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A portable device using a single-board computer for white light and fluorescence widefield images

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ABSTRACT

In a world with a growing need for rapid medical diagnosis, point-of-care devices based on optics have become an interesting solution. Moreover, the low cost, simplicity, and ease of use also become essential to be applied in a clinical environment. Nowadays, smartphones are an attractive, user-friendly option, but the rapid changes in the models, the variety of brands, and the risk of contamination of personal smartphones in a clinical situation make this choose not the best one. Single-board computers as Raspberry Pi can be an alternative for a low-cost imaging device that allows image acquisition, visualization, and processing. This study describes a portable system capable of acquiring and processing white light and fluorescence images, suitable for clinical purposes. The system consists of a single-board computer (Raspberry Pi 3B+, Raspberry Pi Foundation, UK) coupled to a digital camera and a touchscreen display. The portable device comprises six violet LEDs (emitting at 407 nm) to excite the tissue and a long-pass optical filter to acquire the fluorescence images; four white LEDs to obtain the white light one, besides a digital camera to perform the acquisition itself. The images are saved in the single-board computer, where an algorithm written in Python (Python Foundation) calibrates the camera, acquires, and processes the acquired images, interacting with the user through touch with a GUI. Being a portable, easy to use, low-cost system, this device is convenient to be used in a clinical environment and allows a fast diagnosis and the possibility to be reproduced for widespread point-of-care use.

Keywords: point-of-care; m-Health; low-cost; dual modality; fluorescence; single-board computer; oral cancer; Digital dermatoscope

1. INTRODUCTION

The early diagnosis is vital in the treatment of some diseases, like cancer. Due to this, it is of fundamental importance to develop methods and devices to aid the physician's analysis. Moreover, the low cost, simplicity, and ease-to-use also become important to be applied in a clinical environment. Thereat the development of point-of-care or mobile health (m-Health) devices based on optics have become an interesting solution.[1,2]

Nowadays, smartphones are one user-friendly option and have been used in many situations.[3–7] However, the rapid changes in the models, the variety of brands, and the risk of contamination of personal smartphones in a clinical situation make this choose not the best one.[8,9] Another important option is to use single-board computers (SBCs) instead of smartphones. This option is highly attractive, as it significantly reduces the contamination risk and can be developed for the desired application in a specific way.[10–12] Furthermore, the use of dual-channel devices, that integrate both white light and fluorescence widefield imaging can improve the diagnosis[13–15] In this way, an important tool to be approached is the white light and fluorescence widefield imaging, which is able, for example, to monitor the protoporphyrin-IX (PpIX) consumption during photodynamic therapy (PDT),[16,17] and to improve the dermatologist's diagnosis of skin disorders and cutaneous infections.[18,19]

In this paper, we describe the development of a dual-channel digital system based on a Raspberry Pi that allows image acquisition, visualization, and processing for white light and fluorescence images. The use of the dual-modality portable point-of-care system will improve the clinical diagnosis and monitoring, both in performance and in waiting time.

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2. MATERIALS AND METHODS

2.1 Dual modality digital device

This system consists of a single-board computer connected to a complementary metal–oxide–semiconductor (CMOS) camera and a thin-film-transistor liquid-crystal display (TFT LCD) to acquire, display, and process the images. A light-emitting diode (LED) ring is used to illuminate the target area, and a fluorescence filter blocks the excitation light. Also a plastic holder was designed to bundle all the system, as shown in Figure 1, and an application developed in Python to control the camera. The following sections describes the system in detail.

