SUBCUTANEOUS VEIN DETECTION USING EMBEDDED LINUX ON ARM

Vidya Priyadarshini .P[1,] Prof. Leelavathi .G[2], Dr. Siva S. Yellampalli[3]

[1,2,3] *Department of VLSI Design and Embedded Systems, VTU Extension Centre,*
UTL Technologies, Bangalore, (India)

ABSTRACT

The uses of technology in the field of medicine have benefitted the lives of people in many ways. These advanced technologies allow specific parts of the body to be studied in great detail which in turn have helped the doctors to accurately diagnose and treat several problems. Locating the veins for the purpose of intravenous drug delivery is sometimes a problem in case of infants, obese and dark toned people. Though many devices have come up in the markets which resolve the above problem by providing high definition images, the main problem lies in the cost. A low cost vein detection system that uses a VGA camera for capturing the images is proposed in this paper. The captured images are interfaced to the ARM 9 Single Board Computer (SBC). These images are lower in contrast so, histogram equalization technique is used to enhance the contrast of the images and finally the enhanced images is displayed on the LCD of the SBC. The programs for capturing images, enhancing the contrast are written in Open CV. These programs are cross compiled so that they are compatible with the ARM architecture. The reduction in the cost is achieved by using open source software's such as Open CV and Qt frameworks.

Keywords — *Intravenous drug delivery, high definition images, VGA camera, ARM 9, Single board computer, histogram equalization, LCD, Open CV, Qt frameworks*

I. INTRODUCTION

Vein puncture, the process of obtaining intravenous (IV) access is an everyday invasive procedure in medical settings. At times even trained nurses and doctors find it difficult to exactly locate the blood veins on the first hit. Especially in infants and children, recurrent attempts to insert a needle to gain access to vein causes anxiety, pain and distress and elevate the risk of damaging the vein causing infiltration of the surrounding area and subsequent possibility of a catheter-related, hospital-acquired bloodstream infection. It is also necessary to know the exact position of the veins during blood transfusions.

Presently there are many devices like AccuVein AV300, AV400, VascuLuminator, Vein Viewer that cater to the need of vein detection. These devices provide high definition images but at the same time are very expensive. Therefore, a low-cost, portable, compact and efficient vein detection system is the need of the hour.

II. CONCEPT OF VEIN IMAGING

There are many technologies currently being used for obtaining images like x-rays, infrared, ultra scan , ct-scan, Doppler study and MRI. X-rays and infrared techniques are cost effective compared to other techniques mentioned above. X-rays follow a invasive technique i.e. the region is exposed to X-rays and the rays penetrate into the skin. One of the disadvantage of X-rays is that, its prolonged exposure   has adverse effects on the body.

Infrared technique requires no exposure to harmful rays, is contactless, non-invasive and safer compared to X - rays. There are two types of infrared techniques : Near infrared (NIR) and Far infrared (FIR) . Far-Infrared method has difficulties in capturing the vein images in the palm and wrist. It is more suitable for capturing the large veins at the back of the hand . Far - Infrared is sensitive to ambient conditions and does not provide stable image quality. Near-Infrared imaging produces good quality images even in the back of the hand, wrist and palm. It is more tolerant to changes in environmental and body conditions but has problems of disruption due to skin features such as hairs and line patterns. In order to understand the NIR technique better, it is necessary to first understand the manner in which light propagates through the biological tissues.

