EE-304

Design Laboratory

Final Project Report

Group No: 2

Aim: Portable Infrared-based Vein Finder

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Submitted by-

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Abstract

The use of Infrared devices is a relatively new concept in the field of medical technology. These devices are finding greater utility in diverse applications in the field. Injection is a basic medical procedure which requires finding of the patient's vein. In cases of many patients, this becomes difficult. The main aim of this project is to develop a device which can detect the sub-cutaneous veins to provide doctors an easy access for efficient drug delivery. The utility of this device would lie in almost all the fields of medicine, and is aimed at improving patient comfort.

Objective

Our aim is to develop a low-cost vein finding system, which uses infrared light to capture the images of the veins, processes (enhances and contrasts) these images, and points a laser diode to the exact vein location on hand using a couple of servo motors.

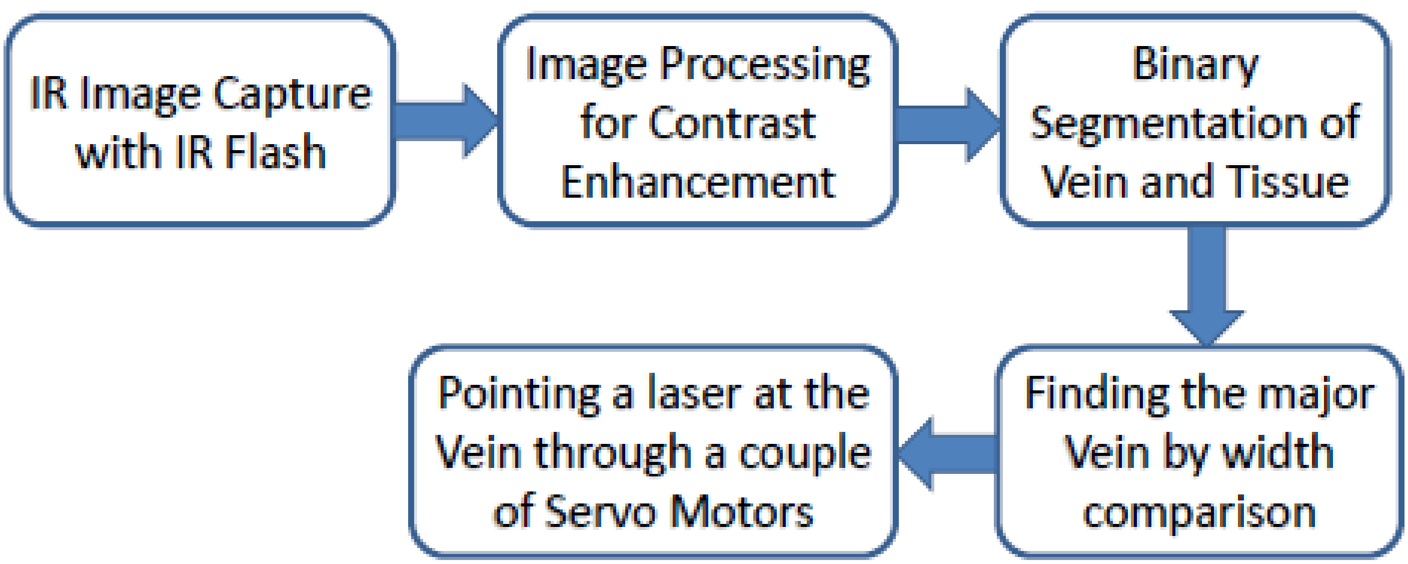
Equipment List

- Infrared Camera
- Infrared wavelength LEDs
- Raspberry pi
- Servo Motors
- Rack-and-pinions
- Relay Switch
- Laser diode
- Li-Po Battery, 9V battery
- Voltage Regulator, IC 7805
- Plywood, Clamps

Introduction

- Near infrared light can penetrate into the biological tissue up to 3mm depth. The deoxygenated blood absorbs more of infrared radiation than the oxygenated blood and the surrounding tissue, so it enhances the contrast of blood veins in the image acquired.
- An IR camera with an IR flash is ideal for acquiring the vein pattern of the desired body part. The IR camera can filter out light of wavelengths less than that of the infrared light used.
- Existing literature in the field of IR based vein sensing focusses on projecting captured image. This, however still leaves room for human error. We have attempted to develop a novel method combining infrared sensing and image processing to identify with greater accuracy the major vein in the part under consideration.

