Vein Sight – Infrared based vein imaging system

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Declaration

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Abstract

Medical testing of laboratory, that mainly utilizes venous blood sample, is among the most frequent methods for diagnosis. This necessitates an intrusive procedure, including cannulation, which necessitates careful vein selection. A vein finder would make it easier for the phlebotomist to identify the vein, reducing the risk of a preanalytical mistake in the collection of specimen & causing the patient even more agony & suffering. Vein detection is among the most cutting-edge biomedical methods currently being investigated. While the method's idea is basic, there are several difficulties to overcome in the design & execution of a device that includes a lighting system & algorithms for image processing at a cheap cost. While just a few infrared-based medical devices have been deployed, there still is a great demand to create such devices. Doctors now confront a significant challenge in gaining access to veins for intravenous medication administration. Bruises, rashes, blood clots, and other complications may result from incorrect vein identification. As a result, a subcutaneous, non-invasive vein identification system depending near infrared imaging & attached with a laptop has been successfully created. The vein pictures are captured using a specialized camera, and the processing is done using Computer Vision. The specifics of the pilot research are also included in this article. Varicose veins, deep vein thrombosis, & vascular diseases may all be treated with this. The study focuses on two important features of this device: portability & cheap cost.

Key Words: contrast stretching, vein imaging, adaptive threshold, infra-red imaging, low-cost imaging

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CHAPTER 1: INTRODUCTION

Getting to veins in instances of old or hefty just as dull conditioned and grown-up patients turns out to be troublesome occasionally for drug conveyance doctors. However critical work has been done around here, and numerous gadgets have come up, yet the serious issue lies in their expense and convenience. A minimal expense, compact and effective infrared imaging discovery framework is the need of great importance. Skin burns & other actual wounds make it hard to find veins and control lifesaving drugs. In circumstances like these, a vein-identifying device is critical. Additionally, knowing the location of the veins is critical when it comes to blood bonding or withdrawal. Obviously, even experienced medical workers and experts consider it difficult to locate blood vessels on the first task. It is important to differentiate the location of the vein in clinical cases. Each second tallies when the specialists are treating injury patients. Among the 0.5 billion intravenous inclusions performed yearly worldwide, almost 0.14 billion disappointment cases happen on the main endeavor. [1] Pain & bruising are common side effects of failed insertions; also, they may potentially progress to venous sclerosis. The challenge of accurately identifying veins dependent on medical experts' visual & tactile expertise is the main cause of failed insertions. Small veins among women & kids, veins under darker skin, especially veins within a fat layer of obese individuals, are very difficult for practitioners to see or detect.

Furthermore, the difficulty of recognizing veins is exacerbated by small veins produced by increased blood pressure and anxiety. The rate of success of intravenous injections may be improved by improving the location of subterranean veins. [2]. Ultrasound may help see the blood vessels; however, it comes at a cost. Thin body parts can also be used to transmit a red or white light source. Excessive heat generation, on the other hand, may result in skin burning.

In emergency medicine, intravenous (IV) accessibility is critical for patient treatment since an estimated 78 percent of Emergency patients will need more than three Emergency resources, including medication, blood tests, contrast, & hydration. Caring for patients having problematic intravenous accessibility (DIVA) could be substantially delayed since establishing IV accessibility in patients undergoing DIVA might take almost 2 hours. Many

DIVA alternatives were developed to prevent central venous catheter administration, such as ultrasound or maybe NIR devices for Venous peripheral insertion.

The use of ultrasonography in the emergency department has been proven to reduce the administration of central venous catheters (CVCs). Ultrasound-guided peripheral I. Venous administration (USGPIV) outcomes, on the other hand, have been inconsistent. Compared to the conventional method of landmark & palpation, Costantino found that USGPIV took a shorter time to achieve good efficacy cannulation & needed fewer punctures to decease intravenous access patients. Many studies, in contrast, found that USGPIV didn't enhance first-time IV administration success compared to conventional IV administration & that this might have taken a similar or even longer time to administer IV properly. Because the success rate of the USGPIV is dependent on the operator, additional training for physicians & Emergency department personnel is required.

Patients experience trouble getting I.Vs. since their veins are clinically inaccessible, for instance, because they're less palpable or visible. NIR imaging technologies, including Christie Digital's Vein Viewer, alleviate this condition by illuminating veins with infrared light.

NIR imaging equipment has been found to enhance the number of successful Intravenous administration attempts in kids having Decrease Intra Venous Access & enhance peripheral vein visibility compared to traditional Intra Venous insertion.

The naked eye only can perceive visible light in a relatively limited region of the spectrum (400-700nm). But there is considerably more stored information in other frequencies of an electromagnetic spectrum denied by points of interest. The human's vein pattern upon its periphery has relatively poor visibility under typical visible light circumstances. Near-infrared imaging (NIR) methods may help with this. Near-infrared imaging has several unique characteristics:

NIR has a depth penetration of approximately 3 mm through biological tissue. When contrasted to neighboring tissues, venous absorbs greater radiation. By firing infrared radiation of a particular wavelength at the targeted body region and capturing the vein picture using an I.R. sensitive camera, the veins look darker than the surrounding tissue within an image.

Between 700 and 900 nm, there is a spectral window where light may penetrate deeply into tissues. The wavelength of an I.R. light beam emitted by a light source is set to approximately 850 nm. This also prevents unwanted influence from the human body's radiation (3 um to 14 um).

Because of preferential absorption of I.R. radiation into blood vessels, radiation within wavelength range 740 nm to 760 nm is used to identify veins and not arteries. One reason for this is because in human veins, deoxidized hemoglobin [Hb or deoxy-Hb] absorbs nearly all the radiation, whereas oxidized hemoglobin [HbO] almost becomes translucent.

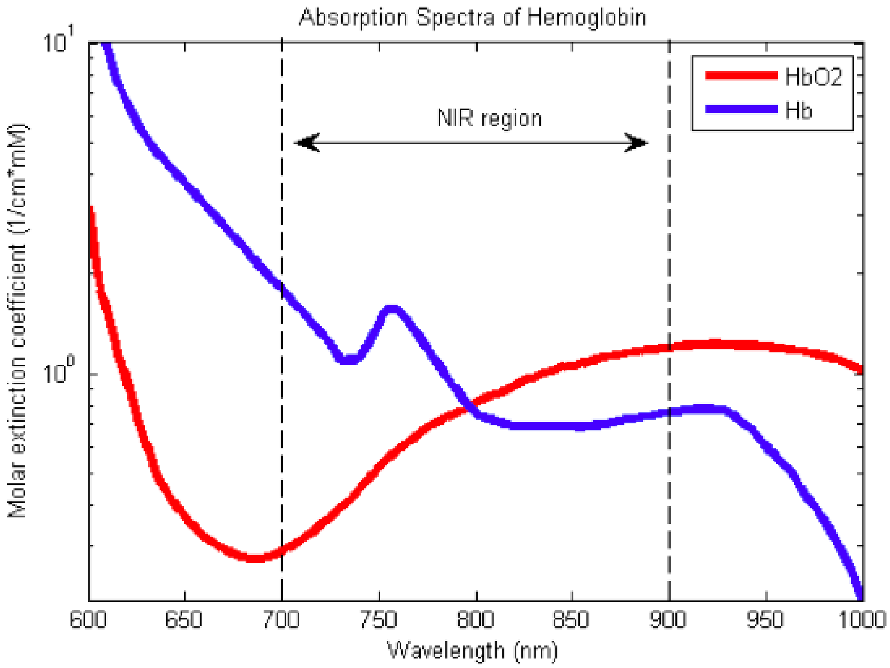

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Figure 1 Oxy and Deoxy Hemoglobin Absorption

CHAPTER 2: LITERATURE REVIEW

The most frequent location for blood extracting, also called phlebotomy, is vein cannulation, which obtains blood samples as a subject of preference for several laboratory tests for illness finding. Furthermore, cannulation is utilized in emergency care to conduct technical operations.[3] It involves peripheral intravenous catheterization (PIVC), which many physicians still find difficult to perform on its first try. [4]. This technique is among the pre-analytical procedures that may influence the correct testing and therapy process by causing variability throughout the laboratory findings. There are ways to aid the phlebotomist in viewing the vein appropriately during venipuncture, including lightly pressing the site [5], using a tourniquet, & implementing cold vibration near the fist clenching & venipuncture site, all of these are thought to root physiological disturbances on veins as well as important variance in many laboratory conclusions.[6]

Because mistakes are continually being discovered and ongoing suggestions for improvements are being supplied, the venipuncture technique cannot yet be called a standard of care. The CLSI H03-A6 paper recommended changes to certain venipuncture procedures, such as cleansing the site & allowing it to drain before placing a tourniquet to examine and choose the vein & then releasing the tourniquet as soon as the 1st tube was filled. It may shorten the time it takes to apply a tourniquet, according to a 2013 research by Oliveira G. et al. Furthermore, it was stated that a trans-illuminator (vein finder) might help with more precise vein vision; nevertheless, it is not frequently applied, owing to the high price of commercially existing equipment.[7]. The primary location for collection of blood samples for testing, entrance site for medicines, & blood transfusions area is the patient's vein. Given the small quantity of effortlessly available veins within the body, venipuncture must be done with caution & precision. [8].