2.1 Light Absorption

The range of frequencies covered by the radiations in infrared region of the electromagnetic spectrum(~ 300THz -300GHz) is comparable to the natural frequencies at which atoms or molecules will vibrate in the absence of an applied field. Thus when infrared radiation is incident on a system of matter , resonance will occur around the natural frequencies where energy is transferred from the incident field to the system and its amplitude of vibration is greatly increased. Although the life time of the excited state is around 10^{-7} to 10^{-8} seconds , the atoms or molecules will usually lose their energy by colliding with one another within 10^{-12} seconds, thereby raising the kinetic energy of the other particles involved in the collisions. Hence the energy associated with the incident field is most often dissipated as heat within the medium. This process is known as absorption. The overall effect of absorption is reduction in intensity of the light beam traversing the medium. The important substances that are generally considered to dominate the absorption of light within the visible region are Haemoglobin , Melanin and water. Haemoglobin is a dominant absorber of light in the dermis. Haemoglobin consists of the protein globin bound to form four haem groups. Each haem group contains an iron atom at the centre of a ring like structure. An iron atom in the ferrous (Fe^{2+}) form will bind physically to an oxygen molecule to become oxygenated. The haemoglobin in the oxygenated state is known as oxyhaemoglobin (HbO_2) and the haemoglobin with no oxygen molecules attached i.e in the deoxygenated state is known as deoxyhaemoglobin (Hb). In the arteries 90 -95 % of the haemoglobin is oxygenated and in the veins more than 47% is oxygenated. The specific absorption spectra of oxy and deoxyhaemoglobin is shown in Figure 1.
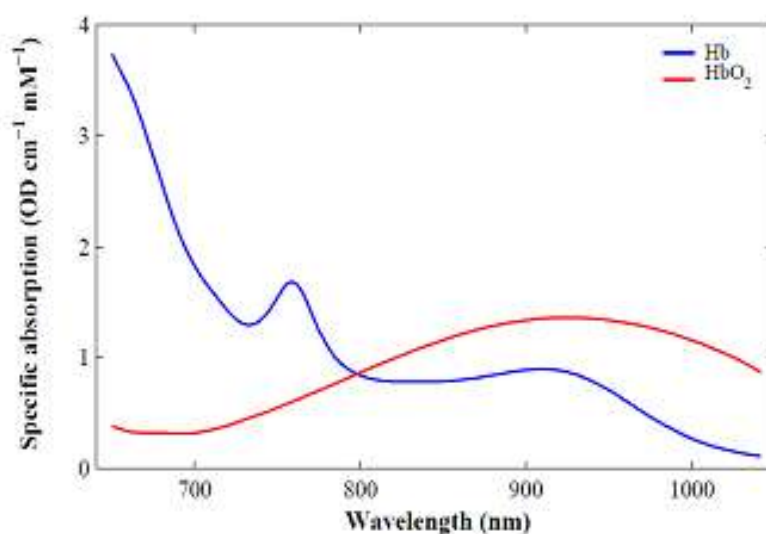

Figure 1. Specific Absorption Spectra of Hb and Hbo₂ in the NIR from 650 - 1050nm

Water is the most abundant chemical substance in the human body accounting for 60 - 80 % of total body mass. Because of its high concentration in most biological tissue, water is considered to be one of the most important chromophores in the tissue spectroscopy measurements.

The absorption spectrum of water reveals a relatively low absorption region between 200 and 900 nm. Above 900nm the absorption coefficient increases rapidly. The region of low absorption acts as a 'window ' of transparency or optical window in the tissues. Very little light can penetrate into the tissues outside this region. The difference in the absorption coefficients lies in the oxygenation of the blood vessels . The veins carry the deoxygenated blood due to which they absorb the radiation completely and the arteries which carry the oxidized blood become almost transparent.

2.2 Light Scattering

Scattering describes a change in the direction, polarization or phase of light and is commonly portrayed as either a surface effect such as reflection or refraction or as an interaction with a small region whose optical properties differ from its surroundings. It is estimated that around 4% to 7% of visible light is reflected from the surface of the skin , independent of wavelength and skin color. The remaining light is refracted as it passes from light into the skin. The interaction of light with human tissue is shown in   Figure 2.
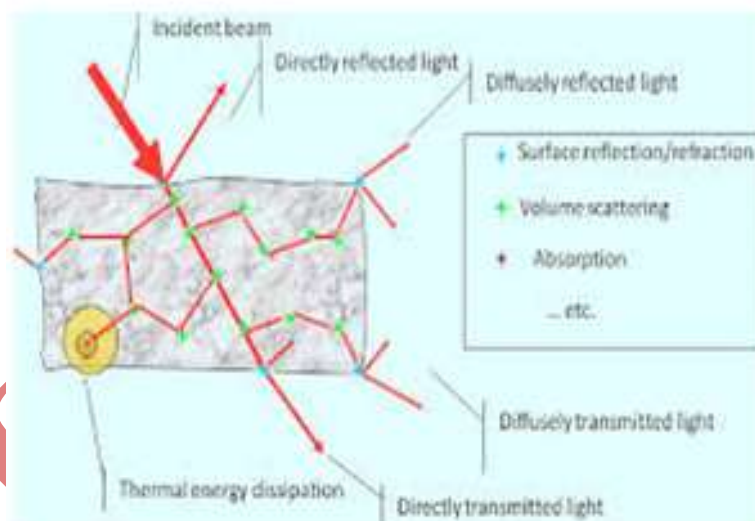

