Real Time NIR Imaging Image Enhancement by using 2D Frangi Filter via Segmentation

(Final Report)

by

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17110

Dissertation submitted in partial fulfillment of

the requirement for the

Bachelor of Engineering (Hons)

(Electical and Electronic)

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CERTIFICATION OF APPROVAL

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SEPTEMBER 2014

CERTIFICATION OF ORIGINALLY

This is to certify that I am responsible for the work submitted in his project, that he original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have no been undertaken or done by unspecified sources or persons.

LEE SHENG SIANG

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ABSTRACT

This paper presents the NIR imaging images enhancement by using 2D Frangi Filter segmentation which specifically apply in biomedical NIR vein localization imaging. The unseen subcutaneous vein causing clinical practitioner face the difficulties to perform intravenous catheterization and thus lead to the needles tick injuries. There are few imaging techniques which can be used for bein localization but the most widely used is Near Infrared (NIR) imaging due to its non-invasive and non-ionizing properties. The input images from NIR imaging setup is processed in order to enhance the vein visibility and contrast between vein and skin tissue. It is required to filter noise from the display image using some image processing technique. This work is done by applying image segmentation method to NIR venous image in order to extract veins and eliminate the noise. First, the gray scale image was segmented to 10 pieces of fragment plane with constant step size to produce 3 set of 2D planes. Second, these 3 sets of 2D planes will then apply in Frangi filter in order to obtain the eigenvalue image structure. Lastly, a least noise image is produce by this integrated plane through the 2D Frangi filter.

ACKNOWLEDGEMENT

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LIST OF ABBREVIATION

NIR	Near Infrared
AR	Augmented Reality
A/V	Audio and Video

CHAPTER 1:

INTRODUCTION

Introduction

Localization of blood vessel with naked eye is hard, however, harder for visualization for Venipuncture purpose which blood attraction action for intravenous therapy, blood sampling and diagnosed purpose. Thus, human negligence is unavoidable factor which effect further procedure like obtain for diagnostic purpose, monitor level (Lavery & Ingram, 2005) [1], therapeutic and discharge of erythrocytes [2]. A widely used technique NIR (Near Infrared Radiation) for capturing the location of blood vessel by far is the best method known for blood vessel visualization and localization. In Previous study, people manage to integrate STAR 1200XL Augmented Reality System to near infrared filter and process data with computer so called Near infrared bench-top acquisition system which shown the blood vein location back into glasses screen [1]. Although the device able to exposing NIR to blood vessel and locate the position by real time imaging, there still have some notion of necessity improvement such as improvement the pixel of imaging which able to measure the depth of vein, and adaptive alignment device for improve the angle of image able to change by movement of eyeballs (especially iris). Thus, there have few part of this project will be implement. First, construct an imaging structure which able to improve the pixel of blood visualization while reducing the noise that created by filtering of wavelength by NIR filter physically. Second, develop a model for IRIS detection for realign of NIR imaging to on screen display via MATLAB iris detection to adapt the focal point as eye movement angle.

IRIS detection algorithm of MATLAB is one of the most accurate and secures identification while also being one of the least invasive. In principle, it is detect the pupil movement follow by edge detection so that able to extract the middle point of pupil location in order to calculate the geometry of camera distance and the angle of eyeball movement.

1.1.Background of Study

Venipuncture and intravenous therapy (IV) is the one most dependent and high value medical behavior in century, but the excessive venipuncture behavior will cause physical and psychological reaction of patient like anxiety, distress, pain, and occasionally cause harmful injuries. In market consist few of devices which able to visualized the blood vein like Computed Tomography (CT) which produce image by x-rays, positron Emission Tomography (PET) which produces gamma rays for imaging. Nevertheless, the most famous imaging device magnetic resonance imaging (MRI) produces ultrasound for vein locating purpose. However, these devices are insanely expensive, bulky and needs time for getting the location of vein, which repulsive inapplicable for ordinary blood sampling, diagnosis purpose. Nevertheless, there have few visualization vein products like AccuVein [3] and veinlite one-stick vein device a tiny bar [4] which are able view the vein with naked eye. However, those devices are not full applicable for vein detection due to not clear of imaging, bulky, and required assist component to hold the device.[5]

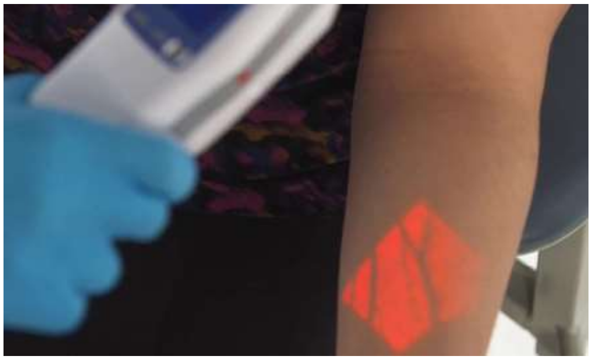

Figure 1.the vein detection of AccuVein

Figure 2. the vein detection of Veinlite.

Figure 1 and Figure 2 shown the current vein allocation technologies which able to allocate vein with limited area of view.

Recent years, near-infrared (NIR) imaging technique used for exposing near infrared to blood vessel and react by oxy-hemoglobin, deoxy-hemoglobin, and water due to the photon carry by those agent to react as *photo motion phenomenon* [6][7][8] [9].

Using NIR imaging technique, previous team managed to integrate STAR 1200XL Augmented Reality System to near infrared filter and process data with computer so called Near infrared bench-top acquisition system which shown the blood vein location back into glasses screen [1]. STAR 1200XL Argument Reality System is a system that interfacing between STAR 1200XL wearable screen-glasses to computer system which delivered a real time operating vision system display [1]. Furthermore, prototype still consist noise dissipation on NIR imaging due to low quality of image processing and required an additional action to realign the NIR image and glasses imaging which is the key factor in utilize the visualization the vein for medical injection. Therefore, in this project a high quality imaging processing unit and auto calibration follow to eyeball movement apply by iris algorithm is going to develop which able to realign the imaging simultaneously providing the high definition of images.

1.2.PROBLEM STATEMENT

Method of improving vein detection using Vizux 1200XL and Near Infrared filter interfacing system has become a subject of research study. Vuzix 1200XL and NIR imaging will assist medical expert to compensate the blood vessel detection problem.

When the NIR exposed to biological tissue, it will react to blood and reflect to NIR filter which block the visible light and left the near-infrared wave in length of 700nm – 1200nm detect to NIR camera. However, when small amount of Near infrared react to blood, the result will cause the image can't show the blood vessel clearly. In the other way, when the image processing not providing high filtering system and modeling system for high definition image. It will cause image that processing consist lot of noise which not an ideal situation for medical usage.

However, from the input of raw NIR imaging image, the appearance is unclear and this require image processing technique to filter those unnecessary noise in order to display the clear image.

Thus, in this project we require to use a smaller size webcam and auto calibration. So that, a cumbrous component which attach with Near Infrared Filter is not efficient as a wearing device and significant adjustment difficulties while wearing it. Wire interfacing between glasses and computer is not efficient and the movement of head position limited by the mess of wires.

Figure 3: Cumbrous component that attached to glasses [1].

Figure 4: The picture that captured which Near Infrared filter with noise [1].

Figure 3 shown the structure of Vuzzix glasses attach with NIR camera. Figure 4 shown the picture that captured from NIR camera which consist of noise.

1.3.OBJECTIVE AND SCOPE OF STUDY

The purposes of study are:

1. Optimization and prototype a Near Infrared Filter with high definition camera which lowers noise will dissipate. Optimization of usage with shrink of camera size.
2. Design and prototype a smaller cumbrous component which suitable for wearing and easier operating especially in medical purpose.
3. Performing Real Time imaging which able to process image with Frangi Filtering system in 30 frames per second as ideal case.
4. Determine 3D visualization of Vessel detection with Frangi Filtering system which process image even with various type of image consist of noise.

Scope of study

In typical medical behavior, blood sample extraction through intravenous inject so called Venipuncture is a fragment of medical procedure.

Based on the Table 1, the first scope of study in this project is deal with Hardware design to improve the performance of NIR filter in high definition quality, suitable size of casing. However, servo motor implement with NIR filter is needed because it makes auto calibration becomes possible. Meanwhile, the hardware's going to use for the project must are the components available in market. The reason of each hardware stated at table below.

Table 1. The reasons of particular hardware design require

Hardware	Time Estimating	Reason
NIR filter (high resolution + smaller size)	2 weeks	Replacement of high definition NIR filter will improve the image processing with better performance of Vein location. Meanwhile, smaller sizes of NIR filter able to fit in glasses and better venipuncture action.
Smaller Casing (cumbrous component)	2 weeks	Smaller casing implement after NIR filter design. Thus, casing makes NIR filter attaches on glasses possible.
Real Time Imaging	2 weeks	Real Time imaging implementation in order to process data with ideal case 30 frames per second.
ROI area localization	2 weeks	The purpose of ROI localization is to segmentation some area of image for processing instead of whole picture.

Limitation:

The limitation in first scope is that sequence of work on 3 of the design is required. Else, the problem of overlapping of design or miscalculation on hardware architecture will occur.