Apart from venipuncture, near infrared (NIR) trans-illuminator illumination was utilized to improve vein therapy by identifying veins undetectable to the human eye but still too deep for ultrasonography detection. [9]. It’s also utilized for your skin’s imaging techniques to assist skin doctor inappropriate disease diagnosis & skincare. For example, Huang K et al., 2012, demonstrate white/black moles skin coarseness imaging into integument & aging of skin tissue or conditions of skin. [10]

Cannulization is seen as difficult owing to a variety of reasons. The following are some of the recognized risk factors causing complications throughout this process: Dehydration, poor vein quality, darker skin, peripheral vasoconstriction, hypotension, obesity, young age, aging, especially term and preterm newborns, vein spot utilized in chemotherapy & addiction of drug, location with rash on skin, telangiectasia, & also the procedure's lower expertise level. [11]. These difficulties require the refinement of cannulation procedures. It involves the creation & usage of the vein finder to identify veins as the location for various operations, intending to reduce missed veins during needle placement during the initial try by healthcare professionals.

Distinctions within number of patients, technique, patients' kinds as per their demographics, as well as constituents utilized in creating vein detector prototypes were noticed into a small number of articles addressing the evaluation for employees conducting venipuncture. The effectiveness of the cannulation procedure is dependent not only on a vein finder but also on a medical professional's abilities. The Chiao et al., 2013 research found that using vein finder equipment to locate a potential cannulation site yielded 9.1 (ninety-five percent CI 8.6 to 9.5) better outcomes than the traditional approach of 5.8 (ninety-five percent CI 5.4 to 6.2). [12]. Furthermore, the results indicate that Asian, American, African race, also obesity are linked to reduced vein visibility, as shown in the Sebbane et al., 2012 research, which looked at obesity as an autonomous menace for problematic peripheral venous entree. [3].

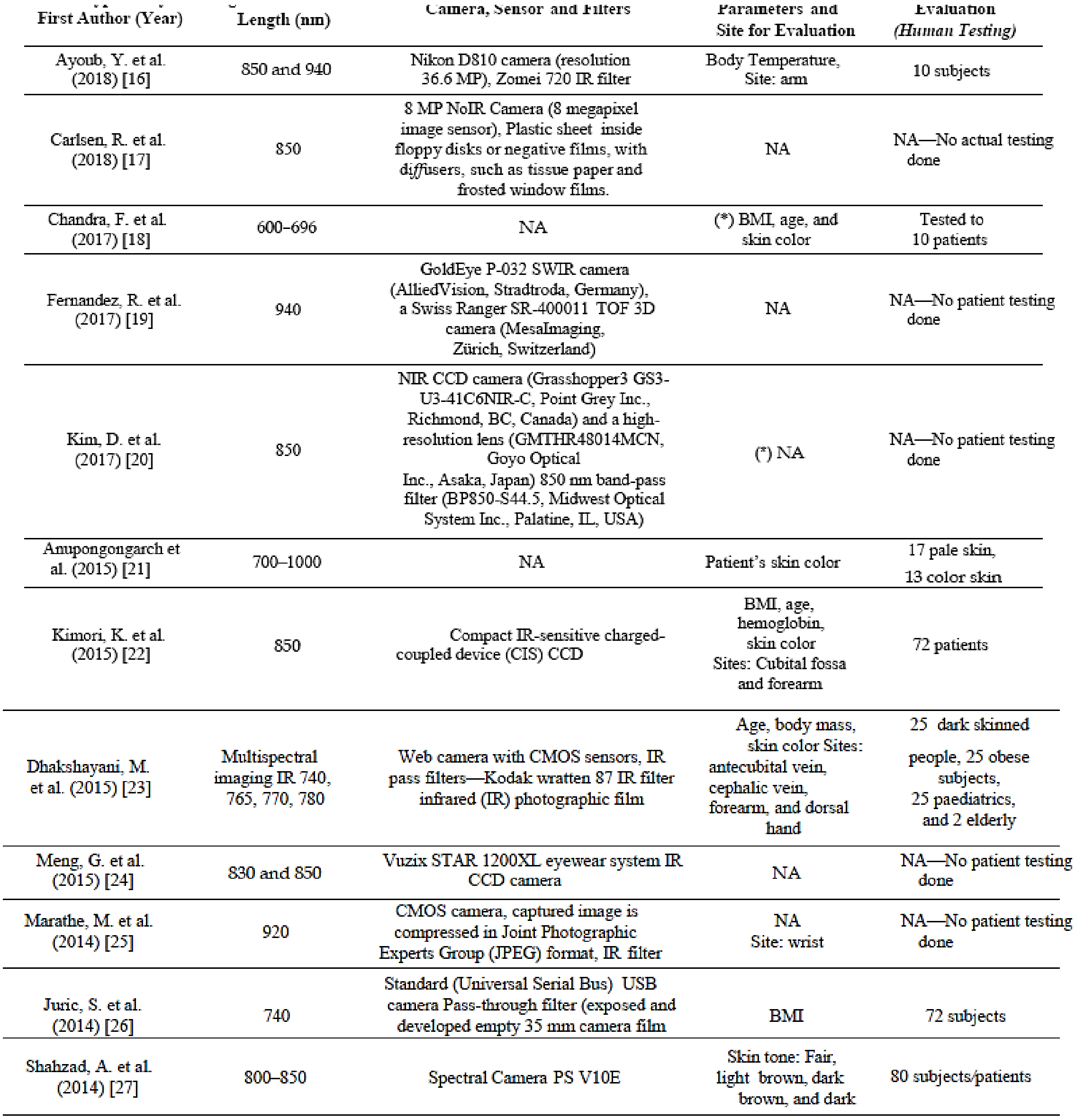
Phipps et al. In 2012 [13] published research that found 59.00 percent (33/56) of successful initial attempts for peripherally placed central catheters using the conventional method (visualization or palpation) & 64.00 percent (38/59) using a vein detector. In 2016 research by Chang & Barreras found that using a near infrared device substantially improved IV admittance accomplishment rates in children with special health care requirements compared to palpation or viewing (26 percent vs. 19.6 percent, correspondingly). [14]. Furthermore, the Fukuroku et al., 2016 [15] research verifying the efficacy of the vein infrared imagining executed by 2nd-year medical pupils verified that vein viewers significantly improved their professional experience in venipuncture, particularly at time of site selection in the older patients.

2.1 Different vein Detector's Characteristics

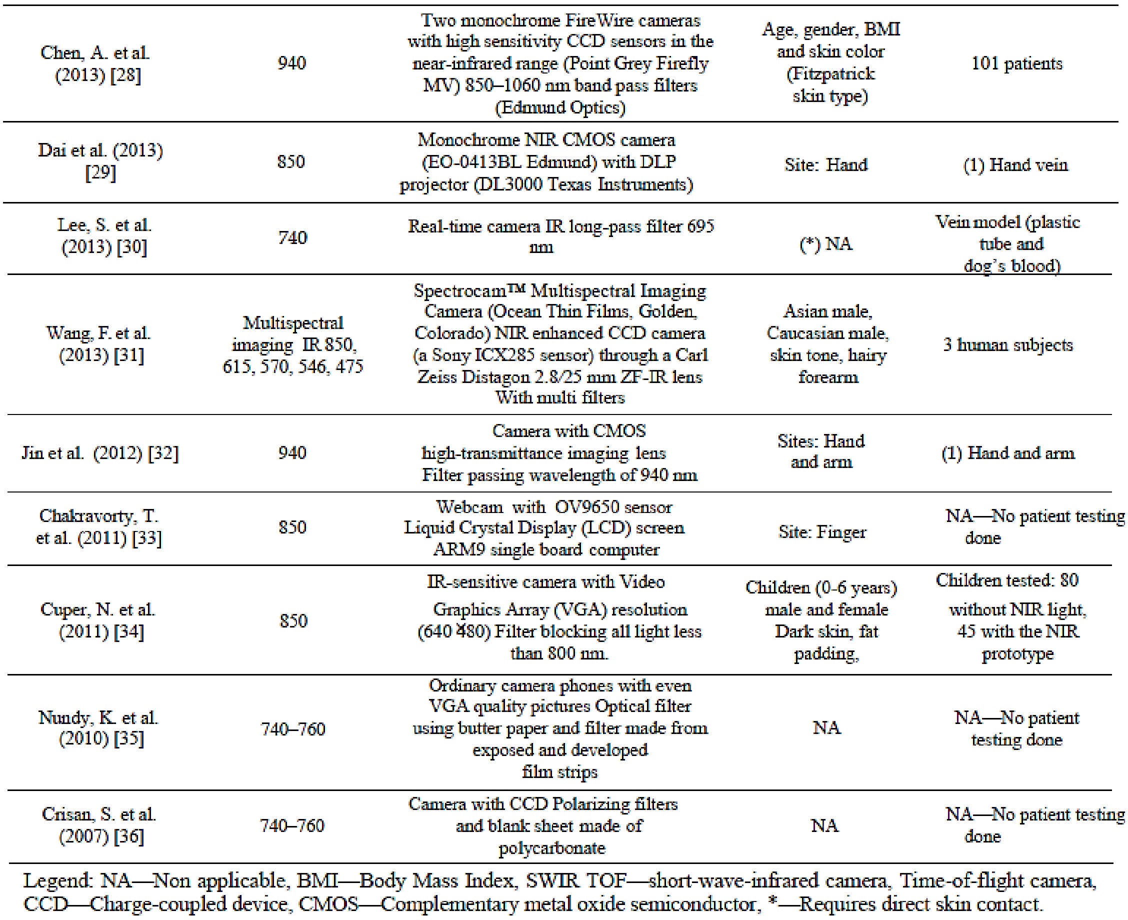
The following table shows the various prototypes with their fundamental features, as well as the

criteria that the researchers used to evaluate them.

