfect viewing (Manu Prakash, 2014) [9]. The choice of the phone for this work is driven primarily by the desire to have a camera placement that allowed easy lens attachment and sample viewing, as well as a touch screen interface to avoid motion[10].

FIGURE 2.: Centrifuge used in the form of Cardboard Sheet

FIGURE 3.: Lens

METHODOLOGY

The methods adopted in developing a working model of the device is discussed. The images recorded by cell phone microscope based on spherical ball lens have high noise ratio and intensity variations compared to images acquired by our optical microscope and hence requires image processing to enhance the images.

OpenCV library which provides a common infrastructure for computer vision application is used to process the input image from the mobile camera. The methods available in OpenCV library were used on the images recorded by cell phone microscope. Briefly first, the images were converted to HSV and the average filter was applied to obtain a uniform background. Second, the background subtraction operations of OpenCV were implemented.

The pathogenic cells are filtered out when the colour range of the pathogenic cells lies in a specific range. For this purpose we make use of inrang() function. Prior to that we need to know the *colorspaces*, ranges and thresholds. For that we have used MAT class provided in OpenCV library. The RGB colour system is the most common as our eyes use something similar, but OpenCV display system uses BGR colours. So, it is better convert the input frame(image) it into HSV/HSL *colorspace*.

The HSV and HSL decomposes colors into their hue, saturation and value/luminance components. There are more than 150 color spaces in OpenCV, here we have used RGB to HSV. The function used for conversion is cv2.cvtColor(input_image, flag)where flag determines the conversion type, here it is cv2.COLOR_BGR2HSV. The OpenCV library requires OpenCV Manager installed on the target machine. This provides the best OpenCV bundle based on the hardware.

The overall scenario can be put into work in a GUI using the GUIDE (Graphical User Interface Development Environment).This gives an interactive user experience. The given code can be further put onto the coder and can be converted into a *.C* file. This helps to create an android application for similar implementation in a Mobile phone. [6]

Design Drawing

The Fig. 4 shows the design drawing of the external setup of the Mobscope.

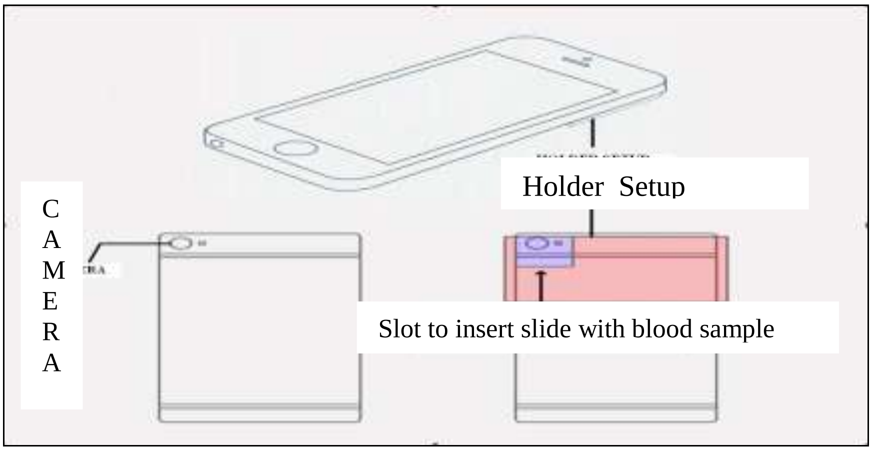

FIGURE 4. External Setup/ Design Drawing

RESULTS

Although much important research has gone into developing very sophisticated diagnostic instruments, many important medical decisions are still based on expert opinions formed by trained professionals on the basis of data gathered via conventional devices such as microscopes, cell counters, and spectrophotometers. Replacing some of these costly and monolithic instruments with cheaper, portable devices that can achieve similar performance is an attractive option for reducing the cost and infrastructure burdens that quality health care places on society. Here two such devices integrated into a cell phone platform is presented. The Fig. 5 illustrates the human blood and Fig 6. shows the onion cells and the sample tap water taken for testing purposes.

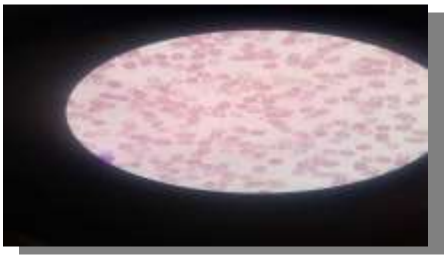

FIGURE 5: Human Blood

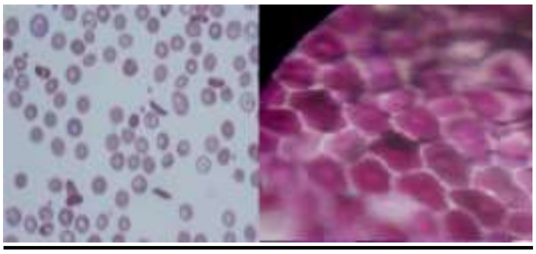

FIGURE 6: Tap Water(Left), Onion Cell(Right)

The first instrument, a cell phone-based microscope has been shown to have a resolution of 1.5 microns in the center of its field-of-view. Although the image quality rapidly degrades in a raw image due to the use of a single ball lens, the images can still be used to accurately diagnose a variety of blood diseases. Using a longer focal length ball lens.