Methodology



Design

❖ **Setting up the Raspberry Pi:**

One of the biggest challenges of the project was to identify and point out the major vein from the image captures using the Infrared camera. Even in infrared light, a lot of noisy features get introduced into the image, due to various external factors including body hair, uneven lighting intensity, presence of body fat and random noise. This required intensive processing of the image, for which an imaging processing tool, OpenCV was used. Using OpenCV requires the use of a microprocessor capable of handling image processing applications. The microprocessor chosen for this was the Raspberry Pi 3 Model B, which has a 1.2GHz 64-bit quad-core ARMv8 processor, a Camera Interface(CSI) and a 1GB RAM which supports image processing at reasonable speeds.

To install the Operating System, we made an image file of the original Raspbian Jessie OS, and then extracted a pre-installed version of OpenCV onto it to save on setup time. VNC Viewer was the software used to create a Virtual Desktop Environment on the Raspberry Pi.

❖ **IR Flash**: Designing a flash with IR LEDs in an arrangement around the region of interest of the veins for illumination of the body part. The flash is controlled by a relay switch circuit. The relay switch is controlled by a GPIO pin of R-pi. Just before image acquisition, the switch is turned ON and the flash glows. The switch is turned OFF after the image is captured and the flash remains OFF for the remainder of the process.

