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Near-Infrared Based Real-Time Peripheral Superficies Venous Imaging Solution for Difficult Venous Access

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Abstract: ***The proposed solution, the vein viewer provides a reliable solution for patients having Difficult Venous Access (DVA). DVA is a medical condition wherein the superficial veins are not easily palpable because of skin tone, obesity or age. The lack of visualization of veins results in wrong site of venepuncture and this can lead to many potential risks. The proposed model is based on the Near- Infrared (NIR) Technology to view the vein pattern which is not visible when seen by normal human eye. The infrared radiations illuminate the subject's hand and the image is captured using CMOS sensor with no IR cut lens. The captured image is preprocessed and image processing algorithms are performed to enhance the vein pattern. The processed image is then displayed real- time on a Liquid Crystal Display (LCD). The components are cased to form a single unit so that it can be handheld or mounted so that the practioner's hands are free for easily placing the needle. The cost of the product is greatly reduced so as to make this technology widely acceptable.***

Keywords**:** ***Near- Infrared, Real Time Image Processing, Highly Portable Device, Difficult Venous Access***

I. Introduction

Healthcare is one of the most crucial areas that incorporates medicine and technology. This has significantly increased the survival rates. Administration of healthcare in combination with imaging technologies has massively evolved over the past few years and it has led to major transitions in the working routine of the imaging specialists. By the way of upgrading the imaging modalities, new approaches have been implemented for the elimination of invasive techniques of tissue sampling for the purpose of pathology demonstration. Technologies that utilize data in the digital form acts as major driving forces in revolutionizing the field of imaging. Vein preservation is one of the most basic forms of medical interventions but at times errors might occur during cannulation. Under such circumstances, vein finders can assist the healthcare professionals throughout the cannulation procedure. The most essential and primary skill in the healthcare environment is the ability to obtain the proper site for the Intravenous (IV) access. Peripheral venous access is the most common invasive procedure performed by doctors, nurses and paramedics.

Ann F. Jacobson et al. conducted a study to quantify the variables related to the difficulties and failures of intravenous insertion. They have collected the data pertaining to 339 IV insertions in patients obtained by 34 registered nurses. The data included the demographic details of both patients and nurses. In addition, the data included the difficulties and the duration related to IV insertion. They concluded that out of 339 insertions, twenty-three percent of the insertions were unsuccessful. According to their study, failure of IV insertions was due to the variables such as resistance of veins to puncture and complexion of the patients. The repeated attempts were also painful and costly. They concluded that future research work has to be carried out to facilitate the success of vein puncture in the first attempt [1]. Olubukola O. Nafiu et al. have found that the children who are obese have lesser success rate of venepuncture at the first time when compared with lean children. They collected the data of 103 children out of which 56 children were lean and 47 children were obese to assess the relationship between the body mass index and peripheral venous access. The children were mostly in the age group of 2 to 18 years. Fifty-five percent of children had their first attempts to be successful while nearly forty percent of children had to undergo two to three attempts before successful venous access. They inferred that the incidence of failure of first attempt is high in case of obese children. Also they stated that the identification of potential venepuncture sites facilitate the increase in success rate for intravenous insertion [2].

Mustapha Sebbane et al. have predicted the difficulty in peripheral venous access in the emergency department by using body mass index as a determinant. This study included 563 patients who belonged to a mean age group of 53 years. The first attempt success rate was observed only in 79 percent of the patients. They divided the patients into groups based on their BMI. Thirty-two percent of the obese patients had difficult venous access. They suggested that the failure of venous access in obese patients may be due to the subcutaneous fat distribution in which the superficial veins become embedded thus making it difficult to visualize. Also they observed that twenty percent of the underweight patients had the problem with venous access. In underweight patients, the thin layer of the adipose tissue was the factor that was reported. They concluded that all the above factors increase the cannulation attempts as well as the rate of procuring infections and other complications related to venepuncture.

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They also found that the central venous access which is the next best alternative possesses potential risks and thus by avoiding the unsuccessful attempts to achieve venous access, the patient distress can be greatly reduced [3].

Intravenous access is needed for the administration of medications, hydration fluids, blood products and other nutritional supplements. Superficial peripheral veins are limited in number. They are prioritized in case of resuscitation, short-term intermittent infusion, and some therapies apart from chemotherapy, high osmolarity and low/high pH infusions, and short-term intermittent therapies. Peripheral venous access may become time- consuming and frustrating in some patients. This condition is termed as Difficult Venous Access (DVA).

II. Difficult Venous Access

Difficult Venous Access is a medical term that refers to the condition where the peripheral veins are not easily accessible. It may occur due to many factors. Physically, this condition may occur due in obese individuals, neonates and in dark skin patients [4]. The fat distribution of the skin in obese patients is different from that of the lean individuals. Also previous chemotherapy treatments tend to alter the fat distribution of the skin, as a result, the veins which are beneath the skin become difficult to visualize and access.

