Smartphone aided real-time blood vein detection system

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ABSTRACT

This paper aims to develop a real-time integrated system for the detection of the blood vein utilizing an Android Mobile App. The system is intended to be a low cost solution for medical teams at clinics, emergency rooms and hosptials. The system reduces the enjuries incurred due to inaccuracies during the process of frequent needle injection when blood vein is not visible during patient's skin inspection. Illuminated infrared light in the blood cells of the vein is absorbed due to the manifestation of the Haemoglobin in blood and the IR non-blocking camera can capture the vein patterns in the IR light spectrum. Contrast Limited Adaptive Histogram Equalization (CLAHE) algorithm was used to enhance the pattern of the vein in the Android application developed using OpenCV3. Developed system can detect the veins up to 7mm underneath of human skin in real time with a frame rate of 25fps. This is a far better improvement than commercial systems that can detect veins only below 10mm underneath the skin. Moreover, this system not only focused on needle infusion but also it can be used to indicate the place of bleeding for the clots from the human body strokes, etc. in the upper layer of skin. It can also be used to detect & measure liquids in encapsulated in confined dark bottles, for example, liquid chemical pouring into the bottles in the chemical companies, liquid medicine pouring to bottles, etc. The system can be further developed to detect skin infection and other dermatological diseases underneath the skin.

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1. INTRODUCTION

Nowadays, the infusion of a needle to the patients for hospitalization has been done by medical clinician in the field of hospitalization and the Clinician must require to find out the veins for the purpose of blood donation, blood transfusion and injection of the ampule liquid or fluid into the patient body [1]. It is a very important process for the phlebotomist or the clinician to find the vein vessel and errors may cause serious and fatal harm to patients because of the sheer number venepuncture procedure is done every day as the chance of error may increase subsequently. There are ways to reduce errors caused by vein puncture procedure using modern technology, one of which is by using smart phone capability but has not still been developed. However, the current vein detection systems are expensive. Moreover, it requires a new type of heavy and large device to detect the blood vein for infusion of the ampule to a human body for treatment or medical purpose. Nevertheless, the currently available solution is developed by capturing a static image and processed in high configuration computing unit. As the smartphones are most widely used computing device, how it can be used to detect the vein from underneath of the human skin in real time with ensuring the lowest cost.

The human eye will react to the obvious light which is between Ultraviolet and infrared rays, the wavelength scope of which is between 390 to 700 nm, where the VIOLET shading covers the lower end and the shading RED retain the higher end. Near Infrared (NIR) Illumination is an imaging technique to see between wavelengths of 720nm and 1µm and Far Infrared (FIR) 15µm 1mm where human eye and frequently used camera is unable to distinguish, as Figure 1 demonstrates, between all obvious and imperceptible wavelengths. The human skin can be partitioned into two layers; the epidermis and the dermis. Underneath of dermis there is a subcutaneous fat layer as in the Figure 2, contingent upon the grouping of melanin, blood, and keratin the response may transferal. The dermis layer contains the blood vessels and nerves [3].

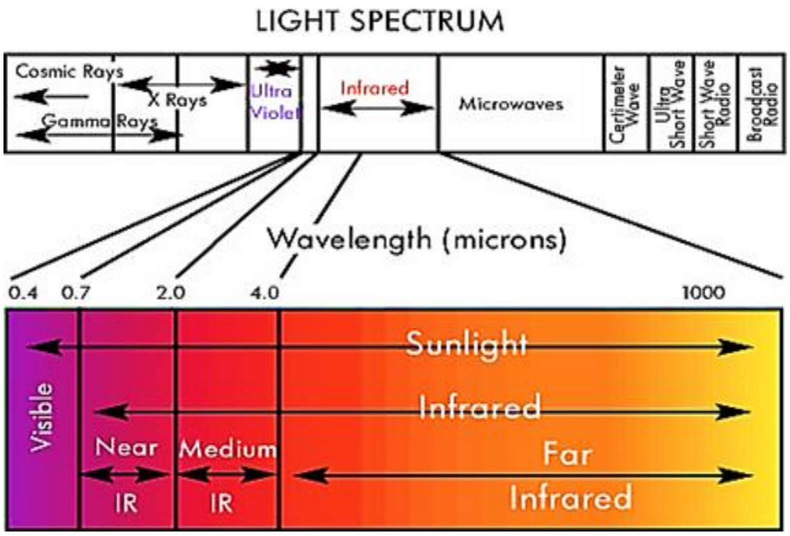


Figure 1. Light spectrum [2]