Table 1 various prototypes with their fundamental features



First Author (Year)	Length (nm)	Camera, Sensor and Filters	Parameters and Site for Evaluation	Evaluation *(Human Testing)*
Ayoub, Y. et al. (2018) [16]	850 and 940	Nikon D810 camera (resolution 36.6 MP), Zomei 720 IR filter	Body Temperature, Site: arm	10 subjects
Carlsen, R. et al. (2018) [17]	850	8 MP NoIR Camera (8 megapixel image sensor), Plastic sheet inside floppy disks or negative films, with diffusers, such as tissue paper and frosted window films.	NA	NA—No actual testing done
Chandra, F. et al. (2017) [18]	600–696	NA	(*) BMI, age, and skin color	Tested to 10 patients
Fernandez, R. et al. (2017) [19]	940	GoldEye P-032 SWIR camera (AlliedVision, Stradtroda, Germany), a Swiss Ranger SR-400011 TOF 3D camera (MesaImaging, Zürich, Switzerland)	NA	NA—No patient testing done
Kim, D. et al. (2017) [20]	850	NIR CCD camera (Grasshopper3 GS3-U3-41C6NIR-C, Point Grey Inc., Richmond, BC, Canada) and a high-resolution lens (GMTHR48014MCN, Goyo Optical Inc., Asaka, Japan) 850 nm band-pass filter (BP850-S44.5, Midwest Optical System Inc., Palatine, IL, USA)	(*) NA	NA—No patient testing done
Anupongongarch et al. (2015) [21]	700–1000	NA	Patient's skin color	17 pale skin, 13 color skin
Kimori, K. et al. (2015) [22]	850	Compact IR-sensitive charged-coupled device (CIS) CCD	BMI, age, hemoglobin, skin color Sites: Cubital fossa and forearm	72 patients
Dhakshayani, M. et al. (2015) [23]	Multispectral imaging IR 740, 765, 770, 780	Web camera with CMOS sensors, IR pass filters—Kodak wratten 87 IR filter infrared (IR) photographic film	Age, body mass, skin color Sites: antecubital vein, cephalic vein, forearm, and dorsal hand	25 dark skinned people, 25 obese subjects, 25 paediatrics, and 2 elderly
Meng, G. et al. (2015) [24]	830 and 850	Vuzix STAR 1200XL eyewear system IR CCD camera	NA	NA—No patient testing done
Marathe, M. et al. (2014) [25]	920	CMOS camera, captured image is compressed in Joint Photographic Experts Group (JPEG) format, IR filter	NA Site: wrist	NA—No patient testing done
Juric, S. et al. (2014) [26]	740	Standard (Universal Serial Bus) USB camera Pass-through filter (exposed and developed empty 35 mm camera film	BMI	72 subjects
Shahzad, A. et al. (2014) [27]	800–850	Spectral Camera PS V10E	Skin tone: Fair, light brown, dark brown, and dark	80 subjects/patients



Chen, A. et al. (2013) [28]	940	Two monochrome FireWire cameras with high sensitivity CCD sensors in the near-infrared range (Point Grey Firefly MV) 850–1060 nm band pass filters (Edmund Optics)	Age, gender, BMI and skin color (Fitzpatrick skin type)	101 patients
Dai et al. (2013) [29]	850	Monochrome NIR CMOS camera (EO-0413BL Edmund) with DLP projector (DL3000 Texas Instruments)	Site: Hand	(1) Hand vein
Lee, S. et al. (2013) [30]	740	Real-time camera IR long-pass filter 695 nm	(*) NA	Vein model (plastic tube and dog's blood)
Wang, F. et al. (2013) [31]	Multispectral imaging IR 850, 615, 570, 546, 475	Spectrocam™ Multispectral Imaging Camera (Ocean Thin Films, Golden, Colorado) NIR enhanced CCD camera (a Sony ICX285 sensor) through a Carl Zeiss Distagon 2.8/25 mm ZF-IR lens With multi filters	Asian male, Caucasian male, skin tone, hairy forearm	3 human subjects
Jin et al. (2012) [32]	940	Camera with CMOS high-transmittance imaging lens Filter passing wavelength of 940 nm	Sites: Hand and arm	(1) Hand and arm
Chakravorty, T. et al. (2011) [33]	850	Webcam with OV9650 sensor Liquid Crystal Display (LCD) screen ARM9 single board computer	Site: Finger	NA—No patient testing done
Cuper, N. et al. (2011) [34]	850	IR-sensitive camera with Video Graphics Array (VGA) resolution (640 ×480) Filter blocking all light less than 800 nm.	Children (0-6 years) male and female Dark skin, fat padding,	Children tested: 80 without NIR light, 45 with the NIR prototype
Nundy, K. et al. (2010) [35]	740–760	Ordinary camera phones with even VGA quality pictures Optical filter using butter paper and filter made from exposed and developed film strips	NA	NA—No patient testing done
Crisan, S. et al. (2007) [36]	740–760	Camera with CCD Polarizing filters and blank sheet made of polycarbonate	NA	NA—No patient testing done

Legend: NA—Non applicable, BMI—Body Mass Index, SWIR TOF—short-wave-infrared camera, Time-of-flight camera, CCD—Charge-coupled device, CMOS—Complementary metal oxide semiconductor, *—Requires direct skin contact.

A new low-cost, but effective vein finder using the NIR electromagnetic spectrum has lately seen considerable use. primarily for finding commercial veins, the cost of which is calculated using NIR technology, which varies from $4,500 (portable) to $27,000 (full-size) (non-portable) [36]. Furthermore, the difficulties which the physician, medical technician (emergency), nurse, as well as any other medical physicians experienced during venipuncture [21], intravenous (IV) medication administration [33], and cannulation are the most important reasons. Veins that are either extremely tiny or very profound, the age of patient (pediatrics or elderly), color of skin [21], & level of obesity [33,35] are all factors that contribute to this. It often leads to repeated needle insertion attempts, resulting in pain, postponed treatment [21], discomfort, discontent, bone cuts [37], hematoma, skin swelling, bleeding, & infection. Multiple tries are frequently inevitable in young kids, despite the devoted & highly experienced doctors, that might be painful [38], even necessitating blind penetration and even needing general anesthesia [34]. Studies have shown that when the variables listed above are considered, it leads to a substantially poor first-attempt venipuncture success rate [30].

2.2 Different vein finder prototype characteristics

The section outlines the characteristics of the various vein detector prototypes including the parameters utilized as well as the assessment procedure.

2.2.1 Wavelength

The light may permeate to approximately 5mm deep into the epidermal tissue, hitting the deoxygenated hemoglobin, thanks to the length of electromagnetic spectrum of 740-940nm. The deoxygenated haemoglobin in the veins has a higher light absorption coefficient, which reduces the backscatter light coefficient. As a result, the veins appear darker on the skin. [41]. In 2015 M. Dhakshayani et al., [42] demonstrated that wavelength optimizing by using an IR multi-spectral source can obtain excellent exposure of veins when taking into consideration the patient's types depending on age, color, & thickness of tissue, as well as the rays (near-infrared) of lower wavelength 740nm, 765nm exhibit high light absorption by deoxygenated hemoglobin, having deep penetration on a higher 77nm wavelength. A hairy forearm appears to improve the reflectance of the veins in photographs, as stated in a separate study conducted by Wang F et al., 2013 [43], where they utilised 850nm light that was transmitted through the subcutaneous tissue. In contrast, Kimori et al., 2015 [44] compared 850nm light that was emitted from a product vein detector to the light source. Another research found that the wavelength used differed depending on skin tone. The picture quality of fair skin was found to be somewhat superior in the spectrum of 750-800nm, compared to darker skin, which has an overall spectrum of 800-850nm [45]. In 2015 Anupongongarch et al., [46] utilized the source of light having the maximum wavelength, almost 1000nm, among the investigations. This variance shows that the standards for the best wavelength for vein imaging has yet to be established.

2.2.2 Camera Types

The capacity of a sensor that detects reflected light & collect pictures in real time [47]. The CCD as well as the CMOS are the two most popular sensors. A charge-coupled device is used in this application. Low-noise, High-quality pictures with great light sensitivity and many pixels have been captured using CCD sensors, while low-efficiency but cheap CMOS sensors are being developed to improve. [48].

In many applications, CMOS image sensors are overtaking CCD due to advantages such as the ability to unswervingly connect the photo-sensitive gadget with electronic readout just at pixel level & improved on-chip functionality [49]. Now, in particular applications such as mobile phones, wearable devices, motion detection, & specially bio-medical imaging sensors like in-vivo imaging sensors (electroencephalogram, optical signals, and electrical stimulation) which aid in the multi-functional use of footage for diagnosis during surgery, a sensor device has been developed that allows for the recording of brain activities. IR detectors using CMOS-based sensors offer high-speed performance/faster readout, low power consumption, low noise, and uniformity according to research conducted by Yacin S. and Dhakshayani M. in 2015 [50]. Since costs and availability are an issue, the Marathe et al., 2014 [51] study went with CMOS rather than CCD in another investigation. the optical filters and diffusers distributed light evenly across the target area, and the device also contained optical filters and diffusers to block wavelengths outside of the near-infrared spectrum.

Low-cost IR filtering may be achieved using a floppy disc or negative film plastic sheet, as well as tissue paper and frosted window films. Filters like the ones listed below were used, including a basic filter. Butter paper, polarizing filters, and polycarbonate sheet with a very high absorption rate at a given wavelength were used for the black paper template [52].Also, Kodak wratten 87 IR filters, as well as pass-through filters that exposed as well as established a photo's empty state (35mm film exposed or developed) were utilized [52].Additionally, Kodak wratten 87 IR filters, as well as pass-through filters that developed and exposed an empty 35mm film container (developer or developer, exposed or developed) were utilized [52]. Although the prototype developed by Wang F. et al., 2013 [50] has a multi-filter, it contains a narrow-band 546-570nm de-oxy and oxy-hemoglobin de-oxy and oxy-hemoglobin absorption filters respectively with a broad-band 475nm filter for the melanin, beta-carotene, and hemoglobin strong absorption bands, and a broad-band 615nm filter for skin pigment regions. Other than the poor contrast, photos produced with a DSLR camera provide better outcomes than those obtained with a web camera, perhaps due to DSLR cameras having superior focus. In the time-of-flight (TOF) camera, veins may be identified easily, because

Cartesian coordinates are gathered quickly, and this method doesn't need the needles normally used in venography [53].