The possibility of obtaining venous access is considerably less in individuals who are exposed to drugs intravenously. This condition is also observed in patients suffering from hypotension. Some people might have experienced traumatic accidents have multiple injuries hence limiting the number the sites available for peripheral venous access. The Difficult Venous Access decreases the success rate of establishing the intravenous access at the first attempt. Thus for obtaining venous access, the medical workers may require more than one attempt. This procedure is time consuming and also it causes discomfort to the patients. The repeated procedures for obtaining the venous access may also bring down the confidence level of the practitioner. Venepuncture at a wrong site or improper placement of cannula may pose potential problems. When the cannula is not properly inserted or dislodged, it causes infiltration where the medication or IV fluid leaks into the surrounding tissues. Hematoma is the most common adverse reaction associated with repeated venepuncture. Hematoma is a bruise which is the collection of blood beneath the skin. When the nurse or the medical practitioner inserts the needle too far into and through the vein, leakage of blood into the surrounding tissue occurs. This causes a blue or violet discoloration at the venepuncture site.

Performing venepuncture at the site of recent bruise may affect the quality of blood being collected and causes discomfort to the patients. Thrombosis of the vein might be caused by previous venepunctures and cannulations. Repeated puncturing of veins causes discomfort and also emotionally affects the patients. The patients experience pain when more number of attempts are performed to establish venous access.

In addition to the medical complications, the environment in which the venous access is performed is also an important factor to be considered. Poor lighting might result in the decreased visualization of the veins. The central line venous access which is described as an alternate procedure for the intravenous access also poses potential risks. The most complicated risk is the improper insertion needle or the cannula into the artery and also the injury to adjacent nerves. Also this procedure is much complicated and requires high skill of the practitioner.

Difficult Venous Access can be solved by means of special interventions. Special interventions refer to those technologies and facilities that tend to increase the first puncture success rate. Traditional methods of warming the catheter site provides better visualization and palpability of the veins. It is done by mild tapping at the catheter site prior to insertion of the needle. The primary focus of vein visualization technology is on children and neonates. This is because the needles are the most distressing part for the children and they may experience emotional traumas during subsequent procedures if they are subjected to repeated venepunctures which may induce pain. The ease of viewing the vein pattern is rendered by the advanced technological improvements such as the trans-illumination and ultrasound guided systems. These technologies assure the correct placement of needle in the patients' vein thereby reducing the complications involved with repeated venepuncture.

III. Related Works

The vein visualization technique can be implemented based on various principles. The two most commonly used technologies are the Near-Infrared (NIR) technology and Ultrasound guided catheter placement procedures. The works done based on these technologies and the products similar to the proposed method are discussed.

Yahia Ayoub et al. have suggested techniques for better visualization of the vein. Their proposed system consists of a camera with infrared filter that captures the images of the superficial veins which are then sent to a laptop for the purpose of being processed using the image processing toolbox available in MATLAB software. The skin temperature of the patient is increased by using a vein warmer. The study was conducted using real images as well as infrared images captured from 10 different subjects. It has been concluded that there is a significant increase in the diameter of the veins when the temperature of the skin surface above the veins is raised using a vein warmer thereby increasing the probability of obtaining a clear vein pattern. In addition, it has been stated that enhancement of the patient's surroundings enables the use of vein finders as a diagnostic tool that can aid in acquisition of better quality images [5].

Keith Boniface et al. have conducted a study to assess various aspects involved in delivery and satisfaction of patients undergoing ultrasound guided intravenous access procedures in the emergency department. About nineteen clinical technicians were trained for the purpose of performing ultrasound guided intravenous access. Patients who are above the age of eighteen and who have had two failed IV access attempts or those who were found to have difficult venous access were considered for the study. After undergoing the ultrasound guided IV access procedure, a questionnaire was used to quantify the satisfaction of patients on a scale of ten. From the results, it was concluded that ultrasound guided IV access was more satisfactory than traditional methods used for IV access.

In addition, ultrasound guided IV access can act as an effective alternative to Central Venous Catheters (CVC) [6]. Vein finder market is highly influenced by a few major manufacturers and the competition is on the basis of the implemented technology, pricing, differential market strategies, market shares, product offerings and the approach of marketing. Nearly 60% of the revenue in the vein finder market is contributed by the major manufacturers. Incorporation of advanced technologies into the devices have enabled the hospitals to achieve a greater degree of patient satisfaction which in turn nurtures the vein finder market. Consistent increase in the number of end-users serves as a driving factor for the market growth of the vein finders.