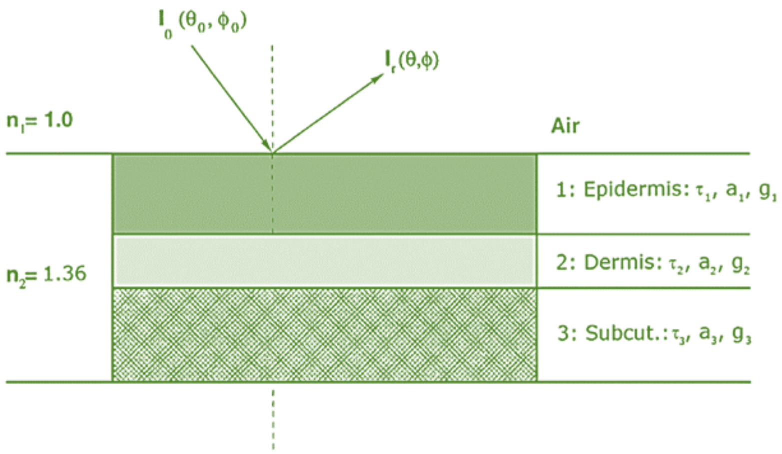


Figure 2. Human skin layer [4]

Moreover, the human eyes are only able to see in the visible wavelength between 380nm which is considered as violet and 720 nm which is red and the tissues underlying in the human skin absorbs the light differentially where the absorption ratio can be increased by the deoxygenated blood haemoglobin. However, the vein pictures by the assistance of NIR LED is non-invasive with no known unsafe impacts. It isn't trustworthy for distinguishing profound supply routes and veins, for example, the advanced conduit [5]. However, the vein cannot be seen clearly on the skin [6] because of its diverted skin tone [7]. Hence, this research tries to highlight the limitation of current clinical vein detection activities with emphasis on the imaging techniques to detect the vein through the use Smart Phone computing powers.

The core characteristics of the vein are its pattern. However, the skin works as protector of veins which are of a really complex pattern and are not to be distorted with bricklaying, dissemination, abrasions, and injuries etc. Detection of the vein is the method for dismembering the vein patterns or the cases of veins under the skin and it is possible to recognize the veins from the binary images from unpredictably start position using line following system [8]. Be that as it may, the radiation of IR is radiated by people and the thermography can be characterized as the image delivered by an IR camera where there are no necessities of light and cannot be influenced by the variety in the intensity of light [9]. The blood vein absorbs thorough going IR radiation onto it whereas the neighbouring muscles do not do so which can be captured by NIR imaging technique. On the other hand, the muscle consuming a greater heat than the neighbouring muscle in the skin surface is captured by the FIR imaging techniques. Furthermore, in both techniques, the camera captures the light beyond the range human is able to see and NIR wavelength range is proficient to penetrate 5mm clandestine into the skin muscle [7, 10].

A line of manufactured goods which offers the medical practitioner a real-time solution with projection on the patient armrest and the principle is still that IR radiation is captivated by the blood more than the neighbouring muscle which is known as Vein Viewer, Vein Finder is CMOS camera using XBee pair with IR illuminator and Wearable Veins Localization [7, 11, 12] respectively. However, the vein shape distinguishing is known to be the most difficult issue by using a combinational sensor between devices. Furthermore, detection of a vein can drastically be enhanced by modifying the lens of the camera to allow sensing IR radiation which cannot be seen in a normal visual procedure, by confiscating IR filter pertaining to General RGB camera [13]. Conversely, one of the major significant issues is the modern camera lenses containing IR-CUT Filter to eliminate IR sensitivity for focusing only on the visible lights wavelengths [14].

The percentage of absorption and reflection of dissimilar wavelengths anticipated in the direction of an entity is the key element for detecting the colour of that entity and it is the reason for which human can see a red ball as red since the entity absorbs the blue and green colour wavelengths although it is reflecting red. In addition, the reflection and retention of wavelengths are restricted to the unmistakable light as whatever is left of the wavelength range likewise takes after a similar thing [15]. Inversely, the intriguing matter is that in the band neighbouring to the red wavelength of the NIR range, the blood responds in an entirely different way where the blood veins absorb IR light [16].

However, the wavelength in the middle of 380nm which is acknowledged as violet and 720nm which acknowledged as red is only visible wavelength that a human can see. Moreover, the absorption percentage can be enlarged by the deoxygenated blood haemoglobin as the muscles beneath of the human skin absorbs the brightness differentially [5]. On the other hand, [6], [7] described that the diverted skin plays a significant role for the representation into the human eyes and as a result, the vein cannot be perceived clearly on the skin.