The image contrast was improved using contrast-limited adaptive histogram equalization (CLAHE), which was conducted in a research paper released in 2018 in Ayoub Y et al. [54] This sharpens the vein image. A technique called CLAHE (Image Noise Reduction and Histogram Equalization Experiment) was created in 1994, and it decreased the produced histogram of a picture's dark level. It then redistributed the pixels throughout the entire histogram, resulting in an enhanced image.

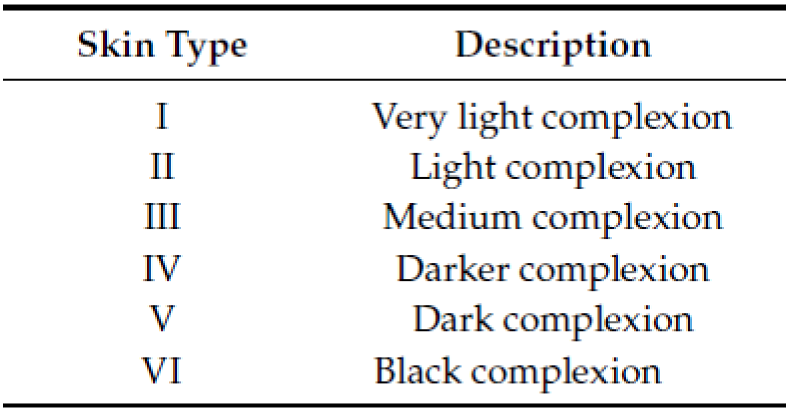
With ordinary camera phones and with VGA-quality pictures, the device can detect infrared images. However, users should strive to improve the quality of their cameras with higher resolutions to get maximum benefit. When you're watching a movie or TV show, it's even more important to turn on the auto white balancing feature since it will make colors seem more realistic. Hemoglobin in the blood fluoresces under infrared light, and this provides a clearer image for vein seekers. This image makes the vein seem darker against the skin because of the interactions of hemoglobin in blood with light. [54].

With such differences in the material used in the creation of a vein detector, like the kinds of sensors, filters, & camera, it's clear that we're looking for the ideal vein detector apparatuses for medical usage. This technology is now commercially accessible, although it is very costly. To address this issue, we may do further research into this technology in order to enhance the requirements for the creation of an effective, low-cost vein finder.

2.2.3 Skin Color

Thomas B. Fitzpatrick developed the skin tone/color meter (Fitzpatrick skin type) categorization system in 1975, depending on skin color of any person, & it was utilized as a benchmark by health specialists & cosmetic consultants in the evaluation of their clients. On a scale of I-VI, it goes from extremely light skin-black skin. The following is the whole scale:

Table 2 Several studies have shown that dark skin tone makes it more difficult to see the vein



Skin Type	Description
I	Very light complexion
II	Light complexion
III	Medium complexion
IV	Darker complexion
V	Dark complexion
VI	Black complexion

[7,46,47,49,55].

Furthermore, a research found that a commercialized NIR arterial imaging equipment had little benefit in increasing intravenous (IV) catheter insertion success in kids with dark skin tone on the first try [56]. Apart from skin color, hairy skin has been shown to produce a lot of reflection glare, which makes vein divergence difficult. It covers the skin below it, & the subcutaneous veins have lower contrast ratios, making them virtually undetectable in NIR images [50].

2.2.4 Age

DhakshayaniMand Yacin S., 2015 [57] explicitly mentioned age as a consideration to explore in their research. Vein accessibility was difficult in the elderly owing to changes in vein shape as thin & frail individuals lose elasticity, though children had smaller marginal veins with greater subcutaneous fat content & are more susceptible to vasoconstriction. This parameter was also taken into account in much research [29,43,46,49].

2.2.5 Venipuncture Site

The antecubital fossa & the hand's back with the superficial vein are the preferable venipuncture locations. Veins are vessels that carry blood back to the heart. When compared to arteries with greater levels of oxygenated blood (oxyhemoglobin), it contains a larger proportion of deoxygenated blood (deoxyhemoglobin) [33]. Hemoglobin (Hb) is the most important part of your blood, particularly the RBCs that transport oxygen [58]. There are 3 veins from which to choose. You should choose the veins on the medial aspect of the arm, followed by the cephalic and basilic veins on the outer thumb side, and lastly the veins on the medial aspect of the arm, which are the median and basilic veins [59]. The main veins of the antecubital fossa (which are represented in this figure by the following three veins: the median cubital vein, the cephalic vein, and the basilic vein) are depicted here. The optimum location for venipuncture is the median cubital vein. It branches between the basilic veins & cephalic and rests above the cubital fossa [21]. It is a well-anchored vein, typically big and conspicuous in comparison to the two other locations [59].

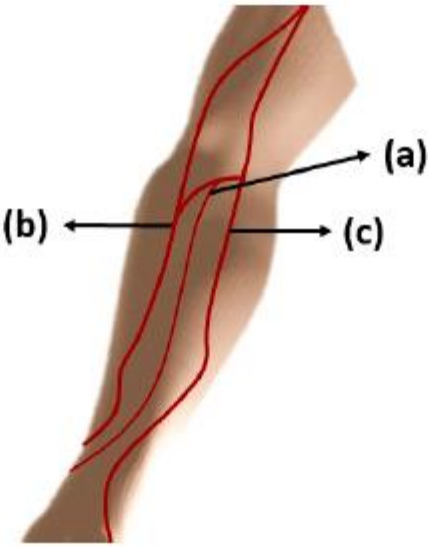


Figure 2 The vessels for venipuncture are located within antecubital fossa.

Furthermore, there have been studies that utilize a vein finder equipment to determine the characteristics of veins such as depth and diameter as a criterion that influences their appearance. The ultrasonic technique was used to measure the two characteristics in a quantitative manner. The ultrasound pictures in Ganesh, S.'s research were produced utilizing techniques like tick-mark & dot approaches and processed using Corel Draw 20. The veins' diameter was calculated as the average of the diameters measured in both vertical & horizontal directions and given in millimeters (mm). According to this research, vein depth and diameter have a linear relationship. [70] Another research published in 2017 by Goh, C. et al. suggested a novel measuring method that infers both the thickness & depth of subcutaneous veins in order to enhance venous access success rates. The method uses diffuse reflectance pictures taken at three isosbestic wavelengths to determine the thickness & depth of subcutaneous veins. The Monte Carlo (MC) technique was used to make the measurements, which included referencing an optical density (OD) ratio to a multilayered diffuse reflectance model. Comparative ultrasound measurements were used to verify all of their findings. It demonstrates that OD ratio inference of thickness & depth must be computed. The 'characteristic angle' acquired during this procedure was then utilized to identify the appropriate Cm group for the vein thickness & depth calculation. To define the vein's location and obtain the OD ratio data, segmented vein imaging is used. As illustrated in Figure [71], the resulting OD ratio is referenced to the 3000 diffuse reflectance models to generate thickness & depth. The above-mentioned vein diameter & depth measurements may be used as a helpful parameter in future research. It may assist enhance the capabilities of a vein finder as a guiding device for medical practitioners doing phlebotomy & cannulation.

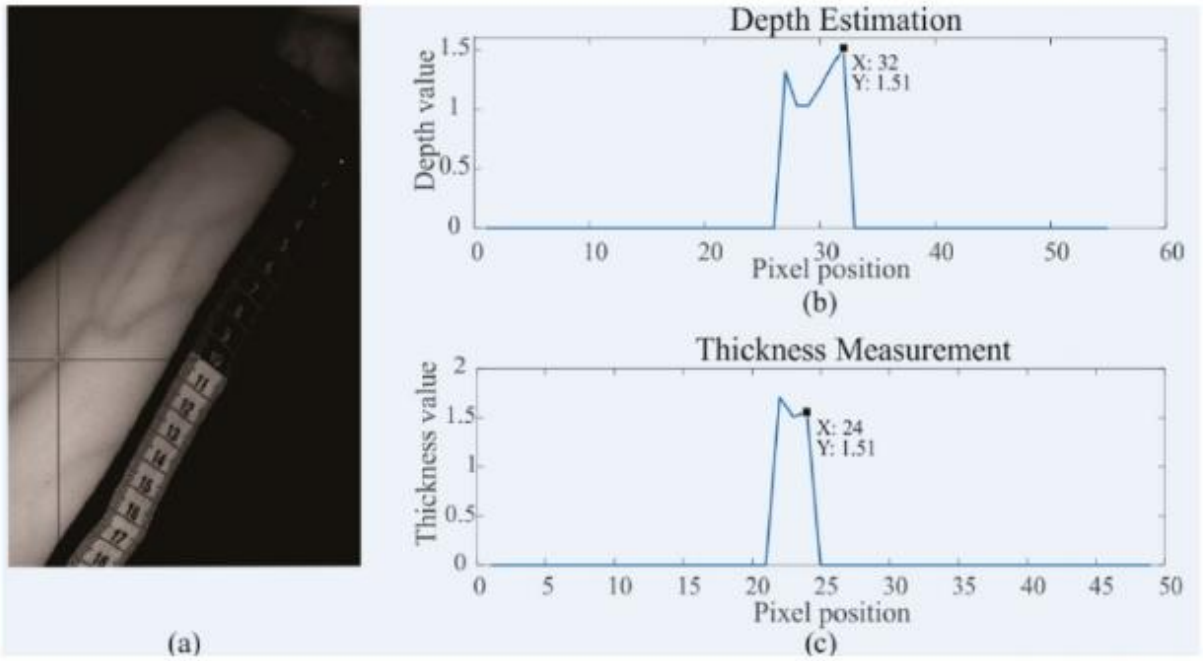


Figure 3 Using the suggested imaging method, (a) selecting a point from fused pictures to extract values of: (b) depth & (c) thickness [71].

