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Preliminary development of Optical Computed Tomography (Optical CT) scanner using transillumination imaging

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Abstract

Near-infrared transillumination imaging is useful in many biomedical applications such as human biometrics and animal experiments. Using near-infrared (NIR) light, we can able to obtain a two dimensional (2D) transillumination image of the internal absorption structure such as blood vessel structure, liver ... in a small animal body. If we can obtain projection images from many orientations, we can reconstruct a three dimensional (3D) image using various computed tomography techniques. In previous studies of our group, even with a simple system (light-emitting diode (LED)'s array and low-cost camera), we can obtain the blood vessel transillumination image of human arm. In this paper, we propose preliminary research on the development a computed tomography (CT) scanner prototype of human body parts using transillumination imaging.

Key words: diagnostic, transillumination imaging, near infrared, computed tomography (CT), Optical CT.

1 Introduction

The importance of transillumination imaging using near-infrared (NIR) light for medical and biometrics fields has been recognized [1],[2]. In previous studies of our groups, active study was conducted on the transillumination imaging for biological bodies [3],[4]. Using a near-infrared (NIR) light with 700-1200 nm wavelength, we can visualize the macroscopic internal structure of an animal body (kidney, liver …), the blood vessels inside the human body parts [3],[4]. In recent years, some devices have been developed by other groups using infrared light to view the blood vessel as VeinLite www.veinlite.com or early detection of breast abnormalities as BreastLight www.breastlightsouthafrica.co.za.

However, the image is severely blurred due to the strong scattering in body tissue. Their system cost about 7000 USD which is again not an affordable amount for many clinics in the world, especially in low-middle income countries.

Several recent studies have also shown that an optical diagnosis can help predict the ability to respond to breast cancer chemotherapy before conducting actual chemotherapy [5],[6]. This helps patients know early that they will not respond to chemotherapy and allows doctors to decide to change their treatment regimen early, thus avoiding unnecessary side effects for the patient. This research field is still relatively new and not widely known in Vietnam due to the requirement of sophisticated and expensive hardware.

To overcome these problems, we developed the NIR transillumination imaging system using a low-cost camera and low-cost controller system. This paper presents a prototype design with the view toward the realization of a novel imaging modality of human body parts.

2 System design

With a view toward the realization of a reliable imaging system with low-cost, based on the idea and works of Ben Krasnow to develop an inexpensive open-source desktop CT scanner which uses a radioisotope check source (Cadmium-109) [7], we propose a system using LED's as a light source. The general block diagram of the whole system was shown in Figure 1.