Specifically, there is distinctive method which can be thought to be utilized for the improvement of images, however, the basic work to get the clearer perspective of the vein from the human body parts progressively. Additionally, the in Brightness Bi-Histogram Equalization (BBHE) the images are extricated to make different sub-image and between two successive pieces of the image, the average to protect the average brightness of the inputs are giving as a yield [17]. However, the researchers show an examination of the yield comes about among BBHE, RMSHE and Recursive Sub Image Histogram Equalization (RSIHE) over a dark picture and found the great outcomes for RSIHE, however, the recursive division on the histogram. By the by, in the Recursive Mean Separate Histogram Equalization (RMSHE) these sub-images of the input is done through the equalization of the data sources recursion level [18, 19].

As of now, by consistent preparing for each of the frame of the video succession, the vein portrayal for each frame is plainly being outlined as appeared in the yield as shown by [20], [21]. Conversely, in the simulational and app based real-time vein detection is also extracted in [22, 23] respectively. Consequently, the clinician can recognize the vein for any sort of needle implantation to the vein all the more proficiently, errorless and easily without much of a stretch.

2. RESEARCH METHOD

In this Section, we will discuss about the performance evaluation metrices, CLAHE and proposed technique to detect blood vein in real time using the smartphone Camera.

2.1. Evaluation metrices

For research technique evaluation purpose, we had taken the entropy of an image, the Mean Square Error (MSE) for an image and the Peak Signal-to-Noise Ratio (PSNR) into our consideration. A factual measure of arbitrariness that can be utilized to portray the surface of the reference is treated as the Entropy of an image. The mathematical expression for the calculation of entropy is

$$ENTROPY = -\sum_{j=0} U.\log_2 U \quad (1)$$

Where U contains the normalized histogram counts returned from the histogram of an image. The MSE is ascertained from the reference input frame and enhanced frame of the input frame. The mathematical formulation for MSE for X and Y element of a matrix,

$$MSE = \frac{1}{ROW \times COL} \sum_{j=0}^{ROW-1} \sum_{k=0}^{COL-1} [X(j,k) - Y(j,k)]^2 \quad (2)$$

The calculation of the PSNR, can be expressed as the following mathematical term:

$$PSNR = 10 \log_{10} \left[\frac{L^2}{MSE}\right] \quad (3)$$

While L is the series of values of a pixel and for the system as we have considered grayscale 8bit image, so, the value for L = 2^8-1 = 255. For our system, higher Entropy and higher MSE value mean the greater changed happens in the frames and lower PSNR value means the lesser noise which is also desired for our developed Smartphone Vein Detection System.

2.2. CLAHE

CLAHE is not the same as genera Versatile Histogram Improvement strategy and was initially connected to pictures with low-Complexity proportion sort of pictures [24]. This method was acquainted with defeated the commotion strengthening issue which progresses toward becoming as the real preferred standpoint of CLAHE through its Clipping Limit (CL) of confinement [25], [26] by clipping its histogram at a predefined contribution before figuring the Cumulative Distribution Function(CDF).

The significant parameters of this procedure are Block Size (BS) and its Clipping Limit of confinement (CL) which are basically used to upgrade low-differentiate image [17]. The strategies to improve the low difference input image utilizing CLAHE involves the following phases:

Phase-1: The aggregate number of sub-image is proportional to U×V, and 8×8 is a good motivating force to spare the photochromatic data by isolating the power of genuine image into non-covering consistent areas.

Phase-2: By assessing the proximity of dim levels in the showed image, finding out the histogram of every logical area.

Phase-3: The solution through mathematical calculation of the contrast limited histogram for the coherent areas utilizing CL esteem:

$$V_{avg} = \frac{V_r X \times V_r \mathrm{Y}}{V_{gray}} \quad (4)$$

Where the fair estimation of the pixel is V_{avg}, the whole number of dark level in the coherent regions is V_{gray}, the whole number of the pixel in the X-axis and Y-axis of the sensible regions are V_rX and V_rY separately. The estimation of CL showed below.

$$V_{CL} = V_{Clip} \times V_{avg} \quad (5)$$

Where V_{CL} is determining real Clipping Limit (CL) of confinement and the estimations of V_{Clip} is the standardized CL in the arrangement between 0 and 1. The pixels will be dealt with as cut if the whole number of pixels is bigger than V_{CL}. The number of the aggregate of aggregate clipped pixels separated as $V_{\sum Clip}$, at that point the average of the outstanding pixels to every dark level is dispersed as;

$$V_{avggray} = V_{\sum Clip} \times V_{gray} \quad (6)$$

The rule for clipping histogram followed by

$$V_{region\_clip}(i) = V_{CL} \quad (7)$$

Else If ($P_{region}(i)$+$P_{avggray}$)>V_{CL} *then*

$$V_{region_{clip}}(i) = V_{CL} \quad (8)$$

Else

$$P_{region_{clip}}(i) = P_{region}(i) + V_{CL} \tag{9}$$

Where the unique histogram is $P_{region}(i)$ and clipped histogram of everyregions at i-th gray level is $P_{region\_clip}(i)$.

