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Economically Affordable and Clinically Reliable Vein Finder

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Abstract

This work presents a portable, affordable and reliable vein locating device to overcome the complications in vein localization irrespective of age and tissue thickness during medical procedures like Phlebotomy and intravenous infusion. A prototype has been developed using infrared (IR) detector and multispectral near infrared (NIR) (740,765,770,780 nm) source. The differential absorption of the NIR by veins due to the presence of deoxyhemoglobin, helps in enhancing the localization of the vein. The detector is integrated with the single board computer (SBC) and connected with LCD through serial programming interface (SPI) for real time display of veins. The initial observations have found to be successful. It is expected that this affordable device will help in reducing time and improving accessibility to locate antecubital and cephalic vein without multiple incision and minimal pain.

Keywords: IR Detector, IR Filter, Near Infrared Rays, Single Board Computer, Vein Access

1. Introduction

Vein puncture the process of obtaining intravenous (IV) access, is an everyday invasive procedure in medical settings and there are more than 1 billion vein puncture related procedures (i.e., blood draws, peripheral catheter insertions, and other IV therapies) performed per year[1]. About in one third of the patients multiple punctures are required leading to hematoma or nerve injury[2] due to various factors like skin colour, fat and age[3].The antecubital vein in the forearm and cephalic vein in the dorsal hand are the most preferred locations in phlebotomy and IV infusion. The visible light was initially used and devices like veinlite using orange and red wavelengths were developed. However due to the poor depth of penetration of visible rays in blood vessels[2], they cannot visualize veins in fatty people. Later ultrasound vein viewer was developed. It requires extra experience and skills and provides inaccurate results. Because of the significant characteristics of near infrared rays like non-invasiveness, non-ionizing nature, and deep penetration into the tissues its applications in medical field is dramatically increasing[2]. Using this technology various devices were later proposed like vasculuminator, accuvein and veinviewer. The clinical testing of these devices showed that vasculuminator lacked the hand and

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eye coordination due to the sophisticated setup. The accuvein and veinviewer projects the vein image back on to the puncture site and results in more artifacts[2]. These systems are either extremely bulky or costly and require sophisticated standalone system with lack of portability and flexibility in use The wavelength chosen in most of the devices are not optimal as they lack either the deep tissue penetration capability nor high deoxyhemoglobin absorption rate. The source detector mismatch is also a prominent reason for the poor vein visibility. Hence to overcome these drawbacks, an extremely low cost and portable vein finder using multispectral NIR source and IR sensitive CMOS detector is proposed.

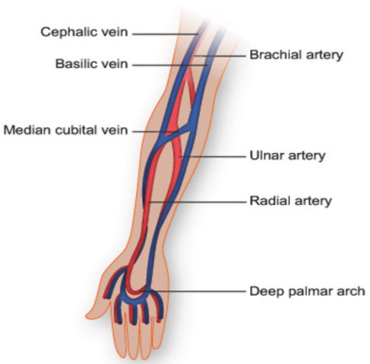


Figure 1. Vein Anatomy

2. Materials and Methods

2.1 Hardware Materials

2.1.1 IR Source

The deoxyhemoglobin in Veins show differential absorption in NIR spectral window (700-900nm)[4]. The experimental testing showed that near infrared rays of shorter wavelength (740,765nm) exhibits high absorption characteristics for deoxyhemoglobin and deep penetration properties at longer wavelength (770 and 780nm). In order to visualize veins clearly with ease in all people irrespective of color, age and tissue thickness, a multispectral IR source (740,765,770,780) is optimized to achieve good visibility of veins. Therefore a circuit is designed using 24 IR LEDs 740,765,770,780nm consisting six LEDs of each wavelength. These LEDs are powered by 12V adaptor. When the LDR is placed in low light, the resistance and voltage becomes high. This causes a little current to flow through the base of the PNP transistor which then results in a lot more current to flow through its collector. These current further flows into the base of two NPN transistors and results in more current flow in its collector thus high current amplification is achieved. So all 24 LEDs will glow. When light hits the LDR, the resistance in the LDR will be less, which means less voltage when there is bright light. So the led will not glow due to the insufficient current to turn on the transistor.

The IR LEDs are arranged in a circular manner because it gives best overall diffusion, uniform illumination and vein viewing capacity. The circuit is then fabricated on the PCB board.

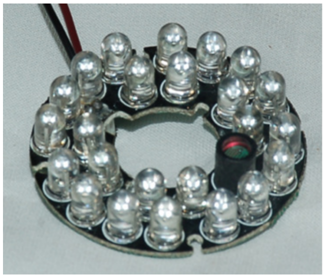


Figure 2. Fabricated IR Source Setup.

