Design & Construction of a Vein Detector Device

Al husseiny Mustafa M., Aly Selim M.

Students, mostafaalhussieni@gmail.com, selimmalah@gmail.com.

Supervisors: Ahmed A. Saad, Assistant Prof., ahmsaad64@gmail.com

Nermen Salama, Assistant Lecturer, Nermen_5@hotmail.com

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Abstract– Peripheral venous access is one of the most frequent procedures performed in all hospitals and clinics to either deliver intravenous (IV) therapy through a peripheral cannula or to perform venipuncture to draw blood samples. Peripheral venous access may be difficult, time-consuming, painful, and frustrating for children, obese patients, dark skin patients, and patients previously treated with chemotherapy. In the past two years, during Covid-19 pandemic, the need for peripheral venous access has been escalated tremendously either for drawing blood samples or cannulation of intensive care patients. In this project a vein detector device is designed and integrated to assist the process of vein detection & selection. The device based upon the utilization of near infrared (NIR) light source to capture the naked-eye invisible veins that are located under skin to a depth up to 2 mm. The device is mainly composed of a NIR LED light source, an Infrared (IR) camera, a Raspberry Pi microcontroller, LCD touch screen, a casing to accommodate all of these components, and a telescopic holder. A light intensity analysis has been performed to find the optimum number & distribution of LEDs. The captured image is digitally processed using an image processing module runs on the Raspberry Pi. Also, a simple Graphical User Interface (GUI) module is designed to allow the operator to fine tuning the quality of the image displayed on the touch screen. The device casing is designed on the SolidWorks and manufactured using a 3-D printer.

Keywords-- Mechatronics – Image Processing - Vein Detector.

I- Introduction

One of the most intensive biomedical techniques in Medical Systems is Vein Detection (VD) for venipuncture and biometrics. Problems faced by doctors and nurses when VD is needed for intravenous drugs make the non-invasive process require hard work and a lot of time. The presented device provides a solution for the competency-based requirements of the nurse or laboratory technician to select the desired antidote and inject it at the appropriate point in the circulatory system for intravenous drug delivery and other purposes. The VD device works for all ages, especially the case of children, people with obesity or dark skin. Besides, wrong injection would lead to several damages including swelling, irritation, bleeding and darkening of the skin.

The upper extremity or arm is a functional unit of the upper body, it extends down from the shoulder joint to the fingers. It also consists of many nerves, blood vessels (arteries and veins), and muscles as seen in Fig 1. The veins of the upper limb are [1]:

- The Basilic vein.
- The Cephalic vein.
- The Median cubital vein.
- The Median antebrachial vein.

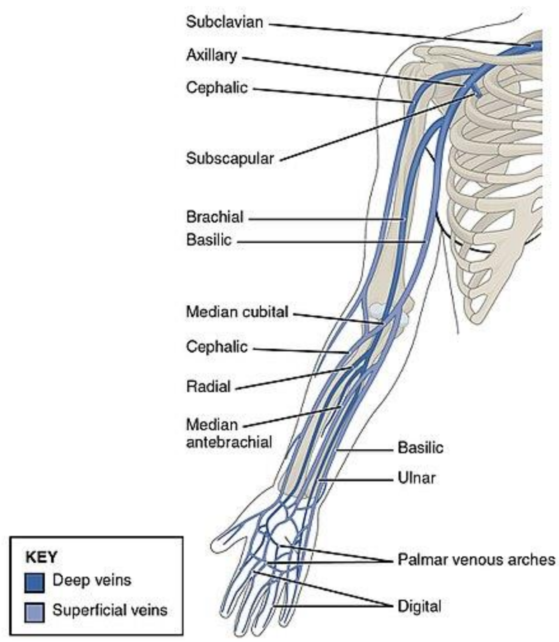


Fig 1 Veins of the Upper Limb

Cannulation of the cephalic, basilic veins of the forearm is preferable where these veins are usually large, easy to find, and accommodating larger peripheral intravenous (IV) catheters. Thus, they are ideal IV locations when large amounts of medications, fluids, and blood can be administered directly into the vein.

In recent years researchers have played an important role in vein identification in the medical field [2]–[4] specially using NIR light to tackle the problem of detecting veins by regular LEDs. NIR light is an electromagnetic radiation in the range of 1 nm to 850 mm.

II- METHODOLOGY

The methodology adopted in the work presented in this paper is that for vein detection using IR imaging. A strong light source is used that is consisting of two LEDs. This light is transmitted on palm hand, and the trans-illuminated image of palm is captured. On this image, the veins clearly appears in black dark lines, while skin appears in red color. This image is converted to a grayscale color, and then processed using image processing algorithms to finally show the clearly veins network.