Phase-4: Reallocating the unresolved pixels while waiting for the unresolved pixels have been all dispersed by

$$Stage = \frac{Q_{gray}}{Q_{remain}} \tag{10}$$

Where V_{remain} is the unresolved pixels waiting for clipping. Phase is progressive numeral no less than 1. The platform starts to look for from the base to the most extreme of the gray-level with the above phases. In case the measure of pixels in the dark level is not as much as V_{CL}, the platform will pass on one pixel to the gray-level. If the pixels are not all appropriated when the request closes, the program will determine the new progress as demonstrated by. (10) and start new interest argument until the argument that whatever is left of the pixels is inside and out dispersed all at once.

Phase-5: Enhancing intensity in each region by Rayleigh Transformation of Distribution function. Clipping in the histogram is changed to aggregate possibility, U_{input}(i), to formal location role. The transmission is forwarded by

$$Y(i) = Y_{min} + \sqrt{2\alpha^2 \ln\left(\frac{1}{1-P_{input}(i)}\right)} \tag{11}$$

Where the inferior limit of the pixel data is y_{min}, and Rayleigh distribution argument for clambering to every input images is represented as α. At this phase, the implication in Rayleigh distribution for α is secure to 0.04. The yield probability of respective intensity value can be expressed as

$$p(y(i)) = \left(\frac{y(i)-y_{min}}{\alpha^2}\right) \times exp\left(\frac{(y(i)-y_{min})^2}{2\alpha^2}\right) \text{ when } y(i) \geq y_{min} \tag{12}$$

In the form through the contrast enrichment turn out to be more substantial by depending on the significance of α. In addition, increasing the value of α also intensified the noise intensities in the same interim.

Phase-6: The re-scaling function can be written by linear contrast stretching from the eq-12 as,

$$y(i) = \left(\frac{x(i)-x_{min}}{x_{max}-x_{min}}\right) \tag{13}$$

Where the revolution progression input is $x(i)$ and the largest and smallest implication of the handover process is denoted as $x_{max}$and x_{min} respectively.

Phase 7: Determining the newfangled gray-level changeover of pixels of a sub-matrix with coherent region by exploiting a bi-straight overview between four individual mappings to smear out the restraint.

2.3. Proposed technique

Before obtaining new skins the IR cut channel is obstructed for lasting night view to maintain a strategic distance from any sort of light impact from outside by permitting just IR brightening. The edge of the human arm is taken from driverless IR night vision camera with 24bit 640x480 determination and 850nm IR illuminator. The acquiring of a frame is the underlying advance in our application and set up with the exact light condition. The pre-enhancement is empowering the system by discovering more straightforward segments of the edge which will be incorporated with some selected highlights of vitality into an image. This is an exceptionally subjective region of that frame. The choice in light of the calculation be utilized relies on the likelihood of the obtained outline. The frame which is procured from the genuine condition may contain commotion which must require smoothing the edge in this progression and this Pre-enhancement fuses with the expulsion of salt and pepper based noise. In Region of Interest (ROI) in the frame is determind by forwarding the process to identify the general information by image thresholding system and intensity change can be selected of ROI with respect to the background frame information. Thresholding is done by changing over of grayscale frame into its binary form and adaptive thresholding is used to create a frame of each fragmented digits in order to get darkest vein by changing elements of the matrix of values>127 will be 255. This binary data is treated as a reference frame which may have unwanted noise or any other small object in the frames. In addition, the background subtraction method of the image processing will applied to the image received from thresholding stage and the recent frame where the noise already discarded, will produce a matrix with darkest data for the ROI. The yield frame will be upgraded utilizing CLAHE to get the brightest perception of the vein by guaranteeing higher complexity proportion in this post enhancement part. For the last stem, it likewise may make another kind of clamour (salt or pepper) which is smoothened by Gaussian smoothing method before it sends to show on the phone screen. Figure 3 shows smartphone vein detection system method.