Figure 2. Interaction of Light with Human Tissue

III. PROPOSED FLOW OF THE WHOLE SCHEME

The image is first captured by an USB camera followed by the visibility check of the veins. The check is made by mere observation. If the vein is visible, then the image is displayed on the LCD screen of the SBC without undergoing any enhancement procedures. If the vein is not visible, then it is converted to gray scale. The conversion to gray scale is done because it is an important requisite in situations where contrast enhancement techniques are employed. The images are subjected to histogram equalization for contrast enhancement. The enhanced image is then displayed on the SBC. The proposed flow is shown in Figure 3
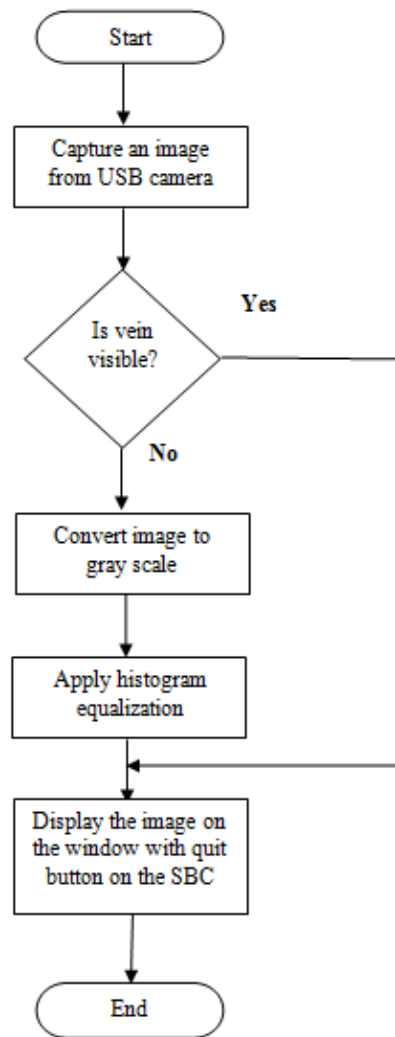
Figure 3. Proposed Flow of the Whole Scheme

IV. HARDWARE IMPLEMENTATION

The hardware required for the implementation of the vein detection system are:

- ARM 9 Single Board Computer (SBC) which is capable of supporting huge libraries and Array LCD.
- Microsoft VX -1000 USB camera.
- LED shoot light to focus the light on region to be detected.
- Host Computer with 80GB Hard disk and 1GB RAM.

4.1 Camera

The camera plays a very crucial role in the subcutaneous vein detection system. The selection criteria of the camera are based on the following aspects:

- The camera should not be bulky.
- The camera should be economical.
- It should have a USB interface.
- The camera's resolution should not be less than 640x480.
- The frame rate per second should not be less than 15.

Based upon these factors, a USB camera, Microsoft's VX-1000 has been chosen for capturing vein images.

Figure 4 Hardware Set Up

The set up consists of the host machine, Mini 2440 Single Board Computer (target), lighting system and USB camera. The enhanced image is displayed on the SBC.

V. SOFTWARE IMPLEMENTATION

To manage the overall functioning of the vein detecting system , starting from powering on the board , enabling the camera, capturing the image, performing histogram equalization on the images and displaying the images on the monitor, an extensive software support is required to execute and manage all these operations simultaneously.

