

A Prototype Design and Image Quality Assessment of Low-Cost Finger Vein Image Acquisition using Logitech Webcam

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Abstract: Finger vein pattern of each person varies one after another because of the blood vessels patterns are unique to everyone. Also, blood vessels are hidden beneath the skin's surface, and thus, it is nearly impossible to imitate them. Hence, this study proposed a finger veins image acquisition system by using a Logitech Webcam. This Logitech Webcam is a Charge-Coupled Device (CCD) image sensor that can see the finger veins with naked eyes. The lights from double-arrangement of NIR LEDs (940 nm) penetrated the finger and the CCD image sensor captured the finger images. The double line arrangement was chosen for the prototype as the finger images taken using this method has the lowest Mean Square Error (MSE) (186.04) and the highest Peak Signal-to-Noise Ratio (PSNR) (25.47) values. In total, 15 subjects were recruited to test the functionality of the developed system. The image of finger for each subject was taken five times and they were analysed using MSE and PSNR to determine the best quality of image. The best image with the highest PSNR from each subject was then used to extract the finger vein using edge segmentation (edge detection method) and feature extraction. Sobel and Canny were used for edge detection whereas Wide Line Detector, Maximum Curvature Method and Repeated Line Tracking were used for feature extraction. For the image segmentation, edge detection was used to detect the borderlines of the finger vein images, making it easier to see the differences between each technique under edge detection. In feature extraction, repeated line tracking method presents the best feature extraction as it can show the remarkable lines of the vein, and this will be beneficial for the biometric application. Finally, the developed graphical user interface (GUI) was able to show how the captured image of finger undergo image pre-processing (grayscale converter, image enhancement, image cropping and image resize), edge segmentation and feature extraction methods.

Keywords: Finger Vein, Image Processing, Graphical User Interface (GUI), CCD, Near-infrared LED

1. Introduction

Practically, vein detection utilizes Near-infrared (NIR) imaging for recognizing veins. This demonstrated technology enables an exact representation of the veins under the skin. To begin with, the haemoglobin in the blood retains the infrared light, so there is a diminished measure of light reflection from the veins [1]. Looking at its applications, vein detection aids healthcare professionals in locating veins within the human body when they cannot identify them with their naked eyes. Basically, the infrared projecting onto the viewing area is absorbed by the areas that have blood. Because the light is absorbed by the blood, less light gets reflected into the veins. It is accomplished by scanning the vein detection, resulting in an image in digital format that is projected onto the view portion of the body. The infrared radiation is absorbed in different sorts of tissue in an alternate manner. It starts with utilizing a camera at the bottom for snapshot captures that respond to near-infrared radiation, followed by a lighting system that provides the precise difference between the veins and the encompassing tissue while downplaying the illumination's mistakes to a minimum [2].

In the field of biometric authentication, finger vein recognition has gained significant attention as a secure and non-invasive method for personal identification. A previous research [3] presented a biometric finger vein-based bank security system using Arduino and GSM technology. The system used finger vein authentication to replace the previous fingerprint system due to proxy issues. Finger vein authentication is used as it is secure and easy to use. Another previous research focused on a real-time embedded finger-vein recognition system for mobile devices, with a unique finger-vein detection algorithm and built on an embedded architecture. The system has four hardware components: finger-vein recognition device, image acquisition module, controller board, and human-machine communication module [4]. Other than that, a real-time embedded finger vein recognition system designed for both personal authentication and vehicle security was developed in [5] where the system comprised of four modules: image acquisition, finger vein matching, embedded main board, and communication. Previous research on finger vein recognition, as stated in [6],[7] and [8] have commonalities in their fundamental algorithms, which involves the extraction of finger vein patterns in the preprocessing stage. The biggest drawback is when the clarity of the vein pattern is low, the extraction becomes challenging and prone to errors, as stated in [9]. According to Kang Ryoung Park. Research, the quality of finger vein images is evaluated by counting the number of detected vein points in relation to depth thresholds, taking into account variations in vein density for a more accurate assessment [10] Lastly, the quality of finger vein images can also be evaluated by determined MSE and PSNR values [11].

