



## DEVELOPMENT OF COST EFFECTIVE VEIN VIEWER FOR MEDICAL APPLICATIONS

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### ABSTRACT

Presently doctors find it very difficult to inject medicine into the veins for any intravenous procedure. This procedure can be cumbersome, especially for subjects with thin veins or who are obese or for patients with damaged skin. paediatric patients also belong to this class of people because their veins are extremely thin due to their infancy. In case of extreme emergencies involving the aforementioned patients, it becomes difficult to feed/detect specific veins for carrying out the IV procedure, and the delay in treatment may become life threatening. Clinical staff often finds it difficult to locate the desired vein in paediatric patients. As of now, vein detection is among the latest techniques being researched today to resolve this issue. The present work includes the development of a cost effective vein viewer using a raspberry Pi kit with the aid of infrared rays to illuminate a region which is then observed using an infrared camera. By using this device, the results achieved were quite encouraging besides indicating the huge market potential for the technology. The results obtained showed that the presently developed technology was quite helpful in detecting the veins.

### INTRODUCTION

Detection of veins in patients can be very difficult and it depends on various factors such as thin veins, fatty deposits, skin colour or skin damage. In case of emergencies involving these patients, it sometimes becomes difficult to carry out an IV procedure in time and the delay in treatment may become life threatening. [1] Even though lots of work has been done in vein imaging and many new devices have come up, the largest obstacle is their cost and portability. The design developed attempts to make the device more cost effective, portable and efficient. Visibility under regular light conditions is extremely low for human vein pattern. This problem is resolved by using infrared imaging. The basic phenomena of radiation of the wavelength region from 740nm is used to detect veins but not arteries. This is because of absorption of IR in blood vessels. The reason for this is that the deoxidised haemoglobin in the veins fully absorb the radiation while the oxidized haemoglobin gets nullified.

### BACKGROUND

#### Optical Properties of Light

Light is a type of electromagnetic radiation. It has properties of waves and particles. The electromagnetic spectrum is classified based on wavelength into several bands based. The visible light wavelength range between about 380 nm and 730 nm. Figure 1 shows the various spectrum of light. The important properties of light are Reflection, Refraction, Dispersion and Absorption

#### Penetration Depth for Different Parts of the body

Table 1 depicts the penetration depth for various parts of the body for various spectrum of light. Figure 2 provides a pictorial representation of the same

### Use of IR in Vein Detection

Intravenous (IV) procedures are the most painful and difficult procedures carried out in hospitals and blood testing labs. Though IV procedures are a common practice, the first attempt is seldom successful. There are many factors that affect these procedures such as movement caused by the patient, patient's skin colour, when the vein is not palpable, or the vein visibility is low, which happens to be the most common reason. Our human eye can only detect the waves which belong to the visible region of the spectrum. Near-Infrared (NIR) spectroscopy has been found to solve the issue and can help us visualize veins as it penetrates into the skin before scattering and deviating from initial direction. [2]

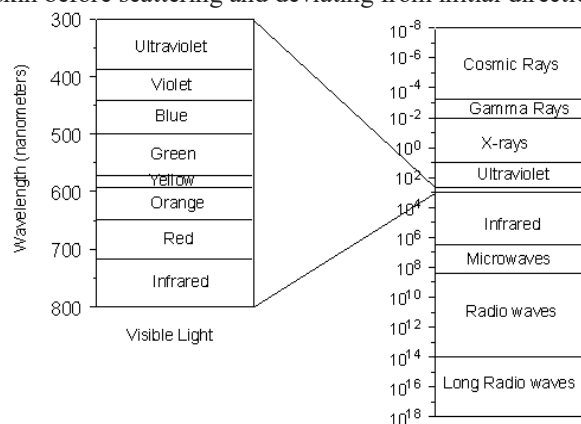


Figure 1: Electromagnetic spectrum

Table 1: Penetration depths. Of various spectrum of light

Wavelength (nm)	Colour Range	Depth(mm)	Layers of skin
150-380	UV	<0.1	epidermis
390-470	Violet-deep blue	~0.3	epidermis
475-545	Blue-green	~0.3-0.5	epidermis
545-600	Yellow-orange	~0.5-1	Dermis
600-650	Red	~1.0-2.0	Dermis
650-950	Deep red-NIR	2.0-3.0	Subcutaneous layer
740 – 760	Deep red-NIR	2.0-3.0	Deoxygenated haemoglobin