In order to separate objects from their backgrounds while processing images, an appropriate threshold of grey level must be chosen. In this regard, several strategies have been suggested. Both binary [5] and Otsu's thresholding [6] methods were implemented in this work.

III-CONCEPTUAL DESIGN OF THE VD DEVICE

The proposed detection system works on the principle of NIR that is absorbed by the veins and propagated into the surrounding tissues and provides good quality images, making the vein appear darker when viewed through a sensitive camera.

The provided robust vein detecting technique focuses on **illuminating**, **identifying**, **analyzing**, and **visualizing** the artificial contouring of detected veins. The steps include:

1. **Illumination:** using IR light for the local area of the upper limb.
2. **Identify:** Pattern detection using camera.
3. **Analyze:**
    a. Pattern abstraction Video frames.
    b. Improve the visibility of veins (Generate artificial contouring).
4. **Visualize:** The improved frames on a 7-Inch touch Screen.

The architecture of the proposed VD device can be summarized as in Fig 2, which depicts the three main phases, firstly the illumination phase that is performed by the NIR LEDs that emit their radiation on the patient skin while the camera takes the photo. The second phase is the image enhancement layer, where image processing techniques are applied by programming the Raspberry Pi. Image processing includes standard image processing tasks like scaling, filtering, and contrasting. The third phase is visualization, where the processed images are displayed on a 7-inch touch screen to facilitate the user to a clear VD.

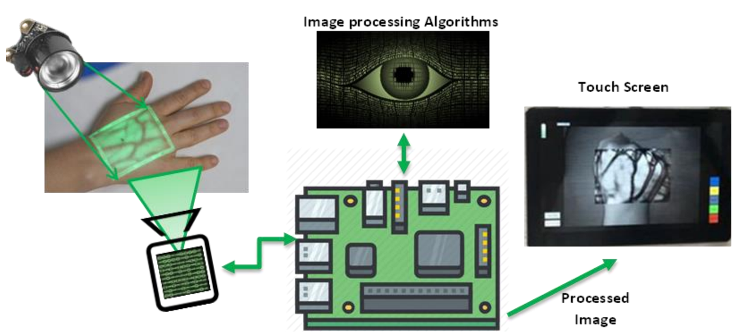


Fig 2 Block Diagram of the Main Layers of Vein Detector

A. *Electronic Hardware*

VD device has been constructed using two IR high power LEDs light source mounted on the side of the Raspberry Pi camera that made the best option for VD device image or video capturing. The image capturing is done by the OV5647 sensor inside the Raspberry Pi camera which is illustrated in Fig 4 has an image array of 2624 columns by 1956 rows (5123544 pixels) [7]. The OV5647 sensor has a field of view of 72-degrees, 3.6 mm focal length, and 5 megapixels digital resolution that delivers static images up to a resolution of (2592 x 1944) pixels, while video capture covers the typical range of 1080p at 30 FPS, 720p at 60 FPS, or 480p at 60 FPS and 90 FPS[7]. Fig 3 shows how the three main phases interact with each other.

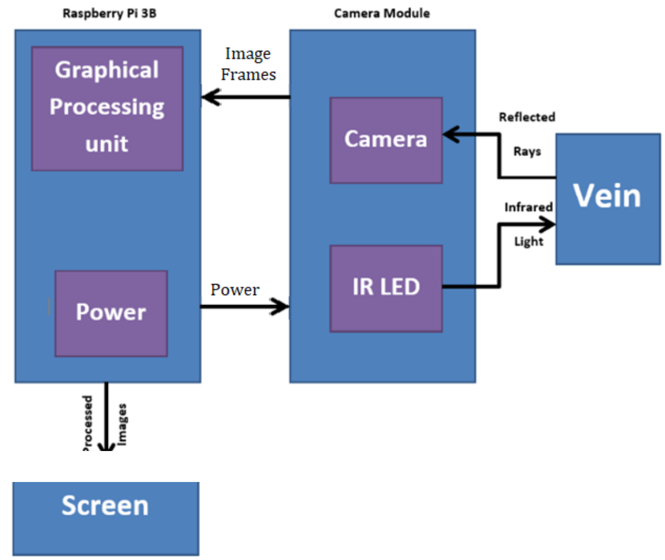


Fig 3 Data/Power Signals Transferred Between the Three Main Layers

B. *Software Programming*

Image acquisition is the first step in any image processing applications from set distance with proper illumination. Conversion of color to grayscale is used for converting color image to a grayscale image. Conversion to grayscale allows for faster processing in the further stages as compared to color images and still yield discernible visualization of the veins in real-time.