Based on table 2, the second scope of study is interface the auto calibration and wireless device interfacing between glasses and computer, in short, software design and implementation. Auto calibrations of servo to NIR filter design is based on the trajectory path motion planning. And wireless device interfacing with computer is done by wireless IP network connection.

Table 2.Table shows that reason of software design is required.

Software	Time estimating	Reason
Frangi Filter implementation	2 weeks	Frangi Filtering is the most effective method that convert 2D blood vessel imaging to 3D localization
Real Time Processing by MEX-File implementation	2 weeks	MATLAB consist a synchronizer between software clocking to computer processing Unit clocking. So, it is necessarily to bypass the synchronization in order to obtain the real time speed of processing data.

Limitation:

The limitation of this session is those real time programming required a lot of troubleshooting and data gathering process which able to make system to work in real time performance.

CHAPTER 2:

LITERATURE REVIEW

Figure 5: Vizux STAR 1200XL visual design

2.1. Vuzix STAR 1200XL Augmented Reality (AR) System

Figure 5 shown, Vuzix STAR 1200XL AR system is visualize device to send data of environment as digital form to processing and reflect to display screen [10]. It has a vast application in visualization purpose and has several advantages like the real time image reinforce over the On Screen Display directly and appear on our eye sight. As the glasses function is to interface between camera and display screen in the glasses to display the real time screening like the movie ironman super suit navigation helmet. The versatility capability leads to its application to use in the field of biomedical imaging for venipuncture purpose. Due to easier for carry and flexible to reinforce the image processing as we wanted like edge detection, track localization and able to do image database saving.

Table 3:Parts of the Vuzix 1200XL and functions respectively.

Element	Description
Video Display	AR-enable video kind-of-display which superimpose computer-generate image on screen of the environment with composite in 2D or 3D.
VGA Controller	Dual controller that interfacing audio/video between glasses and computing system through PowerPak+ Controller.
PowerPak+ Controller	Controlling device connection between host device and glasses with either composite or component A/V connection.
Head Tracker	A Inertial Measurement Unit(IMU) which sensitive to magnetic field interference. Calibration takes part on that particular situation.
Vuzix original Camera	1080p HD camera based on Logictech HD pro Webcam C920 and compatible to Window, Max and Linux.

Table 3 shown the functionality of each part of Vuzzix see-through glasses in order to utilize the function of vein allocation algorithm.

2.2. NIR Imaging

NIR imaging is well known most suitable for biomedical imaging purpose which not cause negative effect to human body in fastest and cheapest way. Tsai (2002) and this team mentioned regarding to water, fat and protein are main component that absorb to spectrum of Near Infrared which more efficiency in high protein carrier (high blood pressure) [9], which means NIR imaging have compensate the problem of vein detection unable to perform the action due to the patient physical condition like old age, dark skin. As long as patient body consist protein and water will possible to detect the location of vein via NIR imaging method. Most notably by the investigation of blood fluid movement, NIR able to measure the performance of coefficient of IR light absorption on rat heart [8], mentioned by Valentina (2008). This means the NIR imaging system able to investigate the absorption coefficient of main absorber like hemoglobin will highly assist to quantify the rate of absorption and the structure of blood of patient which assist for diagnosed diseases.

Figure 6 illustrates the absorption coefficient of NIR to tissue which includes water, acid mixture, gelatin and elastin of eye lens and both are under body temperature condition. The range between 900 – 1200 indicates the most effective region for NIR absorption. Therefore, the most suitable light wavelength for biological tissue absorption purpose is shorter than 1300nm, else the high energy of light might cause thermal damage [9], mentioned by Tsai (2002).

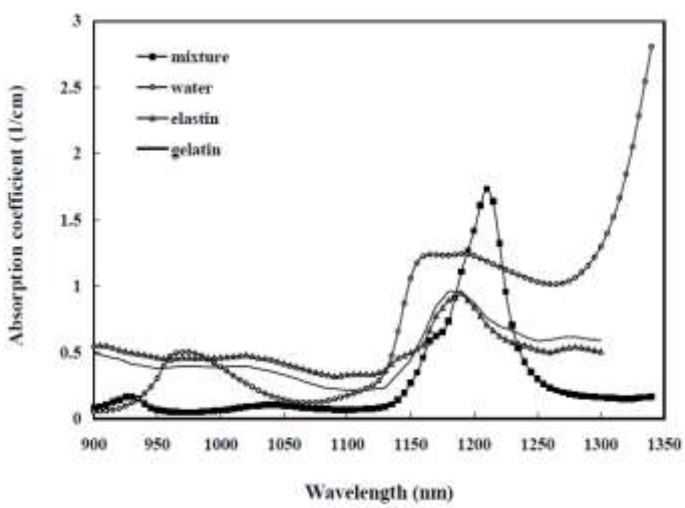

Figure 6:absorption coefficient spectra of water (37 ℃), acid mixture (40 ℃), gelatin (25 ℃), and elastin of eye lens (25 ℃)

2.3. NIR Filtering

As the method of this study, NIR has been took place for vein detection so that a NIR camera will able to detect the vein location through the image processing. Thus, the filtering system has to block the wavelength before 700nm – 1200nm so that utilize the range of detection of Near-Infrared absorption image.

As the technique implementation, NIR filter required extremely small size of filter and fulfill requirement as 740 – 950 $(nm\,\lambda)$ which able to absorb by oxy-hemoglobin, deoxy-hemoglobin, and water due to the photon carry by those agent to react as *photo motion phenomenon* [8][9]. There is possible to get the filters in Malaysia or near with which like Edmund optic (2014) listed the model of NIR filter lens (without cover) with different type of optical density from 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 and each type of lens have diameter of 12.5mm, 25mm, 50mm which are suitable to replace the lens from camera to NIR filter lens [11]. So that, changes the lens to higher definition camera so that it will be able to capture the image with less noise [1]

Figure 7 shown a cover which attach camera and filter together is an ad-hoc task because it will determine the focal point of image. Which mean, a focal point vary the distance of camera to object and the level of image visibility in a set of distance. Sunset (2014), listed the several of lens with cover from 1.1 to 1.97mm focal length [1]. Meanwhile, focal length is an important part of imaging due to angle of view will be affected.

Figure 7:the clear object showed that effective focal area otherwise is outside focal area.

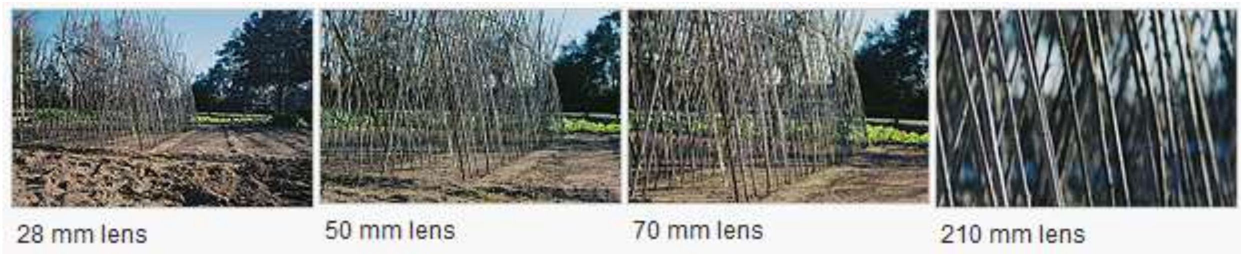

Figure 8:figure shown how lens choice affects angle of view.

Figure 8 shown the focal length different angle of view on different focal length.

2.4. Image Enhancement

Usually, the NIR imaging suffer by low contrast and noise regarding to skin of human by lack of illumination and various of thickness skin [12]. Yakno and team (2011) suggested adjusting the grey level of pixel able to enhance the image and contrast the density level of vein. g(i,j) represent grey level of image pixel (i,j), and g_{max} and g_{min} are the maximum and minimum value of gray level in the input image. This will help the image processing to enhance the location of vein with more contrast quality.

$$g'(i,j) = 255 * \frac{[g(i,j) - g_{min}]}{g_{max} - g_{min}} \tag{1}$$

Whereas, pure gray level adjusting is not fully applicable, the combination of Contrast Limited Adaptive Histogram Equalization (CLAHE) and Fuzzy Histogram Hyperbolization (FHH) having a most significant improvement of image compare to others technique. Means, CLAHE only focus on part of image for enhancement. Cumulative distribution function (cdf) is first calculated for each region of window size w_x by w_y.

$$i_{enh(i)} = \frac{cdf(i) - cdf_{min}}{(w_x \times w_y) - cdf_{min}} \times (L-1) \tag{2}$$

CLAHE and FFH method will be easier to operating if calculated apart, which is both calculated by segmentation like CLAHE alone then follow FHH calculation. In this part, Fuzzy

Histogram Hyperbolization (FHH) is a sequencing work for retune the contrast of image in order to resynchronize the image by fuzzier β [13].