A. AccuVein

AccuVein AV400® is a small and portable device that incorporates Near-Infrared (NIR) imaging technology to facilitate intravenous access without causing any discomfort or trauma to the patient. This technology, also known as vein mapping, provides a real-time visual map of the subcutaneous vasculature on the skin surface when the device is held at a distance of about seven inches above the surface of the skin. The device makes use of two barcode scanner class lasers namely an invisible infrared laser and a visible red laser. Hemoglobin in the blood absorbs the infrared radiation resulting in a reduced amount of reflection from the veins which in turn causes the change in reflection. These changes aids in determining the vein location as well as its pattern and the red laser digitally projects the vein pattern on the skin surface. The device is capable of imaging the subcutaneous vasculature up to a depth of about 10 mm and it weighs about ten ounces. AccuVein AV400® is highly tolerant of patient movement when the usage of the device is proper. Operation of the device is facilitated by rechargeable batteries and it does not require an external electrical outlet. The ease of use of AccuVein AV400® is improved by various other products that are specially designed for the device. It includes protective covers for the entire arm, extended reach powered wheeled stands, unpowered wheel stands, and hands-free solution.

B. Christie Medical Holdings

VeinViewer® is a portable imaging system that enables healthcare professionals to obtain a real-time HD (High Definition) image of the vein pattern on the surface of the skin. There are two variants of the device namely the VeinViewer Flex and VeinViewer Vision2. VeinViewer Flex aims to provide maximum portability to the healthcare professionals and it weighs about 700 grams. VeinViewer Vision2 provides care at the patients' bedside along with the provision of various customization options and it weighs about 24 kg. Both devices incorporate the same technology for vein pattern visualization. The device projects harmless near-infrared light on the skin which gets absorbed by hemoglobin in the blood but is reflected by the surrounding tissues. Reflections are captured and processed in order to project a real-time HD image of the vein pattern on the skin surface by making use of LED projection. The device provides a near perfect accuracy of about ±0.06 mm. AVIN™ (Active Vascular Imaging Navigation) is an innovative technology that brings out various possibilities for peripheral intravenous access and allows the clinicians to view blood patterns up to a depth of 15 mm and clinically significant veins up to a depth of 10 mm. It is made possible by the way of moving the VeinViewer® image along the skin and getting immediate feedback. The particular technology that makes the VeinViewer® stand out from the other devices in the market is the Df2 (Digital full field) technology. It acts as an aid for the clinicians to view much deeper vasculature with increased accuracy. Integration of this facility into the clinical procedures is supported by the device's novel Eyes On Patient (EOP) hands-free technique.

C. TransLite

Veinlite® is a portable vein viewer that provides intravenous access for patients of all ages, skin tones and sizes. It not only locates the veins but also ensures one stick success rate. Vein pattern visualization is facilitated by illuminating the skin surface by using LEDs. There are five variants of vein finders that are being manufactured by TransLite where every variant differ from the other in the kind of illumination they provide. Veinlite LEDX® is a LED transilluminator that incorporates 32 LEDs (24 orange LEDs and 8 red LEDs) along with a wider opening and a larger viewing area. This model is ideal for obese patients since it can focus deeply into the skin and it weighs about 83 grams. Veinlite LED® is a rechargeable and portable vein finder that has been proven effective for patients of all ages, skin complexions and sizes. It incorporates 12 bright orange LEDs for the purpose of high contrast imaging. In addition, it has 12 red LEDs that enables deeper penetration in dark-skinned patients. Veinlite EMS® is highly portable, rugged and it is powered by batteries. Effective vein imaging is delivered by the use of 12 orange and 4 red LEDs in the device. It is highly suitable for patients of all ages and skin tones. Veinlite EMS Pro® is an enhanced version of the Veinlite EMS® that renders the feature of illumination adjustment according to the light available in the surroundings and it weighs about 106 grams. Veinlite LED+® provides higher contrast for vein visualization along with an increased viewing area and it weighs about 77 grams. It delivers maximum versatility and proves to be highly suitable for patients of all ages and skin tones. Illumination is provided using 28 bright LEDs.

Most of the products in the market incorporate the technology of Digital Laser Projection to project the vein pattern back on to the skin. The incorporation of this technology increases the cost of the product to a significant level. One of the leading vein finders' costs around 7 lakhs. Thus the basic motive of the proposed solution is to bring down the cost while serving for the purpose and thus making it a widely acceptable device.

IV. Optical Properties of Tissues

The amount of light that penetrates through the skin depends on the physio – anatomical characteristics of the skin. These properties vary not only among individuals of various age groups but also among different body locations. Therefore, it becomes very important to analyze the nature and properties of the skin at different body locations. The anatomy of the skin and the optical properties of the skin are being discussed.