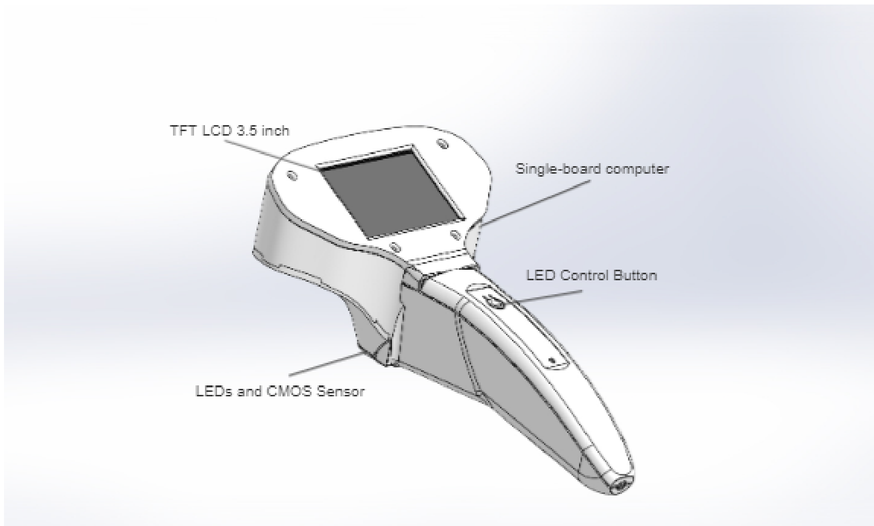

Figura 1: Schematic representation of the Dual Modality Digital Dermatoscope

2.2 Single-board computer, CMOS sensor and TFT LCD screen

The single-board computer elected for this project was a Raspberry Pi (Raspberry Pi 3B+, Raspberry Pi Foundation, UK), because of its low price and affordable documentation, one of the largest and most active. The Raspberry Pi has the function to control the system and integrate its components. Their specifications are described in table 1. The device was connected to a CMOS sensor, with 1.3MP of resolution and a lens, obtained from a digital microscope (Celestron REF.44301). For visualization, a TFT LCD was added in the system. Being very compatible with the Raspberry Pi, the screen is touchscreen, has 3.5 inches, and a resolution of 320x480.

Raspberry Pi 3 Model B+ Specifications
Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz
1GB RAM
Wireless LAN, Bluetooth 4.2 and BLE
4 USB ports
40 GPIO pins
Full HDMI port
Combined 3.5mm audio jack and composite video
Camera interface (CSI)
Display interface (DSI)
Micro SD card slot

Tabela 1: Specifications of Raspberry Pi 3 Model B+.

2.3 LED ring and filter

To illuminate the field of view region, a LED ring was developed. The ring consists of 6 violet LEDs (SemiLEDs SLLP-3020-1520-UV-A) and 4 white LEDs (Cromatek LSUW0805). The light switching is controlled by a single button, which allows three options: light off, white light on, and violet light on. An optical filter is used in front of the camera to block the backscattered excitation light.

2.4 System characterization

The system characterization was performed measuring the spectral irradiance from the excitation LEDs using a spectroradiometer (calibrated USB2000+, OceanOptics, USA), and the filter transmittance using the spectrophotometer (Cary 50 UV-VIS, Varian, Australia).

2.5 Python application

An algorithm was developed in Python (Python Software Foundation, USA) to control the device and provide a graphical user interface (GUI), using two open source libraries: OpenCV and Numpy. With the developed software, it was possible to view the images in real-time, capture them, and even pre-process them. The program operates in two different modules, according to which kind of image the user wants to acquire: the fluorescence module, and the white light module. Each module has been configured to set the camera parameters according to the chosen option.

3. RESULTS AND DISCUSSION

3.1 System characterization

The system characterization was performed as described in section 2.4, with which was possible to acquire the spectral emission from the excitation LEDs, and the optical filter transmission, as can be seen in Figure 2.

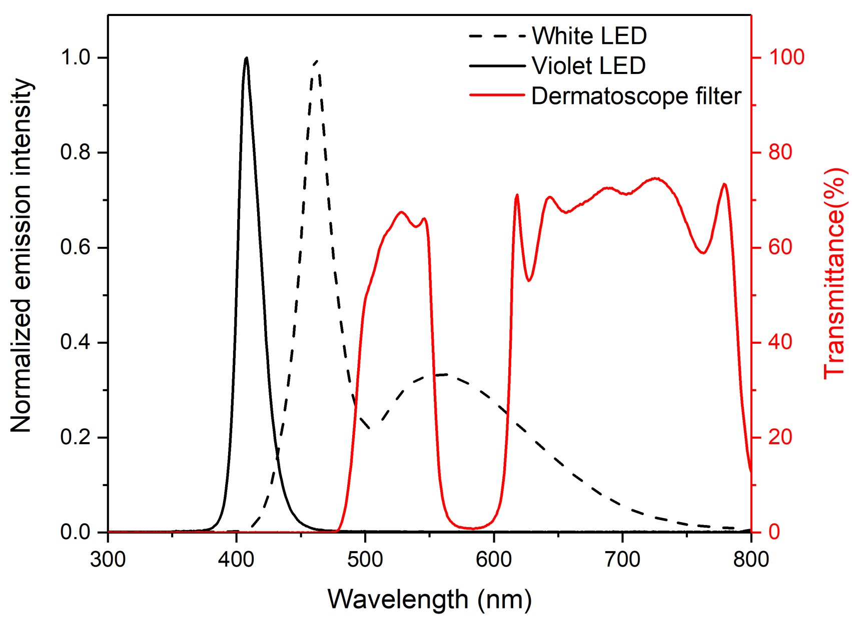

Figura 2: Spectral emission from the excitation LEDs, together with the optical filter transmittance.