1) Gray Level Fuzzification:

$$\mu(g_{ij}) = \frac{g_{ij} - g_{min}}{g_{max} - g_{min}} \tag{3}$$

2) Modification of Membership Function: where fuzzier, β is € [0.5 2]

$$\mu'(g_{ij}) = [\mu(g_{ij})]^{\beta} \tag{4}$$

3) Gray Level Defuzzification which regenerate new image of gray level.

$$g'_{ij} = \left(\frac{L-1}{e^{-1}-1}\right) \times \left[e^{-\mu(g_{ij})^{\beta}} - 1\right] \tag{5}$$

Figure below show the image of low contrast and enhancement with justification of binary detection.

Figure 9: left image is original image, whereas middle is after enhancement. Right hand side image is the detection of binary of image. [12]

Figure 9shown the image after binary converted from the original image which not clears.

Regarding to MATLAB handbooks, histogram can show the intensity characteristic of image in table [20]. So, we able to determine the region of extraction in any picture especially while the picture in high noise condition.

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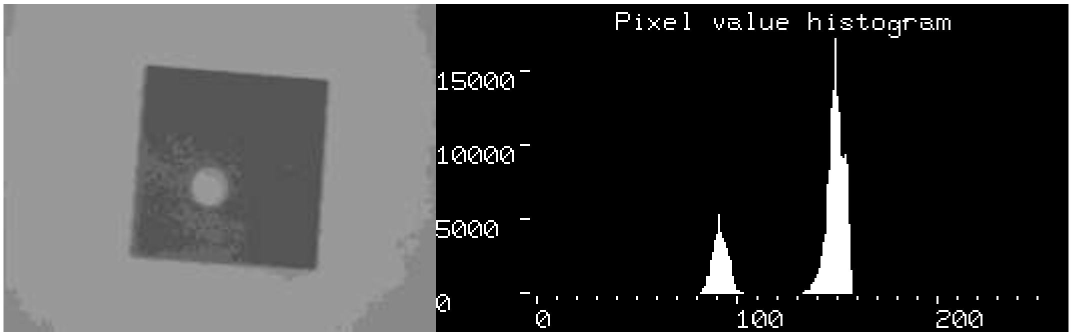

Figure 9: picture above shown the effect of histogram on picture.

Figure 10 shown the histogram of an image. For briefly explanation, 0 of gray scale color represent black and 255 is white. The characteristic of picture accumulate and form a graph according to the intensity. So, histogram approaches able to extract the noise that hidden in image in order to increase the contrast of subject [21][22][23][24]. One of the famous image enhancement technique belong with histogram is histogram equalization. In short, histogram equalization is to enhance and reinforce the quality of picture, by vary the range of dynamic range, intensity, and contrast of picture [21][23][25][26]. The result after using histogram equalization approach has shown as below. At last, MATLAB library for histogram equalization is available in open source webpage [27].

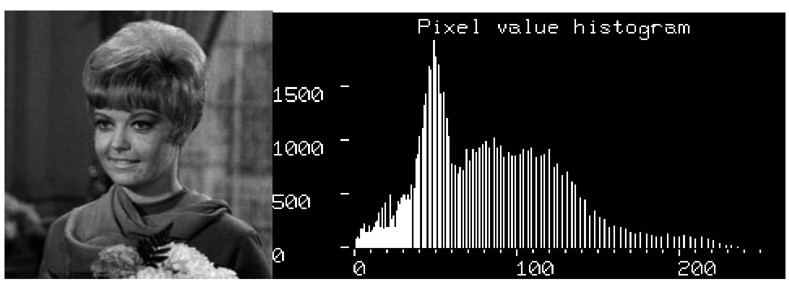

Figure 10: image before apply histogram equalization.

Figure 11 shown another image enhancement technique is called gamma correction or exponential operator which modifies gray scale image and logarithmic transform to change the dynamic range of image. But, it only enhances high intensity pixel values [28][29][30][31]. MATLAB coding explanation is available in open source webpage [32].

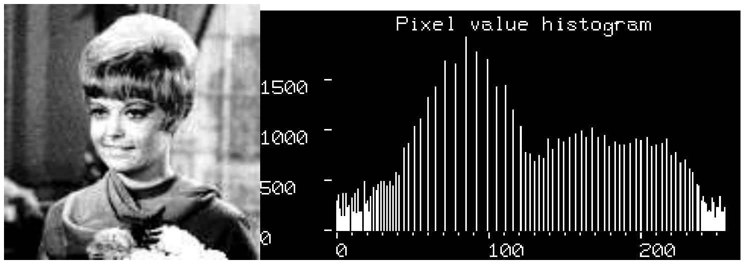

Figure 11: image before apply histogram equalization.

Figure 12 shown the similar function that able to bring out same effect as gamma correction is image adjustment that available in MATLAB, imadjust. The adjustment function is to mapping intensity amount in image then saturated at low and high intensities return to the picture [33].

	
(a)	(b)

Figure 12: (a) Image before image enhancement. (b) Image after image enhancement.

Figure 13 shown the another technique that include in MATLAB programming which is image intensity adjustment from one level to another and improve the contrast of image significantly.

2.5. Frangi Filter

Frangi filtering system is a well-known vessel enhancement system which able to localization vessel and three-dimensional blood vessel. So, it will able to open a possibility which able to detect vessel depth [19]. Simultaneously, noise and background suppression by Frangi will show the vessel maximum intensity projection and volumetric display.

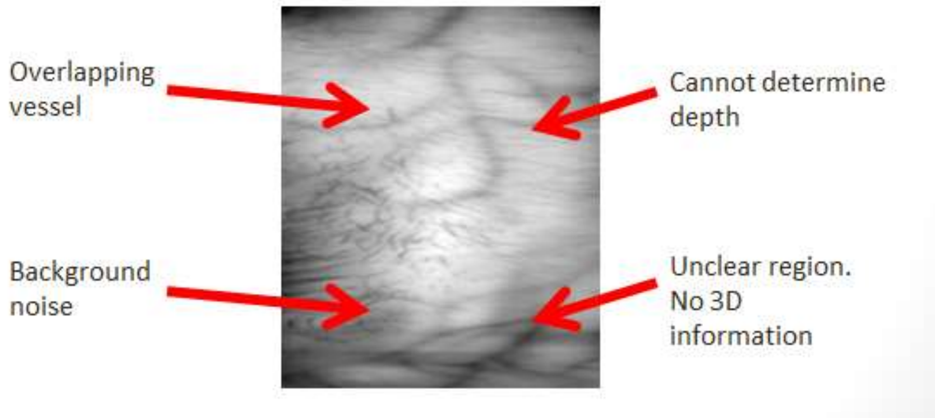

Figure 13: the problem of raw picture that capture by camera which relationship of overlapping and fuzzy area.

Figure 14 shown vein detect by webcam is not clear and blood vessel overlap to each other. So, the exact location of vessel is hard to justify.

Figure 14: the localization and 3D imaging of blood vessel by Prof Fangi [19].

Figure 15 shown, Frangi filtering able to determine the exact position and depth of several of vessels.

$$L(\mathbf{x}_o + \delta\mathbf{x}_o, s) \approx L(\mathbf{x}_o, s) + \delta\mathbf{x}_o^T \nabla_{o,s} + \delta\mathbf{x}_o^T \mathcal{H}_{o,s} \delta\mathbf{x}_o \quad (6)$$

Formula of Frangi Filtering which showing the localization of vessel method. L, is image matrix and the x0 representing pixel point and δ representing the consecutive interval which neighbor of pixel with that pixel in scale, s. it consider Taylor expansion based on point x0.

$$\text{L}(X_0, s) = \text{Gaussian convolution}$$

$\delta X_0^T \nabla_{0,s} + \delta X_0^T H_{0,s} \delta \text{X}_o$ = Third order directional derivative which corporate with Hessian

By the way, the S scale is represented by the scale of direction of derivative between region inside and outside which measure the contrast between the differential of inside and outside.

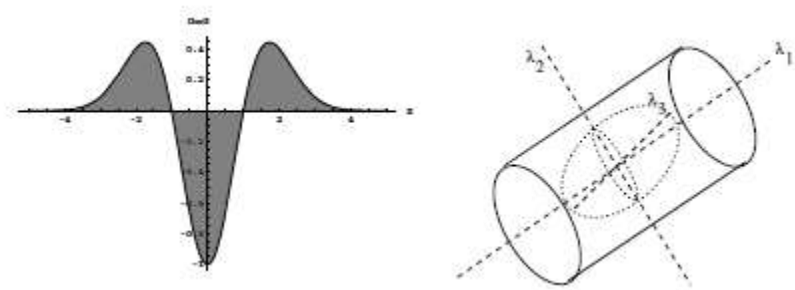

Figure 15: Gaussian kernel probes second order derivative in (-s, s) and ellipsoid on local directional curvature principle. [19].

$$\mathcal{H}_{o,s} \hat{\mathbf{u}}_{s,k} = \lambda_{s,k} \hat{\mathbf{u}}_{s,k}$$

$$\hat{\mathbf{u}}_{s,k}^T \mathcal{H}_{o,s} \hat{\mathbf{u}}_{s,k} = \lambda_{s,k}$$

Based on Figure 16 displayed, eigenvalue analysis is obtaining the direction of local second order structure of the image that able to decompose. So, vessel computation requires a discretization of the orientation space on structure. Based on formulae above, Hessian $H_{0,s}$ all compute at range of s then the Eigen value homologous to k-th eigenvector (normalized) $\widehat{U}_{s,k}$.