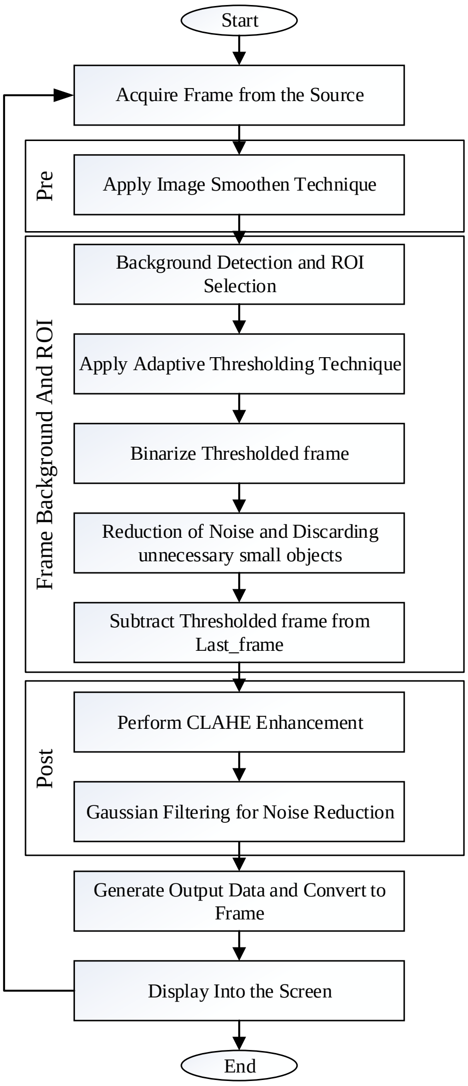


Figure 3. Smartphone vein detection system method

3. RESULTS AND ANALYSIS

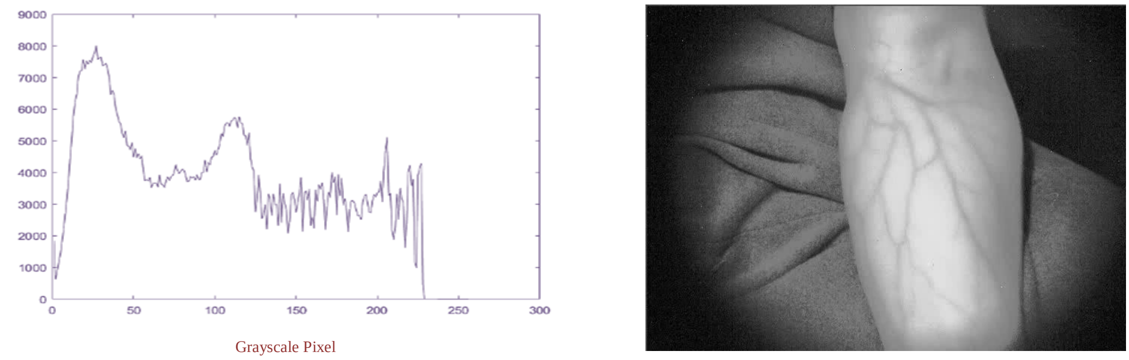
3.1. CLAHE Benchmarking and Analysis

To verify the theoretical analysis, we use evaluation of CLAHE over BBHE, RMSHE, RSIHE enhancement technique through the MATLAB software for a static IR frame. As of now, by consistent preparing for each of the frame of the input, the vein pattern for each frame is plainly being outlined for the clinician who can recognize the vein for any sort of needle implantation to the vein all the more proficiently, errorless and easily without much of a stretch.

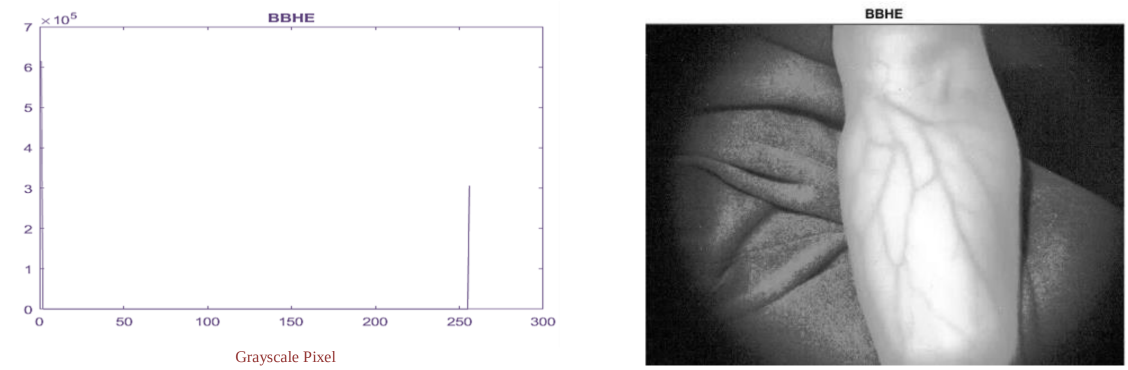
Table 1 shows a detailed comparison among different contrast enhancement techniques for the Figure 4 where the initial entropy was 7.7316. It is being illustrated from the table that both Entropy and MSE the CLAHE return higher changes ratio which is actually our requirement for SmartPhone Blood Vein Detection System. Moreover, the lesser PSNR value indicates the less Signal to Noise Ratio which is also our one of the concerned issue.