2.3 Principle of Vein detector prototype

When it comes to light and the veins they contain, the vein finder is based on two sources of illumination: reflected light and transillumination. When the light source was pointed at the place, the reflected light gave an example of a hand surface and was captured by the camera for reflected light. in contrast, transillumination includes the skin and tissue being penetrated by light, which is then captured by the camera red blood cells (also known as hemoglobin) in the venous blood absorb light, allowing phlebotomists and medical practitioners to trace veins. This process starts with the use of infrared (I.R.) light, which helps heat tissue. Once the tissue is warm, deoxyhemoglobin in the blood will absorb more I.R. light, and that will provide more energy to the tissue. As a result, the reflected light vein detector has found its way into commercial equipment, where it is widely used. Because it uses less light intensity, it is excellent for battery-powered devices; because it uses less electricity, it is suitable for smaller vein detector designs. Furthermore, with Transillumination, the light intensity must be higher, which necessitates a larger power draw, and the hand or arm must be located in between the light source and the camera. A prototype for an infrared vein finder was used on the sample, and an image of a dorsal hand appeared.

CHAPTER 3: METHODOLOGY

This chapter discusses the methods used to design and develop a Vein Sight – Infrared-based vein imaging system that meets the objectives discussed previously in this study. The chapter first outlines the system model used, the limitations and problems faced during system model of the system. A system mechanism is mentioned which is involved in the model design. Hardware design is outlined as well as the software to monitor the output.

3.1 System model:

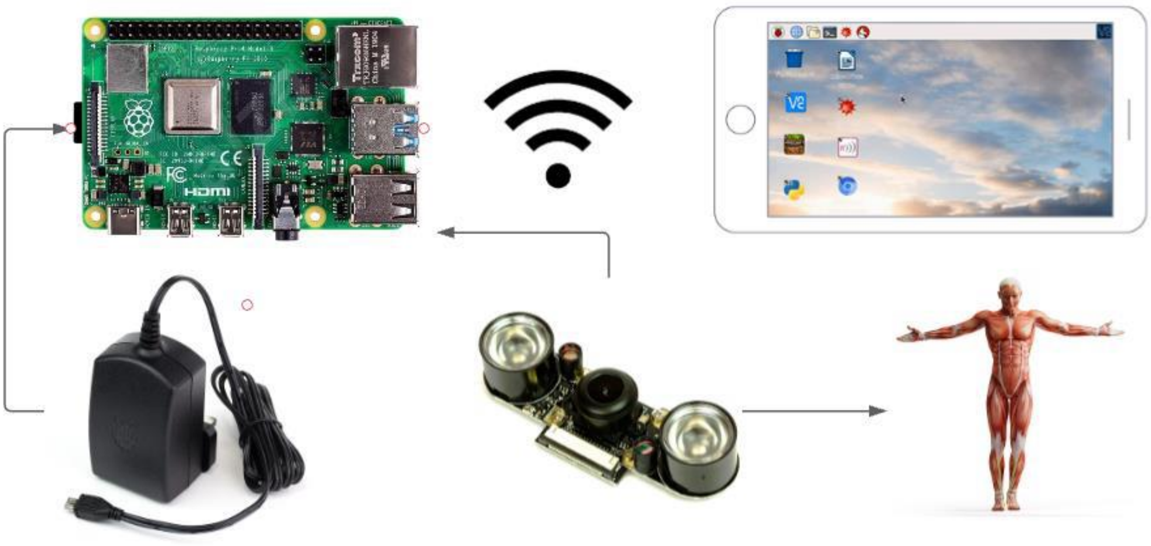


Figure 4 System Model

3.2 System Mechanism:

The acquisition system (Figure 1) consists of an I.R. camera with LEDs for infrared lighting of the required body portion. The LEDs & Camera is powered by Raspberry Pi via a serial connector (flex cable). The suitable emission spectra of the sensor (CMOS) in the NIR region of light, its compactness, & the communication protocol that allows both video signal transmission and hardware setup, and the cost were all factors in our decision. The processing is completed after the signals are transmitted to the laptop, and the findings are seen on the laptop screen.

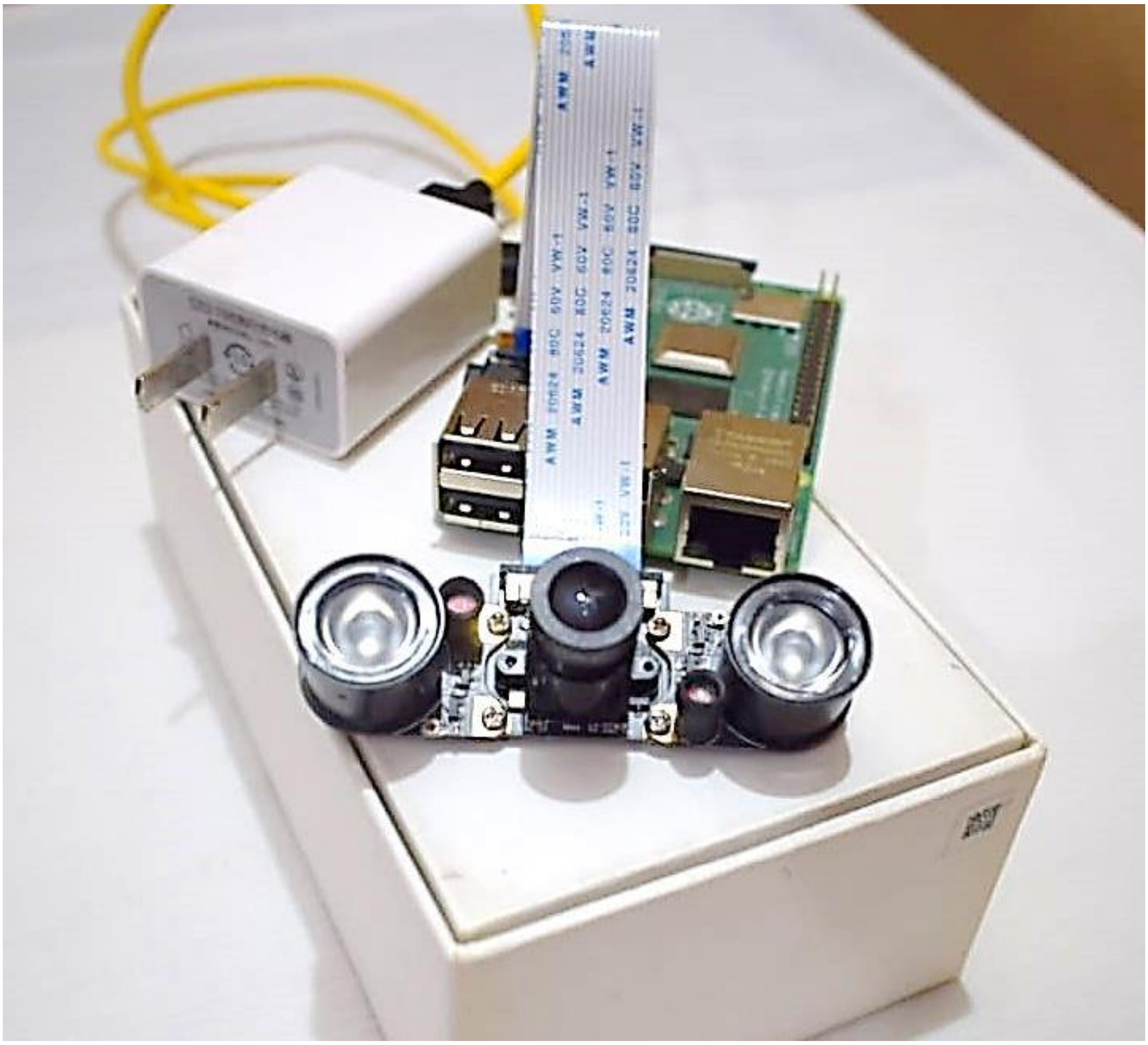
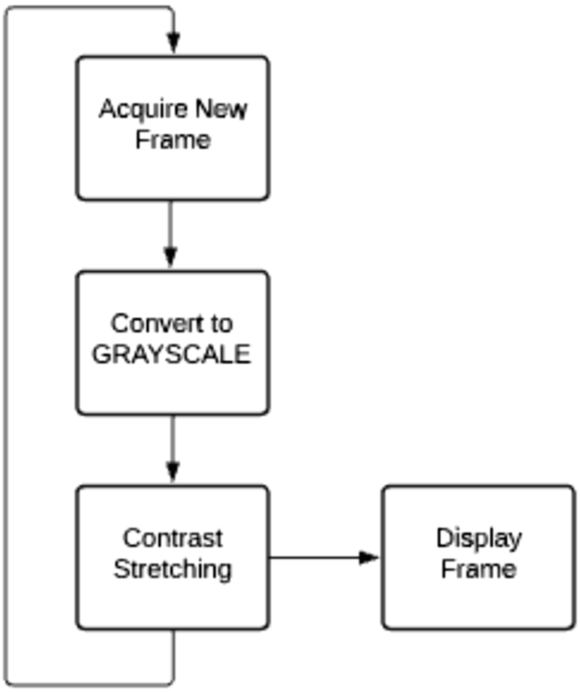


Figure 5 System Mechanism

Computer Vision (Open CV) on Raspbian OS was used for processing; it's just an open-source computer vision library initially created. The Open CV library includes approximately 500 functions covering various fields of vision, including industrial product inspection, stereo vision, medical imaging, camera calibration, user interface, security, & robotics. It is written in C & C++ that works on Linux, Windows, & Mac OS X. This saves a lot of money as it's free plus provides a good platform for the user.