Since the Eigen value is corresponding to k-th of sequence, so smallest magnitude between $|\lambda_1| < |\lambda_2| < |\lambda_3|$ representing a relationship between different structure detection with $\widehat{U}_1$ which signified the direction along vessel, and $\widehat{U}_2$ *and* $\widehat{U}_3$ form a orthogonal plane. same theory, λ_2 *and* λ_3 indicate brightness/ darkness.

Table 4: A table showing relationship between lamda1, lamda2 and lamda3.

λ_1	λ_2	λ_3	Structure
0	0	0	No noticeable structure
-	0	0	Plate-like, bright
+	0	0	Plate-like, dark
-	-	0	Line-like, bright
+	+	0	Line-like, dark
-	-	-	Blob-like, bright
+	+	+	Blob-like, dark

Nevertheless, the Deviation of a plate-like structure will be:

$$\mathcal{R}_A = \frac{|\lambda_2|}{|\lambda_1|}, \quad \mathcal{R}_A \in [0,1] \subset \mathbb{R} \tag{6}$$

Similarity to blob-like structure:

$$\mathcal{R}_B = \frac{|\lambda_3|}{\sqrt{|\lambda_1 \lambda_2|}}, \quad \mathcal{R}_B \in [0,1] \subset \mathbb{R} \tag{7}$$

Frobenius norm. Second-order-like structure:

$$\mathcal{S} = \|\mathbf{H}[L(\mathbf{x})]\|_F = \sqrt{\lambda_1^2 + \lambda_2^2 + \lambda_3^2}, \quad \mathcal{S} \in \mathbb{R}^{0+} \tag{8}$$

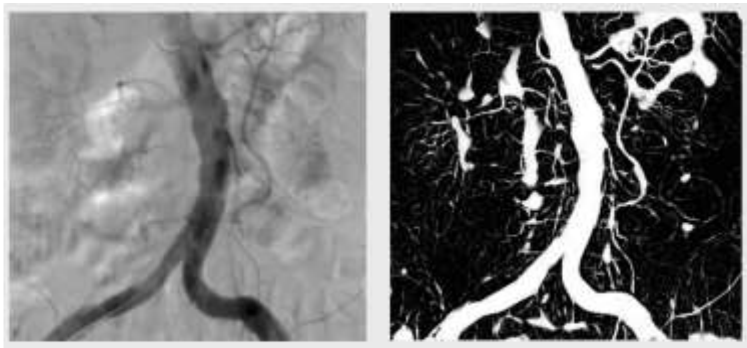

Figure 16: the blood vessel that through 2D image processing.

Figure 17shown the only disadvantages of Frangi Filtering in 2 dimension due to its consist less satisfaction of image information for example depth of vessels is not clear in 2D processing as shown as diagram above. So, it is necessary to compute the 3D effect image based on 2D processing in Frangi Filtering.

CHAPTER 3:

METHODOLOGY / PROJECT WORK

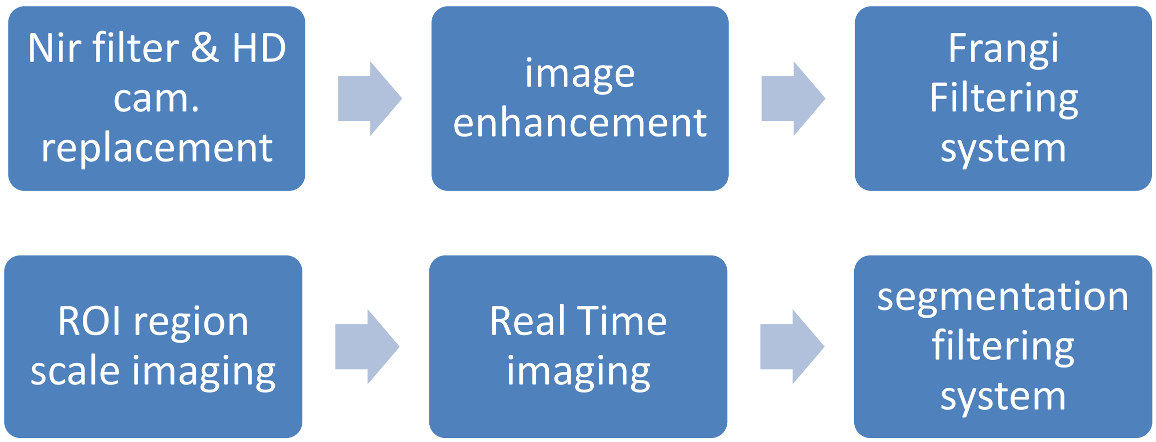

Figure 17: the flow chart of method process

This chapter discuss about the procedure of method to achieve the project objective. In Figure 22 show the main part of method which includes Hardware and software wise.

3.1 NIR filter and HD camera replacement and implementation

Figure 18: the flow chart of NIR replacement

Figure 23,24 and 25 show the process of the NIR replacement. his part is dealing on the hardware implementation, and the smallest camera chosen as shown as picture below and it advantage is small as 2cm wide which easier to attach and hiding in the casing. Then, follow by the NIR filter which order from Edmund optic from Singapore. Now the progress is under pending from implementation.

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Figure 19: the smallest HD camera which going to replace to the glasses.

Figure 20: NIR filter which is most suitable for near infrared filtering.

3.2 Image enhancement

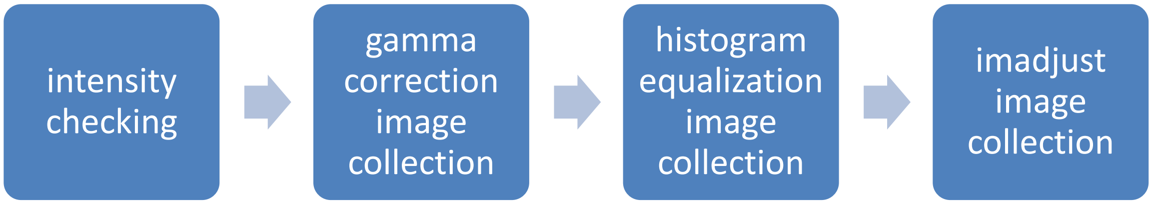


Figure 21: the flow chart of image enhancement finding

Figure 26 show the intensity checking is to make sure the intensity of image of vessel ranging in order to improve the adjustment of contrast of image.

Intensity Checking

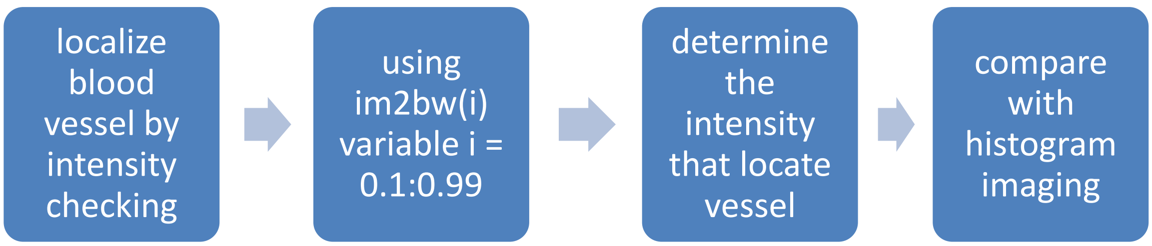


Figure 22: the flow chart of intensity checking in image

Figure 27 show the flow char of intensity checking, which means to check the intensity of image in several of range. The purpose of the checking is to investigate the region of blood vessel hidden in in order to process adjustment of contrast. The reason of discover blood vessel location graphically is to justify the exact region of intensity due to image might including a lot of noise. So, it is not suitable to rely on histogram imaging.

The coding that uses for intensity check attached in appendix (1). And the variable of im2bw(i) is 0.1 to 0.99. Variable of (i) is to determine the first 0.1 scale of intensity of image, in other words, 90% in 255 color scale (more than 225) in image will be 1 and the rest will be 0. Same theory, 0.99 means the color scale more than 2.55 will be 1 and the rest will be 0.

The graphical image of intensity will display in sequence, the range of blood vessel intensity will be determine. So, particular intensity will be using for image adjustment coding in frangi filter. Histogram of image will be compare with the blood vessel intensity range.

Image collection (gamma correction, histogram equalization, imadjust):

Obtain object which apply gamma correction, histogram equalization and imadjust on image for comparing result in Frangi Filter, the coding have attached in appendix (2).

3.3 Frangi Filtering System

Based on the online source [33], have converted the algorithm to coding which able to process the blood vessel by determine depth and provide 3D information. But, the only disability of this algorithm is only provided for detect 2D vessel in x-ray and 3D detect in CT volume. So, based on previous method, the comparison of image is needed for quantify a clear imaging enhancement technique. Figure 28 shown the relation of algorithm process the images.