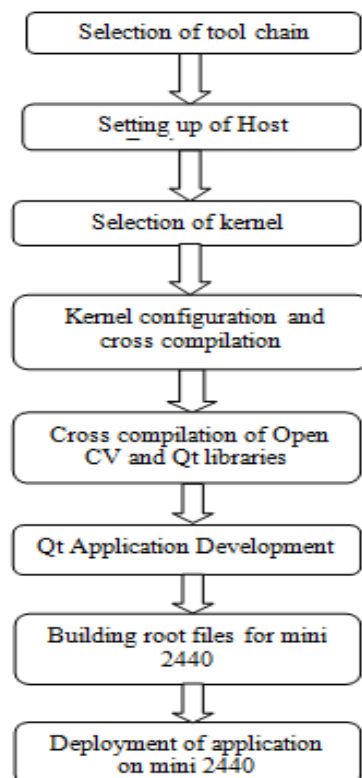### 5.1 Software Implementation Steps

Figure 5. Software Implementation Steps

- A toolchain is a collection of utilities that help in converting High level language like C, C++ , ADA to machine level code that can be executed by the microprocessor. The GNU toolchain plays an important role in the development of Linux and software for embedded systems.

- The development environment on the host machine must be first setup before starting the development for the SBC. Installing Ubuntu LTS as the development platform is the first step in setting up the host.

- The kernel acts like an abstraction between the real hardware and the user space applications. The linux kernel version 2.6. is used for the development and the kernel is modified accordingly.

- Cross compilation is the act of compiling code for one computer system (often known as the target) on a different system, called the host. It's a very useful technique specially when the target system is too small to host the compiler and all relevant files.

- Before building the root filesystem for mini board, there are set of image processing libraries (OpenCV) and GUI libraries(Qt) which are to be cross-compiled and put into the mini FS directory structure.

- The root file system contains all the required libraries and the user-applications arranged in a hierarchical manner. The root file system can also either be located on the ROM/Flash memory mostly as a YAFFS2, JFFS2 or a CRAMFS type file system.

5.2 Histogram Equalization

A histogram is a graphical representation of the distribution of data. Histograms provides a global description information about the appearance of the image and its properties. The histogram of a digital image with gray values r_0 , r_1 , r_2 .....r_{L-1} is given by a discrete function :

$$p_r(r_k) = n_k / N \ , \ 0 \le r_k \le \ 1 \ \text{and} \ k = 0 \ , \ 1 \ , \ 2 \ .... L - 1 ....(1)$$

where r_k - normalized intensity value.

     L - no. of gray levels in the image.

     n_k - no. of pixels with gray level r_k.

     N - total number of pixels.

A sample image and its related histogram obtained using Open CV is shown in Figure 6 and 7 respectively.

Figure 6. Sample Image Of The Fist.   Figure 7. Histogram Of Figure6 Obtained Using Opencv

Histogram equalization is a powerful point processing enhancement technique that seeks to optimize the contrast of an image at all points. Histogram equalization seeks to improve the image contrast by flattening or equalizing, the histogram of an image.

VI. RESULTS

Initially, the images that were captured from the USB camera were subjected to histogram equalization. The images before and after subjecting to equalization and their corresponding histograms are shown below:
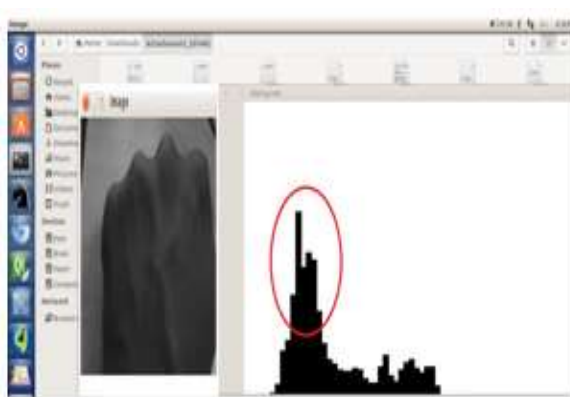

Figure 8. Image of the fist before equalization and its corresponding histogram.
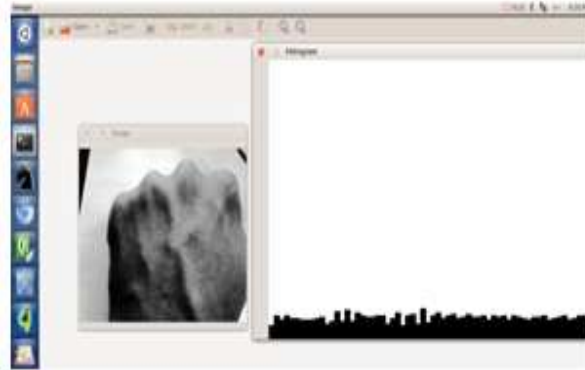
Figure 9. Image of the fist after equalization and its corresponding histogram.