2.1.2 IR Filter

The CMOS sensors are sensitive to the entire spectrum of light, in order to allow only visible light to pass through the lens, a hot mirror filter is placed which allows only visible to pass and cuts infrared radiation. This filter is placed in front of the image sensor. To make the camera IR sensitive this filter has to be removed and replaced by the IR pass filters. The deoxy hemoglobin in human blood shows peak wavelength in the range between 740-780nm, Hence the Kodak written 87 IR filter is used here which passes rays between 740-790nm in combination with the IR Photographic film.

Figure 3. IR Film.

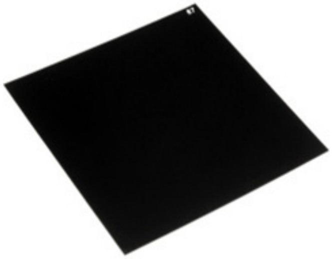


Figure 4. Kodak wratten 87 IR filter.

The hot mirror filter is taken out and replaced by this filter. The filter is cut to the size that fits best on the image sensor. The filter thus looks black or deep red to block all visible light.

2.1.3 IR Detector

2.1.3.1 Webcam based IR Detector

The IR detector is designed using a web camera. This camera has a high quality CMOS sensor that has various advantages over CCD sensor like smaller system size. Faster readout, low power consumption, higher noise immunity, and it is very sensitive to both visible as well as IR spectrum of light[5]. But the internal optical low pass filter which is placed in front of image sensor will block IR light and allow only visible light to pass through and reaches the image sensor[6]. This filter is removed and replaced by 35mm exposed photographic film and Kodak wratten IR filter to block visible light thus webcam becomes sensitive only to IR light. The 0.3x objective lens with eyepiece is fitted to the lens of the camera, to get the highly focused view. The inner side of eyepiece is sprayed with aluminum spray to reduce the diffusion of IR rays and narrow down the rays. The IR detector is connected to the single board computer (Raspberry pi) via USB 2.0 which provides power required for driving the device.

Figure 5. IR Detector.

2.1.4 Block Diagram

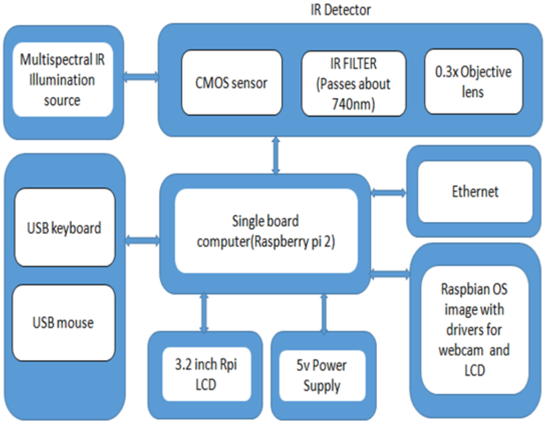


Figure 6. Block diagram.

2.1.5 Raspberry PI

The Raspberry Pi is a low cost, single board computer with chips and I/O connectors. It has 900MHz quadcore ARM Cortex-A7 CP, 1GB RAM, 4 USB ports,40 GPIO pins, Full HDMI port, Ethernet port, Display interface (DSI),Micro SD card slot[7]. The keyboard, mouse, IR detector are connected to the SBC through the USB ports, Ethernet cable is connected to the Ethernet port and a 5v power supply is given through power supply port.

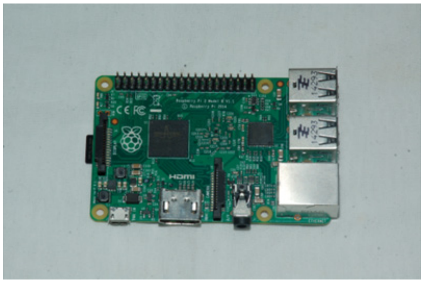


Figure 7. Raspberry pi.

2.1.6 Memory Card

2.1.6.1 Noobs Software

To get started with Raspberry Pi you need an operating system. It is an easy operating system install manager for the Raspberry Pi. This operating system is copied in a memory card and inserted into the memory card slot in raspberry pi to boot the system[8].

2.1.6.2 Motion Software

For this motion application to work we need to install the software to access the USB webcam and to stream it via built in webserver.Steps involved in working with *USB webcam on raspberry Pi*

- Get the software Ready
- Plug in your webcam
- Configure the software
- Start the software

2.1.7 LCD

A 3.2 inch wave share LCD is used here for the display purpose.

