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Design and implementation of low-cost vein-viewer detection using near infrared imaging

Abdulrafa Hussain Maray[1], Saba Qasim Hasan[1], Naqaa Luqman Mohammed[2]
[1]Department of Computer Systems Technologies, Mosul Technical Institute, Northern Technical University, Mosul, Iraq
[2]Department of Computer Eng. Technical College, Northern Technical University, Mosul, Iraq

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ABSTRACT

There are some medicines and medical treatments that need to be injected into the human body through the blood vessels, and this requires placing the cannula in the patient's body. The blood vessels in the human body differ from one person to another, and medical personnel face major problems in finding the blood vessels in most cases, because of The difference in skin color, where it is difficult to see the blood veins in the skin with black pigment, and it is difficult to find it in people with obesity because of the layers of fat, and in children and newborns because these veins are small. This study talks about finding a way to photograph these veins, see them by design and implementation low cost prototype used equipment that were recycled old device, such as a web camera, infrared lamps and overhead device, All of these devices are of low cost. Then process these images using binary image, histogram equalization, segmentation and threshold to detect these blood veins. The algorithms for edges images detecting are many and complex, this study used five methods to detect vein image, such as Sobel, Laplacian, Canny, Roberts, and Prewitt.

Corresponding Author:

Abdulrafa Hussain Maray
Department of Computer Systems Technologies, Mosul Technical Institute, Northern Technical University
AlMinsaa St, Mosul City, Nineveh Governorate, Iraq
Email: Rafiallwaze@ntu.edu.iq

1. INTRODUCTION

Previous studies show that nearly more than ninety percent of patients in different countries of the world requires peripheral cannulation of the intravenous route to perform laboratory tests in order to diagnose diseases. Blood samples are taken from millions of people monthly. The economic vein viewer has approximately four thousand five hundred dollars for small devices. While for the large devices, their material cost reaches twenty-seven thousand dollars [1].

There are many advanced medical devices and equipment that can photograph veins, but they are not available in hospitals because of their high price. In this study, a locally made device was design and implementation low cost prototype device used equipment that were recycled. This device to detect blood veins was manufactured in a simple and inexpensive way. One of the reasons that this study focuses on is solving the problem of seeing the blood vessels in the human body, when the cannula is placed in the vein in order to give patients gonorrhea, medical solutions, and needle glaucoma. People who have dark skin complexion, it is difficult to identify and see the blood veins, as well as those who have many layers of fat, children and newborns [2]-[10].

Table 1 shows a comparison between previous studies from (2010 to 2017). The average analytical error rate is 61.5%. The researchers have been capable of lessen the mistake costs mentioned on this table in

2017. The researchers had been capable of table for the proportion of 46.2%, while the percentage in 2010 grow to be approximately 77.1% [11]-[16].

Table 1. percentage of analytical errors

Author	Year	Percentage analytical error (%)
[11]	2017	up to 68.2
[12]	2017	up to 70.0
[13]	2015	60.0 to 70.0
[14]	2013	46.0 to 68.2
[15]	2012	46.0 to 68.2
[16]	2011	60.0 to 70.0
[17]	2010	77.10

2. THE PROPOSED METHOD

The following block diagram represents the most important material parts that were used in this model show Figure 1. The first block in this diagram represents data acquisition such as infrared source, near-infrared (NIR)-camera. The second block in this diagram represents processing methods such as edge detection, segmentation, and classification. The final block in this diagram is the result for the vein finder.

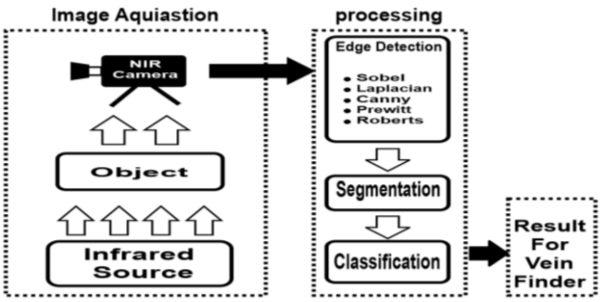


Figure 1. Block diagram of the system design

2.1. Basic hardware composition design

The equipment has been recycled of the old overhead device, which was used in the presentation of the presentation slides. Make use of lenses, body and moving levers. The distance is variable between the camera and the infrared source is 13-37 cm, see Figure 2 design of the prototype device.