A. Anatomy of Human Skin

Skin is the largest organ of the human body which accounts for about 15% of the entire body weight.

It has many functions such as protection against external factors, prevention of water loss and thermoregulation.

It is a multilayered structure which includes the epidermis, dermis and the subcutaneous layer also known as the hypodermis as shown in figure 4.1. Epidermis is the outermost layer of the skin with an average thickness of 100µm which does not contain any blood vessels. It allows the transmission of light. The dermis is a much thicker layer compared to epidermis usually about 1 – 4mm thick. The dermis comprises of the capillaries, hair follicles and glands. The third layer that's is the hypodermis consists of a large number of fat cells and has a thickness of about 4 – 9mm. The penetration of light into this layer is dependent on the amount of subcutaneous fat present. Children and neonates possess skin of lesser thickness compared with adults. The thickness of the epidermis in children is about 5.37µm.

B. Skin Optics

The optical properties of the skin vary from layer to layer and also from person to person. Light propagation in the epidermis and dermis varies due to the difference in structure, density and thickness (Refer Fig 1). Once the light interacts with the skin it undergoes various phenomenon like scattering, absorption, reflection. Among these the two most important phenomena are the scattering and absorption. Around 5 to 7% of the incident light is reflected and the remaining light is either absorbed or scattered by the different constituents of the skin layer. The outer most layer absorbs some light and transmits it into the tissue layer beneath it. The dermal collagen is responsible for most of the scattering. The fat tissues present in the hypodermal layer further scatter the light. The remaining light that that passes to the blood is absorbed by the hemoglobin.

Hemoglobin is the major constituent of blood which is responsible for increasing the oxygen carrying capacity of the blood. Both type of hemoglobin possesses different light absorption properties. The blood in the veins predominantly contains deoxy-hemoglobin than the oxy-hemoglobin which is abundant in arteries (90%-95%). Oxy-hemoglobin absorbs more infra-red light and allows more red light to pass through whereas deoxy-hemoglobin absorbs more red light and allows more infra-red light to pass through. These two types of hemoglobin exhibit different light absorption property. Both possess same absorption till the wavelength of 600nm.

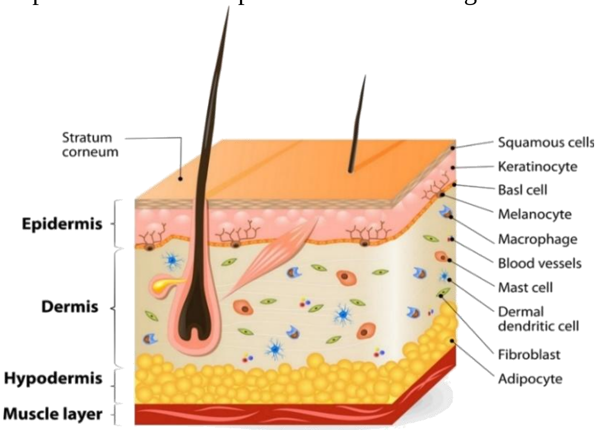

Image Courtesy: Anatomybodydiagram.com

Fig. 1.Structure of Skin

II. From the Fig. 2, it is evident that the veins have higher absorption than arteries between the wavelengths 600-850nm. Also different wavelengths of light reaches different depths. The curve falls rapidly for deoxy-hemoglobin while it rises a little and then falls for the oxy-hemoglobin. Visible light has wavelength ranging from 400nm to 700nm while infrared radiations have wavelength of 700nm-10^6 nm. Light at wavelength 300nm and 400nm reach only the epidermal and dermal layers of the skin which do not contain any veins. The infrared radiations are less absorbed by other tissues and they reach the blood vessels in the subcutaneous tissue. Hence we have employed the usage of 800nm IR flash for illumination. As a result, the veins appear darker on a dull backdrop.

The proposed solution employs the Near Infrared (NIR) Technology for imaging the vein pattern to facilitate intravenous access. Infrared radiation of 800 nm is employed since it is the medical grade and also the suitable wavelength for imaging the veins based on the absorption level of hemoglobin.