The image obtained from global thresholding is masked on gray image which is obtained from color to gray conversion. Thershoding is used for converting grayscale image into binary image. Global thresholding with the simplest property that pixels in a region can share is intensity. So, a natural way to segment such regions is through thershoding, the separation of light and dark regions. Thershoding creates binary images from grey-level one by one turning all pixels below some threshold to zero and all pixels about that threshold to one.

It is important in picture processing to select an adequate threshold of gray level for extracting objects from their background. A Variety of techniques have been proposed in this regard. In an ideal case, the histogram has a deep and sharp valley between two peaks representing objects and background, respectively, so that the threshold can be chosen at the bottom of this valley, However, for most real pictures, it is often difficult to detect the valley bottom precisely, especially in such cases as when the valley is flat and broad, imbued with noise, or when the two peaks are extremely unequal in height, often producing no traceable valley. There have been some techniques proposed in order to overcome these difficulties, for example, the valley sharpening technique

C. Mechanical Design

Mechanical design is concerned with the design of the box holder of the device assembly that should provide an appropriate material selection, internal cooling, and a proper control of the display screen to provide proper facing to the user. The box holder is manufactured by a 3-D printer technology. Polylactic Acid (PLA) and Acrylonitrile butadiene styrene (ABS) are the most common materials used for Fused Deposition Modeling (FDM) 3-d printing materials. Both are thermoplastics, because of this they pass right into a soft and supple state whilst heated, after which go back to a stable state whilst cooled. Through the FDM process, each is melted after which is extruded via a nozzle to accumulate the layers that make up the very last part.

These environmental credentials, and the fact that it is clean and speedy to print, make it an appealing desire for 3-d printing applications, and the PLA properties are regularly selected for its aesthetic properties. The melting temperature of PLA is low (around 145 °C) that is proper to the fused filament fabrication (FFF) 3-d printing process. The use of PLA prints guarantees a clean finished surfaces, which is the best for architectural models, product prototypes, and educational aids.

The mechanical properties of PLA are appropriate regarding hardness, strength, with a flexural strength of 103 MPa. PLA is likewise incredibly stiff, brittle and vulnerable to being chipped or harmed differently by impacts, which may be appropriate for a few packages. In practice, PLA isn't always appropriate for packages wherein the broadcast component is exposed to temperatures higher than 50°C [8].

ABS properties come with thermal resistance as much as 85 °C, ABS may be utilized in much hotter environments than PLA. Compared to PLA, the strength of ABS filament is barely decreased in phrases of the loads it could bear (70.5 MPa). But it makes up for it with its different mechanical properties. With excessive effect strength (Izod examined to 10.5 kJ/m²), ABS components will show greater durability than PLA if getting used for useful prototyping or end-use elements.

Reasons for choosing ABS for the Project are:

- The affordable ABS plastic manufacturing expenses to its sturdy, aesthetically beautiful structure. It is light-weight and appropriate for a considerable variety of packages.
- ABS has low warmness and power conductivity; this is mainly beneficial for merchandise requiring electric insulation protection. It additionally gives awesome effect resistance and may take in surprise correctly and reliably [8].
- Heat resistance: For excessive temperature applications, ABS (glass transition temperature of 105°C) is more appropriate than PLA (glass transition temperature of 60°C). PLA would lose its structural integrity and may start to slump and deform [9].

The prototype VD device design main dimensions can be seen in Fig 4 were (220x144x98) mm. The design has adjustable low weight handheld or can be held on a stand.

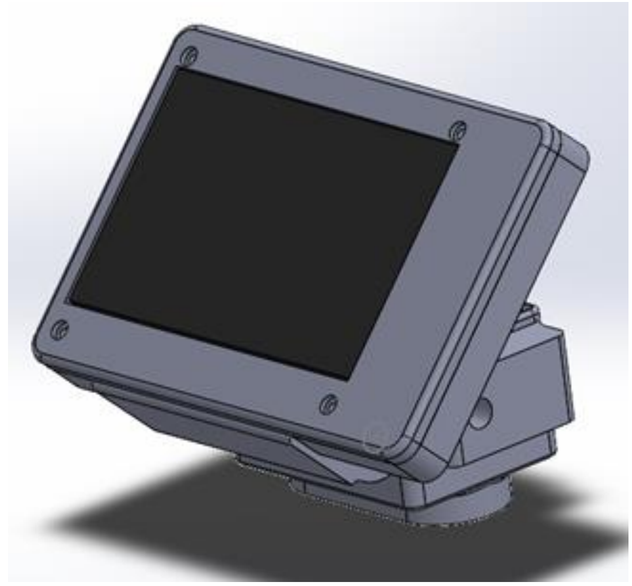


Fig 4 The Prototype Vein Detection Device

D. Design of the Graphical User Interface (GUI)

A ***GUI*** has been designed to provide soft buttons to do the following functions:

1- Controlling the operation of the camera without switching the system on/off (Fig. 5).
2- Switching the system on/off (Fig. 6).