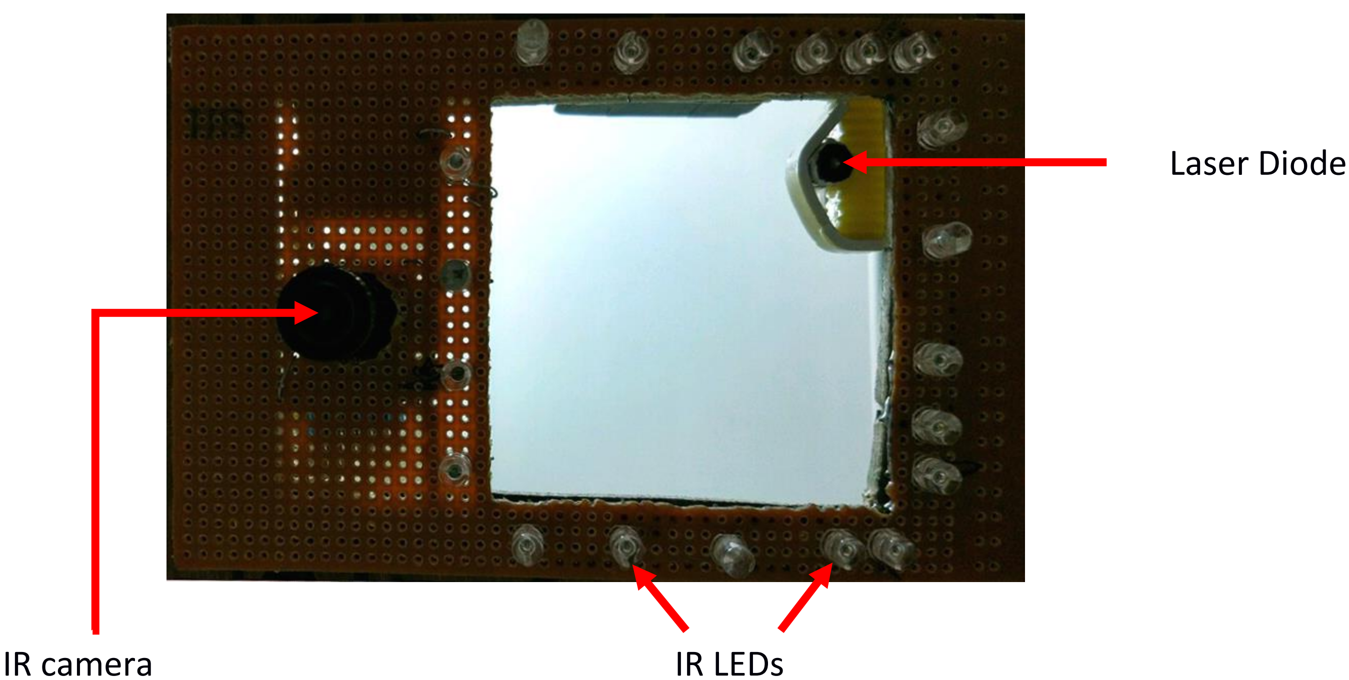


Fig 1. Image Acquisition System

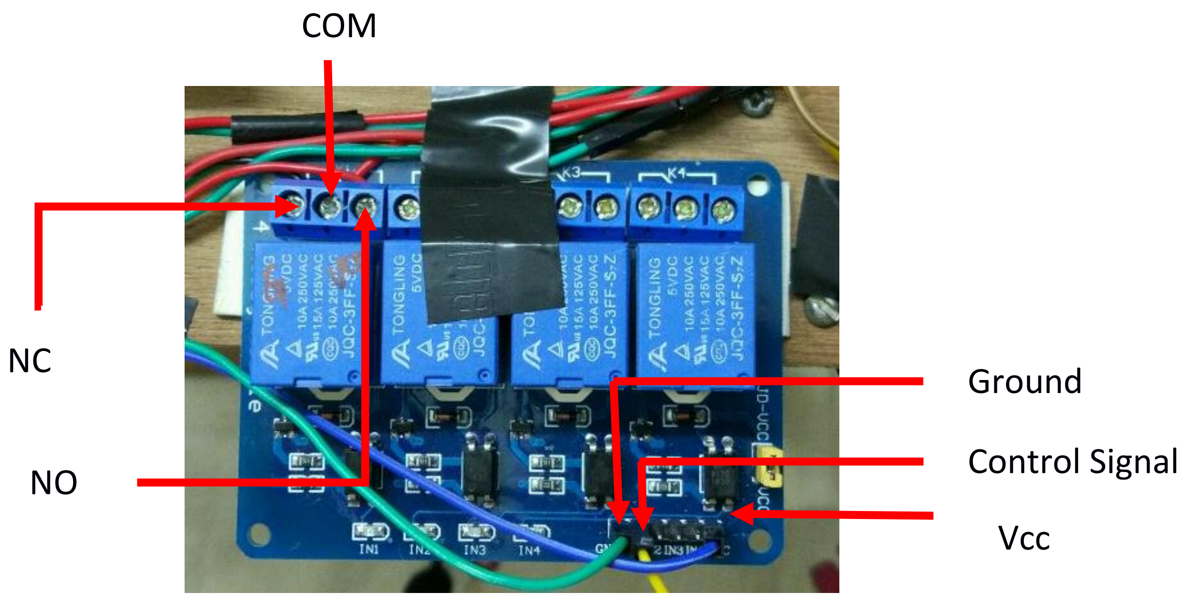


Fig 2. Relay Switch Circuit

- **Image Capture:** The Raspbian Pi NOIR IR camera, with the designed IR flash captures the image of the desired body part. The veins have distinctive contrast as compared to the surrounding tissue.

- **Image Processing:** The acquired IR image is first converted into grayscale image using OpenCV. This image is then further processed for contrast enhancement of veins using Adaptive Histogram Equalization. The enhanced image is then binary-segmented into veins and tissue using adaptive Otsu thresholding. Majority of the patches of noise can be removed by median filtering.
  - **Adaptive Histogram Equalization**: Contrast-limited adaptive histogram equalization (CLAHE) operates on small regions in the image, called *tiles.* The contrast of each tile is enhanced, so that the histogram of the output region approximately matches a specified histogram. After performing the equalization, of individual tiles it combines neighboring tiles using bilinear interpolation to eliminate artificially induced boundaries.
  - **Otsu Thresholding**: It is used to automatically perform clustering-based image thresholding. It converts a gray level image to a binary image.
  - **Median Filterin**g: The **median filter** is a nonlinear digital filtering technique, used for noise removal. Median filtering is very widely used in digital image processing because, it preserves edges while removing noise. The main idea of the median filter is to run through the signal entry by entry, replacing each entry with the median of neighboring entries.