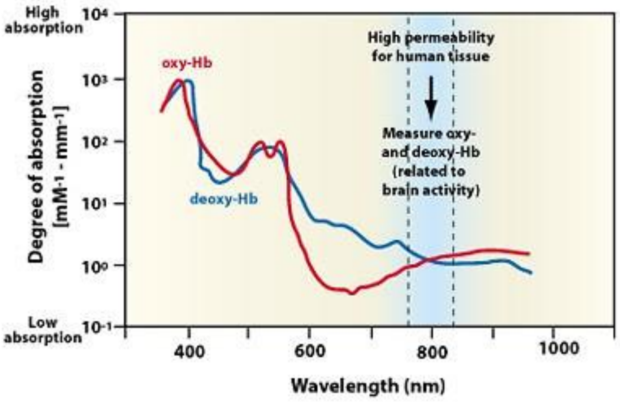

Fig. 2. Rate of Absorption of IR by Oxygenated and De-oxygenated Blood

V. METHODS

The proposed methodology for the condition of Difficult Venous Access involves the use of Near-Infrared (NIR) technology. The proposed solution employs the hardware components such as the processor, camera and the display and image processing software to enable the viewing of vein pattern on the skin. The principle of operation and the various components used in the proposed solution is discussed. Human eyes can detect only a narrow range of electromagnetic spectrum from 400 to 700 nm. The vein pattern visualization is low under normal visible light condition. Near-Infrared (NIR) imaging techniques can be used to overcome this condition.

The infrared radiations can penetrate up to 3 mm into the skin. It is based on the basic principle that the blood in the veins can absorb more infrared radiations than the surrounding tissues. As a result, the veins appear darker than the surrounding areas. This can be imaged by using IR sensitive camera. A simple representation of the operation is shown in Fig. 3. Undesirable interference due to radiations from the human body which are in the wavelength of 3um to 14um can be avoided by using a light source that can emit Infrared light beam of around 850nm.

The proposed method incorporates the use of 800 nm IR flash for illumination and NoIR (No-Infrared) camera for capturing the video. The captured video is processed by to obtain the vein pattern of the individual. The vein pattern can then be viewed on the display mounted on the device.

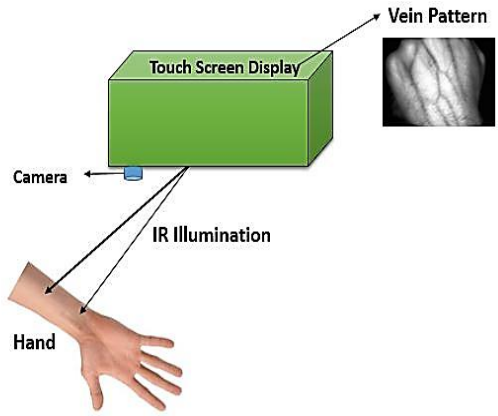

Fig. 3. Schematic of the proposed solution

The proposed method, shown in Fig. 4, involves the usage of Raspberry pi 3 Model B+. Raspberry pi 3 Model B+ is a 1.4GHz, 64-bit quad core processor with inbuilt Bluetooth and Wi-Fi modules. The reason behind choosing Raspberry Pi is that it is the only completely open source development board for integrating python with external modules. Secure Shell (SSH) is used for wireless display on smart phones.

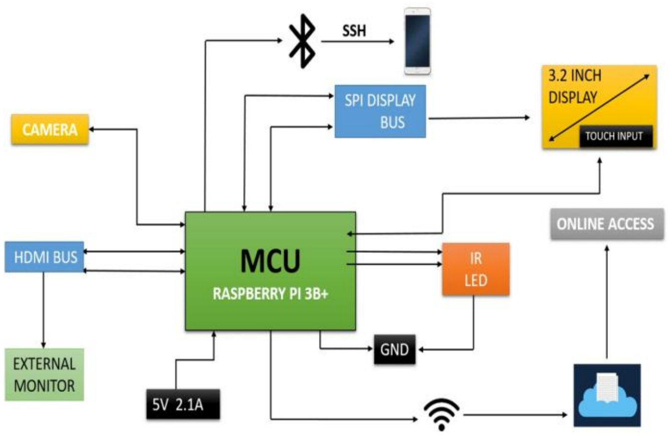

Fig. 4.Block diagram

Serial Peripheral Interface (SPI) for displaying the vein pattern on the 3.2 inch display. The High-Definition Multimedia Interface (HDMI) bus can be used to connect external monitor and camera port. The software employed is developed using Python 3.5 along with OpenCV on Raspbian platform. Open Source Computer Vision Library (OpenCV) provides an infrastructure for computer vision and applications and to accelerate the use of machine perception. Raspberry Pi has two interfaces - Mobile Industry Processor Interface (MIPI) and Camera Serial Interface type 2 (CSI). CSI -2 standard is very popular among mobile phone and many hardware. CSI-2 has 4 lanes with 1GBps bandwidth per lane rendering a total bandwidth of 10GBps. CSI-2 interface is scalable to any number of lanes. The interface works at a high speed with low power consumption.

High Definition Multimedia Interface (HDMI) uses Transition Minimized Differential Signaling (THDS). It is a type of encoding for digital communication which prevents degradation of signal along the cable length.