Table 1. An effective frame rate comparison of the outcomes

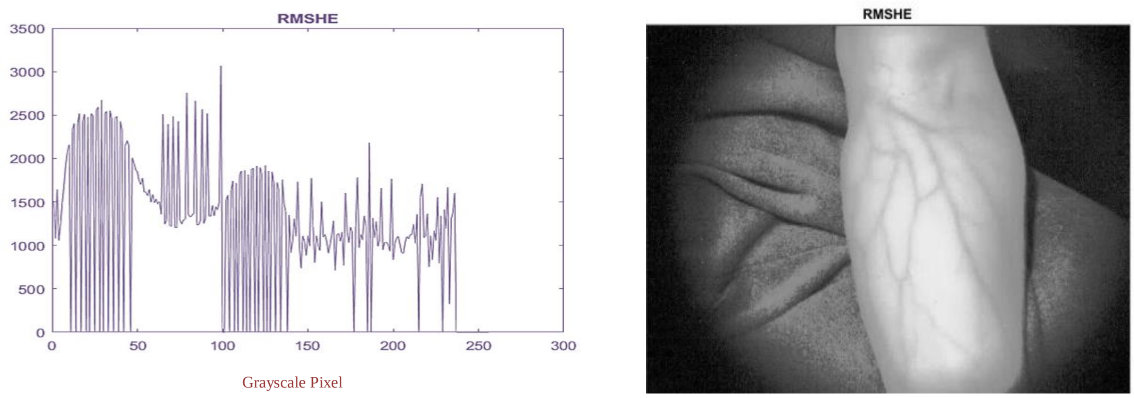
Performance	Matlab (fps)	Smartphone (fps)	Output
Before Enhancement	22	29	Noisy with crisp vein information.
After Enhancement	17	21	Noise Reduced but frame rate dropped from 29fps to 21fps.
After Enhancement with Gaussian Filter	19	25	Still Noisy.



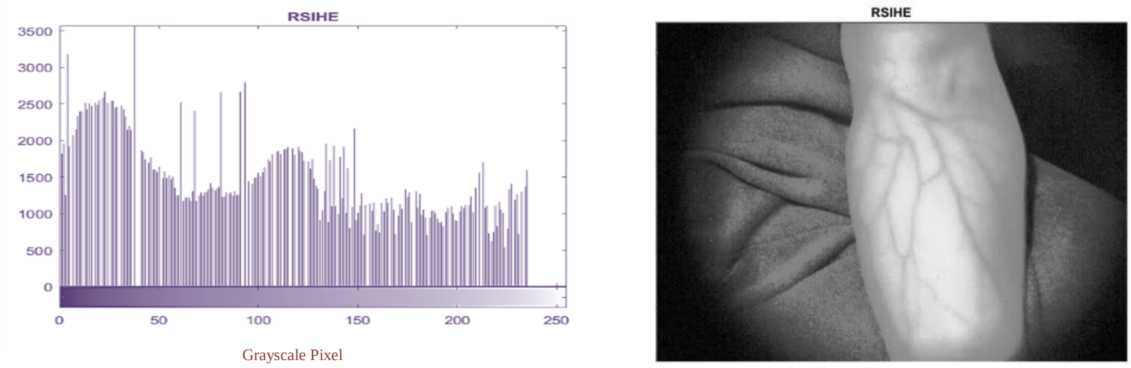
Input Image (Entropy 7.7316)



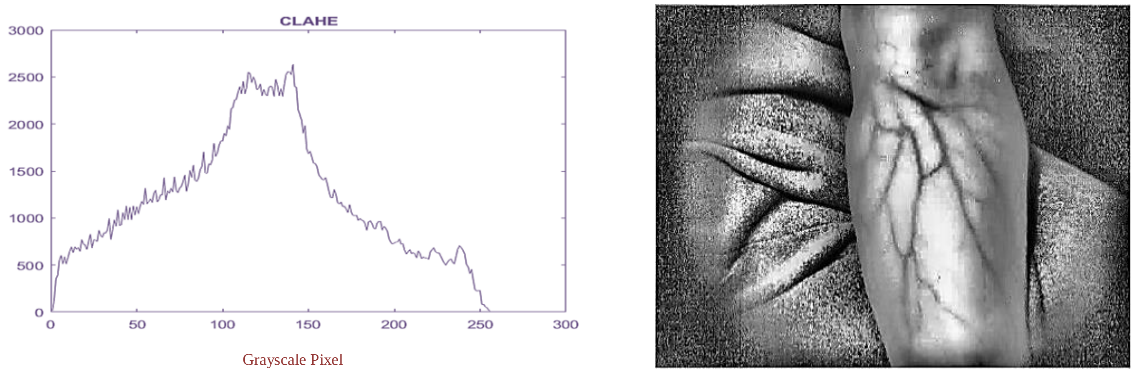
BBHE Enhanced (Entropy-0.91763, MSE-238.6895, PSNR-24.3525)