It can be clearly observed that image in figure 8 is darker compared to the image in figure 9. This infers that the contrast of the image is enhanced after subjecting to equalization procedure. The narrow peak in the histogram which is indicated by the circle shows darker portions of the image. In the darker regions, the pixels are clustered together or unevenly distributed. It can also be observed that the narrow peaks that were visible in the histogram of figure 8 is not seen in the histogram of figure 9. In other words, the pixels of the image are uniformly spread across the entire image. The final output is obtained on the LCD display of the SBC. Images of the fist and wrist are captured from dark toned , medium toned and obese persons.The circle in the figures indicates the vein .
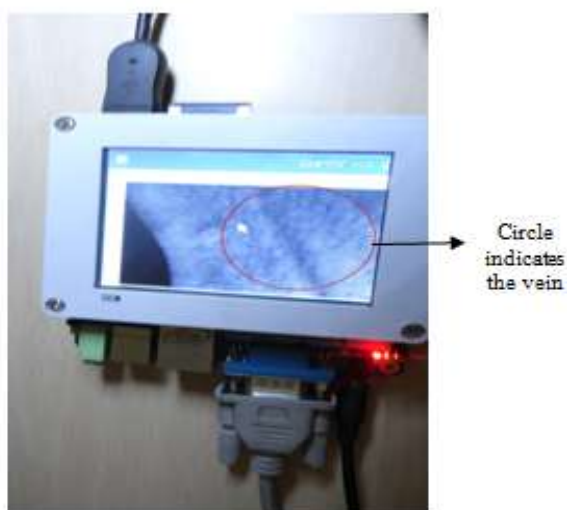

Figure 10. Image of the fist of an obese person displayed on the SBC
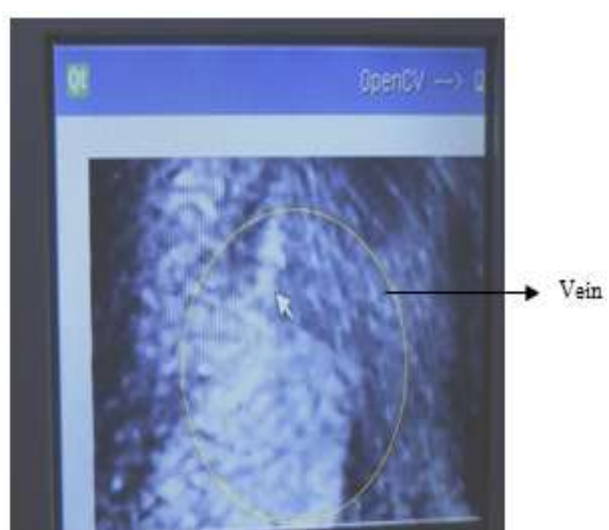

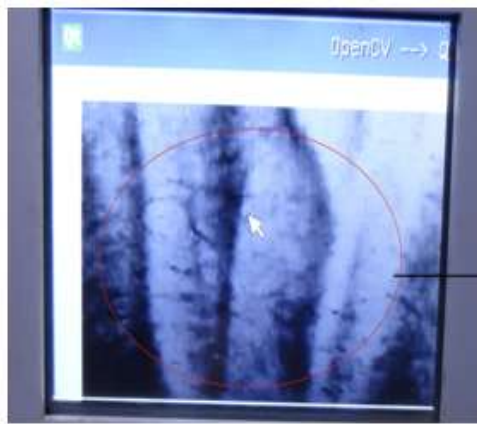Figure 11. Image of the fist of a dark toned person displayed on the SBC