The first step of this diagram is to image acquisition from the infrared (IR)-camera, which needs an infrared lamp at 100 Watt. This type of lamp is used in medical devices to treat the skin, as it gives a dim heat that is used in the treatment and beautification of the skin. Figure 3 shows the best results between changing the distance of the camera location and taking the most focus of the histogram IR-images. The intensity of this IR-lamp is controlled by connecting a simple electronic circuit. This circuit consisting of a thyristor by pulse width modulation (PWM) technology. Figure 4 shows the electronic circuit that shows how to control the infrared lamp.

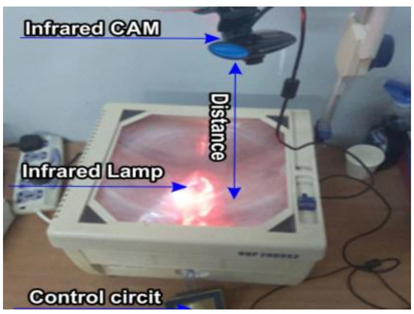


Figure 2. Prototype design

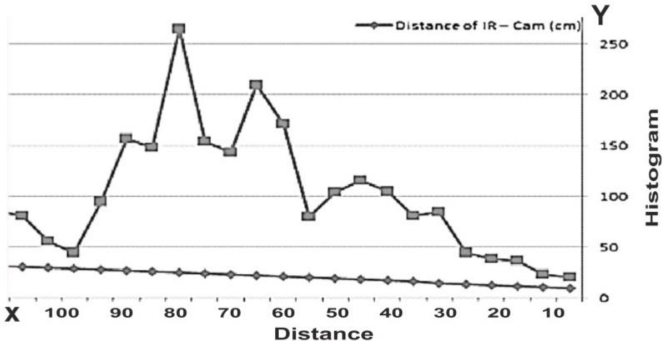


Figure 3. Distance of the IR-camera location and IR-images focus

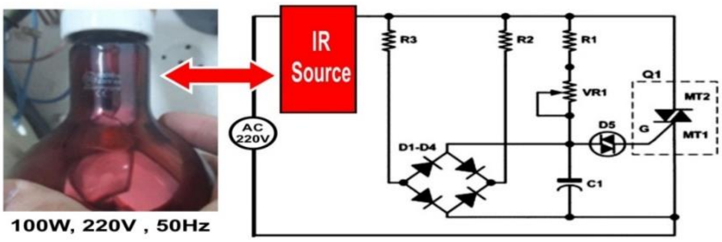


Figure 4. Control circuit diagram for IR-source

The circuit is based on the principle of changing the root mean square (RMS) value of the voltage by cutting off parts of the wave. The since wave with its positive and negative parts is (360) degrees, so only the positive or negative part consists of (180) degrees, and if I say that I am firing at an angle of 90, then this means that I am firing in the positive half of the wave and also in the negative half of the wave and so, as we increase the angle of the IR-lamp to the triac (Q1), we lower the RMS voltage applied to the load, thus changing the brightness of the IR-source. Where the RMS voltage is given by the (1) [17], [18]:

$$V^2{}_{L(RMS)} = \frac{Vm2}{4\,\pi}\ [\ i\ 2\pi -\ 2\alpha i + \sin 2\ \alpha] \tag{1}$$

and we control the time required to open the diac (D5) (which will trigger the triac (Q1)) by changing the time required to charge the capacitor, so changing the resistance will cause a change in the angle of the trigger (alpha), which will change the RMS voltage leaving the circuit, see the Figure 5.

A webcam with a resolution of 15FPS images per second and a USB connection was used to connect it to the computer. The filter inside it that blocks infrared rays from entering the camera was removed and replaced with a filter to prevent the transmission of visible rays and allows the passage of infrared rays, equipment has been recycled which is a small piece of old floppy disc, see the Figure 6.