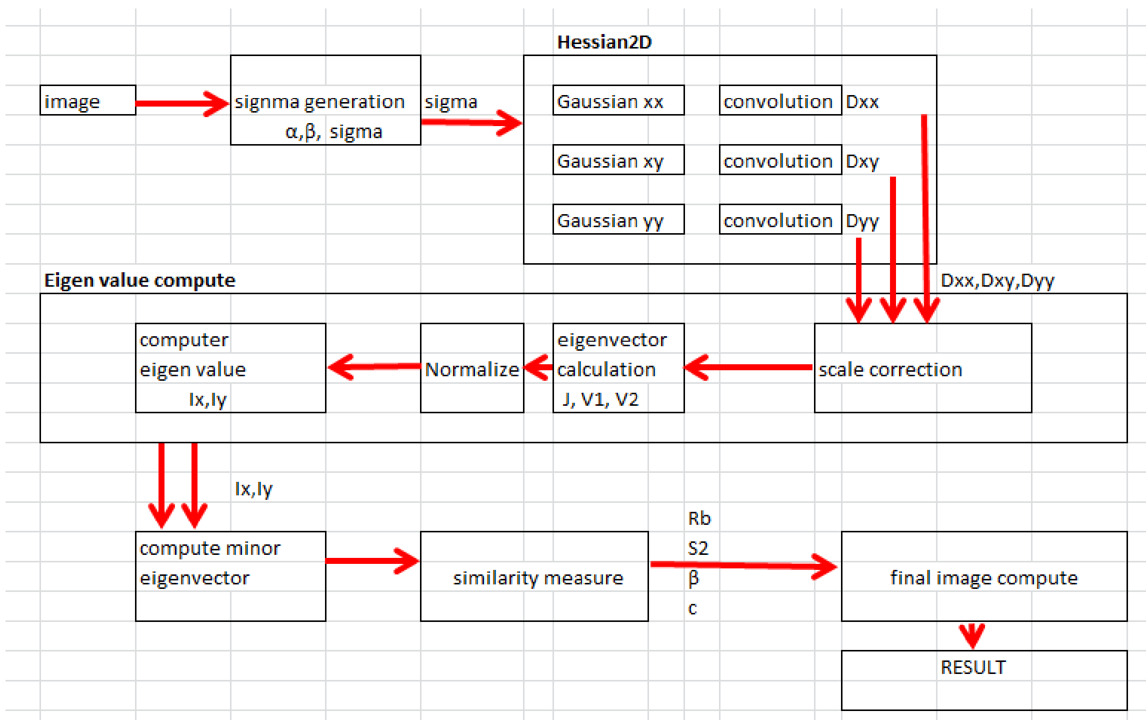


Figure 23: the block diagram that shown the relationship between Hessian2D and eigen value computation.

Regarding to the algorithm, the more contrast different between blood vessel to background, the most possible to generate a high quality of result.

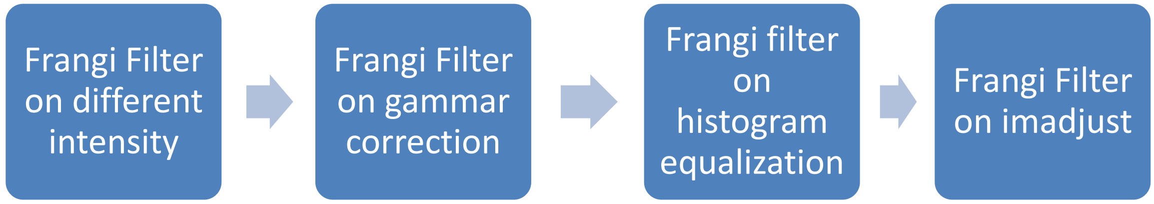


Figure 24: the comparison of different approach on Frangi Filtering effect

Figure 29 and 30 shown the comparison between different approach effect of frangi filtering. Although binary value image unreliable for processing compare to gray scale image, because the information that consist in image is too limited to 2 edge instead of 255 in gray scale. However, it consist the most direct and simple information as well as least noise in an image. So, it is a good technique to justify the hypothesis which is more contrast, clearer image.

Also, as stated in literature Review, 3D effect is hard to process based on Frangi 2D filtering. It is due to lack of plane of dimension (2 instead of 3).

(a) (b) (c) (d)

Figure 25: (a,b) the Frangi Filter 2D processing, (a)result of Frangi2D, (b) raw image that using for process, (c,d) 3D imaging which is the result of Frangi filtering 3D processing.

The combination result of different image enhancement like gammar correction and imadjust is required to confirm the strength and weakness of technique. The coding have attached in appendix (3).

3.4. ROI region and scale Imaging

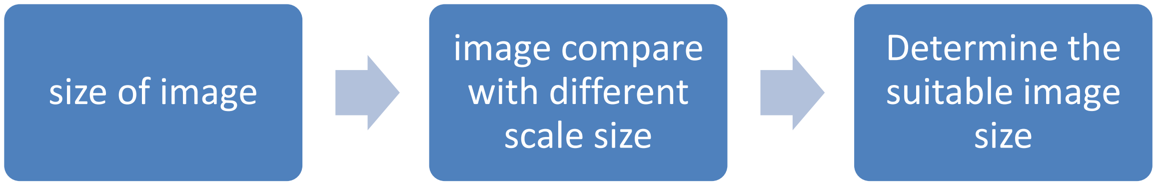


Figure 26: The scale size of picture finding which suitable for Frangi processing.

Based on the Figure 31 which is Frangi Filtering behavior, it is process image data with compare to the neighbor pixel in order to determine different layer of image (3D effect). However, most of the time different size of image consist different size of noise. So, if able to convert big scale picture into small scale it is more able to filter the noise with clearer contras. Then, picture with high contrast able obtain the clearer Frangi Filtering result.

By using the rescale function, image that rescale and send to Frangi filtering process in order to determine the suitable image size for most suitable Frangi filtering image. The coding included in appendix(4).

3.5. Real Time Imaging

Previously, vein detect has been done by using Frangi filtering system which achieved vein 3-dimentional effect (depth, localization and clear differentiation between properties).One of the crucial part of this project is to allow user to locate the vein while wearing vein detector glasses. So that, delay, picture shifting and noise is not allowed in that particular moment.

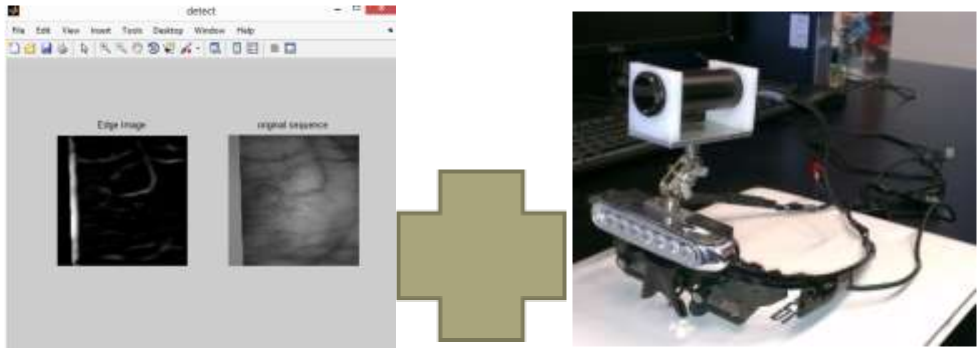


Figure 27: the combination between NIR camera and Vuzix glasses to perform real time imaging.

Based on Figure 32, to achieve real time screening is a hard task in MATLAB due to the programming structure is different with C++, so that it will slower then any real time screening SDK.

The method that using for real time imaging is show as Figure 33:

1. globalization variable
2. parsing input and environment
3. window locking which only updating frame instead of whole window refresh
4. investigate performance by using “profiler”
5. TIC/TOC assisting profiler to investigate processing unit time.
6. using MEX-TOOL module in order to using compiler directive for MEX generate reasonably fast code than conventional way.

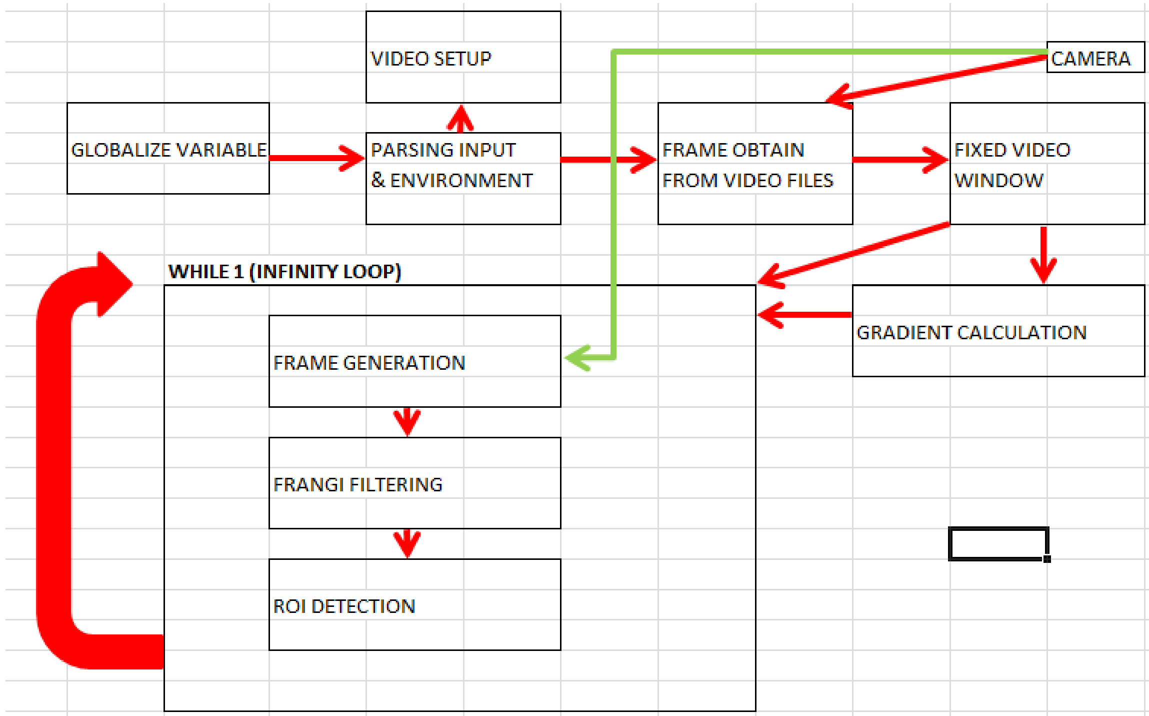


Figure 28: the block diagram that describe the algorithm of real time imaging processing in matlab.