From a medical field perspective, the vein detection application is used in medical imaging, whereby it is a procedure where interior parts of the human body are clinically investigated and visually portray body organs and tissue. Let say if the doctors have not tracked down the patient's vein, utilizing this application will be helpful in the medical field [12]. However, the finger vein detection on the market can reach thousands of Ringgit Malaysia (RM). Significantly, this existence device is unsuitable for research development due to its expensive price and unsuitable for this purpose. In fact, these finger vein devices have their own verification software, which prohibits any study and development, particularly in image processing.

Therefore, this project is focusing on designing and developing a low-cost finger vein image acquisition device. This device can capture the image of the finger veins. The penetration of light from a bank of NIR Light Emitting Diodes (LEDs) through the finger will cause the hemoglobin in the blood absorbing the areas around veins which eventually appeared as dark areas in the image. The Charge-Couple Device (CCD) sensor will then capture the image of the finger veins that located on the opposite side of the finger. On the other hand, the scopes of this research can be divided into three phases. Phase 1 covers the development of hardware, phase 2 involves the image processing of the finger using MATLAB software and final phase covers the functionality testing of the overall system.

2. Materials and Methods

Figure 1 shows the block diagram of the overall system. Briefly, a modified Logitech C270 HD Webcam with 0.9 mega pixel was used for capturing the images of finger during the penetration of NIR LEDs (940nm wavelength) through the finger. Then, MATLAB software was used to do all the steps of image pre-processing stage including converting the RGB image to greyscale image, image enhancement, image cropping, image resize and image detection (Sobel and Canny). Furthermore, feature extraction is very important to extract the lines of vein. Thus, three methods of feature extraction which were implemented namely as wide line detector, maximum curvature method, and repeated line tracking method. A GUI was also developed for the project's output. The users can select images of the finger vein from the database and run them through the system to see how to pre-process images, detect edges of vein and extract features by using this graphical user interface (GUI). Final works involve the evaluation of developed system. 15 subjects were recruited in this experiment to test the system. Each subject's finger was tested with the develop system and later, the image quality assessment of the finger vein was carried out. Image quality assessment was done to determine the MSE and PSNR values for the images captured to choose the high-quality images of the finger vein.

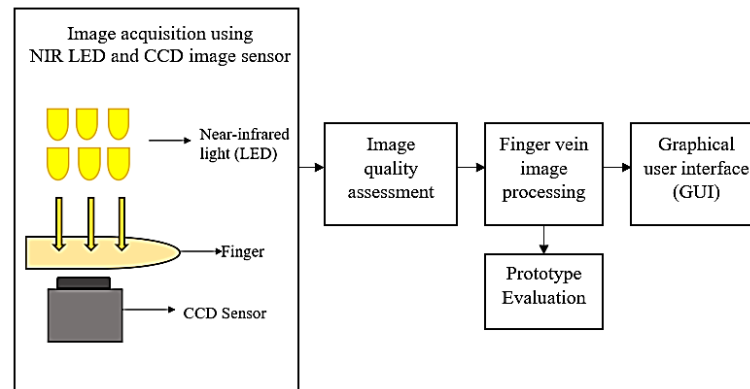


Figure 1: Block diagram of the overall system

2.1 Development of Modified Logitech C270 HD Webcam

The camera used for this project was Logitech C270 HD webcam, but it was modified to be the NIR camera. The camera of C270 was chosen due to the moderate price, high pixels, high definition (HD). The IR filter that attached to the front of the camera lenses was removed cautiously to avoid damage the sensor and caused the lens malfunction. Removing the IR filter is to ensure the camera can see the infrared light from NIR LEDs.

Figure 2 shows the process to remove the IR filter. The first step in converting a webcam into a NIR camera involves opening the casing of the C270 Webcam by removing three screws and locating the lens and sensor. The sensor holder is then found to be glued to the board and carefully removed by hand. Once the filter holder is removed, the small glass filling the inner circle can be clearly seen. If the holder is turned upside down, the IR filter, which appears as a reddish color on the top of the lens, can be seen. The IR filter needs to be removed carefully to avoid scratching the lens. After that, three strips of exposed negative film (Kodak ColorPlus) were cut and shaped to fit in the camera lens, making it easier to secure the filter in place without the use of glue. The reason for using three strips of negative film is to avoid visible light and only allow infrared. During this step, the film cutouts must be clean without fingerprints or dust. To avoid this, gloves must be worn while cutting the film.