Figure 8. 3.2 inch LCD.

The raspberry pi is interfaced with LCD through the serial programming interface. Its features are

- Supports any revision of Raspberry Pi.
- Driver for any Pi Supports Raspbian system.
- Support software keyboard (system interaction without keyboard/mouse)[9].

2.1.8 Expermental Setup

The above images represent the experimental setup. The three USB ports in SBC are used to connect the keyboard, mouse and USB web camera. NOOBS, an operating system to run the raspberry pi is installed in 16GB SD card and inserted in the SD card slot. To stream the live video through web camera MOTION package is used. To power the entire setup a 5v power supply is given. Finally the SBC (single board computer) is interfaced with 3.2 inch LCD through the SPI to make the device portable. The multispectral IR illumination source powered by 12v supply is placed below the area of interest and the detector is navigated along with the source to acquire the live video of veins.

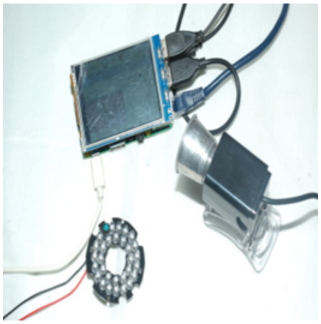


Figure 9. Experimental Setup.

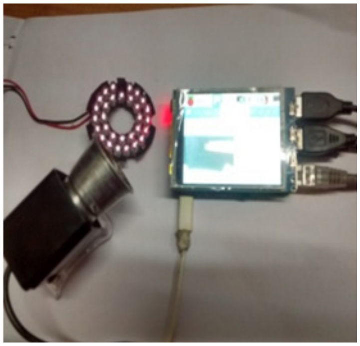


Figure 10. IR Detector streaming.

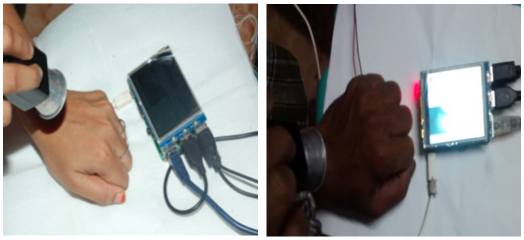


Figure 11. Image acquisition.

3. Results and Discussion

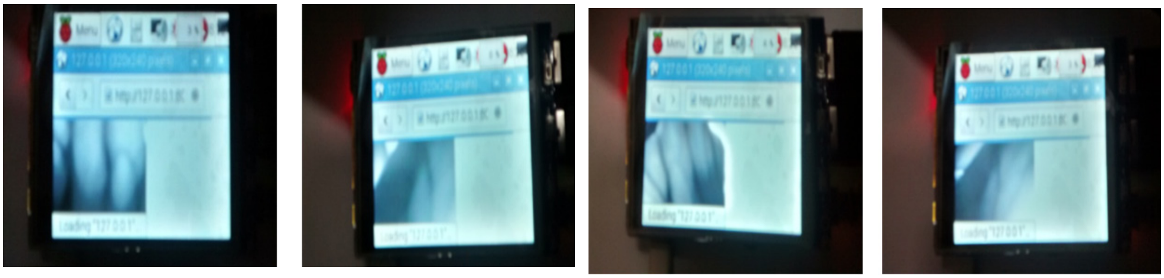
Optical absorption of blood is stronger in the NIR window (700–900) nm and the depth of penetration is more compared to visible range[10]. As a result, the subcutaneous blood vessels appear darker in white background. Access to the antecubital vein is a big challenge for doctors in case of fat people, pediatrics, elderly and dark people[10]. It is the most preferred location for phlebotomy. Near infrared rays of 740, 765, 770, 780 nm is optimized for our proposed work due to its increased absorption rate in veins. The CMOS based sensor is used as IR detector due to its high uniformity, low noise and high speed performance

The Figure 12(a) represents the antecubital vein in forearm and cephalic vein in dorsal hand of the dark person. The effective light path for light through the skin will vary with skin pigmentation[11]. The magnitude of this effect will vary with skin pigment; but with the multispectral wavelength being chosen where the absorption rate of melanin is low and with the optimal IR detector the vein are visualized with ease.