Parsing input & environment: choosing the lowest resolution for processing.

Fixed video window: latest frame only required update in same window instead of refresh a whole new window per frame.

Gradient calculation: mex module handle which able to compile more faster real time screening.

3.6. Segmentation filtering system

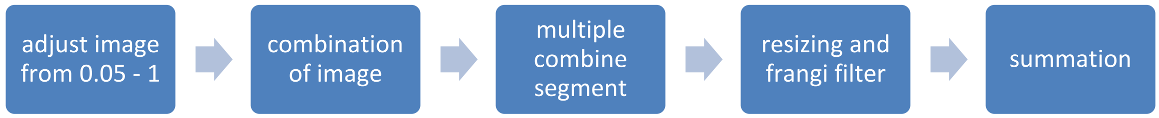


Figure 29: The combination of all algorithm for 3D imaging

Figure 34 shown the method to maximize the contrast of image, adjustment of image has to be adjusting in 0.1 short intervals. The small interval also called as segmentation in intensity basis, which is detect to particular range of intensity and classify as new image.

Figure 35 shown the process after segmented image based on intensity, it is like 2 kind of disk one smaller, A another bigger, B. The bigger disk, A consist some element that B does not need it. So, when both disk have to combined (A+B) without that unused element, cropping method in B is needed. However, cropping algorithm required a single cropping procedure, because the combination of A and B is a subset for another bigger disk C.

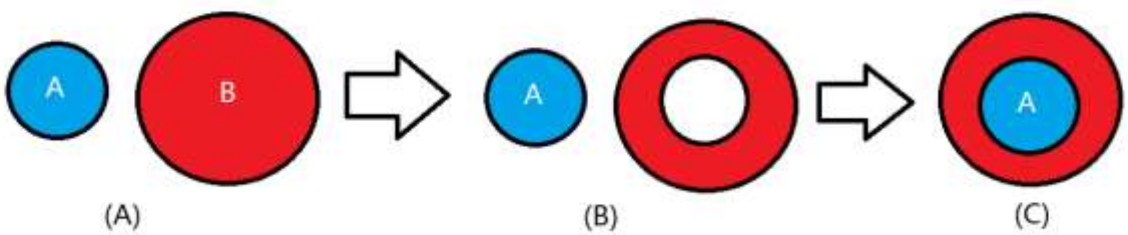


Figure 30: (A) disk B consist element from disk A, (B) cropping algorithm with size of disk A, (C) combination of A and B.

Algorithm for cropping (B): (B – (B-A)/2)

Resizing of image is rescaling of image picture from original size to 150 – 200 pixel square.

3.8 Project Work

This is the part which indicates what work has already done [red color] and which still pending [green color].

Table 5: the project work schedule among 2 semester of final year project.

Final year batch	**1**								**2**							
Weeks	**6**	**7**	**8**	**9**	**10**	**11**	**12**		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
NIR filter design calculation																
NIR filter ordering and implement																
NIR filter measurement for design																
Image enhancement																
Image enhancement and comparison																
Frangi Filtering System localization vessel by intensity																
Frangi Filtering behavior checking																
Frangi Filtering located blood vessel																
Frangi Filtering compare with histogram imaging																
Frangi Filtering comparison on different image enhancement approach																
ROI region scale imaging																
Real Time imaging																
Segmentation filtering system																

CHAPTER 4:

RESULT AND DISCUSSION

Result:

Result that obtain from simulation and testing including the angle tuning with servo motor, image enhancement to prove that image processing and angle tuning is able to achieve by communicate with MATLAB as well as synchronization with iris.

4.1. Localize the region of blood vessel

Figure 38 show the image that using for black and white adjustment.

Figure 31: References picture that using for determine intensity.

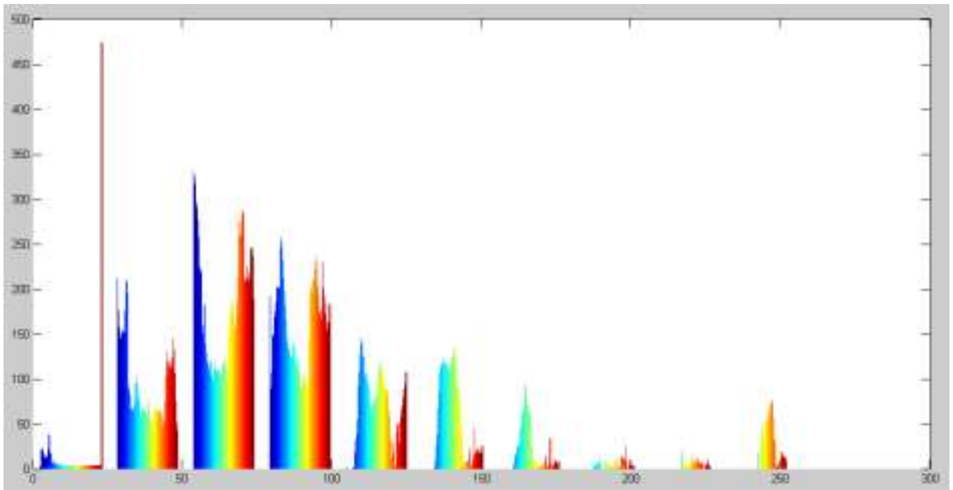
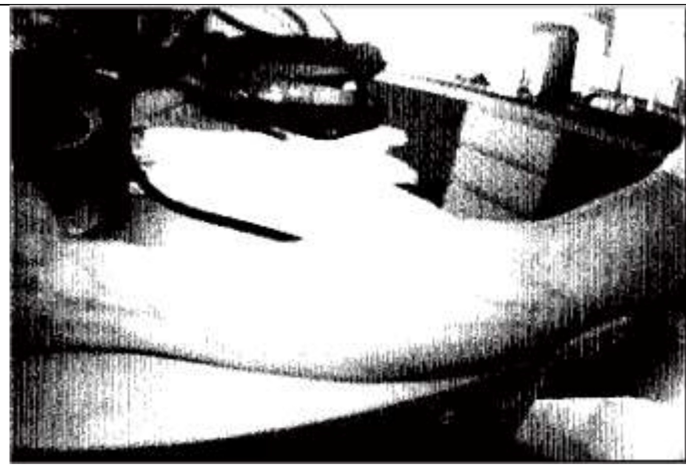
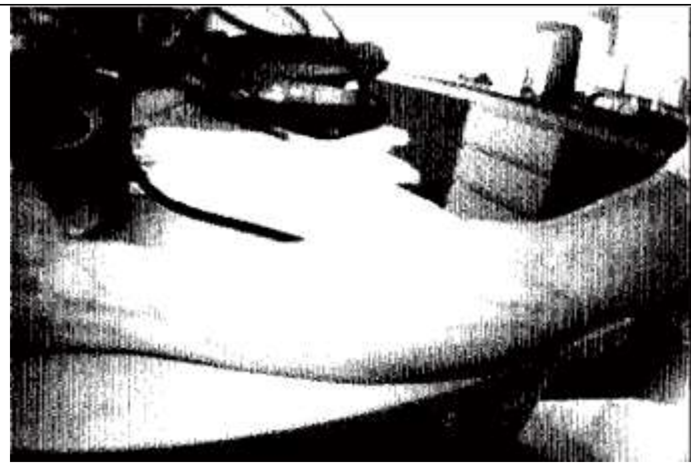


Figure 32: showing that quantity of pixel in color 0-255.

Figure 39 show the blood vessel are lying on the range from150 to 255 which around 0.58 scaling – 1 in im2bw based on the reference picture.

Table 6: table below shown the graphical diagram after compress based on intensity scale.

Scale, i	Picture (im2bw, i)
0.1	

0.2	
0.3	
0.4	

0.5	
0.6	
0.7-0.99	

Table 6 show the blood vessel lied on the intensity 0.2-0.6. in other words, color scale from 102 to 204 consider as blood vessel region. Regarding to histogram, bandwidth that match to the blood vessel region is 100 to 255.

