Development of a Low-cost Smartphone-connected Digital Microscope

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Abstract

Introduction: Modern light microscopes are available with built-in illuminator and facility of photomicrography. This enables the microscopy to be ready for telemedicine. However, resource-limited settings still find difficulty in procuring those microscopes. Aim: The aim of this study was to upgrade a light microscope to a smartphone-connected digital microscope with minimal cost to make it ready for telemedicine. Materials and Methods: A commercially available (price: ₹389) Universal Serial Bus (USB) web camera was set on the eyepiece and fixed with the help of an aluminum sheet. Light emitting diodes (LEDs), covered with an optical diffuser, were set below the condenser. The camera was connected to an Android smartphone with an application for capturing image and video. Sixteen faculty members provided their opinion about the new device. Results: The smartphone-connected microscope was successfully used to focus and capture image and video of various slides. The images and videos were stored in the smartphone and shared via E-mail and other channels (e.g., WhatsApp and Telegram). This camera was also successfully connected to a laptop for projecting the real-time microscopic field on a screen. According to faculty members, focusing an object and capturing the image are the best features of the device; however, development of the device received lowest score. Conclusion: A light microscope was upgraded to telemedicine ready microscope with nominal cost and moderate effort. It can also be used in medical teachings as it can project real-time images of a slide under the microscope. As it is equipped with LEDs, powered by the same smartphone, it can be operated without daylight or during a power outage.

Keywords: Microscopy, photomicrography, smartphone, telemedicine, videomicrography

Introduction

In 1590, the first compound microscope was made by Hans Janssen and his son Zacharias. Later, in around 1625, Giovanni Faber coined the term “microscope.” With the initial interest of observing insects and flies, the microscope now became an inseparable part of scientific research. Compound microscopes have now been upgraded to a digital microscope which uses the digital camera fitted at the level of eyes. Further addition of built-in illumination eliminated adjustment of the mirror below the condenser to get adequate light. When these microscopes are connected with computers, the images of the slide can be captured and used for further analysis or distant diagnosis. Addition of these new technologies increases the overall cost of these microscopes. In developing countries like India, in many resource-limited settings, these microscopes are not available. This hinders reach of telemedicine or facility of distant diagnosis in those settings. In India, especially in rural areas, frequent power outage causes interruption in microscopy. For solving this issue, a smartphone torch-based illumination system for microscope has been developed. However, in that case, the smartphone would only be used as a light source, not a hub for telemicroscopy.

This was the triggering factor to upgrade an old microscope to a digital microscope with minimal cost, fully capable of streaming microscopic filed on a computer or smartphone. Furthermore, using a smartphone would help us capture...
image or video of the field and to use it for distant diagnostic purpose.

**Materials and Methods**

**Materials**

1. A light microscope (Unicon®, India) with 10× eyepiece and three objective lenses (viz., 10×, 45×, and 100× oil immersion)
2. A commercially available web camera (QHM495 LM, Shenzhen Hiper Song Electronic Limited, Hong Kong, China) with complementary metal oxide semiconductor sensor which yield interpolated 25 mega pixel images. Its captures video with maximum 30 fps with 50 Hz antiflickering technology
3. An empty soft drink aluminum can
4. A white polyethylene plastic
5. A pair of scissors, polyvinyl carbonate tape, screw driver, hacksaw blade, and glue.

Major components are shown in Figure 1.

**Method**

The web camera casing was dismantled to get the camera with its hood. Five among the six light emitting diodes (LEDs) were removed from the circuit board. The microphone kept intact with the circuit. The hood of the camera was in excess that we require. Hence, the excess portion was cut with the help of a hacksaw blade. It is shown in Figure 2. A piece of aluminum sheet was taken from an empty soft drink can with the help of a hacksaw blade and scissors. The technique of cutting the can and taking a piece of sheet can be found elsewhere.[5] It was wrapped on the eyepiece and the shape was secured with the help of polyvinyl chloride tape. Thereafter, the camera was positioned on the eyepiece and fixed with the aluminum cylinder. Some extra wire was used to connect two LEDs in a parallel connection and it was attached with the legs of the circuit board-attached LED. The LEDs were covered with a white polyethylene plastic for making the light diffuse.