An image processing method is illustrated above, and the specifics of each phase are as follows: (The vein detector works in real-time, but in this illustration, one frame sample is elaborated.

3.2.1 Image Acquisition:

The vein imaging camera detects light, including infrared wavelengths, which are critical for identifying veins. Because this imaging is measured in real-time, the result is presented in the form of video. And, since we all understand, video is nothing more than a series of still pictures known as "frames." As a result, individual frames are processed to bring the veins out more clearly in the obtained colored video.

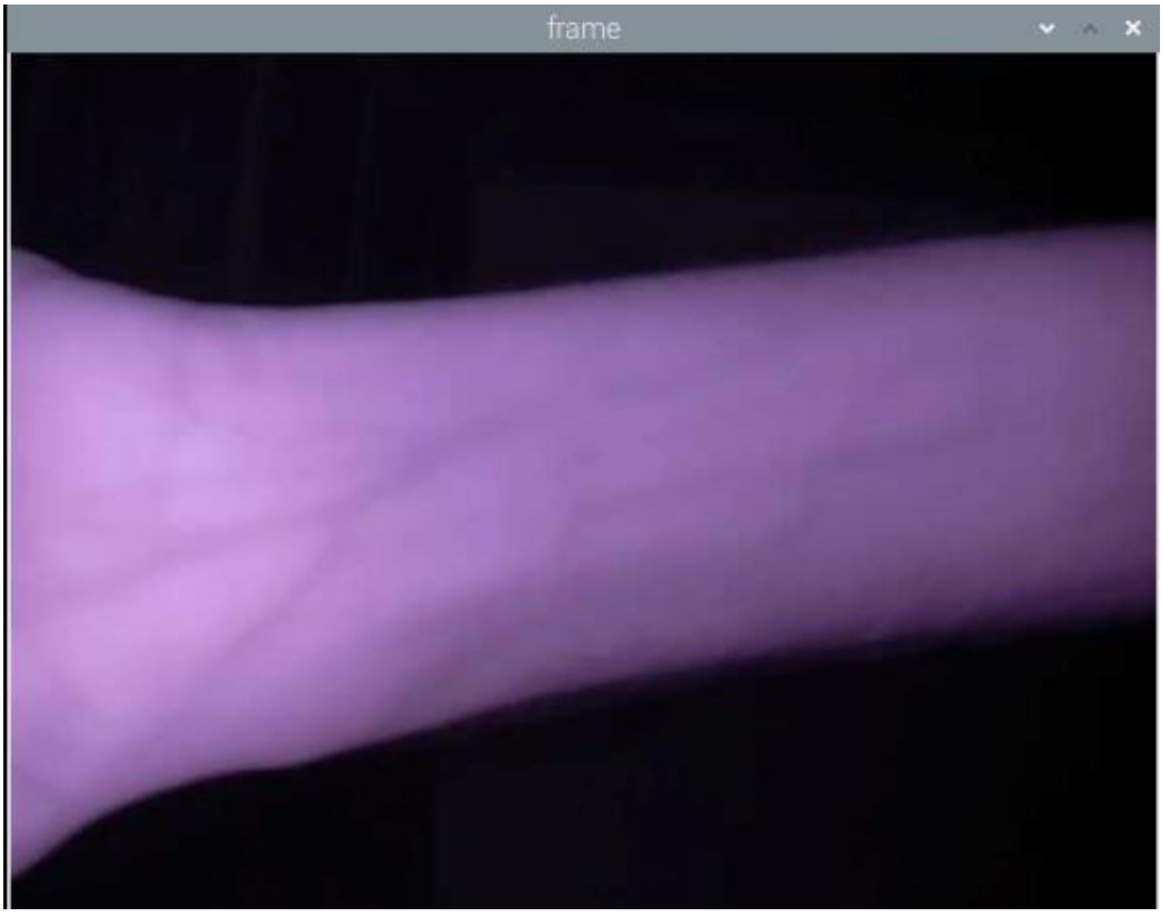


Figure 6 Image acquisition

3.2.2 Convert to Grayscale:

The initial stage in image processing is to improve image quality. And by this, we imply distinguishing the pixels or enhancing the contrast in layman's words. Compared to colored pictures, converting to grey scale enables quicker processing in later stages while still allowing for identifiable vein visualization in real-time. Noise reduction & smoothing.

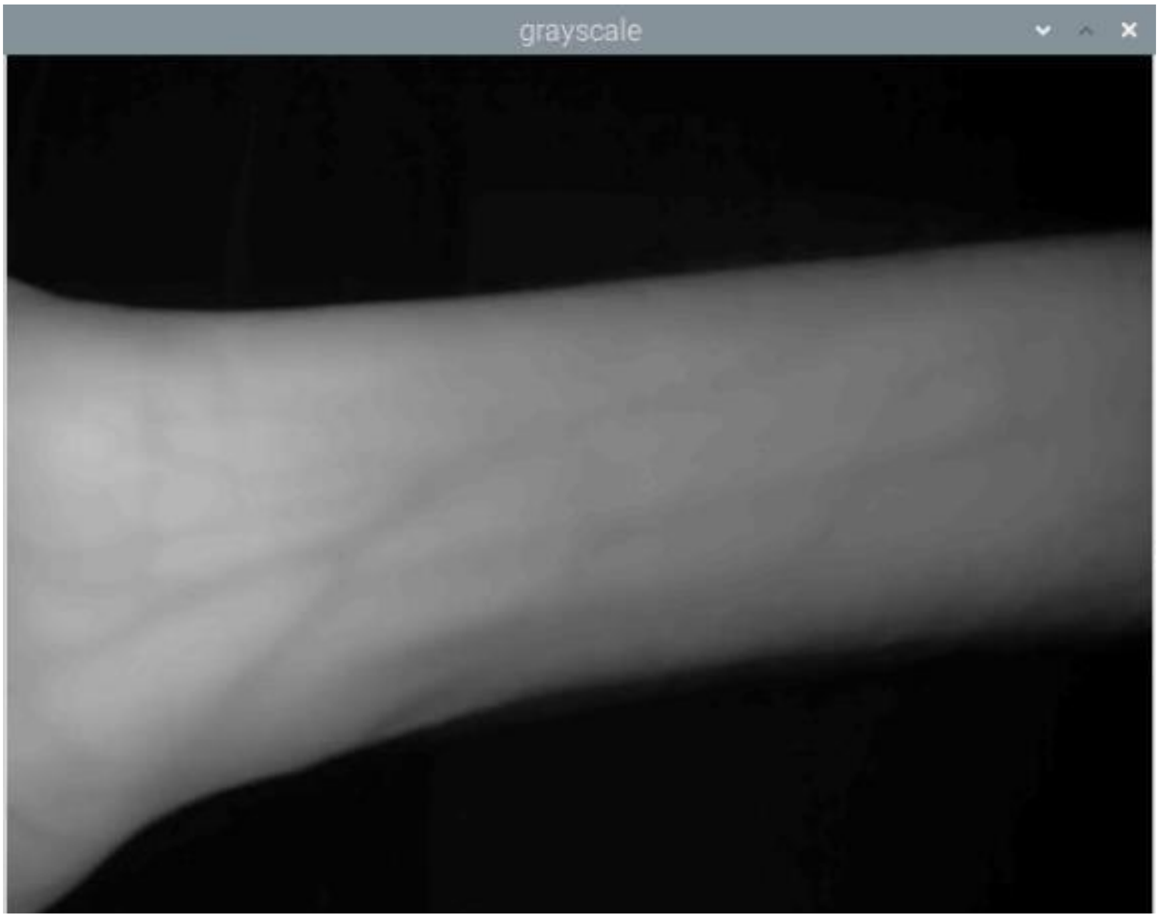


Figure 7 Gray scale Image

3.2.3 Contrast Stretching:

Now that the picture has been converted to a grey scale and the noise has been eliminated, the user may extend it beyond its given values to meet their needs. The somewhat darker veins look darker due to making it simpler to distinguish among the veins & their surroundings. Instead of the traditional 0-to-255-pixel intensity range, this picture now has a contrast range of -255 to +255. Adaptive thresholding is used because it offers several benefits over standard histogram equalization.