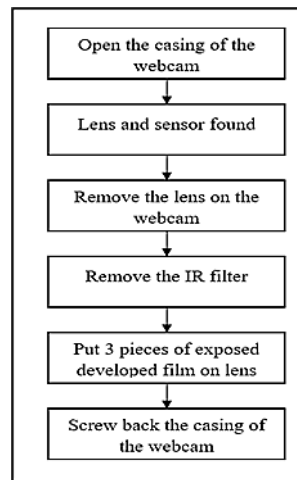


Figure 2: Process to remove IR filter

2.2 NIR LEDs Simulation and Arrangement

Figure 3 shows the NIR LEDs circuit design and simulation using Multisim. The peak wavelength of the NIR LED used in this project is 940 nm. Based on the NIR LED datasheet, the forward current and voltage drop of the NIR LED is 20 mA and 1.7 V, respectively. The power supply voltage used is 12 V since the total voltage drop of NIR LED is 10.2 V (1.7 V times 6 NIR LEDs). Therefore, the maximum resistance value can be determined by using Equation (1).

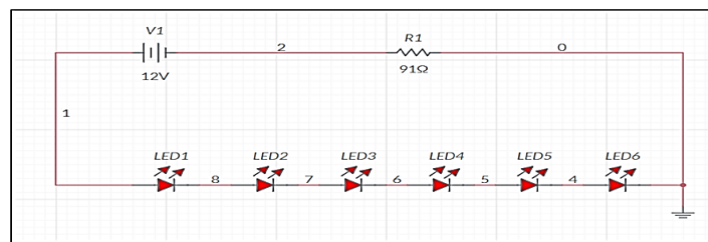


Figure 3: NIR LEDs simulation

$$\text{Resistor Value} = \frac{[\text{Power Supply Voltage} - (\text{LED Voltage drop} \times \text{number of LEDs})]}{\text{Forward Current}} \quad \text{Eqn. (1)}$$

$$\text{Resistor Value} = \frac{[12V - (1.7V \times 6)]}{0.02} = 90\Omega$$

From the calculation, the value of the resistance that can be used is more than 90 Ω. However, the value of the resistor that is used in this project is 91 Ω as 90 Ω is not available at nearest electronic shop. Two NIR LEDs arrangements were experimented; straight-line and double-line arrangements. Figure 4(a),(b) shows the NIR LEDs in a straight and double line that connected to the 12V power supply.

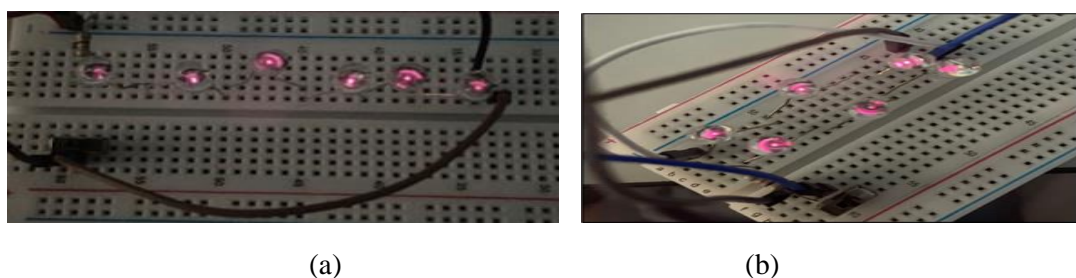


Figure 4: NIR LEDs arrangement: (a) Straight-line and (b) Double-line

2.3 Image Pre-processing, Image Segmentation, Feature Extraction and GUI Development

Figure 5 shows the process of image processing techniques implemented in this project. There were four stages of image pre-processing: converting RGB to the greyscale image, image enhancement, image cropping and image resize. First, the captured image was converted to the greyscale image from the raw image in RGB format. Then, the image was enhanced by using Gaussian High Pass Filter as raw images were in low contrast. Next stage was cropping the image to eliminate all undesired background noise and just focusing on the finger. Last stage was to resize image by downscaling the image of the finger vein from 720 x 1280 pixels to 98 x 297 pixels.