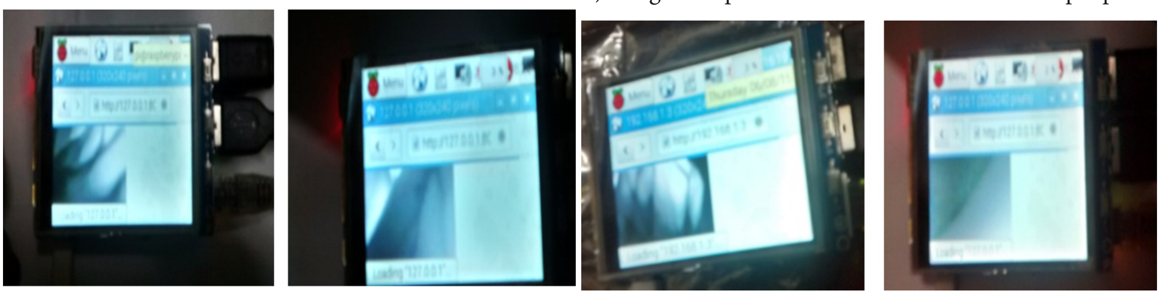
The Figure 12(b) represents the antecubital vein in forearm and cephalic vein in dorsal hand of the fat person of 88kgs.The deposition of subcutaneous fat under the skin wall affect the ability of the light path to pass and penetrate through them[3].But the proposed prototype was able to locate veins with the optimal detector and multispectral wavelength that has deep penetration into tissues in the presence of fat.

The Figure 12(c) represents the antecubital vein in forearm and cephalic vein in dorsal hand of elderly people of 58yrs of age. Gaining vein access in them is a big challenge because the veins in them are thin and become fragile as they lose elasticity and a large vein has to be chosen[3].But the proposed work found to successful in locating veins with less difficulty.

The Figure 12(d) represents the antecubital and cephalic vein in the pediatric who have smaller peripheral veins, more subcutaneous fat and are prone to vasoconstriction, the proposed prototype achieved successful results with the multispectral wave length and optimal detector being chosen at



a) Image of cephalic and antecubital vein in dark person b) Image of cephalic and antecubital vein in fat people



c) Image of cephalic and antecubital vein in elderly people d) Image of cephalic and antecubital vein in pediatric people

Figure 12. Images of various anatomical locations.

which the veins has peak absorption rate and deep tissue penetration.

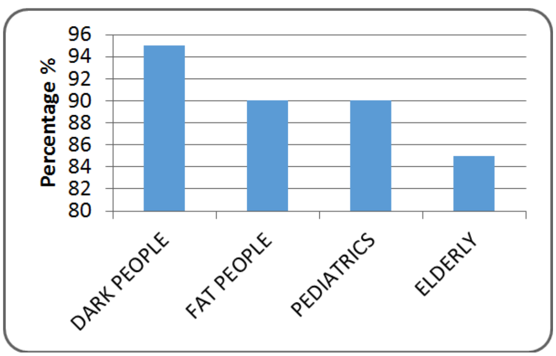


Figure 13. Success rate of indentification veins.

The testing involved four groups, in which the first group consist of 25 dark people, the second group and third group consists of 25 fat subjects and 25 pediatrics of 1 ½ -2 yrs and the fourth group consists of elderly people of 55-60 yrs of age. The success rate was 95% for first group, 90% for second group, 90% for third group the success rate was 85% for fourth group.

Thus initial observations have found to be successful. It is expected that this affordable device will help phlebotomist and nurses in reducing time and complications in accessing vein in fat, dark, pediatrics and elderly people with minimal efforts without the use of tourniquet.

4. Conclusion

The results obtained are the images of antecubital vein and cephalic vein in the forearm and dorsal hand which are the most preferred sites for phlebotomy and IV infusion[3]. The testing of the proposed prototype on various groups of people like dark, fat, elderly and pediatrics people found to be successfulin terms of accessibility to antecubital vein, cephalic vein, visibility of more number of veins, reduced complications in accessing veins in pediatrics, obese and elderly people at affordable cost and minimal pain. Thus our proposed work gives a quantitative and qualitative insight into the optical properties of blood vessel interaction at specified near infrared wavelengths its contribution to the development of a simple portable vein viewing device.

The outcomes of the project

- The multispectral illuminating source using NIR rays at four different wavelengths (740-780nm) was fabricated.
- The IR sensitive detector using modified web camera was designed.
- The IR detector is interfaced with Raspberry pi and driver software was installed to stream the IR Detector.
- The IR source, IR detector is interfaced with LCD displays to make it as a portable and reliable device.
- The clinical testing was performed on various groups of people including fat, dark, pediatrics and elderly people.
- The antecubital and cephalic vein was accessed with ease in fat, dark, pediatrics and elderly people by nurses and phlebotomists with minimal pain and affordable cost.

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