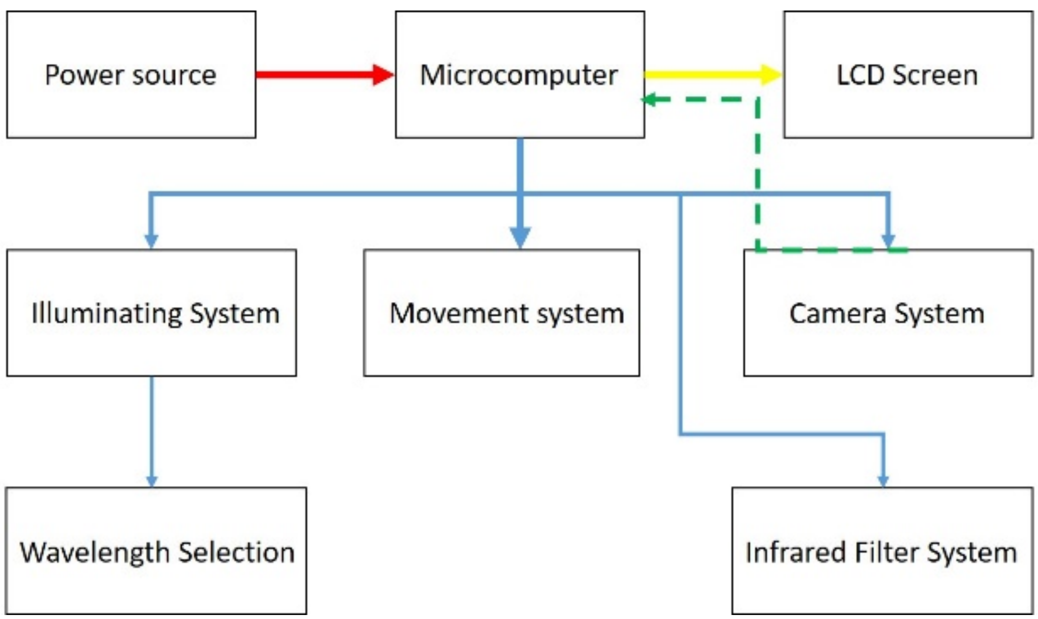


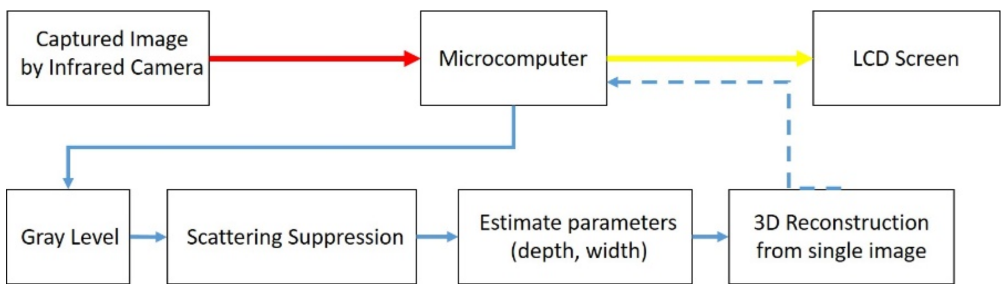
Figure 1: Block diagram of the hardware system

By utilizing the absorption property of the hemoglobin in red blood cells, macroscopic structure (like blood vessels) are allowed to be displayed differently from other tissues. According to our previous studies, the vein regions appear darker with respect to the surrounding tissue at 850 nm infrared wavelength [8],[9],[10],[11]. The absorption of deoxyhemoglobin has a peak value close to 750 nm.

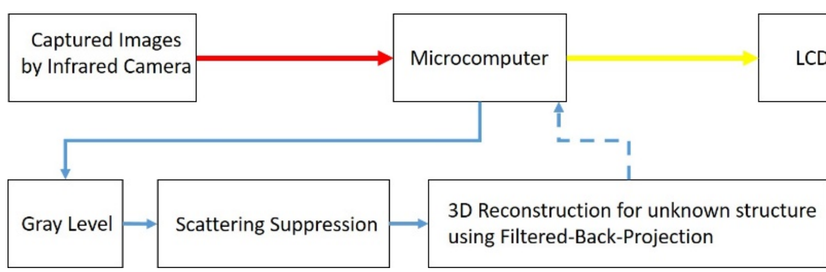
However, the maximum intensity ratio between the blood vessel and the surrounding tissue has a peak value close to 850 nm [8],[9],[10],[11].

In our system, we design to use the wavelength of light source (730 nm, 850 nm, 940 nm). In this paper, because the vein regions were seen better at this wavelength, LED's with wavelength of 850 nm were used. In this study, the array with 16 LED's near-infrared 850 nm 16480 mW (ILR-IW16-85SL-SC211-WIR200, Intelligent LED Solutions, UK) was used to illuminate the subjects. Also, we designed two high power infrared LEDs were focused on the target area and mounted to the left and right of the camera (Dorhea Raspberry Pi Camera module 5MP 1080P OV5647) that connected to the BCM2835 processor on the Raspberry Pi via the CSI bus. The camera and LED's were connected to the Raspberry Pi 3 model B+ with flex cable. The Raspberry Pi 3 and NIR LEDs were derived by a 5 V 2.5-A power supply. The illumination was almost constant during the experiment with the help of constant current supply of the LED system. In terms of still images, the camera is capable of 2592×1944-pixel static images, and also supports 1080p30 (30 frames per second).

A long pass filter LP780 Near-IR Longpass Filter (MIDOPT LP780, USA) was attached to the camera module in order to eliminate the visible lights and increase the signal to noise ratio. After recording the raw images, various signal processing methods were applied which were shown at following method sections. The data was processed by a Raspberry Pi 3 module B+ microcomputer. The processed data was visualized by a 7-inch LCD screen module via HDMI connection. The general block diagram of the whole process system was shown at Fig. 2.



(a) Process for single captured image



(b) Process for multiple captured images at different angle of views.

