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Vein Detection Using Infrared for Venepuncture

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Abstract: Vein detection for venepuncture and biometrics is one of the most researched biomedical techniques. Problems faced in accessing veins by physicians and nurses to administer intravenous drugs make non-invasive vein detection the need of the hour. This project works on the principle of absorbance of infrared (IR) light by veins and its diffusion to surrounding tissues which makes the vein appear darker when viewed through an IR sensitive camera. One of the challenges faced while implementing this system is to make an efficient system for image acquisition and image processing at low cost. Thus, a customized sensitive camera is used to cut down the cost. This paper presents a vein detection device that uses IR light for illuminating the localized area, a modified camera for capturing images, and an image processing software. Image processing to enhance the visibility of veins is done using MATLAB.

Keywords—*MATLAB, Near Infrared sensors, Venepuncture, Vein detection.*

I. INTRODUCTION

The designed vein detection system in this project comprises of an easy-to-implement device that uses a modified IR sensitive camera to take a snapshot of the subject's vein under a source of infrared radiation at a specific wavelength. Such a system is able to detect veins but not arteries due to specific absorption of infrared radiation in blood vessels [1]. NIR and FIR are two imaging techniques used for this purpose [1].

Multitudinous challenges are faced on a day-to-day basis by phlebotomists, nurses and pathologists while detecting a patient's vein for venepuncture. Improper puncturing may lead to problems such as swelling, bleeding or permanent damage to the veins, especially in cases with elderly subjects. To overcome these problems various devices have been developed but the challenge that remains is cost and portability factor. Also, very few devices have been implemented using infrared radiation, which is highly instrumental in detection of superficial veins in the human body. Therefore, the crux of the project is based upon implementation of near infrared light to detect veins and consequently carry out smooth vein puncturing.

NIR imaging works within the range of 700-1000nm and provide good quality images as NIR falls under a specific range of wavelength that can penetrate human tissues (up to 3mm of depth) resulting into a significantly better quality of images [2]. The vein pattern is captured, stored, and software-processed for better visibility. Thus, vein detection for vene puncture provides a non-invasive way to detect veins thereby preventing complications arising from invasive techniques.

There is a medical spectral window of light which extends approximately from about 700 to 900 nm, where light penetrates into the tissues, thereby allowing non-invasive investigation [2]. Therefore, typically, the wavelength of the infrared light beam coming out from a light source is chosen to be within 850nm [2].

The basic phenomenon governing the vein viewing devices is that Near Infrared (NIR) radiation of the wavelength region 740 nm-760nm is able to detect veins but not arteries due to the selective absorption of infrared radiation in blood vessels [2]. The reason for using the aforementioned phenomenon is the fact that the deoxidized haemoglobin [deoxy-Hb or H] in the veins almost completely absorb the radiation while the oxidized haemoglobin [HbO] in the arteries become almost transparent [2].

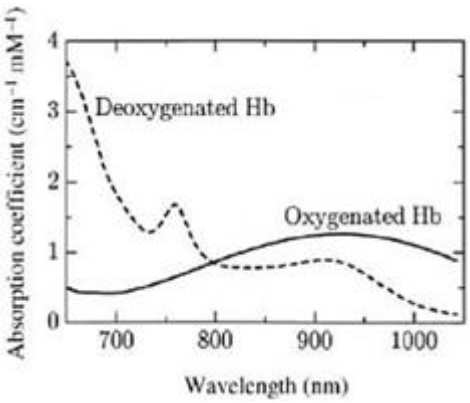


Figure 1: Absorption of light by blood [2]

II. HARDWARE

Implemented hardware system plays a critical role in acquisition of images. Hence the following should considered:

1. The camera sensor should be to detect infrared radiation for taking vein images.
2. The light source should provide uniform illumination so that the veins have desirable contrast to distinguish them from the surrounding tissues.

The arrangement for the same can be observed in Fig. 2 shown below:

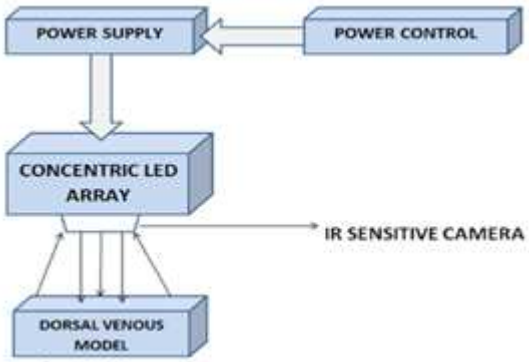


Figure 2: Block diagram of the vein detection system

A. Modification of the camera

All general purpose cameras have a built-in infrared blocking filter. The cheaper the camera, less effective is the infrared blocking filters.

In order to view the vein patterns, modification of the camera by removing the IR blocking filter becomes necessary. To

remove the filter, there is a need to first unscrew the webcam casing, look for the IR filter (tiny coloured film-like object) and remove it safely without damaging the camera. Thus, the filter is removed to obtain infrared visibility by the camera.

A negative film may be placed over the lens to block visible light but doing so may degrade the image quality significantly. During final modification, the initially placed negative film was removed for better image quality.



Figure 3: Modified webcam



Figure 4: IR LED array as observed from the modified camera.

B. Near Infrared source

NIR ring of LEDs is used for illuminating the localised body part. Power to the LED ring is provided from a DC voltage supply. The design of the light source should facilitate uniform brightness so that good contrast can be captured between the veins and the surrounding tissue [1]. Experiments conducted have shown that illumination depends on: the number of IR LEDs, design of the array, and value of the resistors used.