The concept behind the vein detection is that the deoxygenated blood will have properties of absorbing infrared light. When a region is illuminated with the IR source, the light gets absorbed into the blood and the surrounding tissues reflect the light back. This light is then captured by the infrared camera and the captured image is sent to raspberry pi for processing, the image is sent to the display. 24 frames are captured per second and the processing is done frame by frame. Each frame is taken as an image, the processing is done and then sent to the output for display. [3]

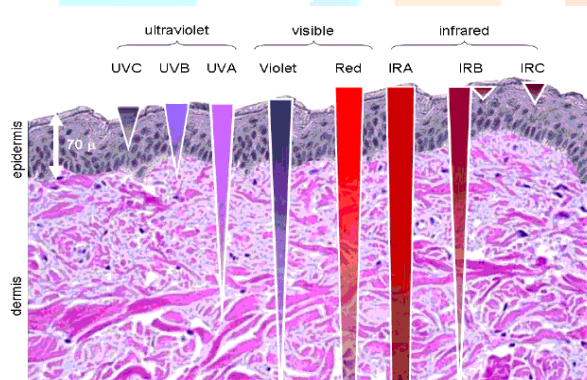


Figure 2: Ability of light to penetrate through the skin

## MATERIALS AND METHODS

### Work Flow:

The method devised to approach the solution requires the use of infrared radiation to illuminate the region of interest.[4] The image received is then processed in the controller and sent to the display. The pre-processing of the images is performed using contrast enhancement algorithms such as histogram equalisation, adaptive thresholding. These algorithms are implemented using Open-CV, because Open-CV provides extremely efficient algorithms for image processing.

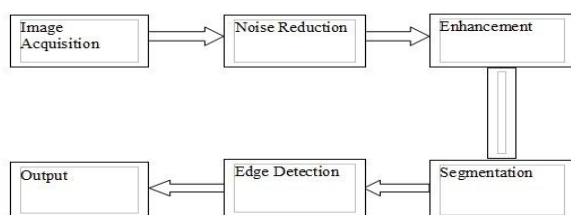


Figure 3: Vein Viewer – process flow for image processing

### Image Acquisition:

The IR light source is illuminated onto the region of interest. Most of the light falling on the hand gets absorbed by the deoxy-haemoglobin compared to the surrounding tissues.[5] This causes the veins to appear darker than the surrounding tissues when viewed by the camera. The NoIR camera of 8mp is used to capture this image and run it through the raspberry pi controller. An IR pass filter is placed in front of the camera to negate all the visible light and allow only the IR light of required wavelength to pass through. Raspberry pi is used to perform further enhancement of the image.

### Noise removal:

- Gaussian filter: This Gaussian filter is used to blur the image. It used a Gaussian function to find the transformation to apply to each pixel in the image. It is synonymous to convolution.
- Wiener adaptive filter: Adaptive filters are used to restore or enhance data by removing disturbance by blurring the structures.[6] The Wiener filter has low pass characteristics, which cause lots of blurring. The reason wiener filter blurs the image significantly is cause a fixed filter is used throughout the entire image: the filter is space invariant.
- Median filter: The median filter is a nonlinear filtering technique. It is a pre-processing step to improve later processing.

### Thresholding methods:

- Otsu thresholding: Otsu method converts greyscale images to monochrome. This is a binarization algorithm. Otsu's thresholding method generally involves through all the different possible ways of getting threshold values and calculating the measure of spread in the pixel levels on each side of the threshold value that if the pixels that either get in foreground or background. The purpose is to get the threshold value where the total sum of foreground and background spreads is at its minimum. By calculation of mean and variance this can be found out.[7]
- Adaptive thresholding: In this thresholding method, the threshold value depends on its neighbouring pixel intensities. To do this, first the region is selected. The next step is to calculate the weighted average of the selected region. Finally, the threshold value is found.