A. Prototype Design

During the first phase, the overall design of the prototype was concentrated on functionality. A fail proof table based prototype was designed involving all the components. This prototype made use of an external display. Thus was more of a kiosk like design than a handheld compatible one. The design of the first prototype is given in Fig. 5 shown below. The illuminator design of the first prototype is given in Fig. 6. This design though was efficient in operation, it was not easily portable and it did not have the ergonomics of an appealing medical device. Thus more work was done later on for developing an ergonomic and handy prototype for easy use along with improved efficacy.

Fig. 5.Initial Prototype

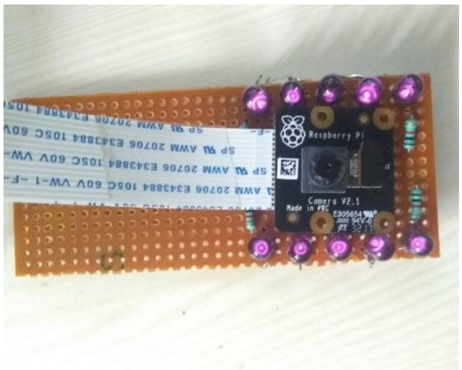

Fig. 6.First design for Illuminator

B. Rapid Prototype using CAD

To eliminate hardships faced in the first prototype design and to improve the efficiency of the overall device, a new model was designed using CAD Tool – Solid works. The design of the model is shown below in Fig. 7.

The precise cutouts for I/O and the housing for an onboard display improved the ergonomics of the prototype and making it a comfortable device to carry around. This hand held design not only improved the ergonomics but also improved the illumination by using a ring like arrangement for the LEDs. The 3-D printed prototype is shown below in Fig. 8 and Fig. 9 represents the new arrangement of LEDs.

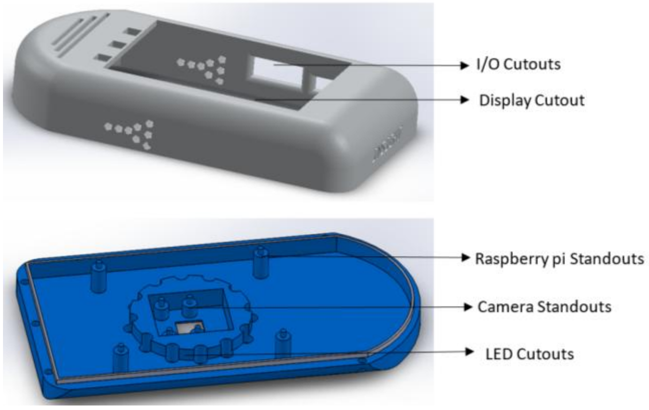

Fig. 7.CAD Design for Prototype

Fig. 8.Protoype of our Design

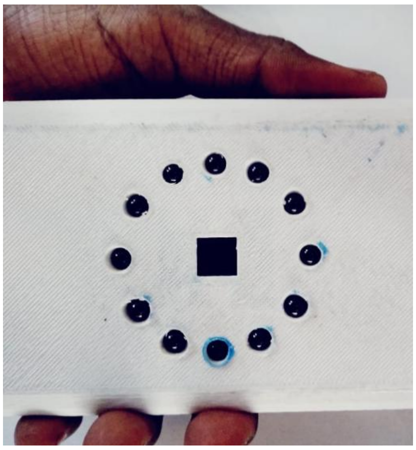

Fig. 9.Arrangement of LED and PI NoIR camera

C. Image Processing Steps

On illumination in IR, the veins are blacked out in the image spectrum captured. Thus there is a relation between the dark pixels captured. Since RGB is only numeric representation of the pixel values of the 8-bit image across R, G and B planes. HSV model is easily perceptible by the human eye. The first step of the algorithm is to convert the image captured in RGB mode to HSV, to improve the relations of the pixels mixed with black (Value). In HSV, H stands for Hue, S stands for saturation and V stands for value. The color is represented using Hue, pixel values relation with white is represented through saturation values. By nature, in an RGB image color information cannot be discriminated. Thus HSV model is used for clamping changes to Value factor of the image. Once all the processes are done, the image is converted to grayscale before proceeding to further steps. Bilateral filter is used to remove noise from the input image. It is more effective in noise removal when compared to other blurring filters as it retains the edges as sharp from input. In case of a conventional Gaussian filter, the neighborhood of pixel is taken and averaged. As a result, the edges and sharp lines as details in the original image are also blurred and averaged. Thus it causes loss of details in the process of removal of noise in the image. Bilateral filtering makes use of two Gaussian filters in space, one for a blurring function in image space and one more for denoting the function denoting difference of pixels. The second Gaussian filter that takes into account for the pixel difference, discriminates edge pixel from region pixel. Thus the edges are preserved upon filtering too. Post Bilateral filtering, the results are passed upon to the next stage of the algorithm – Contrast Limited Adaptive Histogram Equalization (CLAHE).