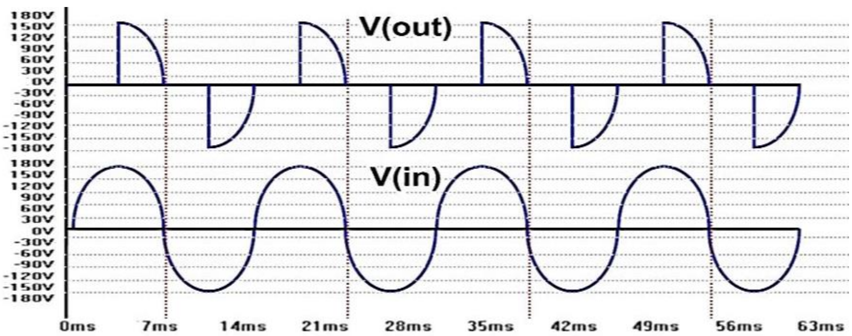


Figure 5. Input and output signals (trigger at 90 degrees)

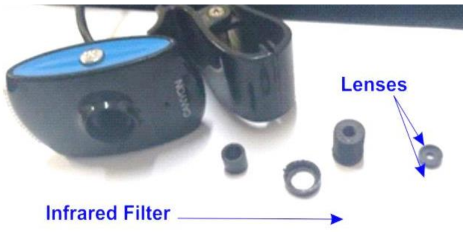


Figure 6. Internal component of web cam

2.2. Software methods

The tactics on this paintings consist of three main block diagram: first block is preprocessing, second block is edge detection, and last block is segmentation. Inside the first block it contains of image acquisition, histogram analyzing, and convert image data to gray method. Secondly block: the opposite technique of edge detection changed into applied to part stumble on the vein pictures. The algorithms for edges images detecting are many and complex, they used five methods to detect veins in the study such as: Sobel, Laplacian, Canny, Roberts, and Prewitt. Inside the ultimate step, we followed the orientated bounding containers, the last block represents the final results, the process of images segmentation and choosing a bounding for the final images. see Figure 7.

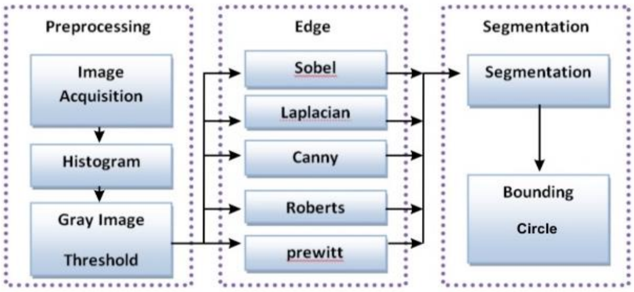


Figure 7. Flowchart for evaluate system of vein edge detection

2.2.1. Preprocessing

After sampling the images with different levels, different lights, different ages and different skin colors, treatments were carried out for these images and by designing algorithms to detect veins and arteries. The (2) shows that the lowest value is zero and the highest value is 255 [18].

$$J = 255.\frac{I - I\,min}{I\,max - Imin} \tag{2}$$

The infrared image is converted to grayscale to focus on important details and subtract the background of the image. The threshold is selected after the spectrogram is performed by using histogram.

2.2.2. Edge detection method

In this study, many methods were used to determine the edges of the images, and these methods were compared and the best ones were selected. Where the method Laplacian, Canny, Sobel, Roberts, and Prewitt was chosen and these images are analyzed in these different ways to find the best results. All of these methods are used on the gray image data, whose dimensions are (250×250).

2.2.3. Laplacian differential method

Laplacian operator is an isotropic operator, it is greater appropriate in satisfactory care approximately the brink Feature without considering its surrounding pixel distinction. Laplacian operator responds to Isolate pixel extra immoderate than to the threshold or line, so it's miles handiest carried out to the pics without noise. In existed noise condition, it's far wanted low-bypass clear out before the use of above operator [7]. Laplacian operator is defined as:

$$\nabla 2f(x,y) = \frac{\partial^2 f(x,y)}{\partial x^2} + \frac{\partial^2 f(x,y)}{\partial y^2} \quad (3)$$

$$\nabla 2f(x,y) = f(x+1,y) + f(x-1,y) + f(x,y+1) + f(x,y-1) - 4f(x,y) \quad (4)$$

2.2.4. Canny method

The Canny filter is one of the best and most widely used filters for defining the edges of images, as it gives great results. The images taken from the camera have noise that negatively affects the edges of the images, this noise must be eliminated and the image smoothed by using a Gaussian filter with the image. This step will reduce the volume [18]-[21]. Gaussian function is:

$$\mathrm{G(x,y)} = \frac{1}{2\pi\,\alpha^2}\ \exp\ \frac{(\mathrm{x}^2+\mathrm{y}^2)}{2\,\alpha^2} \quad (5)$$

$$Gn = \frac{\partial G}{\partial n} \quad (6)$$

$$n = [\, cos\, \emptyset\ sin\,]T\ , \nabla G = [\, {}^{\partial G}/_{\partial X}\ {}^{\partial G}/_{\partial X}] \quad (7)$$

when obtains the maximum = $f(x, y) * Gn$.