RMSHE Enhanced (Entropy-7.5759, MSE-70.2982, PSNR-29.6614)



RSIHE Enhanced (Entropy-7.5932, MSE-17.3980, PSNR-35.7258)



CLAHE Enhanced (Entropy-7.7798, MSE-2693.8455, PSNR-13.8271)

Figure 4. The histogram comparison among image enhancement technique and their output

The Entropy, MSE is calculated from the Sub-Section of this lection Now, after consideration of the above table, it can be clearly seen that from ENTROPY and MSE ratio of the input and CLAHE enhanced output is surprisingly exceptional with respect to other technique and the PSNR is also so lower than the other technique which is so helpful for representation of clearer vein. So, for our work it is found that the CLAHE technique proved better from other algorithm.

3.2. Outcomes and analysis

The smartphone aided real-time apps has been developed where the consequences is something different with respect to Matlab simulation as the information after the ROI boundary is being taken into our consideration. In the following Figure 5, some extended outcomes of Smartphone Vein Detection System apps is exemplified.

(a)

(b)

(c)

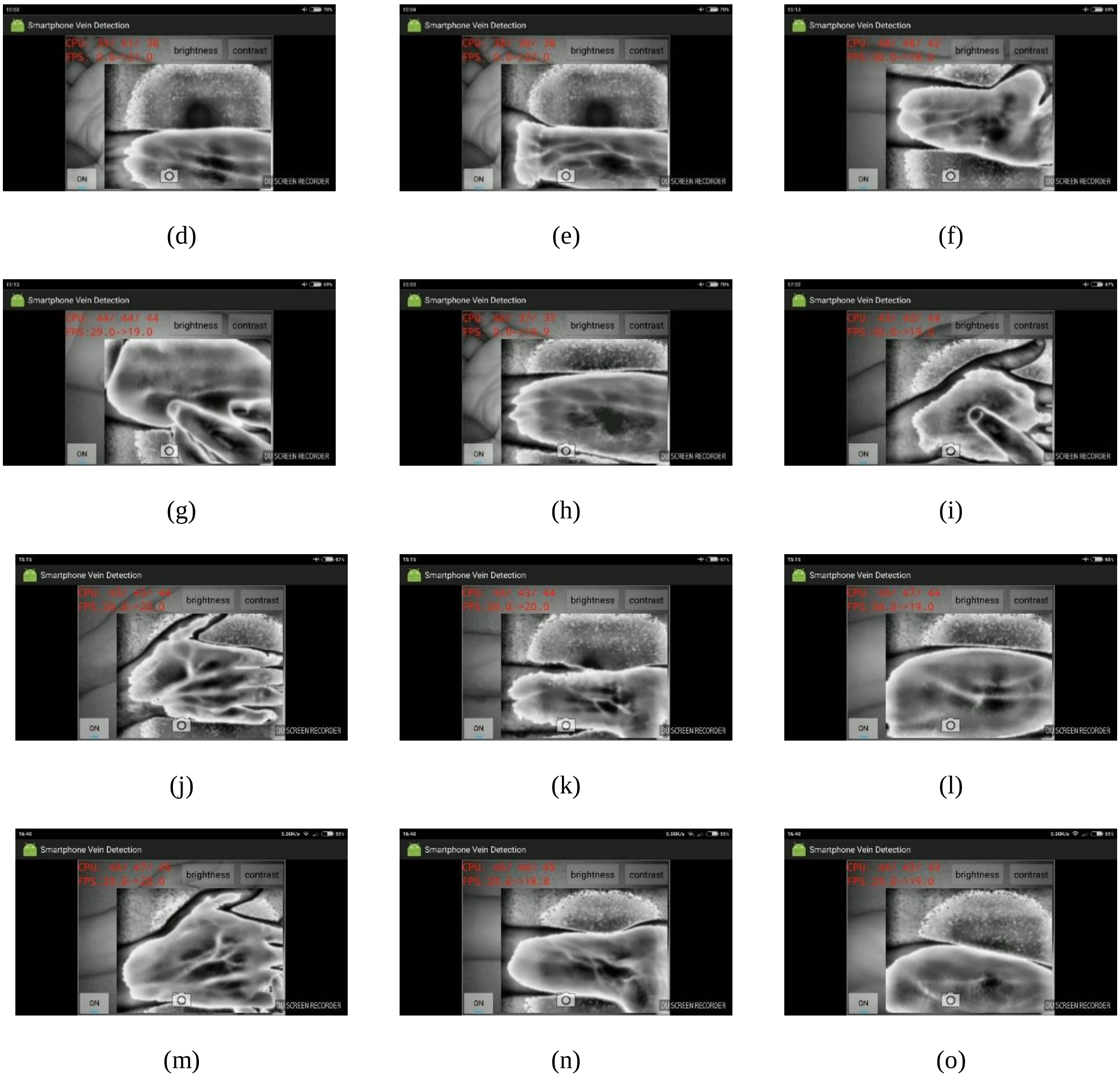


Figure 5. Frames recorded in Real-time, (a)-(b) is the type of RGB image,
(c) is the type of raw input from camera, (d)-(o) are some sample of voluteers hand

As it can be seen that the system works satisfactorily in any surroundings as there is no affect of light for determing the vein pattern. However, the pattern of the vein is so clear from the detection and the hassle of identification of the vein in the human hand is reduced in the higher percentage. Nevertheless, it can also be seen that the human skin is not a great deal in this system, and it is found that the vein pattern is unique for each and individual human being. On the other hand, it can also be found that the NIR light effect is not going more than 7mm of the human skin in our case. Thus, for the healthy people whose vein is underneath of more than 7mm of human skin, is require more infrared illumination. Conversely, those findings are steady with outcomes for all cases of the substantiation test to the volunteers and have the optimistic effect of enjoyment to users' acuities of benefits of thermography image processing.

An effective comparison table for the real-time vein detection is shown below. As it can be seen from the table, the Matlab simulation is always giving lesser frame rates than SmartPhone application because unlike the laptop, the SmartPhone processor architecture is developed to support real-time application. So, for every single case, the SmartPhone application frame rate is higher. However, the frame rates also dropped in Gaussian Filter after enhancement been applied. This is only because Gaussian Filter uses a different kernel value and convolution method which makes the process slower.

More interesting part is that to perform the experiment, the hand wasn't tied up with anything and also need not require slap on any location of the hand for gathering clear vein of the frame. Furthermore, we able to achieve the vein pattern up to the depth of 7mm of human skin with a cost effective solution with the modified camera SmartPhone. So, by considering this scenario we can say that we achieve our objective of SmartPhone Blood Vein Detection System. Thus, it is forwarding the vein puncture process more efficient ways with respect to the consumption of time.