**Smartphone application**

By searching the words “USB camera” on Google Play store, we got several applications which are capable of connecting a web camera to the smartphone. Among the applications, “USB Camera - Connect EasyCap or USB WebCam” (ShenYao, China) had the highest rating. It allows a user to use it free of cost (application shows advertisements). Hence, we installed the application on the smartphone (Redmi Note 4, Xiaomi, China).

**Connection**

The smartphone we used in this study allows only a micro-USB. Hence, we used an OTG connector to connect the USB camera with the smartphone. A schematic of the connection is shown in Figure 3. As the LEDs are connected with the camera circuit, connecting the web camera with the smartphone simultaneously provides power to the camera and LEDs for illumination.

**Usage**

The method of focusing an object under the microscope remains the same as we do normally. However, here we do not see through the eyepiece. The camera was connected with the micro-USB and camera application on the smartphone was started. Unfocused field appeared on the smartphone screen. Then, the slide with the object of interest was placed on the microscope stage and the desired objective lens was set on the place. According to working distance, the body tube was lowered and then gradually moved upward with the help of coarse adjustment screw by looking at the smartphone screen. After coarse focus, fine adjustment screw was used to adjust the focus. The field under the microscope was captured by the “Snapshot” button and video was recorded by the “Record” button on the user interface of the smartphone application [Figure 4].

**Sharing captured image and video**

By default settings, photomicrograph or videomicrograph was saved on the internal storage of the smartphone (can be changed to external storage from the application settings). These images and videos were viewed from the gallery of the smartphone. These files were shared directly from the smartphone via E-mail, WhatsApp, Telegram, and Bluetooth.

**Opinion survey**

Sixteen faculty members were explained about the making, connection, focusing, scanning of slides, capturing image and video, observing the captured image and video, and sharing it
with others. Their opinion about the device was collected on a questionnaire with five-point Likert-type response option.

**Statistical analysis**
The survey response was coded in a spreadsheet with the following codes: strongly agree = 5, agree = 4, neither agree nor disagree = 3, disagree = 2, and strongly disagree = 1. Scores were presented in mean, standard deviation, and range.

**RESULTS**
The outcome of this study is a low-cost digital light microscope [Figure 5], which is capable of transferring real-time images to computers and smartphone. It is capable of capturing images and videos of the microscopic field. Some captured images (after removing vignette from the image with a 3:4 crop ratio) are shown in Figure 6a-i and a video is shown in Video 1.

The survey scores are shown in Table 1. The highest score was received for focusing an object under the microscope and capturing images and videos of that field. The lowest score was received on the process of making the device.

**DISCUSSION**

**What is already available?**
Digital microscopes are available on the markets which are fitted with digital cameras. These microscopes are supplied with built-in illumination. A power supply is needed to use the camera and the illuminator.

**What are the limitations of those devices?**
High cost is the limiting factors for its usage in resource-limited settings. These devices are connected to computers or to a combination of proprietary software and display device. Further, a power supply is required for using it (both the microscope and computer). In any emergency power outage, the microscopy is not possible.

**Why the new device?**
It is a low-cost alternative to commercially available digital microscope. We invested only US$5.5 for development of the device. Anyone can make the device with a simple light microscope. For this study, we used an abandoned microscope. As this can be used with a smartphone, it eliminates the need of computers. However, connected to a computer, it can be used for projecting the images on the projection screen. A video can also be captured with voice description of the microscopic field. This would help in teaching medical and allied branch students. In India, power outage is a frequent problem. The LEDs of the developed digital microscope is powered by the same smartphone which is used for focusing and capturing the images and videos. Hence, it can be used during power outage. This would help for emergency microscopy in remote and rural area where there is frequent power outage.

**Limitation of the device**
We used a low-cost web camera. The image quality could have been better with the use of a high-resolution camera. As the device does not come with a warranty, any further servicing should be done from developers’ capability. During usage,
the smartphone remains engaged in microscopy. Hence, we
either may be disturbed by calls or messages or sacrifice them
(i.e., keeping phone on airplane mode) for the microscopy.

**Conclusion**

A compound microscope was upgraded to a digital microscope
with the help of a web camera. Illuminator was also made
with the help of LEDs of the camera. This low-cost digital
microscope can be powered and used with a smartphone. This
enables to capture photomicrographs and videomicrographs
easily and share those with others over the internet.
Furthermore, it can be operated during power outage or where
getting daylight becomes difficult.

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Nil.

**Conflicts of interest**

There are no conflicts of interest.

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