2.2.5. Sobel method

The Sobel operator is used to process the edges of images. The brightness intensity of each image is calculated along with the contrast intensity of the image using a small, detachable filter with a correct value in the horizontal and vertical directions. In concept the operator includes a pair of 3×3 convolution kernel as shown under [18].

$$\mathrm{Gx} = \begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 0 \\ -1 & 0 & -1 \end{matrix} \quad \mathrm{Gy} = \begin{matrix} 1 & 0 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{matrix} \quad (8)$$

This design reaches the edges of the images more successfully, and the pixels are taken in the form of horizontal and vertical, relative to the pixel grid [19]-[26].

$$G = \sqrt{G^2x + G^2y} = Gx + G \quad (9)$$

The direction of the edge angle which gives results upward is taken by (10).

$$\emptyset = \arctan\left(\frac{Gy}{Gy}\right) \quad (10)$$

3. RESULTS AND DISCUSSION

In this study a system was designed and implemented for a system to detect veins from recycling old devices, such as a web camera, an infrared lamp, an old overhead device, a floppy disk, and an electronic circuit to control the intensity of the lighting. All these features made the design of the platform low cost.

Most of the previous studies use an IR-LED whose power does not exceed (10 Watt), and this low power cannot penetrate the skin to a large thickness, so the infrared source is placed from the same side of the camera. They are linked in one site. Their results will be limited. As for this innovative design increased power of the infrared source to (100 Watt), and intensity of the lighting is controlled by an electronic circuit to get the best results see Figure 8.

The best result obtained is at a distance of 16 cm from the camera and 90% of the energy of the IR-lamp. The Figure 9 shows the image of the infrared camera with histogram for chosen the threshold filter point. In this analysis points are threshold chosen between 150-66 to get the best results.

The Figure 10 shows the difference between the techniques used in detecting the angle in images. The algorithms for edges images detecting are many and complex. They used five methods to detect veins such as Figure 10(a) Sobel, Figure 10(b) Laplacian, Figure 10(c) Canny, Figure 10(d) Roberts, and Figure 10(e) prewitt. The Figure11 shows classification result, these (1 to 7) circles represent the best places to use the cannula. This image represents the best result obtained. It is possible to specify more points by changing the filter values, or by changing the illumination values of the infrared source. All of these points that were detected in this study are valid for using the medical cannula or taking blood samples from the patient's body.