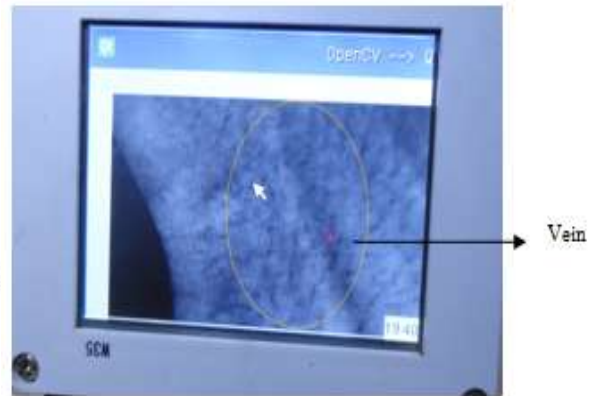Figure 12. Image of the fist of a fair complexioned person

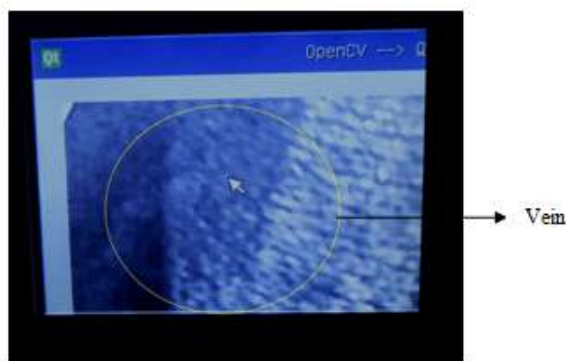Figure 13 . Image of the wrist (dorsal side) of an obese person

Figure 14 . Image of the wrist (dorsal side) of dark toned person
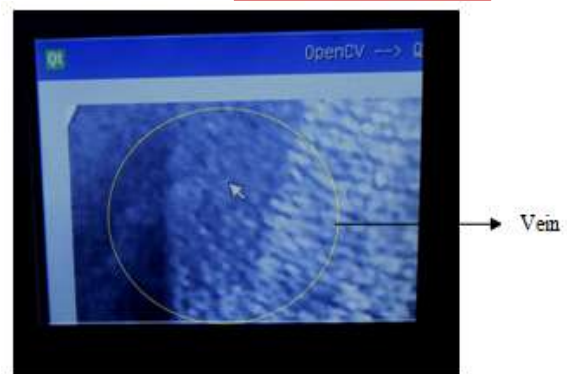

Figure 14 . Image of the wrist (dorsal side) of dark toned person
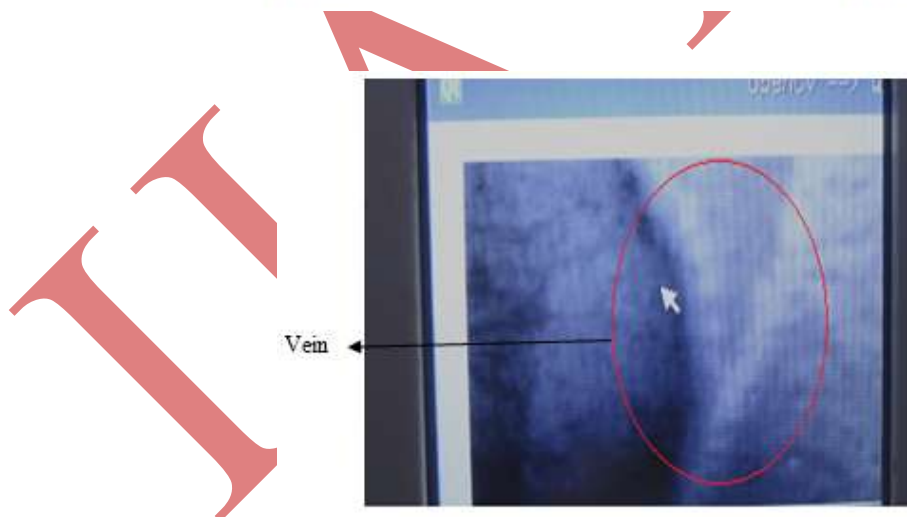

Figure 15 . Image of the wrist (dorsal side) of fair complexioned person

The testing of the system carried out on 4 patients for each of the three cases : obese , dark toned and fair complexioned.