Figure 2: Block diagram of the software system

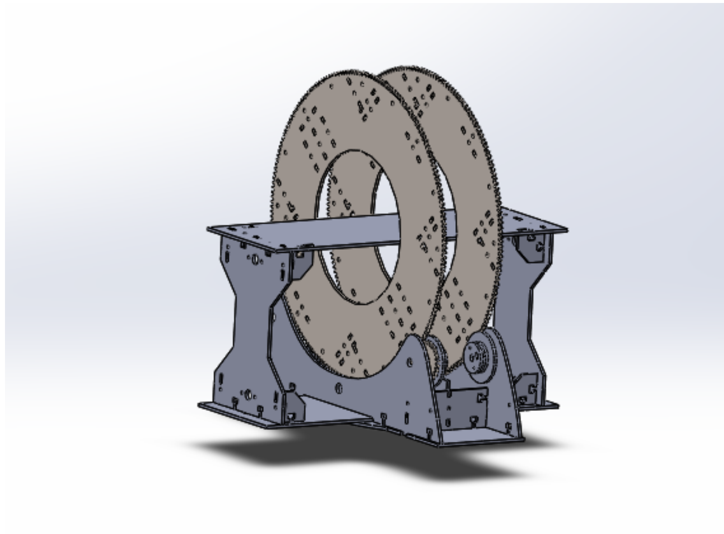


Figure 3: 3D structure design of rotation part

Figure 3 shows the main rotation part, which hold the light sources and the camera. Almost of the prototype machine (Optical transillumination CT scanner) were made with acrylic by use a CNC laser cutter. There are two modes of movement: conventional and spiral/helical CT movement.

3 Preliminary result

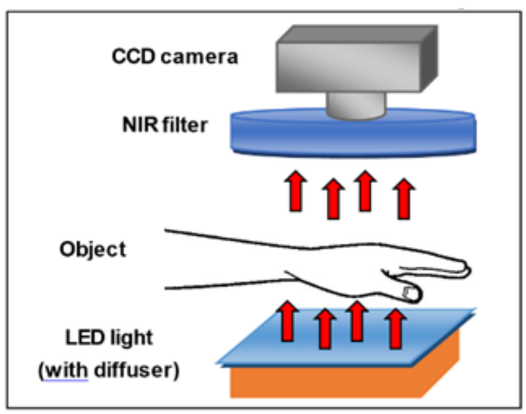


Figure 4: Schematic of image captured system

Figure 4 shows the schematic of image captured system.

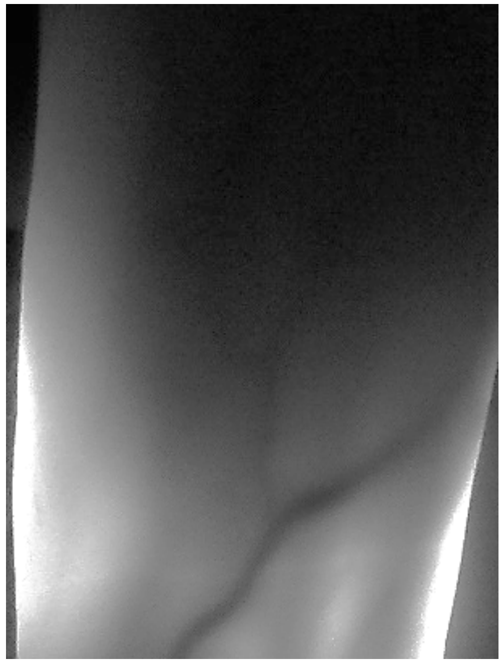


Figure 5: Captured image of adult wrist

As a result of the prototype making, Figure 5 shows the captured image of adult wrist using the system.

4 Conclusions

To make the NIR transillumination imaging more useful in clinical applications, we have proposed a novel modality design for Optical Computed Tomography using transillumination imaging. In previous studies of our groups [3],[4], we developed a technique using the deconvolution with a depth-dependent point spread function to suppress the scattering effect and verified their feasibility in experiments. With obtained projection images from many orientations after suppressing scattering effect, we can reconstruct a three dimensional (3D) image using the common filtered-back-projection technique [3].

The feasibility of a transillumination imaging system with the view toward the realization of the novel imaging modality of human body parts, especially in breast tumor diagnostic imaging was confirmed. The proposed technique should be applicable to the 3D imaging of blood vessel structure or absorbing from the 2D transillumination image of human body parts.

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