Conventional histogram equalization can degrade the quality of the image as the contrast is stretched across entirety. In case of CLAHE algorithm, the limit up to which contrast is stretched is controllable. Two of the primary factors in CLAHE are the adaptive histogram equalization which is applied over separate regions and locally reducing the noise by partially reducing the range of local histogram equalization. The technique of bilinear interpolation has been employed to mask the boundaries of various regions while using CLAHE algorithm to filter the images.

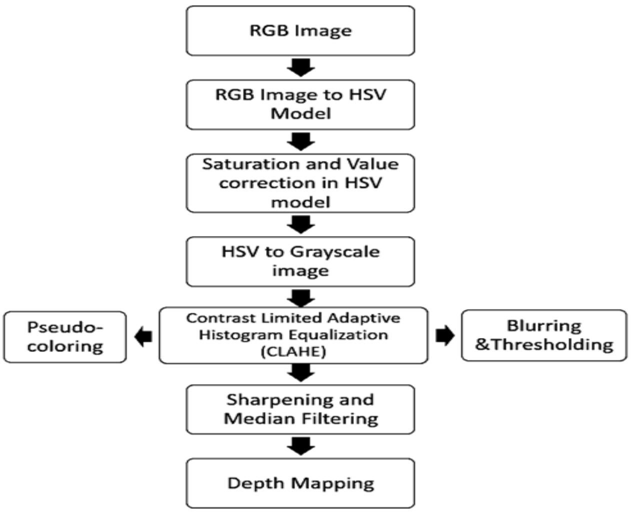

Fig. 10. Image Processing steps

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Once the histogram is equalized, the intensities are clamped to a lower bandwidth of intensities to prevent the over bleeding of excess illumination caused by improper luminescence. Thus the image is voluntarily made duller to improve the quality of veins. Pseudocoloring is a powerful tool in image processing. It assigns values to grayscale pixels highlighting the image's details in a way that is very easily understood upon visualization by the user. Human's interpretation of a pseudo colored image will bring in more insights and perceptions than the interpretation of the same image in grayscale. This image is then displayed at the resolution captured at the rate of 24 fps thus causing a live video stream that can be used for assistive help during cannulation procedures for blood test, infusion insertions and catheter insertions. Entire pictorial description for the process flow is shown in Fig 10.

VI. RESULT AND DISCUSSION

The following are the images taken using the prototype. These results are taken under the same ambient light conditions. All locations are taken for the same person thus not involving any external factors influencing the results. The most commonly preferred sites for venepuncture are the forearm veins, metacarpal veins and the veins in the Antecubital Fossa region. The results are taken in the wrist, elbow, carpel and the leg region an individual and outputs of each image processing step is also shown in the following figures.

A. Forearm veins

The cephalic veins and the basilic veins in the forearm are the sites preferred for venous access. The cephalic veins are formed from the cluster of veins at the base of thumb and passes radially along the forearm into the Antecubital fossa region. It is splinted by the forearm bones and it can easily receive large cannula. The basilic veins are formed from the confluence of veins at the wrist. It is the large vein that is mostly preferred for venous access. Thus this region was imaged and the image processing algorithms were performed as discussed in the previous chapter. The results of these image processing steps are shown in Fig. (11 to 14).

Fig. 11. Original Image

Fig. 12. HSV Ambient Corrected Image

Fig. 13. CLAHE Clamped Output

Fig. 14. Color Jet Mapped Image

B. Metacarpal Veins

The forearm veins can be confused with the radial artery and hence metacarpal veins are the best site for cannulation. The metacarpal veins are easily palpable and they are splinted by metacarpal bones. The vein access can become difficult if the skin is thin and fragile. The metacarpal region is imaged and the results are shown in Fig. (15-18)

Fig. 15. Original Image

Fig. 16. HSV Ambient Corrected Image

Fig. 17. CLAHE Clamped Output

Fig. 18. Color Jet Mapped Image

C. Antecubital Fossa

The Antecubital Fossa region, which is the elbow region, has three major veins- cephalic, basilic and the median veins. These veins are most prioritized choice in case of emergency situations. These regions have larger veins and hence can easily accept a large needle or cannula. The venous access can become difficult during elbow flexion and extension. Also proper care is needed so as to avoid puncturing the brachial artery. The results obtained from the imaging of this region are shown in Fig. (19 to 22).

Fig. 19. Original Image

Fig. 20. HSV Ambient Corrected Image

Fig. 21. CLAHE Clamped Output

Fig. 22. Color Jet Mapped Image

D.Lower Limb

In some cases, when the veins cannot be accessed in the upper limb, the lower limb regions are also considered for cannulation. The veins of the lower limbs are also viewed in medical conditions like varicose veins. The images obtained are shown in Fig. (23-26).