### Image Enhancement:

- Adaptive histogram equalization: Histogram equalization is a method of adjusting the contrast using a histogram. This technique computes several histograms are at once where each histogram corresponds to a separate section in the image, this can be used to rearrange the light values in the image. It is used to improve the local contrast and enhancing the definitions of edges in each region of an image. [8]
- Contrast enhancement: Contrast enhancements is used to improve the perception of objects in the scene by enhancing the difference in contrast between backgrounds and objects. This is performed by using a contrast stretch and then a tonal enhancement [6]. The contrast stretch will enhance the difference in brightness evenly across the image where the tonal enhancements highlight the brightness differences in the shadow (dark) region, tone of mid (grey), or highlight (bright) regions at the expense in the brightness differences in the other regions.

**Edge Detection:**

Sudden changes of discontinuities in an image are called as edges. Significant transitions of an image are called as edges. Generally, edges are three types namely:

- The Horizontal edges
- The Vertical Edges
- The Diagonal Edges

Most of the important shape information of an image is enclosed within edges.[9] So initially we have to find these edges in an image and also by making use of these filters technique and then enhancing these areas of image which includes edges, sharpness of an image will increase and image is clearer. Some of the most common masks, known to be either linear or smoothing filters, used to detect the edges are given below.

- Prewitt Operator: Prewitt operator can be used for detecting edges only in the horizontal and vertical directions.[10]
- Sobel Operator: It works as a derivate mask and can be used to detect edges. It's working is very similar to the Prewitt Operator
- Roberts Operator: (AKA: direction mask) For this one, mask is taken and rotated along the 8 compass directions to calculate edges.
- Canny Operator: The algorithm runs in 5 separate steps.

**Hardware design**

The design implemented in the current work makes use of raspberry pi 3B, NoIR camera, IR light source (700nm to 1000nm) and an IR pass filter of 720nm. [11]

**Raspberry Pi 3B:**

It is a low-cost, basic computer that was originally intended to help in computing.

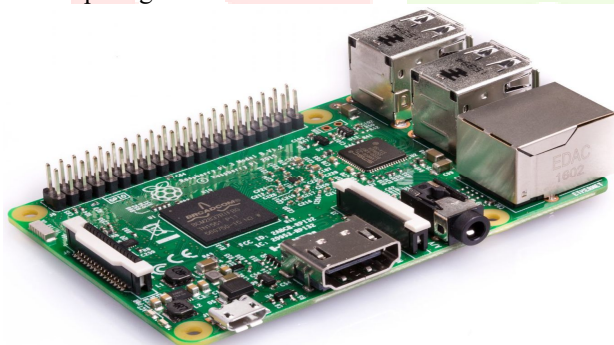


Figure 4: Raspberry pi 3B

**Technical Specifications:**

- Quad Core 1.2GHz Broadcom BCM2837 64bit CPU
- 1GB RAM
- BCM43438 wireless LAN and a Bluetooth Low Energy on board
- Extended GPIO of 40pin
- 4 Universal Serial Bus and 2 Port devices
- Four Pole stereo output and the video port device
- Full size HDMI
- CSI camera port for making connection to a Raspberry Pi camera
- DSI display port for making connection to a Raspberry Pi touchscreen display
- Micro SD port is used for loading your operating system and also used for the storing data
- Upgraded switch of Micro USB power source up to 2.5A

**IR LED:**

- An array of led's particularly arranged in a circular form which is used here.
- These LEDs are in the range of 700 to 1000nm.



Figure 5: IR LED array developed

**NoIR Camera:**

- It's an 8 Mega Pixel camera.
- This NOIR camera is used to acquire real time images from the human body i.e hand.
- This camera doesn't have a IR cut filter installed and hence the name.

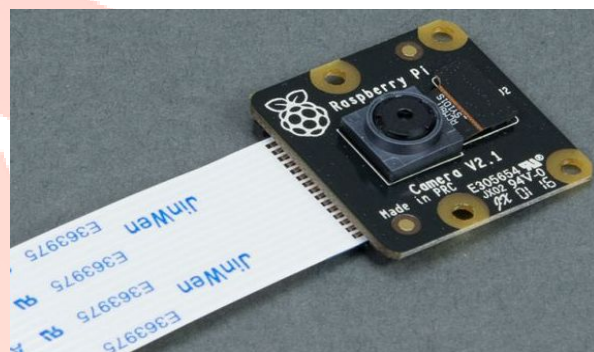


Figure 6: No-IR camera used for image acquisition

**IR pass filter**

Filters come in different versions and the maximum wavelength is assigned to each version at which the filter blocks light. Lower the number indicates a greater amount of visible light from the upper wavelength range passes through the filter. The 830nm filter which being the filter used lets information pass through. The cutoff for the filter used is 720nm