Additionally, we have shown that although the field-of-view has field dependent distortion and defocus when using the 1 mm ball lens discussed in this article, the aberrations are amenable to image processing. Furthermore, we have made an initial attempt at performing a red cell count of a blood sample imaged by the cell phone microscope. Although in this case we only report results of an algorithm locating and counting cells without regard to size or shape, the CellC algorithm or one similar could be easily used to report morphometric parameters that could enable an approximate complete blood count (CBC), discriminating cells into several blood cell classes.[5]

OBSERVATIONS

An initial attempt of red cell count of a blood sample imaged by the cell phone microscope is done. So the first step is to eliminate the count of the pathogenic cells by detecting them via colour based image processing. This is showcased in **Fig 7** (*the appearance of the falciparum in blue stains taken as an image by the cell phone microscope). The detected image as seen on XPS vision is shown in* **Fig 8.**

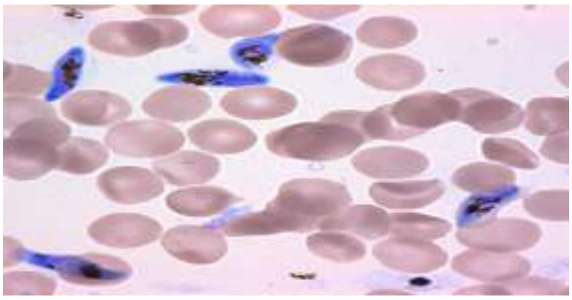

FIGURE 7.: Malarial Parasites

FIGURE 8.: Image detected on the cell phone

SIGNIFICANCE OF THE RESULTS

The focus of this project is to make field microscopy practical and cost-effective at the same time. The approach combines the following characteristics:

Cost-effective: Only a single lens is required in addition to a cellphone camera.
Non-intrusive: Our setup does not require intrusive modification of the phone.
Flexibility: Our detached camera-lens configuration allows any camera to be used for microscopy.
Minimal computation: We do not require extensive post-processing, as e.g. holographic approaches.
Computational illumination: Using a second cellphone display as the background illumination allows enhanced microscopic images to be captured.

POTENTIAL BENEFITS

The bulky nature of the detection machines used these days is a major drawback. Being a portable, hand-held device, Mobscope makes it possible for easy detection of malaria right at home. Another major advantage is the cost, which is much lower than the tedious laboratory detection procedure and is affordable even in the economically backward regions.

Mobscope enables lesser time and energy consuming diagnosis of malaria from home. This entire setup behaves like a Shell, which could be fed any domain specific knowledge to make it work on that domain.

ADVANCEMENTS

A spectroscopic system may be included in future may not currently have the throughput to measure more weakly fluorescing compounds, or obtain high quality diffuse reflectance or transmission spectra in the presence of low signal, these are actually not intrinsic limitations to the system. For example, with a diffuse reflectance system where source and detector are coupled to the tissue through optical fibres, a designated attachment could be designed that would obviate the need for the lossy collimation tube. Currently exploring these and other options to help improve the efficiency of the detection system**.** The cell-phone microscope can work in multiple modes of operation, including polarized and transmission modes. The ability of the microscope to easily obtain simple but visually striking images points to the camera's usefulness as an educational tool.

CONCLUSION

The proposed module demonstrates the basic clinical utility for the diagnosis of malaria through experiments. The device built through adding simple and inexpensive attachments to a standard cell phone. The basic clinical utility of these devices are demonstrated through some initial experiments. The choice of the iPhone as the camera for this work was driven primarily by the desire to have a camera placement that allowed easy lens attachment and sample viewing, as well as a touch screen interface to avoid motion due to button pressing. The work presented in this paper has the potential to make disease diagnosis and screening accessible in parts of the world that have no adequate access to healthcare. Some of these experiments are performed using other phones from different manufacturers with qualitatively similar results indicating that the choice of phone and camera specifications are not the limiting factors in the performance of our system. The work presented in this paper has the potential to make disease diagnosis and screening accessible in parts of the world that have no adequate access to healthcare. The module developed can be further extended to the diagnosis of diseases such as sickle cell anaemia through the shape of the cells.

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