Fig. 23. Original Image

Fig. 24. Fig 6.2.2 HSV Ambient Corrected Image

Fig. 25. Fig 6.2.3 CLAHE Clamped Output

Fig. 26. Fig 6.2.4 Color Jet Mapped Image

The following two images Fig 27 and Fig 28 show the operation of the prototype during testing. The desired results are obtained for the prototype.

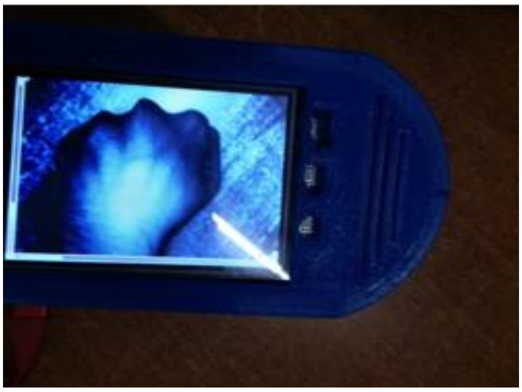

Fig. 27. Imaging using the prototype

Fig. 28. Display onscreen in the device

VII. CONCLUSION

The proposed solution has some areas for improvements. The improvement of the device can be broken down into developments in each modality used. Overall functioning of the device can be improved by using more adaptive components. The changes that can be made to the camera, illuminator and the display devices and also the advanced works that can be carried out are discussed.

A. Future works

The main modalities in the device is the camera and the illuminator. The camera used as mentioned earlier is the Pi NoIR Camera manufactured by SONY Corporation. This camera has a fixed infinite focal length, thus not adaptive to the movements of the subject. Moreover, the resolution of camera is not up to the mark of a medical grade camera. The illuminator used is manufactured in house. Though, the illumination is powerful enough, there isn’t a wide field of luminescence. The design incorporates an on-board display, making the entire device handy and easily portable.

In spite of providing more ergonomic advantages, the design overall falls short in adhering the need, when the subject considered is non-compliant. Use of a compensator on the subject and changing the position of the camera and illuminator with response to movements by the subject will improve the efficacy of the device.

The camera that is apt for the usage in this design is an autofocus high resolution camera with a lens assembly of macro focal lengths. When the device operates in coherence to the position of the limbs of subject, the camera can even make use of a tighter fixed focal length, with specific distance maintained between the camera and the subject. The standards to be followed for a camera to be adhered with a status of Medical Grade includes higher resolution and bit depth along with rapid autofocus. One of the manufacturers specializing in manufacture of medical grade infra-red cameras is SPECTRON IR. It employs a software controlled electronic focus mechanism. Though the True resolution of the camera is 640x480, the semiconductor array that receives the image from the lens is a VOx Focal Plane Array, with resolution electrically capable to suit needs for imaging human tissues. Such cameras can replace the Pi NoIR camera to improve the quality of image obtained.

The design uses conventional LEDs having a field of luminescence of ±15° from the median of 90°. If used Surface Mounted LED matrix for illumination there will be a wider field of luminescence increased to ±65° from ±15°. This will not cause the image to be bleached due to bleeding light localized at spots over the subject’s limbs. Moreover, use of a higher power LED will increase the range of prediction in subjects with thicker and less translucent skin types. Proper illumination is mandatory for functioning of device.

The overall end use case of the device is to find the veins with accuracy. When a subject moves his/her limbs, the device is aligned to a wrong position thus affecting the effluence of the capturing technology. There must be an incorporation of an adaptive response canceller to compensate for the movements of the subject under study.

A proposed idea will be to use a combination of accelerometers and gyroscopes on both the subject's limbs and the device itself to actively track the difference in alignment between the subject and the device. Then compensatory action can be taken using a three axis gimbal based setup for mounting of the camera and illuminator cancelling out the displacements. Use of a digital Laser projector will reduce the complexity of the device and by large its size too by making it more compact and user friendly. The digital laser projector will project the scaled image of veins over the subject's skin after processing the images and rendering the highlights to the veins. This will ease the difficulties faced by monitoring the process over a display.

Post vein detection, the output of this phase can be fed into an automate catheter insertion system. As a preliminary action, the best vein can be chosen using a logistic regression based classifier. The input for the classifiers can include a parameter articulating to a doctor's advice on choosing the best vein for catheter insertion. Post selection of vein, a marker will be used to quantify physical length in pixels. Knowing the pixel to physical length relation, instructions can be generated for a motor drive to exactly locate the spot using x, y, z locations. For knowing the depth of veins from the surface, the infra-red based imaging can be combined with ultrasound imaging to estimate the depth of veins by using a principle similar to the operation of sonar in sea water.

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