- **Servo motors:** The X and Y position co-ordinates of the vein are returned by the program carrying out the image processing. This point now needs to be actually made available to the user for intravenous vein injection. For this, a laser diode was used to point the exact location of the image on the hand. This diode was moved along the X and Y directions with the help of two servo motors which were used to move this in perpendicular directions. The servo motor are powered up using a LiPo(Lthium Polymer) battery, which can provide up to 3A current.

  A servo motor is a closed-loop servomechanism that uses position feedback to control its motion and final position. The input to its control is a signal representing the position commanded for the output shaft.In our case, the control signal is a Pulse Width Modulated signal whose frequency is set to 50 Hz. The time period of this is hence 20ms. The duty cycle of this PWM signal is varied from 2.5 ms, which is the neutral position of the motor, to 12.5ms, which is the extreme position of the motor.

- **Laser Pointing**: The laser is connected to a rack that can move in XY directions. One to one mapping of image pixels to X-Y co-ordinates of hand is achieved, by co-ordinate transformation to account for the small errors in the alignments of the camera and the laser diode. An appropriate pixel depicting the centre of the major vein is chosen by width comparison and respective co-ordinate is stored in a file. A python script reads the co-ordinates from this file and sends appropriate control signals through GPIO pins to the servo motors. The motors move the racks connected to them appropriately in X-Y directions and the mounted laser diode points to the exact vein location on hand.

- **Alignment of Image and Laser Pointer:** Even after careful alignment of the camera with the axis of the laser pointer, there exists a slight induced error in the system. A mapping was created to ensure that the laser pointer aligns exactly with the pixel values of the image.
  The following mapping was calculated:
  A=pulse width of the first servo motor
  B=pulse width of the second dervo motor
  (pixel value of image x, pixel value of image y)->(PWM pulse width for motor 1, PWM pulse width for motor 2)
  (146,576)->(2.5,2.5)
  (204,1186)->(2.5,11)
  (853,1153)->(12,11)
  (793,510)->(12,2.5)

  This gave rise to the following equations for the position mapping:
  A=0.0014*x+0.0138*y-10.6846
  B=0.0145*x-0.00139*y-3.82672

Automating the Setup:

An important part of creating a portable design for the Infrared based vein detector was to make the system fully automated which could be run on powering up the system without needing to control the Raspberry Pi via desktop PC or an external monitor display. This was done by creating a bash script file with all the programs and commands needed to run the program for the vein detection. The bash file was made executable using:

sudo chmod +x mainrun.sh

and then placed in the bootup directory using the Crontab feature, which is available on Linux based Operating systems.

After this, the system worked automatically on bootup without requiring any manual intervention in the middle.