The measured irradiance was 930±10 $\mu W/cm^2$ for the four white LEDs, and 740±10 $\mu W/cm^2$ for the six violet LEDs. With the system assembled, we imaged a positive USAF 1951 target, as shown in Figure 3, the field of view (FOV) being 10 mm × 7.1 mm. It is also shown in Figure 3 the assembled system, together with the LED ring to illuminate the sample.

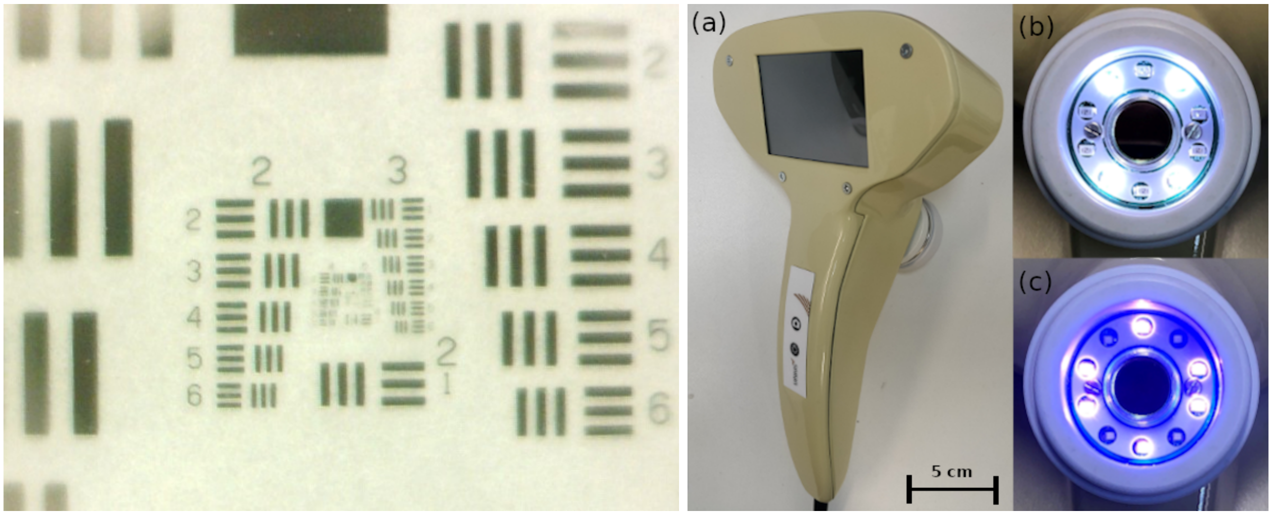

Figura 3: On the left, the image of a positive USAF 1951 target, taken with the prototype. On the right, (a) the dual modality system, with its LED ring with (b) the four white LEDs on, and (b) the six violet LEDs on.

3.2 Python application

The developed software has a simple and intuitive GUI, based on a touch menu with four possible options. The first option allows the user to save the image, along with type and date information. The second and third options are the fluorescence and white light options, used to set the camera parameters for acquiring the fluorescence and white light images, respectively. In the last option, the user can exit the application. Figure 4 shows an example of using the equipment.