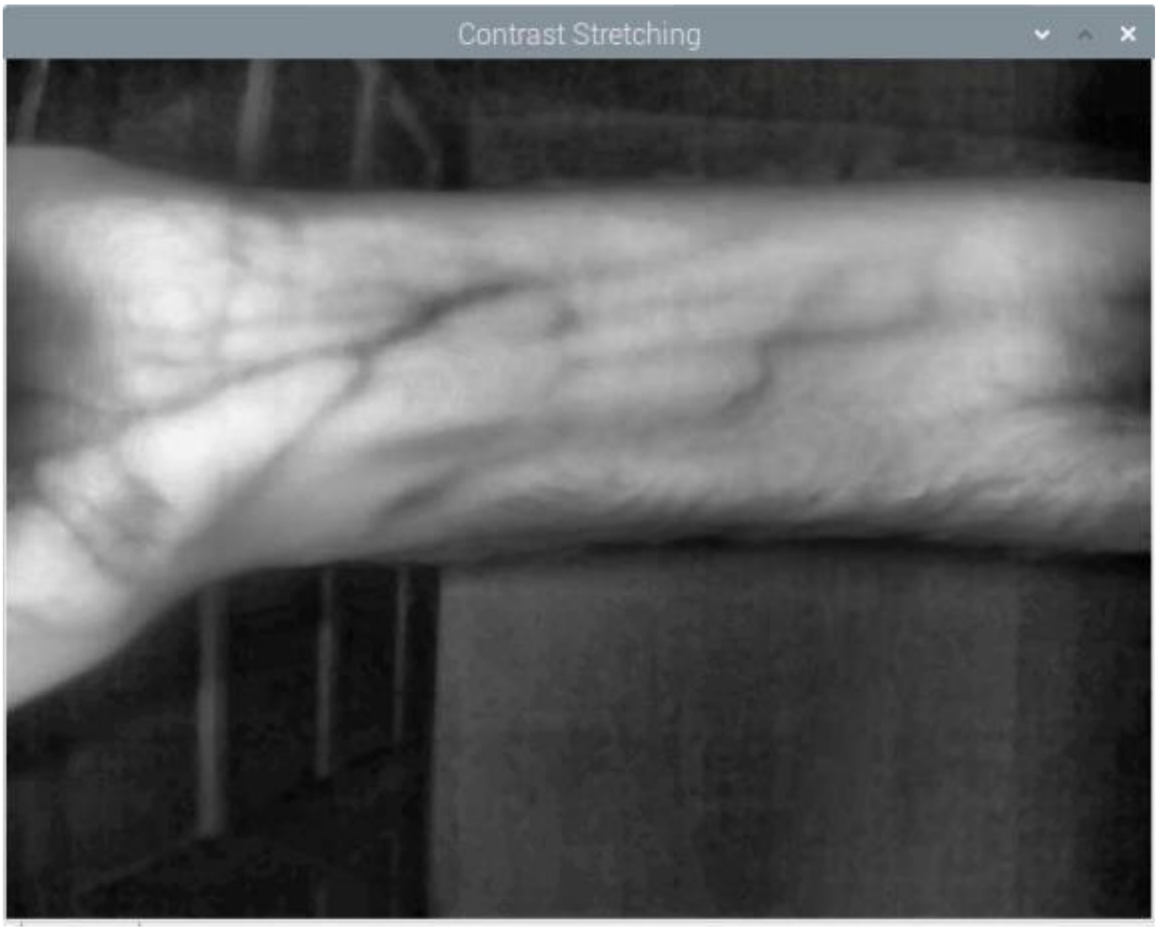


Figure 8 Contrasted image

CHAPTER 4: RESULTS

This apparatus was used to examine veins on various individuals of various sexes, ages, complexions, & body types. Below is a summary of the test results. Here's an example of an illustration done on a person that is 20 years old, male, and has limited visibility of veins with the naked eye.

The outcomes were positive.

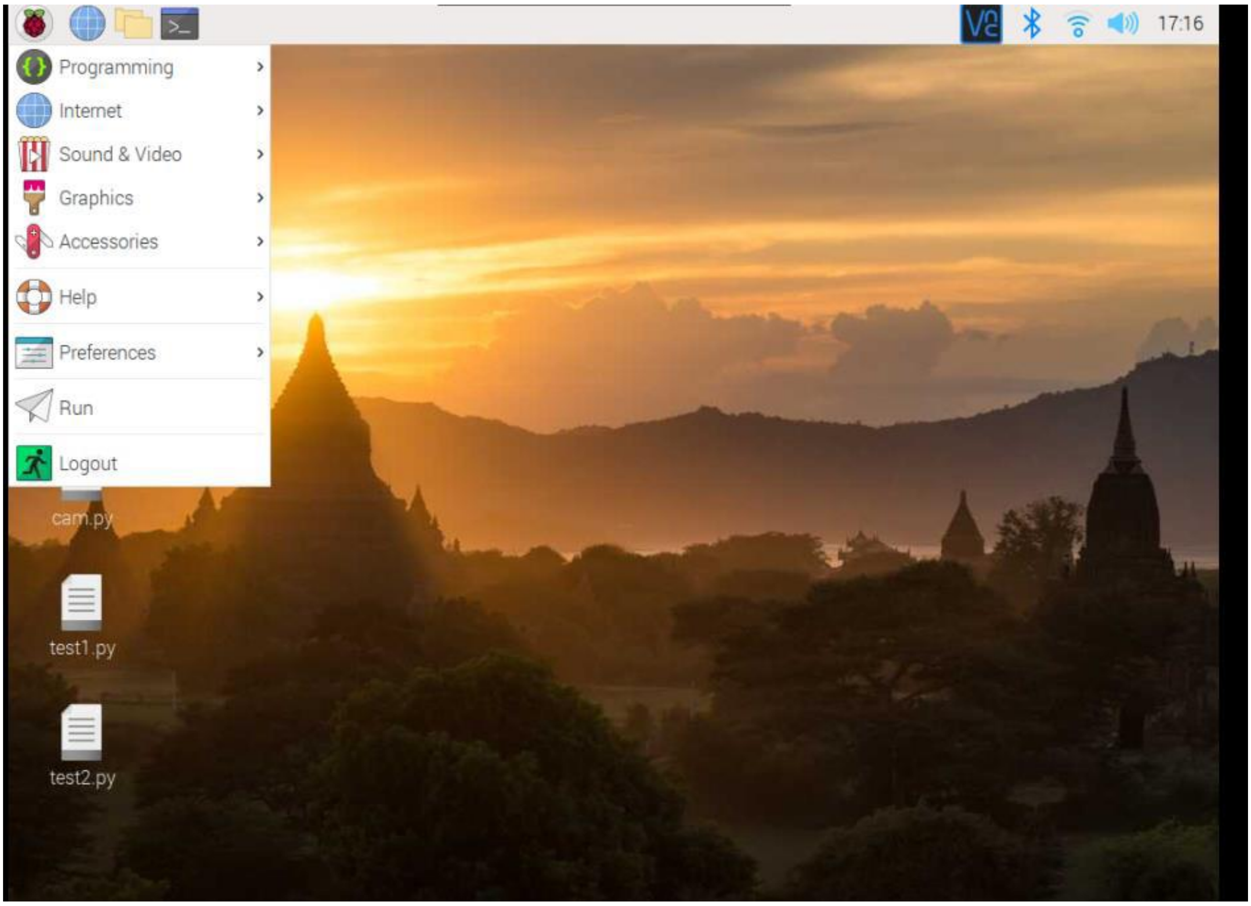
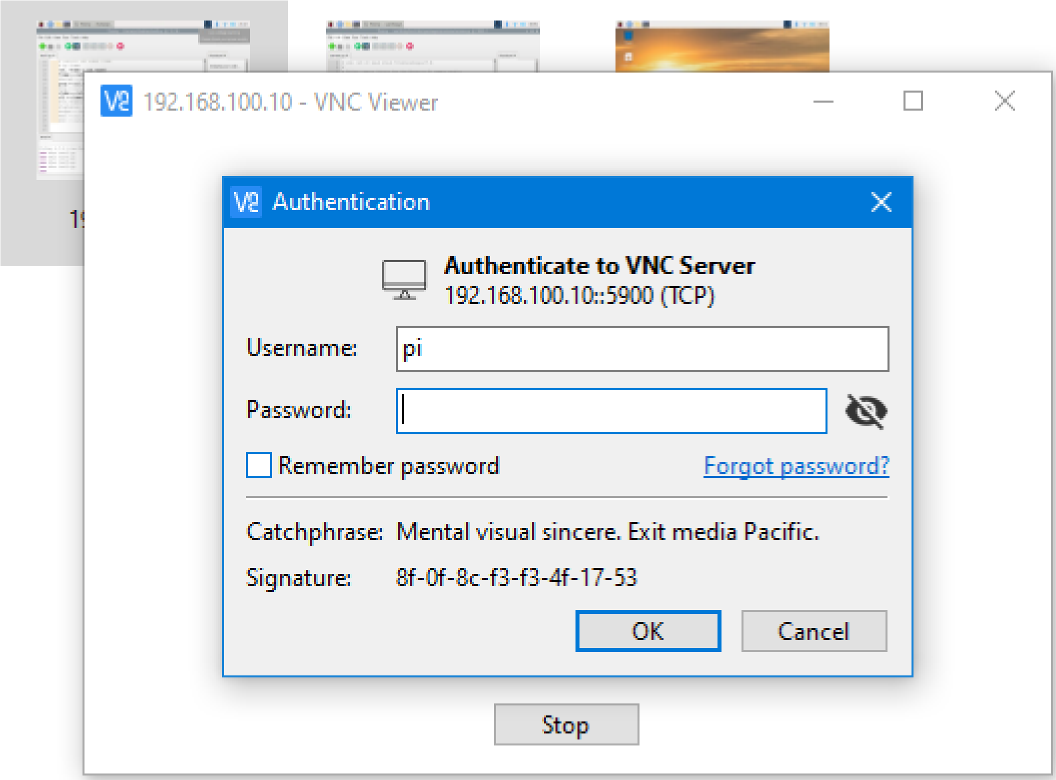


Figure 9 Laptop Screen



192.168.100.10::5900 (TCP)