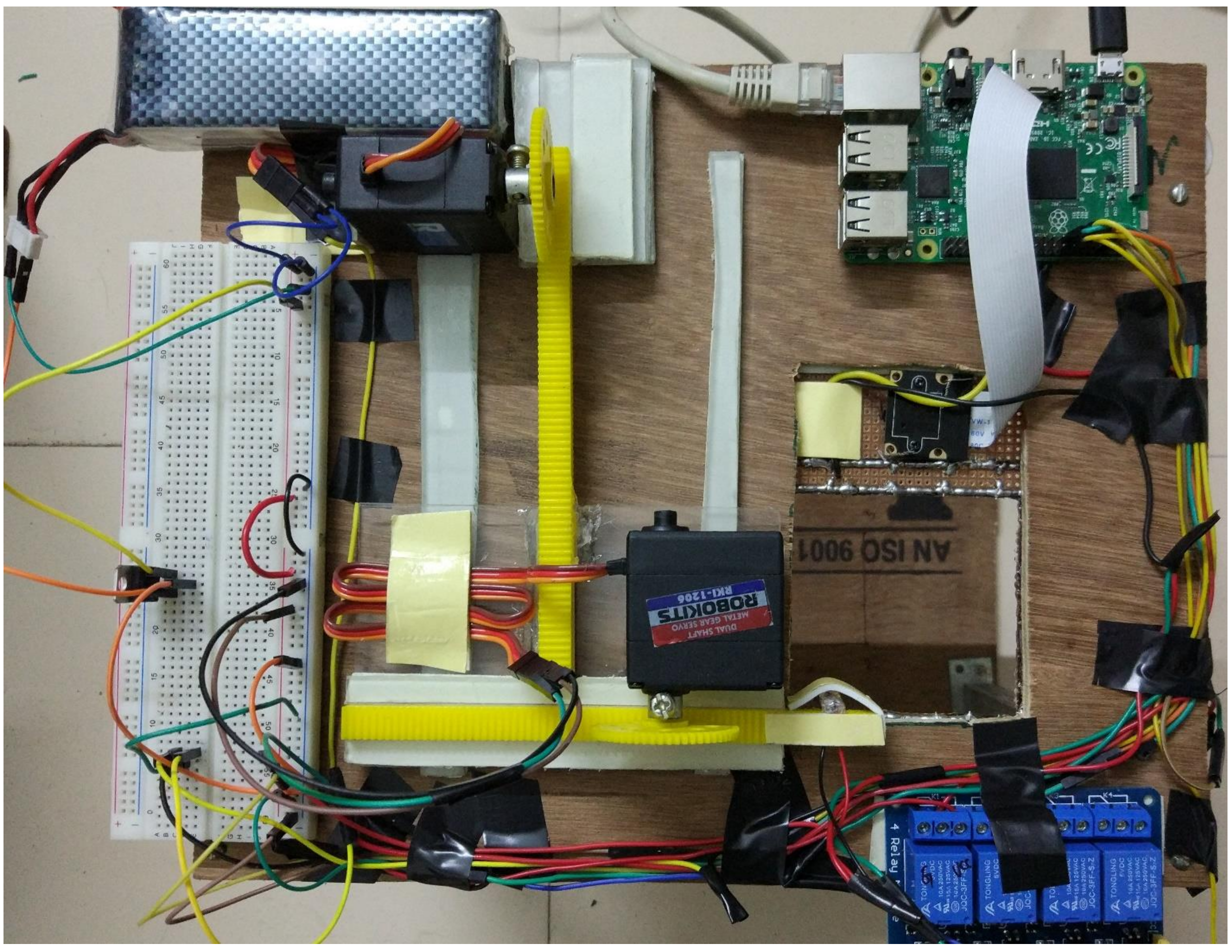


Fig. 3: Experimental Setup

Results

The captured images are shown below:

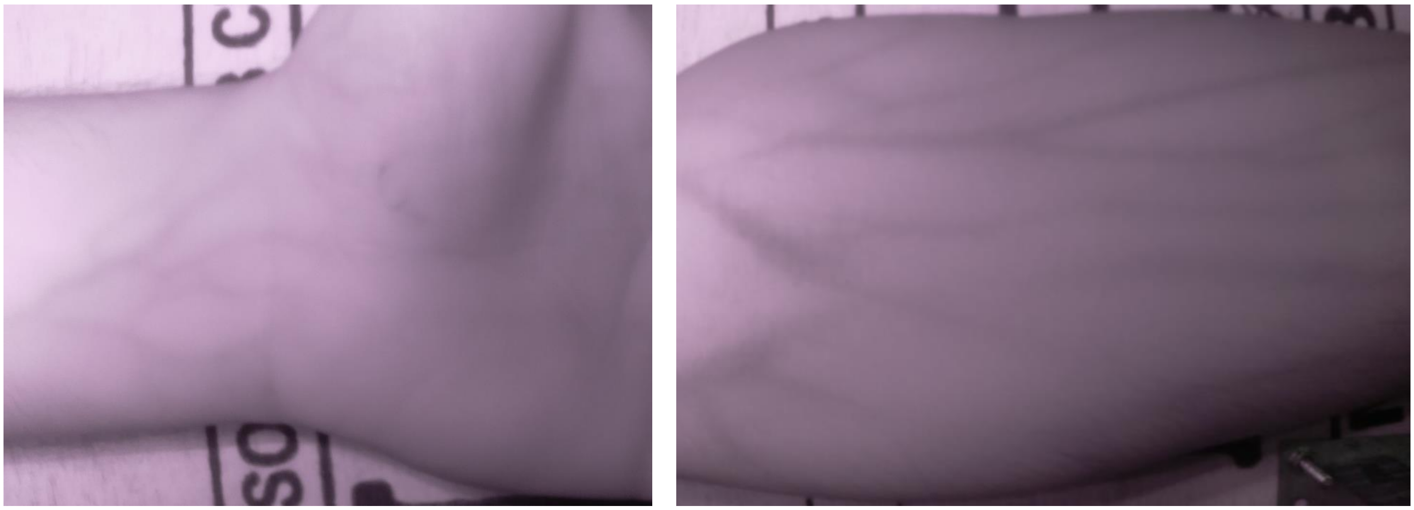


Fig. 4: Images captured by IR Camera

The image is converted into grayscale and region of interest is cropped and then adaptive histogram equalization is applied to the images.

Fig. 5: Cropped images of region of interest

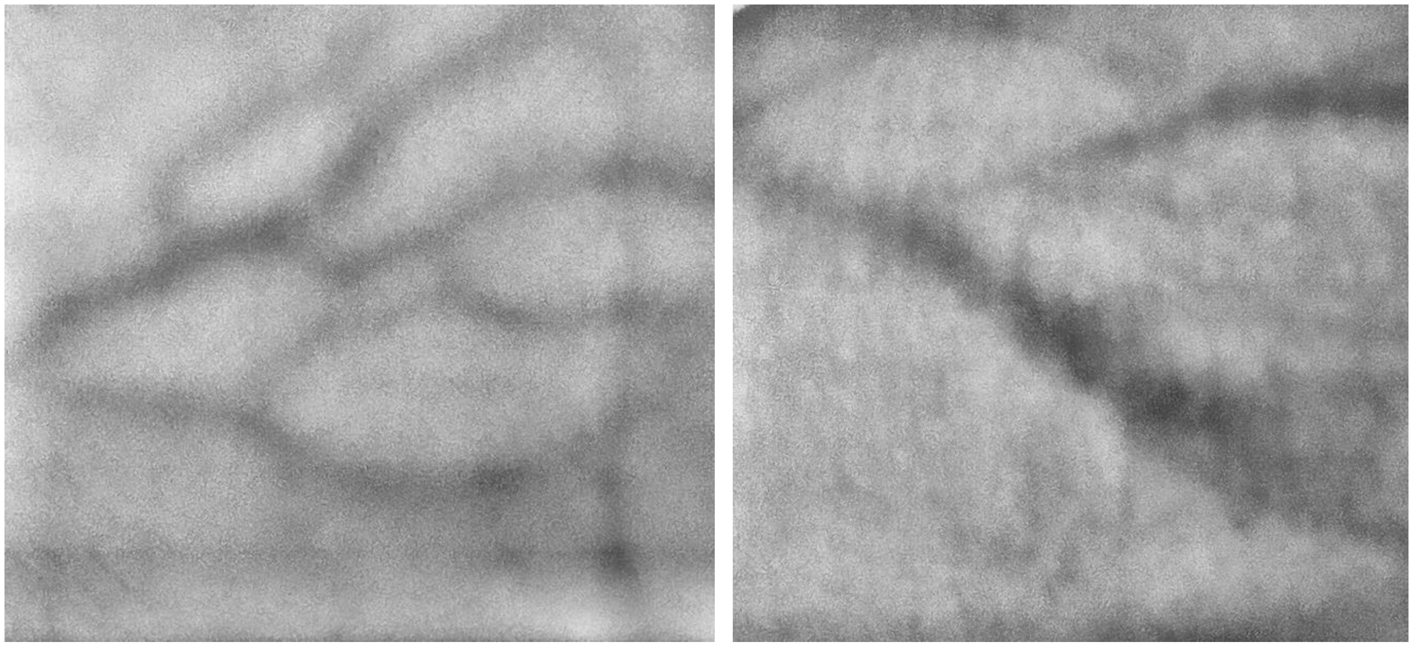


Fig. 6: Regions of interest after Contrast-limited adaptive histogram equalization

Otsu thresholding is then applied to these images.