Table 7: Collection of image (gamma correction, histogram equalization and imadjust)

Method	Image after modified.
Gamma correction	
Histogram equalization	
Imadjust	

Regarding to table 7, there have 3 kind of method that attract feature of image.

Gamma correction will intense the whole image to darker on blood vessel, but the problem of this method will increase the intensity of background which consist a lot of noise make whole image.

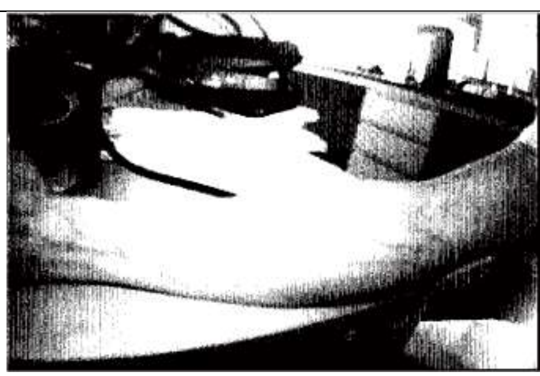
Histogram equalization able to filter the background noise, but it also decreases the quality of blood vessel region. The decreases cause the Frangi filtering not able to classify the region of blood vessel.

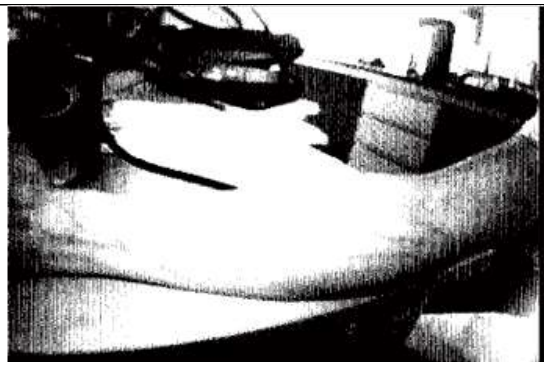
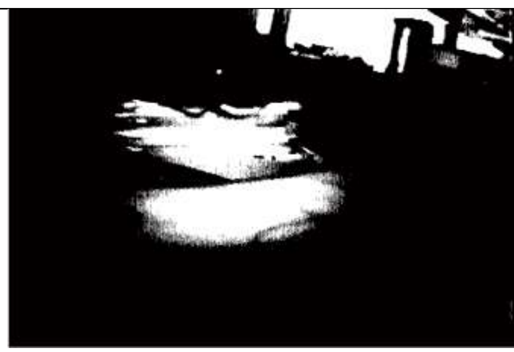
Imadjust have filtered the background while enhance the blood vessel. However, apparently the effect of adjustment stills not enough to clean all the noise and enhance the blood vessel.

The result of Frangi filtering will be show on next session which compares the effective of enhancement system.

4.3. Frangi Filtering System

Table 8. Comparison of im2bw image and after processing with Frangi Filtering

scale	Previous	After
0.1		
0.2		

0.3		
0.4		
0.5		
0.6		

0.7 - 0.9		

As the result from table 8, the Frangi Filtering is working based on the region of feature which is Frangi Filtering will not able to process data when the image is too much noise, contrast is not in the discussion because this raw data is binary value, so that intensity and contrast of image is not available in here.

Table 9: Comparison of gamma, histogram and imadjust image and after processing with Frangi Filtering

method	previous	Frangi Filtering
gamma		
histo		
Im adjust		

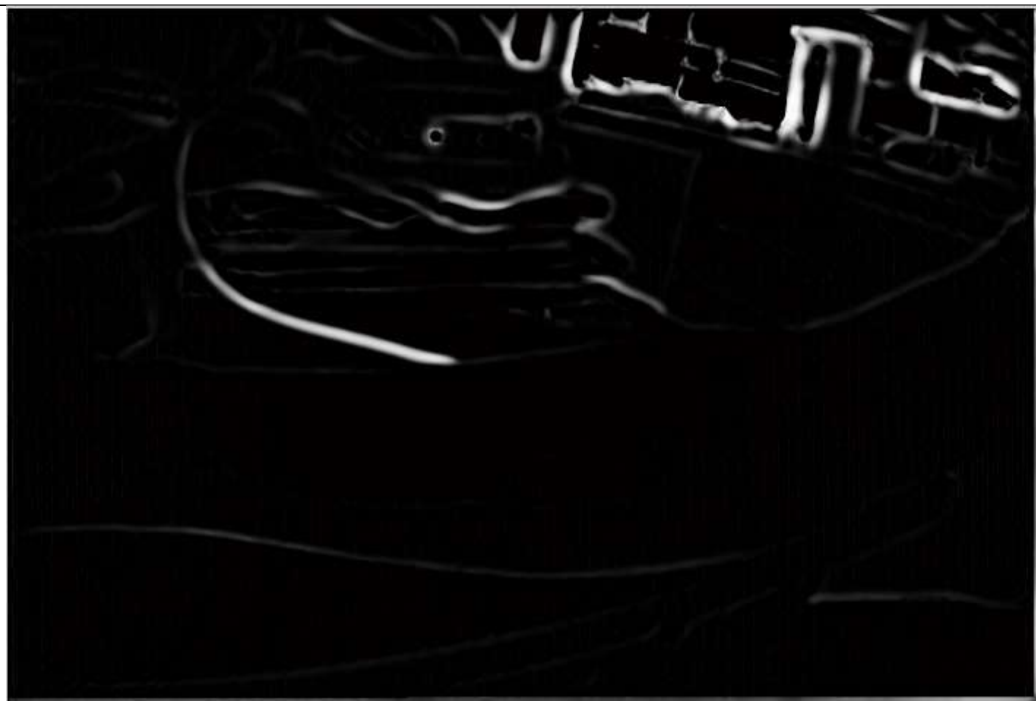
Table 9 show the Gamma correction although able to improve the contrast of, but it cannot able to successful process in Frangi filter because the different between blood vessel and surrounding is not clear.

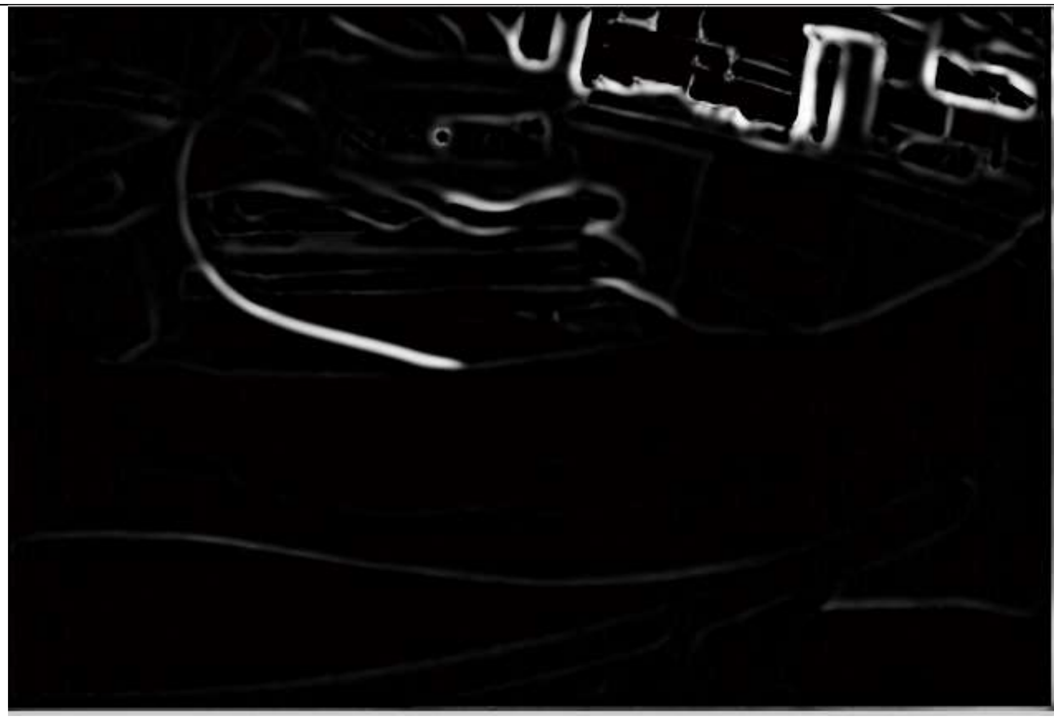
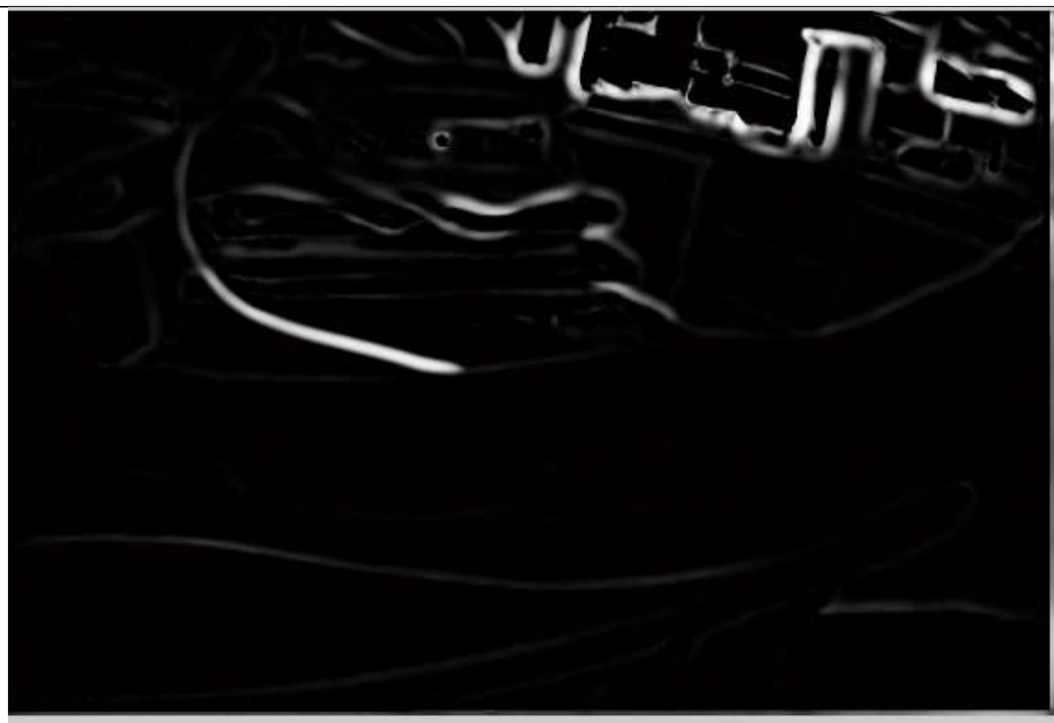
Histogram equalization able to provide the most clear frangi result as shown as above, but also the noise is the most ever compare to other 2 methods. Technically, histogram equalization required some noise filtering for better image quality.