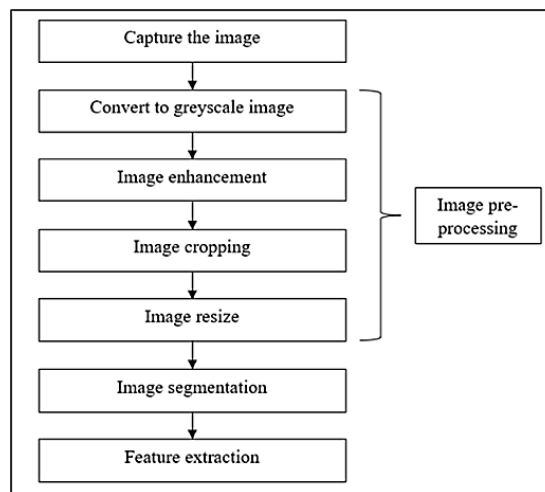


Figure 5: The process of image pre-processing, image segmentation and feature extraction

Then, the finger vein image underwent image segmentation by utilizing the Sobel and Canny edge detection algorithm. These two methods are the popular techniques used in image processing for edge detection and therefore, they were selected for edge comparison. These methods can be used to detect the boundaries between the foreground (finger veins) and the background (skin). The final step in image processing was to implement the feature extraction methods by using Wide Line Detector, Maximum Curvature Method, and Repeated Line Tracking. The maximum curvature method is good for detecting curved lines and has high accuracy, repeated line tracking is good for detecting long and continuous lines and is robust to noise, and wide line detector is good for detecting wide lines and has high accuracy. The choice between these techniques depends on the desired balance between the type of feature to be extracted (curved, long and continuous, or wide lines).

Finally, the GUI output in this project was developed in the MATLAB. The process of GUI design development typically involves the following steps as shown in Figure 6. First, open GUIDE on MATLAB and start to drag/arrange the components using MATLAB's built-in GUI design tools, including buttons, sliders, text boxes, and other components. Next, integrate the code written for data processing and visualization with the user interface design and callback functions. Lastly, test the GUI to ensure that it functions as expected and meets the requirements established in the planning stage.

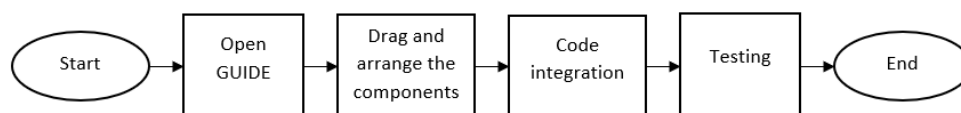


Figure 6: The process of design the GUI

3. Results and Discussion

This section discussed the results obtained from this research project.

3.1 Prototype of Developed System

Figure 7 shows the prototype of the developed system whereas the corresponding labels description of each component.

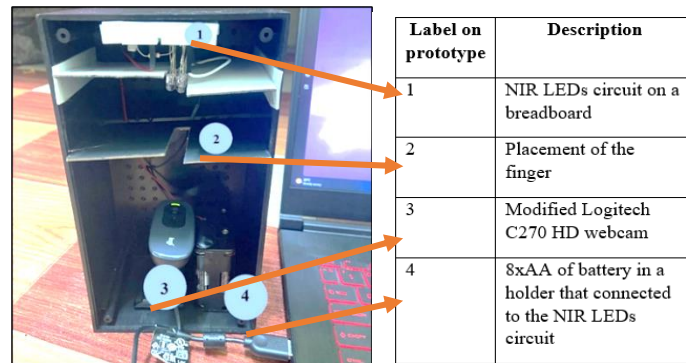


Figure 7: The arrangement of the components inside the finger-vein capturing device with its corresponding label description

3.2 Straight-line and Double-line NIR LED Arrangement

Figure 8(a) shows the image of the finger veins that was captured using Logitech HD C270 Webcam with the straight-line of the NIR LEDs. The finger veins could still be seen but the vein was not too visible. Meanwhile, Figure 8(b) shows the image of the finger in a double-line arrangement. This technique produced a much clearer and better of finger vein visualization compared to the straight-line. To check the quality of the image, the PSNR and MSE values were determined in MATLAB. Table 1 shows the PSNR and MSE values for both arrangements. The higher PSNR value with lower MSE value, the better the quality of the image. The image with double-line arrangement has high quality compared to the straight-line arrangement due to high PSNR value. Hence, double line arrangement was chosen for the prototype as it can get the better images of the finger vein.