**Near Infrared (NIR) Transmitter:** An IR transmitter is used for illuminating the arm. The wavelength being used lies in near infrared region, which stretches from about 750 nm to 900 nm. In this region, the absorption of IR wavelength in the blood is maximum[12]

**Infrared Camera:** Infrared camera is a special type of camera being used in this project. It is a camera which has an infrared filter, which can block the infrared light. Therefore this special camera has the ability to block all the visible light and let all the Infrared light pass.[13]

**Raspberry Pi 3, as Image Processor:** Raspberry Pi 3 is being used as an image processing unit here. It is a Linux-based computer, which can be used for embedded applications. [14]



Figure 7: IR filter

**Pico Projector:** Pico-projector is miniature sized projector which is used to project the image back to the arm.[15] Since the central mark of the image being captured by the camera is different than that being projected back, we need type of calibration to make the central point of captured image and the projected image same.

### RESULTS AND DISCUSSIONS:

Mentioned in this section is a glimpse of the hardware module developed along with a pilot set of results obtained for veins imaged with the aid of the developed vein viewer hardware module. Figures 8-11 provide a pictorial representation of the results obtained for sample images acquired using the currently developed hardware module.

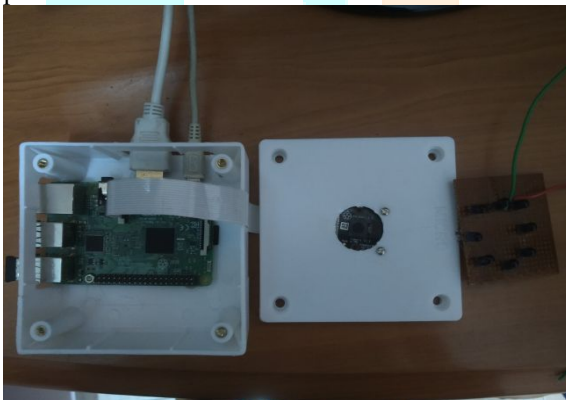


Figure 8: Vein Viewer – hardware module

In order to quantify the images acquired as well as the process followed, parameters such as Signal to Noise Ratio (SNR), Peak Signal to Noise Ratio (PSNR) were calculated and the average of the 20 images were found to be as follows: SNR = 4.379, and PSNR = 13.2815

The vein imaging device developed at present was found to be cost effective. While the existing vein viewers cost about Rs 75,000/- in Indian market, the presently developed module would cost close to Rs 15000. Usage of raspberry pi along with the NoIR camera and IR filter helped in obtaining images with a better visualization of the veins when compared to that viewed under visible light.



Figure 9: Image acquired using vein viewer



Figure 10: Skeletanized image

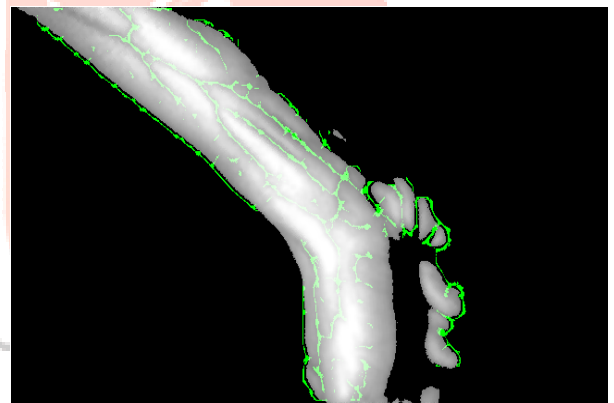


Figure 11: Sample output – veins detected

The algorithm developed using Open CV provided a clear view of the veins. Based on the parameter obtained such as SNR, PSNR, MSE and SSI, further processing of the images could lead to the betterment of the images processed as of now which can improve the quality of the images being viewed. This approach can further be extended to video processing. Also instead of viewing the processed vein images on a screen, the video can be fed live and projected on to the hand itself thereby helping the clinicians to view the veins easily.

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