4. CONCLUSION

In the medical or pathological treatment, detection of blood vessels for medical or pathological treatment is the main resolution for poking a needle into the vein from the above of human skin to inject medicine and bestowment of blood in a campaign or health center. Nonetheless, the practices for the detection of blood vessels still remains manual because of the cost of relevant solutions is high and reliability is low. This proposed solution can be considered as a step forward in the modern multifarious medical treatments for its ability to sort out the visibility of the blood vessels to a great extent using the most widely used smart devices as well as in the different platform. In the daily medical practices, our developed system will greatly impact as the percentage of inaccuracies in needle infusion is anticipated to cut off the rate to a decent extent. As per our research objective, the cost and the performance, as well as accuracy, has been achieved by our proposed methodology over the most widely used handheld device, Android Smartphone and the future works can be focused on real-time RGB type coloured vein pattern. Our developed android app will be considered a viable alternative solution with the lowest cost. However, the frame rate is up to 25fps and the vein can be visible to the human eyes from the depth of up to 7mm of the human skin can reduce the percentage of errors. The portability and the availability of the total work will be extremely admirable to the user as there will be no possibility of damage to the human health. is the main reason for poking a needle into the vein of human skin to inject medicine and donation of blood in a campaign or clinic.

However, the practices for the detection of blood vein still remain manual since the cost of relevant solutions is high and trustworthiness is low. Our vein detection system can be considered as a breakthrough in the current complex medical works for its ability to make the vein visible to a great extent using the most widely used Android devices as well as the different platform. This will greatly impact on daily medical practices as the percentage of errors in needle infusion is expected to decrease to a good extent. As per our research objective, the cost and the performance, as well as accuracy, has been achieved by our proposed methodology over the most widely used handheld device, Android Smartphone and the future works can be focused on real-time RGB type coloured vein pattern. Our developed android app will be considered a viable alternative solution with the lowest cost. However, the frame rate is up to 25fps and the vein can be visible to the human eyes from the depth of up to 7mm of the human skin can reduce the percentage of errors. The portability and the availability of the total work will be extremely admirable to the user as there will be no possibility of damage to the human health.

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