For the final arrangement, a circular LED array of 8 LEDs of wavelength 850nm was used. A common resistance of 33 ohms was provided in the final array. Lastly, a cavity was created in the centre of the array to affix the camera lens.



Figure 5: Final arrangement of sensors and camera

III. SOFTWARE

The software used for the processing of the obtained images is MATLAB™. MATLAB™ (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language [3]. For software implementation, the image after acquisition, was post-processed to highlight the vein patterns on the subjects.

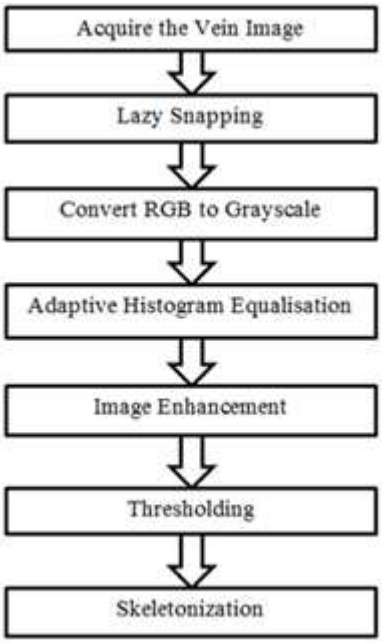


Figure 6: Algorithm for software processing

A. Image acquisition and Processing

The camera captures the image of vein. The image acquired is read in the MATLAB environment to begin the stage of processing and improving the image. Figure 7 is the image of one of the subjects wearing a black wrist band.



Figure 7: Original Image

Segmentation is carried out to separate the unwanted background from the region of interest. Lazy snapping is performed on the image [4].



Figure 8: Segmented Image

Colour to grayscale conversion is used for converting colour image to gray image. Converting to grayscale allows for faster processing in the further stages as compared to colour images.



Figure 9: RGB to grayscale

To distribute the pixel intensities uniformly throughout the image, adaptive histogram equalisation is performed on the image. A modification of histogram equalisation called adaptive histogram equalisation, works only on small regions

of the image, called tiles. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches a specified histogram [4].

The neighbouring tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries [4].



Figure 10: Adaptive Histogram Equalised Image

Median filter is used to remove the noise in the images. In this step, salt and pepper noise is added and later removed with a view that the inherent noise in the image reduces too.



(a) (b)

Fig. 11(a) and (b) Addition and removal of salt and pepper noise

Dilation (edge smoothing) is performed to remove noise and enhance the image. The veins can be seen clearly. The image is convolved with structuring element and the width of veins size is reduced to enhance the image [5].



Figure 11: Edge smoothened image

Thresholding is used to segment the veins from the background image.



Figure 12: Thresholded image

Morphological close operation is performed to remove noise obtained in the image after thresholding. It also removes insignificant objects present in the background [5].



Figure 13: After noise removal

Skeletonization is used to reduce all lines to a single pixel thickness. Here, we detect the medial axis of vein after which region growing is applied to remove the background noise. It mainly deals with pixel-based segmentation. The seed point and threshold are selected. The veins to be segmented must be within the threshold [5].



Figure 14: Skeletonized image

B. Quantitative analysis

Quantitative analysis is performed by taking the standard deviations of the input and the output images using the region and image properties module in MATLAB.

Standard Deviation: In statistics, the standard deviation is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A low standard deviation indicates that the data points tend to be close to the mean, while a high standard deviation indicates that the data points are spread out over a wider range of values [6].



(a) (b)

Fig. 15(a) Grayscale input image and (b) Histogram equalised output image for data set one



(a) (b)

Fig. 16(a) Grayscale input image and (b) Histogram equalised output image for data set two

Table 1: Calculated values for the input and output images for data set one and two

Sr. no.	Standard Deviation		
		Input	***Output***
1	Data set one	67.6189	67.1440
2	Data set two	76.3958	75.9122

Thus, it is observed that the properties of the images remain almost unchanged on the application of the various image processing techniques because the dispersion about the mean for the output images undergoes an insignificant change when compared to the input images.

IV. EXPERIMENTAL RESULTS

Vein detection was carried on 12 different subjects for 3 localised areas. Different skin tones, weight group and gender were taken into consideration. All the subjects belonged to the same age group.

Table II: Desirable results obtained for the various localised areas.

Sr. no.	Gender		
		Male	*Female*
	Number of subjects	7	5
1	Wrist	6	5
2	Back of the hand	5	4
3	Arm	5	4

From Table II, it is observed that, in majority of the cases vein patterns are seen clearly if wrist area is localized.

The images were obtained using a circular array as mentioned previously. Final resistances used were of value 33 ohms. The images were obtained by illuminating the circular array via a DC voltage source and placing the camera in an appropriate direction to capture images. The voltage values were adjusted to acquire desirable brightness. After the image acquisition, the images were processed using MATLAB software and final images were obtained.

CONCLUSION

Various samples of a subject's wrist, arm and back of the hand were taken for 12 different subjects to test the efficiency of the system. The implemented system met the requirements of a desired result when wrist area was localized as it is seen in the aforementioned table. As observed in the processed images, Adaptive histogram equalisation worked well to enhance the contrast of veins as opposed to the surrounding tissue and background, making the veins distinguishable. Thus, the goal to implement an efficient, non-invasive technique for vein detection using near-infrared source at an affordable cost was accomplished.

FUTURE SCOPE

This project intends to emphasize upon three aspects:

- The first aspect draws attention towards the portability of the vein detection system for sophistication and convenience.
- The project can be improved upon to display vein patterns in real-time.
- Lastly, the third one wades into the territory of vascular biometrics. This project can be taken a few steps further to function as a "vein recognition system".

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