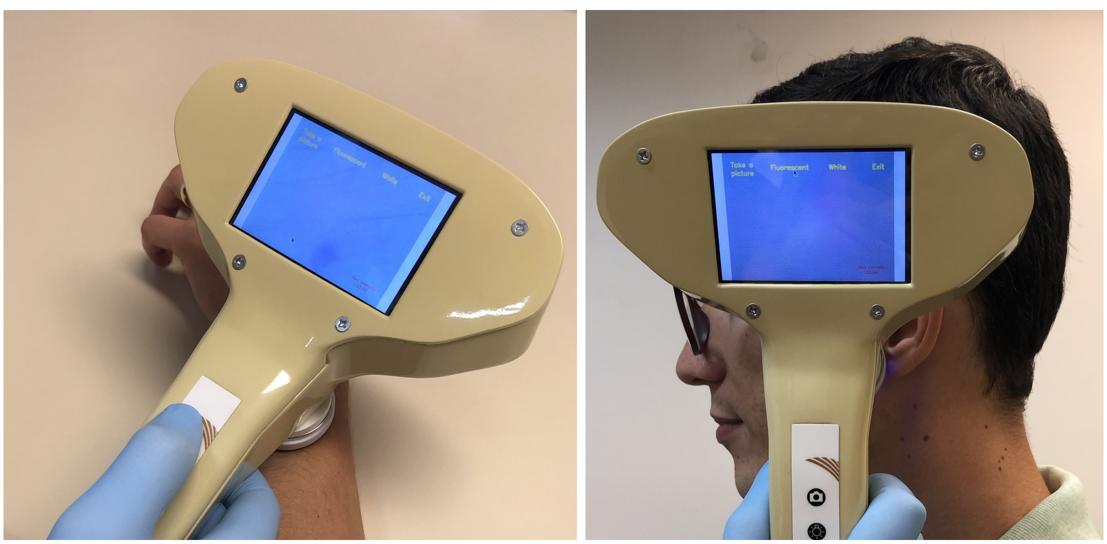

Figura 4: Example of using the dual modality system.

3.3 Clinical images

In order to test the system, the dual modality system was used to image the skin of a healthy volunteer. The acquired white light and fluorescence images are shown in Figure 5.

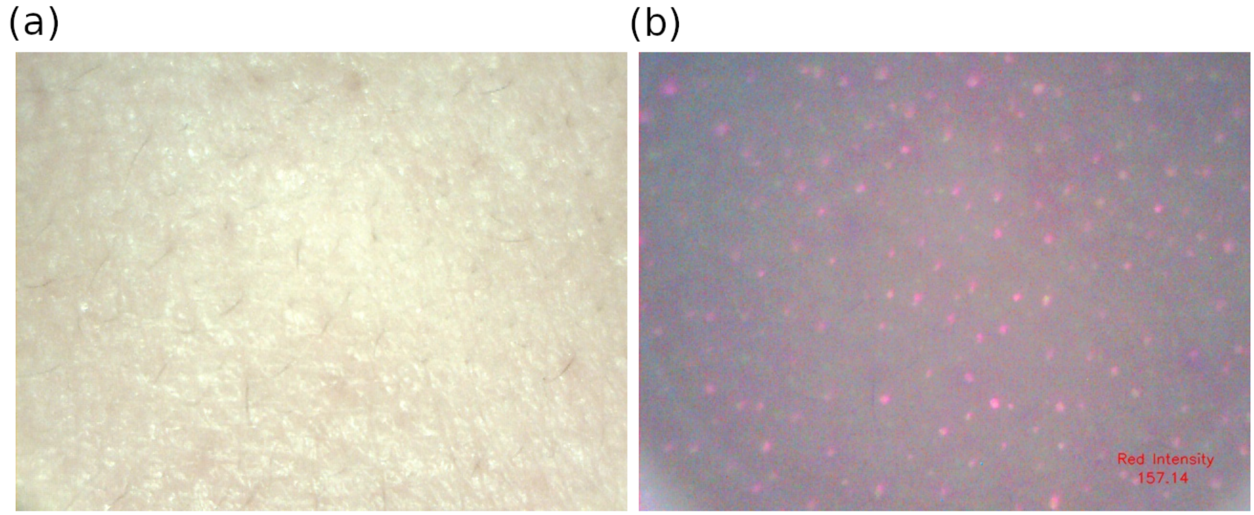

Figura 5: (a) White light and (b) fluorescence images of a healthy volunteer's skin, in the face region, acquired with the dual-channel system.

4. CONCLUSION

This paper describes the development and characterization of an SBC-based dual-channel low-cost system, capable of performing white light and widefield fluorescence imaging. This equipment can be used for dermatology purposes, and also for the photodynamic therapy monitoring[20–23] and oral lesion detection,[24,25] as well as similar devices were used. For future work, we intend to develop image processing algorithms to improve the assistance. We also intend to perform some technological improvements, such as using batteries instead of USB power and enable an easy wireless connection to transfer the acquired images to the user.

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