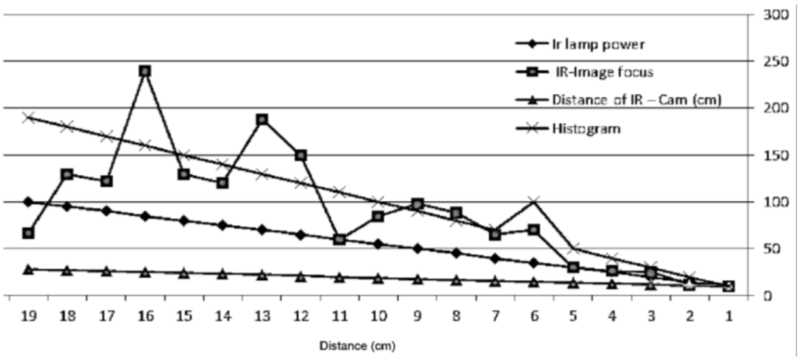


Figure 8. Beast results of IR-image focusing

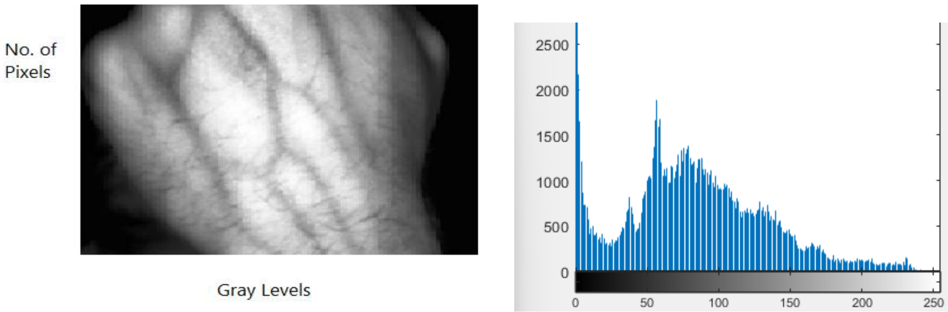
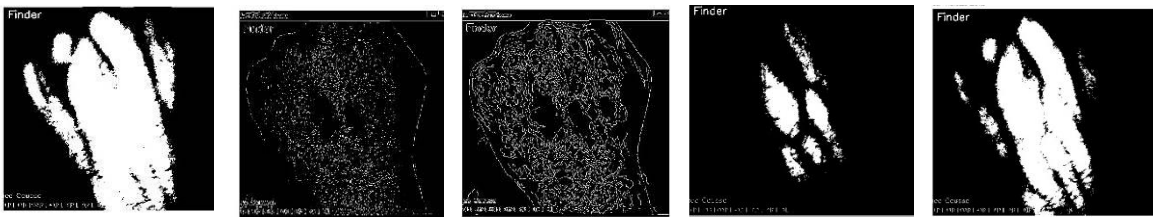


Figure 9. Infrared image acquisition and histogram



(a) (b) (c) (d) (e)

Figure 10. IR-image with edge detection result; (a) Sobel, (b) Laplacian, (c) Canny, (d) Roberts, and (e) Prewitt

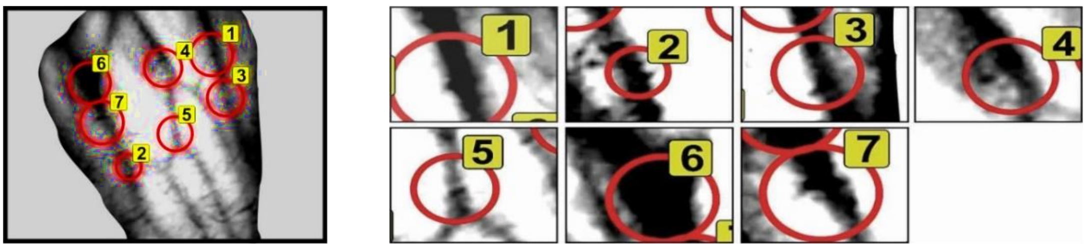


Figure 11. Edge detection and classification

4. CONCLUSTION

The economic vein-viewer has an estimated value of approximately $4,500. For the mobile type, about $27,000 for the non-mobile type. In this study, a system was designed, priced at only $25. This price is considered very low for the efficiency it performs. Primarily based on the review, the low-cost vein-viewer development system designee using near infrared imaging, in the segment of improvement, in particular, targeting its goal to reduce the instances of ignored peripheral subcutaneous veins in the course of blood collection and intravenous insertion for medicine. Common parameters used in evaluating the device were the following, color skin, venipuncture, temperature and age, the illumination of the ambient place and the intensity of the infrared source. When using a set of edge detection filters, the best results were obtained in a filter Sobel and Roberts. The edge detection performance for the Canny 55.6%, Laplacian 42.89%, Robert's 95.51%, prewitt 87.41%, and Sobel 97.21%.

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BIOGRAPHIES OF AUTHORS

Abdulrafa Hussain Maray he received his B.Sc in computer engineering from Northern Technical university, Mosul, Iraq at 2003 and the M.Sc in Microelectronic from computer Technical engineering department Northern Technical university at 2013. He is currently working as lecturer in Mosul Technical Institute/Northern Technical University in Mosul Iraq. He can be contacted at email: Rafiallwaze@ntu.edu.iq.

Saba Qasim Hasan received her B.Sc in computer science department Mosul University, Mosul, Iraq at 1996 and the M.Sc in Image Security Processing from Computer Science department Mosul university at 2003. She is currently working as lecturer in Mosul Technical Institute Northern Technical University in Mosul Iraq. Her research interests image security and objects detection. She can be contacted at email: Saba.qassim73@ntu.edu.iq.

Naqaa Luqman Mohammed received his B.Sc in Computer Engineering from Northern Technical university, Mosul, Iraq at 2003 and the M.Sc in Image Security Processing from Computer Engineering from Northern Technical university in 2011. She is currently working as lecturer in Computer Engineering Northern Technical University in Mosul Iraq. Her research interests' control, arduino, and FPGA. She can be contacted at email: naqaa_alhamo@ntu.edu.iq.