Obese : 3 out of 4 persons veins were visible clearly, which gives a success rate of   75%. However the percentage might decrease by a small value for dark toned , obese patients.

Dark toned : 2 out of 4 persons veins were visible which gives 50% success rate. The percentage might reduce further if the patient is obese apart from being dark toned.

Fair complexioned : The veins of all the four test subjects were visible clearly. Only slight variation can be seen in extreme cases where the patient is highly obese.The results are summarized in table 1 shown below :

Parameter	Types of patients		
	Obese	*Dark toned*	*Fair*
Vein visibility on the fist	Fairly visible	Least clearly visible	Most Clearly visible
Vein visibility on the wrist (dorsal) side	Fairly visible	Better visibility compared to image of the fist	Most Clearly visible
Contrast Enhancement	Depends on the skin tone	Mostly enhanced	Least enhanced
Visibility success rate	60 -75 %	40 - 50% (better results for dark toned -thin patients)	95%

Table 1 Summary of the Results

VII. CONCLUSION

New technological innovations are becoming available that deliver practical, reliable, and low-cost solutions to the healthcare sector. With minimum investment, a system which detects subcutaneous veins is developed. A customized application is also developed for displaying the processed vein images on the VGA monitor. Image processing on ARM9 platform is implemented successfully by porting OpenCV image processing libraries on SBC. OpenCV and Qt Frameworks are integrated and deployed successfully on the SBC. An external USB camera is used instead of expensive NIR specific camera since the project mainly focuses to reduce the cost. The system is tested for different types of patients whose vein accessibility is a reason of concern. It is observed that the veins are very clearly visible for fair complexioned (both lean and obese) patients. The vein visibility of a lean, dark toned person is better than that of a dark toned obese person. The clarity can be improved by employing NIR specific camera in which case there is a trade - off between clarity and cost. The use of Open Source tools have proven to be effective and reliable for development. The extensive use of open source software packages and tools have helped in making the system low cost to a large extent. The number of cases of wrong vein detection or side effects of providing drugs to wrong veins can be reduced.

REFERENCES

[1] Tom Lister, Philip A. Wright, Paul H. Chappell , *"Optical properties of human skin,"* J. Biomed. Opt, vol. 17(9), pp. 1 - 12, September 2012.

[2] A. N. Bashkatov, E. A. Genina, V. I. Kochubey, and V. V. Tuchin, *"Optical properties of human skin, subcutaneous and mucous tissues in the wavelength range from 400 to 2000 nm,"* J. Physics D: Applied Physics, vol. 38, no. 15, pp. 2543 – 2555, 2005

[3] S. Crisan, I. G. Tarnovan, and T. E. Crişan, *"A low cost vein detection system using near infrared radiation,"* in Proc. IEEE Sensors Applications Symposium (SAS '07), pp. 1 - 6 , February 2007

[4] Wang Lingyu, Graham Leedham, *"Near- and far- infrared imaging for vein pattern biometrics,"* Proc. IEEE International Conference on Advanced Video and Signal Based Surveillance, vol. 0, p. 52, 2006

[5] Yeganeh . H , Ziaei . A , Rezaie .A , *" A novel approach for contrast enhancement based on Histogram Equalization,"* 2008 International Conference on Computer and Communication Engineering (ICCCE), pp. 256 - 260, 2008

[6] Mini 2440 friendly arm [Online]. Available :   " http://www.friendlyarm.net/ ".

[7] Karim Yaghmour , *Building Embedded Linux Systems*, 1st ed. O'Reilly & Associates   Inc., 2003.

[8] Gary Bradski , Adrian Kaehler, *Learning OpenCV*, 1st ed. O'Reilly Media, Inc., 2008.

[9] Fengtao Wang, Ali Behrooz, Michael Morris, Ali Adibi, *"High-contrast subcutaneous vein detection and localization using multispectral imaging,"* J. Biomed. Opt,   vol.18, no.5, pp.1-3, May 2013.