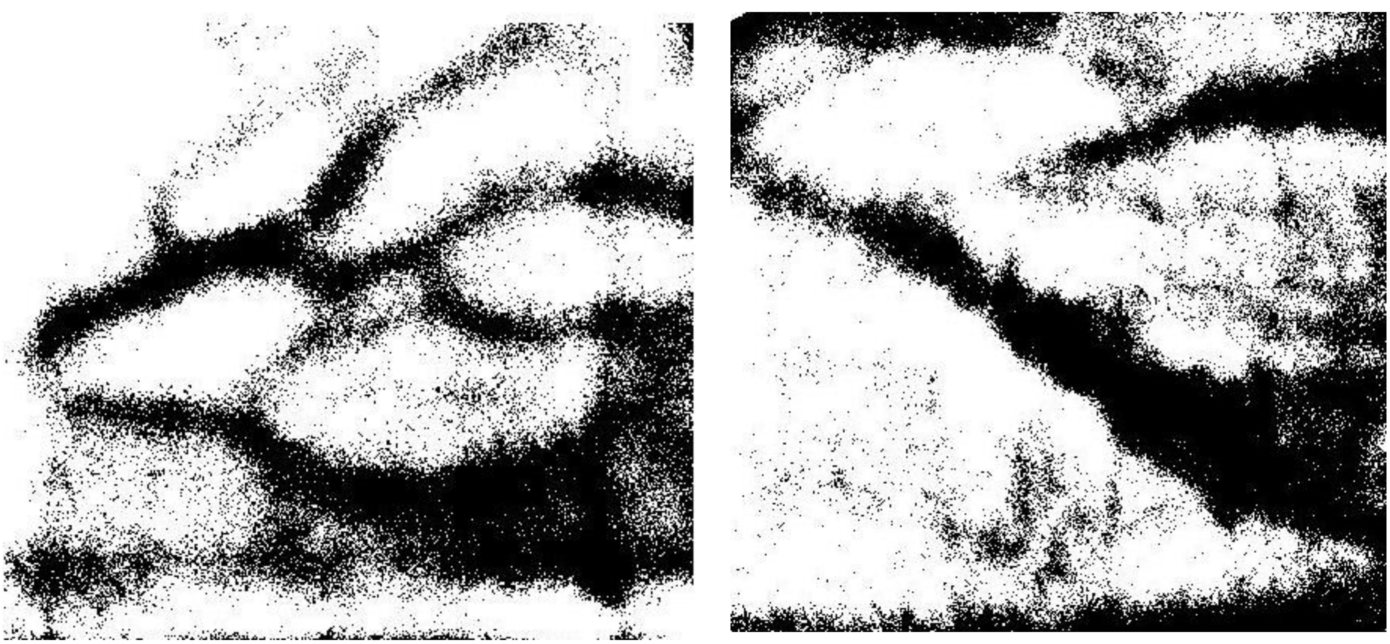


Fig. 7: Region of interest after Ostu thresholding

The noise in the images are removed by median filtering.

Fig. 8:Region of interest after median filtering

- Some small dark patches also appear along with the veins due to non-uniform illumination of the IR flash.
- The laser was pointed towards the thickest available vein in the system, closest to the center of the region of interest.

Conclusion:

- An infrared based vein detector was developed based on the differential adsorption of IR light of the veins and surrounding tissue. A flashing circuit consisting of 16 Infrared LEDs was made, which was controlled by a relay unit driving a BJT used as a switch. This circuit helped co-ordinate the flash with the capture of the image and hence ensured minimum wastage of power for driving the flashing circuit. A laser pointer mounted on a motor is used to point out the location of the identified vein. The 9V potential provided by the battery is stepped down using an LM 7805 voltage control IC, which steps down this voltage to 5V.
- The accuracy is observed to be good in different lighting conditions, and on different test cases. However, since the LEDs used only provide a maximum of 3mm penetration on the sckin, presence of extra fat and hair on the skin interfere with the functioning of the image processing algorithm, and give rise to small errors in the detection of the veins due to the introduction of non-uniform noise in and around the veins.