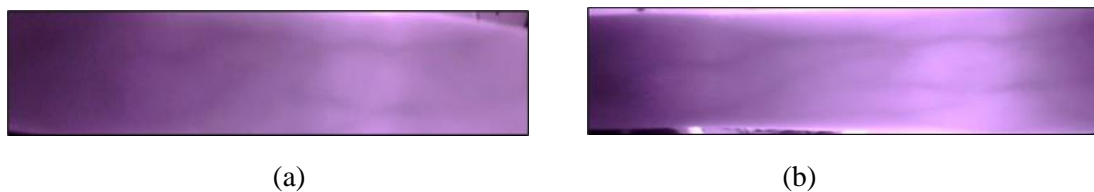


Figure 8: (a) The finger vein image in a straight-line arrangement (b) The finger vein image in a double-line arrangement

Table 1: The MSE and PSNR values for both arrangement

Arrangements	MSE	PSNR
Straight Line Arrangement	194.26	22.28
Double Line Arrangement	186.04	25.47

3.3 Database of the Raw Finger Vein Images

Figure 9 shows the examples of the captured finger vein images using developed finger vein capturing device. The database of raw finger vein images was collected from fifteen female and male subjects who volunteered to participate in this experiment. The age of the subjects ranged from 24 to

27 years old. Each subject provides five images of index finger. Consequently, there were 75 sets images of one index finger. The raw images were in RGB format with the pixel size of 720 x 1280.

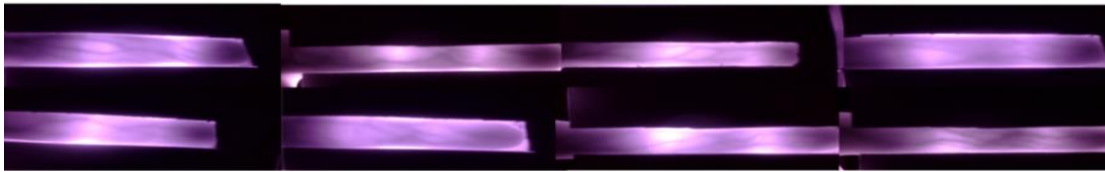


Figure 9: Examples of the captured finger vein images

3.4 Image Quality Assessment

The image quality assessment was conducted as to find the best images to be used in the image segmentation and feature extraction. The image of the finger vein with the lowest MSE and highest PSNR indicates a high-quality image. Table 2 concludes the best quality image for each subject.

Table 2: The best finger vein image based on MSE and PSNR values for all subjects

Subjects	MSE	PSNR
1	147.80	26.47
2	141.79	26.65
3	144.44	26.57
4	140.38	26.69
5	146.68	26.50
6	143.83	26.59
7	139.82	26.71
8	135.44	26.85
9	141.43	26.66
10	146.79	26.50
11	137.16	26.79
12	143.12	26.61
13	135.22	26.85
14	133.09	26.92
15	136.38	26.82

3.5 Image Segmentation and Feature Extraction of the Finger Vein Images

The results of image segmentation and feature extraction were discussed here. It is worth noting that the image analysis for all these techniques mentioned here was outside the scope of this study. Therefore, the comparison analysis was executed based on the visual observations. Figure 10(a) shows the differences between Sobel and Canny Edge Detection. Sobel edge detection is a simple algorithm that can be quickly implemented and provides fast results, making it ideal for real-time applications. This algorithm works by convolving the image with a Sobel filter to calculate the gradient of the image intensity, which highlights the edges in the image. Sobel is a good choice that require quick results, as it is relatively simple to implement and provides good results for many applications. On the other hand, Canny edge detection is a more sophisticated algorithm that provides better edge detection results compared to Sobel. This algorithm uses multiple stages to detect edges, including noise reduction, gradient calculation, non-maximum suppression, and thresholding. The multi-stage process of Canny

makes it more suitable for detecting delicate and fine edges, such as those found in finger veins. From the result obtained, Sobel Edge Detection (Figure 10(a)(ii)) detected the borderline of the fingers whereas Canny Edge Detection (Figure 10(a)(iii)) detected the overall lines on the images of the finger vein. From this analysis, Canny method can produce good edge detection compared to Sobel as Sobel only showed the borderline of the finger.