Fig. 5 Camera On/Off Soft Button

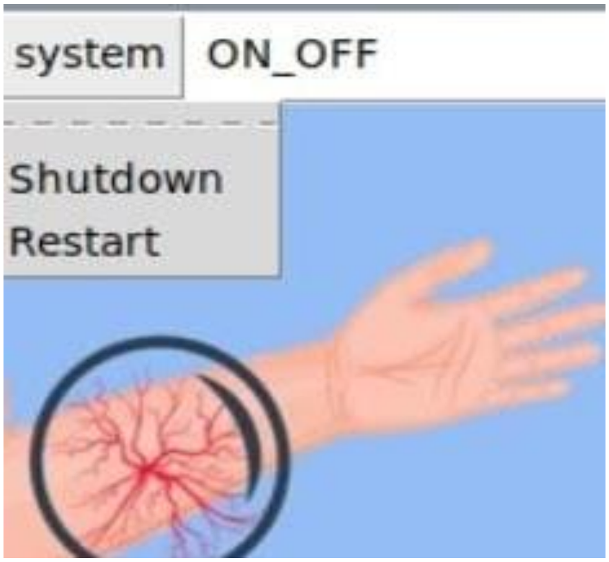


Fig. 6 System On/Off Soft Button

The following libraries has been adopted to develop the GUI:

- **python3 version 3.9.2**
- **Tkinter (tk) version 0.1.0**
- **pillow (PIL) version 9.2.0**

```
import cv2
import numpy as np
count3 = 180
count2 = 80
camera = cv2.VideoCapture(-1)
while cv2.waitKey(1)==-1:
    retval, img = camera.read()
img_grey = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
clahe = cv2.createCLAHE(clipLimit=2, tileGridSize=(8,8))
cl1 = clahe.apply(img_grey)
clamp = np.uint8(np.interp(cl1, [count2, count3],[0,255]))
equ = clahe.apply(clamp)
cv2.imshow('equ',equ)
cv2.imwrite('/home/pi/Desktop/test12.jpg',equ)
if cv2.waitKey(1) & 0xFF == ord("q"):
    cv2.destroyAllWindows()
    camera.release()
```

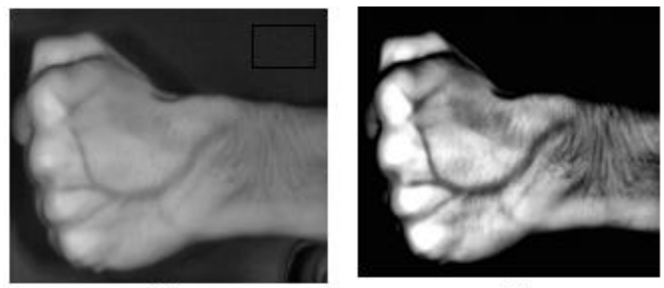
Fig 7 Sample Code of the Used OTSU Algorithm

IV- RESULTS

The code in Fig. 7 was applied to the grayscale and the histogram on coloured images of the wrist. The image after detection and isolation are depicted on Fig. 8 (a), (b). The process was repeated on the back of hand, which is seen after detection and isolation clearly on Fig. 9 (a), (b).

(a) (b)

Fig 8 (a) The Wrist Image After Grayscale and the Histogram And (b) After Detection, and Isolation



(a) (b)

Fig. 9 (a) The Back of the Hand Image After Grayscale and the Histogram and (b) After Detection, and Isolation

V- CONCLUSION

A low-cost VD device has been designed and constructed that utilizes the NIR spectroscopy to visualize veins. The design consisted of a Raspberry Pi with an NIR light source, an IR camera along with a touch screen. The device was assembled in a 3D-printed housing and a stand.

Otsu threshold segmentation method works well and is easy to use. The use of the 2D Otsu algorithm in vein image recognition can reduce the time spent searching threshold and increase system effectiveness with strong anti-noise and improved segmentation.

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