Username: pi

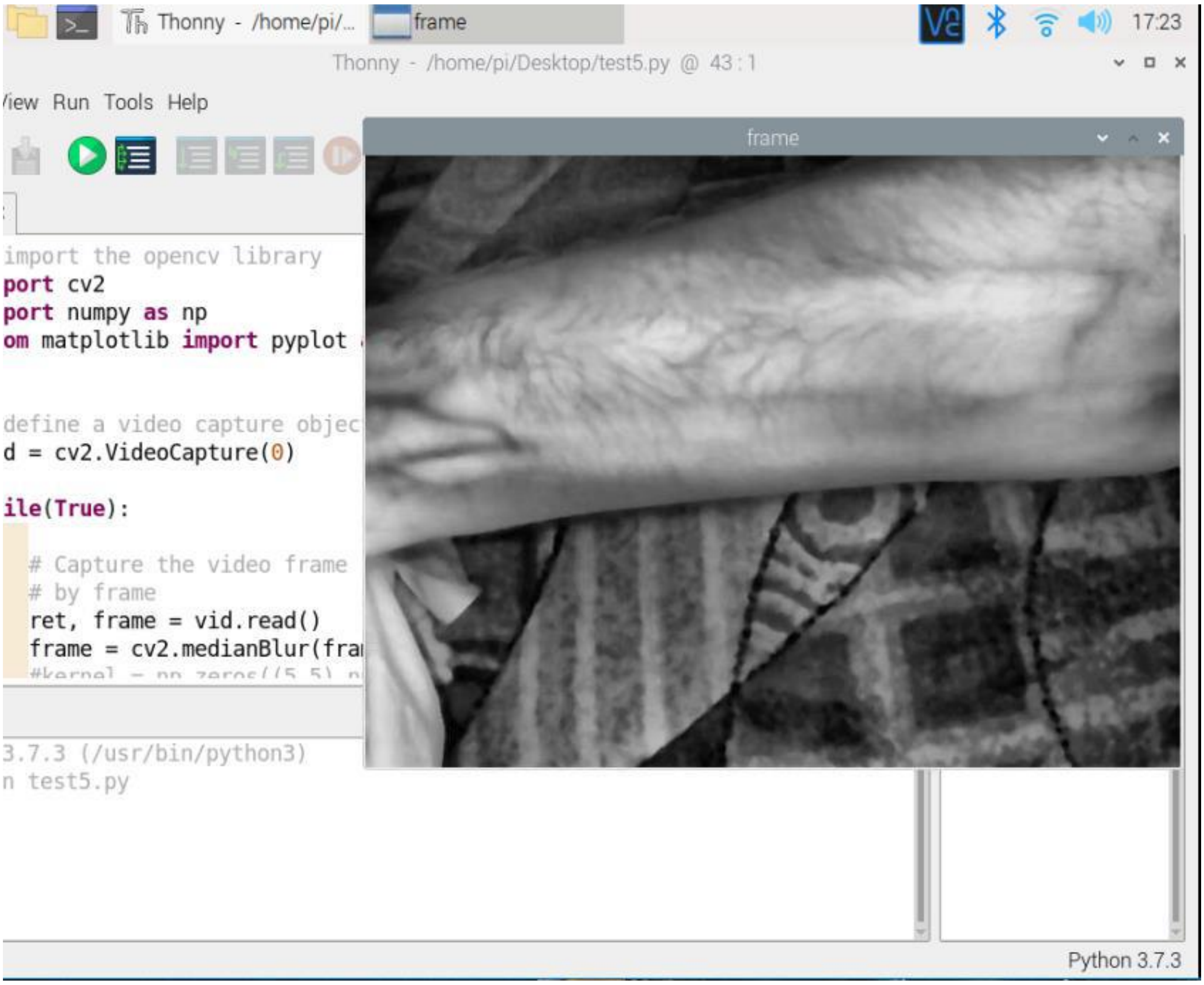
Password:

☐ Remember password

Catchphrase: Mental visual sincere. Exit media Pacific.

Signature: 8f-0f-8c-f3-f3-4f-17-53

Figure 10 Application Interface



```
import the opencv library
port cv2
port numpy as np
om matplotlib import pyplot

define a video capture objec
d = cv2.VideoCapture(0)

ile(True):

    # Capture the video frame
    # by frame
    ret, frame = vid.read()
    frame = cv2.medianBlur(fra
    #kernel = np.zeros((5,5),n
```

```
3.7.3 (/usr/bin/python3)
n test5.py
```

Figure 11 Model Working

The figure above shows a glimpse of the laptop screen for the topic discussed before. Here you can view the picture after noise reduction, followed by the improved image, and lastly, the increased show of veins. The track bars are given to modify the contrast stretching threshold to get excellent results for all participants in most environmental situations. This is a unique opportunity.

The device is extremely user-friendly and displays the veins in real-time. This offers physicians and clinicians real-time information.

4.1 Test results for different subjects

Figure 12 Test result for slim (17 years)

Figure 13 Test result for slim Fatty (18 Years)

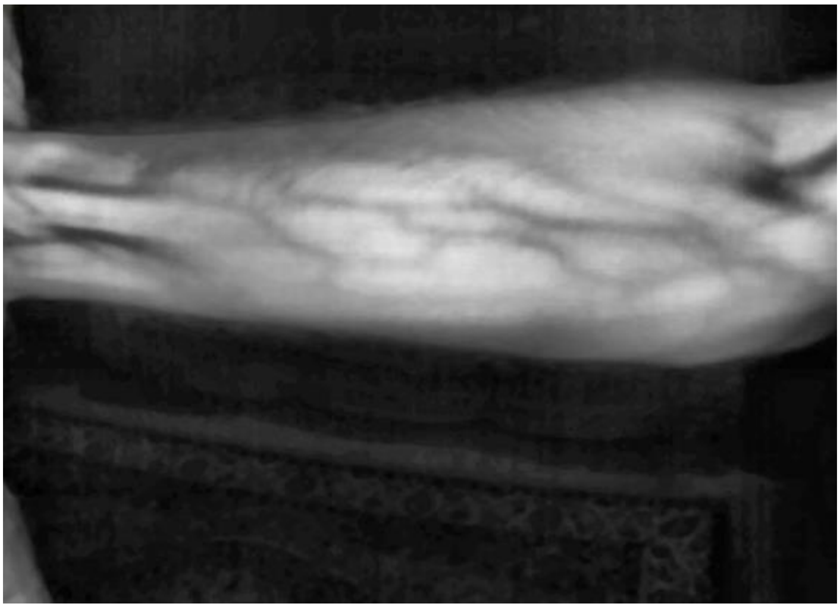


Figure 14 Test result for slim (25 years)

Figure 15 Test result for Fatty (24 Years)

Figure 16 Test result for slim (33 years)

Figure 17 Test result for slim Fatty (31 Years)

Figure 18 Test result for slim (50 years)

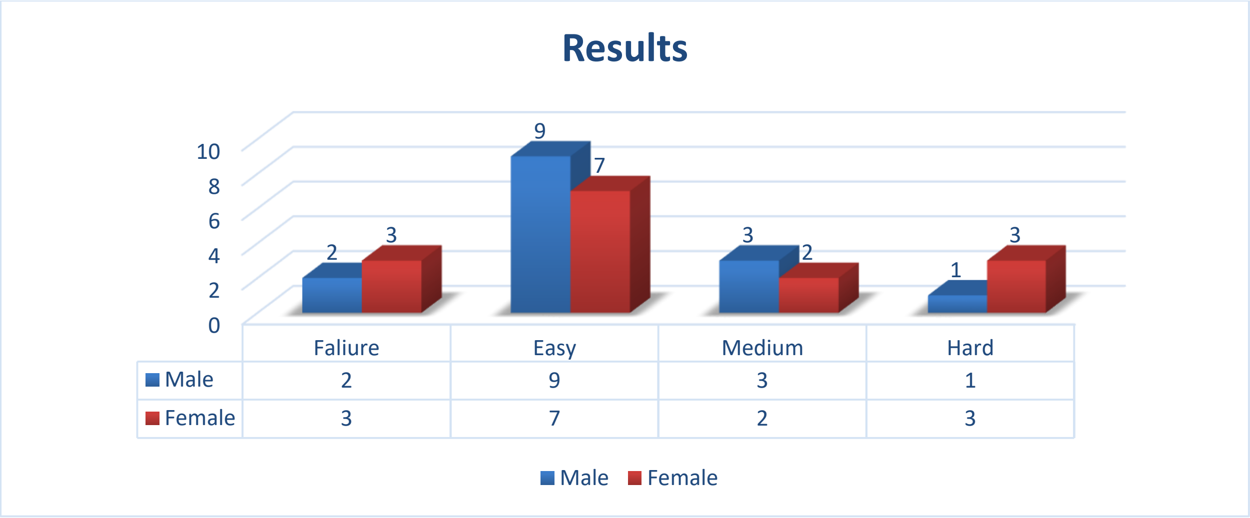
Figure 19 Test result for slim Fatty (48 Years)

Figure and table 3 show the test analysis of the studies conducted on the various age group samples.

Table 3 Results for the multiple individuals

Result	Male	Female
Failure	2	3

Easy	9	7
Medium	3	2
Hard	1	3
Total	15	15



CHAPTER 5: CONCLUSIONS & DISCUSSIONS

Our primary objective of developing a low-cost, portable, and effective vein imaging device was achieved. We conducted the study for participants with a broad variety of sex, skin color, & age, as shown in the tables. Only the acquisition of the image has been completed, allowing for further development. SNR, MSE, & the beta testing success rate are given as verification performance metrics. We have experienced several motion artifacts since we haven't built a stationary I.R. imaging system. We're attempting to eliminate the noise to a greater extent, so the veins are much clearer & error is decreased.

An NIR low-cost vein detector for the manufacture of which is now underway, intended to decrease the number of missed peripheral subcutaneous veins between blood collection and intravenous medication delivery. These characteristics and materials, including the wavelength, camera, and sensors, as well as the other components, are presently being tested to discover the ideal combination. Increasing the number of criteria and participants/humans for actual prototype testing is also recommended for commercialization potential. Additionally, cannulation utilizing the vein detector training will assist to minimize concerns.

To get a clearer image, our system must be upgraded, and further hardware and software modifications are required. In spite of our higher-than-expected success rate, we are actively trying to enhance it and to better understand why a run fails, or a picture that seems to be devoid of veins.

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