On the other hand, Figure 10(b) shows the differences for each method in feature extraction. The first method is wide line detector (Figure 10(b)(ii)). This method can also enhance the information of the extracted feature and provide exact information about the vein's breadth from a low-quality image. The green lines on the result obtained were the blood veins of the finger. Next method was maximum curvature method (Figure 10(b)(iii)). This method is basically extracting the vein pattern based on the local maximum curvature of the cross sectional-area which is the center lines of the veins. By looking for locations where the curvatures of a cross-sectional profile of a vein image are locally maximal, the centerlines are found [6]. Last method was repeated line tracking method (Figure 10(b)(iv)). This method achieves good segmentation for the low-quality images as it extracts the clearer images of vein compared to the maximum curvature method. From the visual observation, it is obvious that the repeated line tracking method presents the best feature extraction as it can show the remarkable lines of the vein, and this will be beneficial for the biometric application.

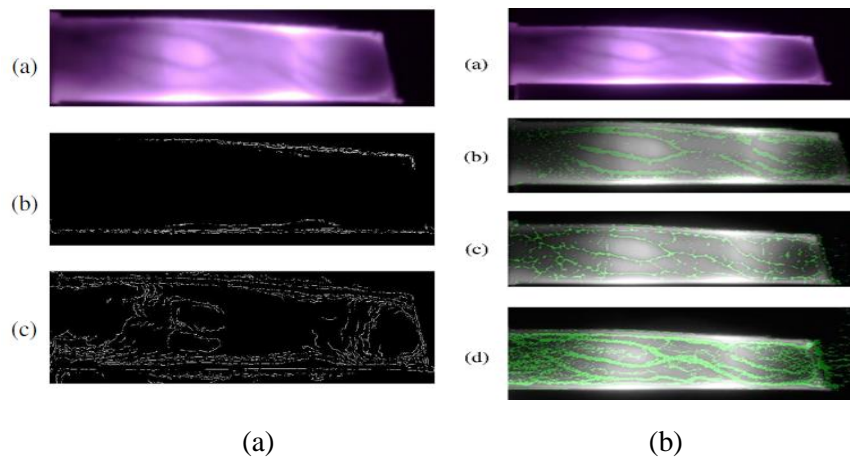


Figure 10: (a) Edge segmentation for: (i) Original image, (ii) Sobel Edge Detection, (iii) Canny Edge Detection and (b) Feature extraction for: (i) Original image, (ii) Wide line detector, (iii) Maximum curvature, (iv) Repeated line tracking

3.6 Graphical User Interface (GUI) Outcome

Figure 11 shows the resulted GUI of the developed system. Overall, the GUI has one button to upload the image, four pushbuttons for the image pre-processing, two pushbuttons for image segmentation, three pushbuttons for feature extraction and one button to exit the GUI. Additionally, three figure axes were used to show the output. The first figure, second and third figure axes were used to display the uploaded images, the image pre-processing stage and the image segmentation and feature extraction methods, respectively.

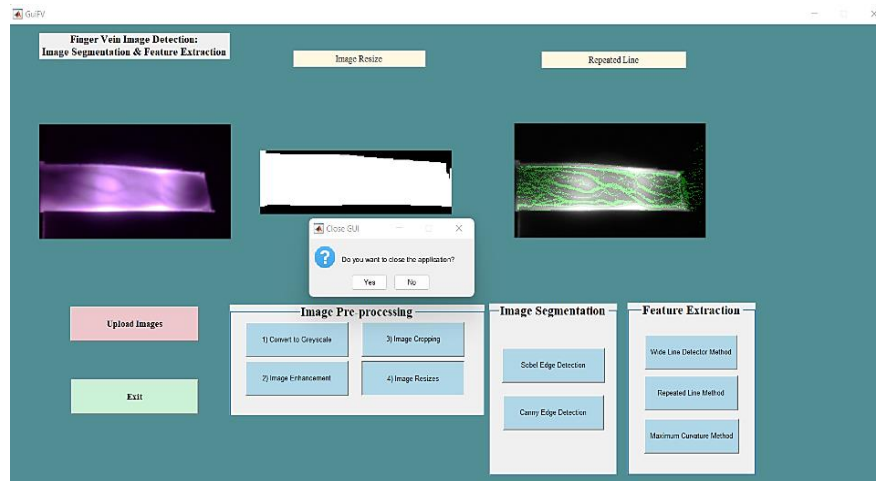


Figure 11: Developed GUI for finger vein image processing

4. Conclusion

In conclusion, an image acquisition system based on near-infrared (NIR) LEDs and webcam using modified Logitech C270 HD webcam and 940nm wavelength of NIR LEDs was successfully developed in this project. The acquired finger vein image underwent these image processing methods: converted from RGB to greyscale image, image enhancement using Gaussian High Pass Filter, image cropping, image resize, and image segmentation (edge detection). Furthermore, there were three methods for feature extraction namely as wide line detector method, maximum curvature method and repeated line tracking method with repeated line method producing the most visible vein lines. Finally, the functionality of finger vein image acquisition system was successfully evaluated by recruiting fifteen female and male subject to test out the developed prototype and to get their images as a database for image segmentation and feature extraction.

As for recommendations, some improvements can be done in the future to make this project even more successful and serve as inspiration and guide. First, the NIR LEDs circuit can be improved by adding the potentiometer to control the brightness of the NIR LEDs. Therefore, the camera can capture clearer and better images of the finger vein. Besides that, this project can be extended by adding vein matching stage and veins image database for biometric application.

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References

- [1] G. K. Sidiropoulos, P. Kiratsa, P. Chatzipetrou, and G. A. Papakostas, "Feature extraction for finger-vein-based identity recognition," *J. Imaging*, vol. 7, no. 5, 2021, doi: 10.3390/jimaging7050089.
- [2] R. S. S. Al-Khafaji and M. S. H. Al-Tamimi, "Vein Biometric Recognition Methods and Systems: A Review," *Sud. Ekspert.*, vol. 16, no. 1, pp. 36–46, 2022, doi: 10.12913/22998624/144495.
- [3] L. J. A. Marcilin, "Biometric Finger Vein based Bank Security System Using ARDUINO and GSM Technology," vol. 13, no. 11, pp. 8774–8777, 2018.
- [4] N. V. Vara Prasad and K. V. Murali Mohan, "A Real Time Embedded Finger Vein Recognition System for Authentication on Mobile Devices," *Int. J. Eng. Trends Technol.*, vol. 8, no. 2, pp.

- 105–108, 2014, doi: 10.14445/22315381/ijett-v8p220.
- [5] V. Ramya, P. Vijaya Kumar, and B. Palaniappan, “A novel design of finger vein recognition for personal authentication and vehicle security,” *J. Theor. Appl. Inf. Technol.*, vol. 65, no. 1, pp. 67–75, 2014.
- [6] N. Miura, A. Nagasaka, and T. Miyatake, “Extraction of finger-vein patterns using maximum curvature points in image profiles,” *IEICE Trans. Inf. Syst.*, vol. E90-D, no. 8, pp. 1185–1194, 2007, doi: 10.1093/ietisy/e90-d.8.1185.
- [7] T. Jain and R. Kumar, “a Study of Vein Recognition System,” *Acta Inform. Malaysia*, vol. 3, no. 1, pp. 13–15, 2019, doi: 10.26480/aim.01.2019.13.15.
- [8] Z. Zhongbo, M. Siliang, and H. Xiao, “Multiscale feature extraction of finger-vein patterns based on curvelets and local interconnection structure neural network,” *Proc. - Int. Conf. Pattern Recognit.*, vol. 4, pp. 145–148, 2006, doi: 10.1109/ICPR.2006.848.
- [9] “Finger Vein Recognition Using Minutia-Based Alignment and Local Binary Pattern-Based Feature Extraction | Request PDF,” [Online]. Available: https://www.researchgate.net/publication/227960486_Finger_Vein_Recognition_Using_Minutia-Based_Alignment_and_Local_Binary_Pattern-Based_Feature_Extraction. [accessed Jan. 30, 2023]
- [10] D. T. Nguyen, Y. H. Park, K. Y. Shin, and K. R. Park, “New finger-vein recognition method based on image quality assessment,” *KSII Trans. Internet Inf. Syst.*, vol. 7, no. 2, pp. 347–365, 2013, doi: 10.3837/tiis.2013.02.010.
- [11] A. R. Syafeeza et al., “Design of finger-vein capture device with quality assessment using Arduino microcontroller,” *J. Telecommun. Electron. Comput. Eng.*, vol. 9, no. 1, pp. 55–60, 2017.
- [12] D. Tordera et al., “Vein detection with near-infrared organic photodetectors for biometric authentication,” *J. Soc. Inf. Disp.*, vol. 28, no. 5, pp. 381–391, May 2020, doi: 10.1002/JSID.891.