Last but not least, imadjust provide a less noise frangi filter like gamma correction. Although the track of blood vessel not as clear as histogram. However, imadjust is more flexible because it has an option to adjust the intensity as user wish.

4.2. ROI and scale imaging

Table 10: showing the relationship between scale of image and frangi filtering system

Size of image	Frangi Filter
473x710	

426x639 (0.9x)	
379x568 (0.8x)	

332x497 (0.7x)	
284x426 (0.6x)	

237x355 (0.5x)	
190x284 (0.4x)	

142x213 (0.3x)	
95x142 (0.2x)	

48x71 (0.1x)		

Regarding to the result that show at table 10, most significant image scale is 0.4 to 0.6 which 190-284 in height, 284-426 in width. The reason of high scale image not able to process is due to the image consist certain amount of noise that resist frangi filter process image, and too low scale image lead pixilation of image.

4.3. Real Time Imaging

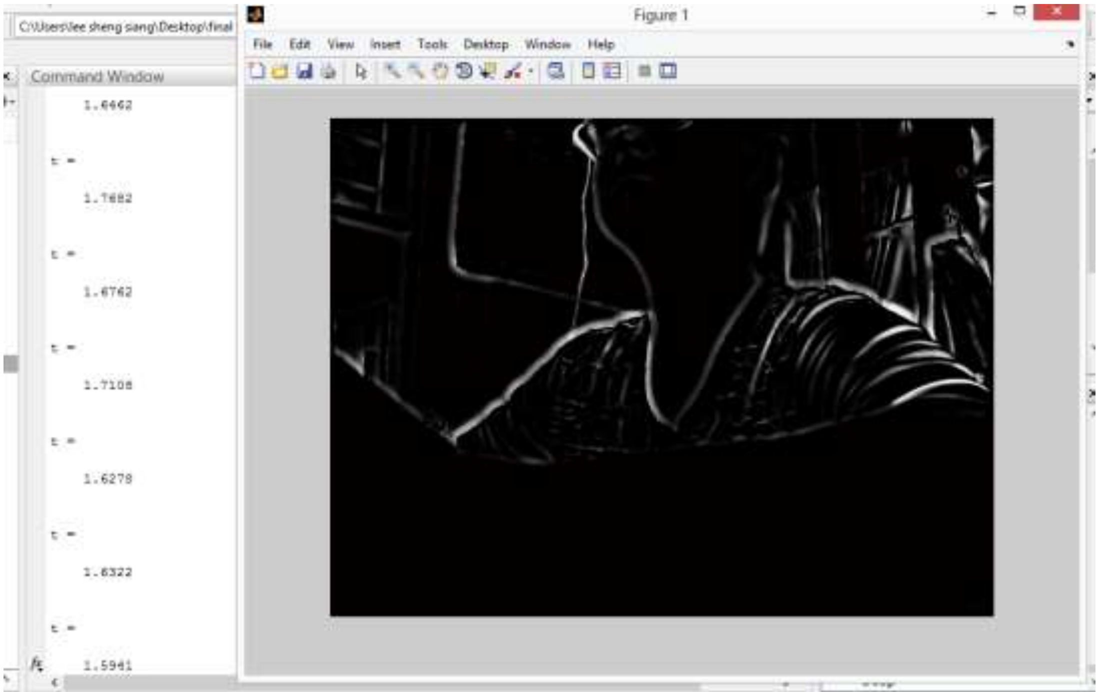


Figure 33: Conventional image Processing without using MEX – file which bypass clocking from MATLAB to CPU.

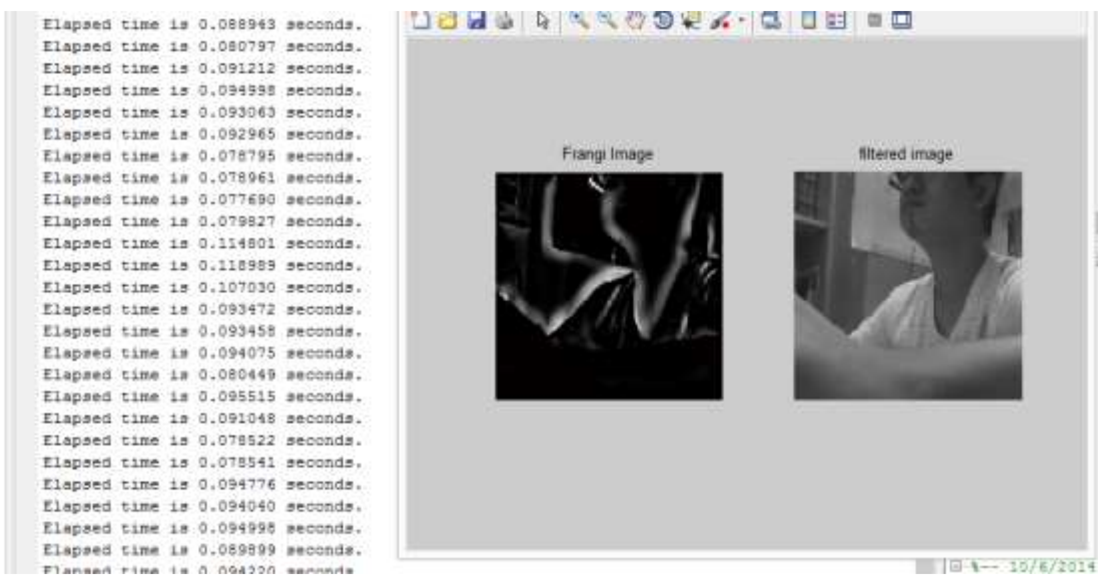


Figure 34: Imaging Processing with using MEX – file which bypass clocking from MATLAB to CPU.

As the result shown at Figure 40 and 41, conventional way to process frangi filtering is not applicable which is require at least 1 to almost 2 second for each frame. Image processing have enhanced 28times than conventional method. Performance increase significantly, even have more timing to processing the filtering image in same window.

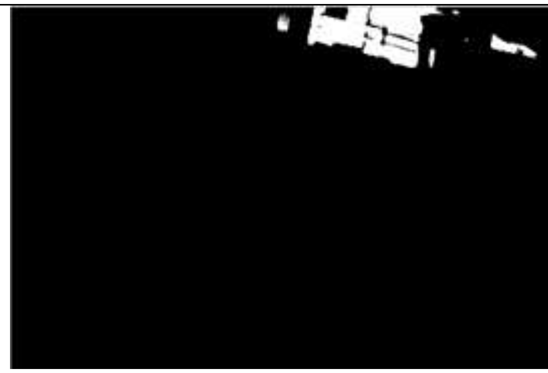
4.4. Segmentation filtering system

Adjust image

Table 11: table below shown the image adjusting contrast

Imadjust	Image (contrast from 0 to 1)
0.05 to 0.15 (J10)	
0.15 to 0.25 (J9)	
0.25 to 0.35 (J8)	

0.35 to 0.45 (J7)	
0.45 to 0.55 (J6)	
0.55 to 0.65 (J5)	
0.65 to 0.75 (J4)	

0.75 to 0.85 (J3)	
0.85 to 0.95 (J2)	
0.95 to 1 (J1)	

As shown as table 11, images from J1 to J10 are overlap to each other from J1 (since black color). So, the formula for this session will be:

$$J(n)_{n=1\to 10} = A_{i,i+0.1,0,1,img}\ ,\ \ i(n) = \{\ 0.05, 0.15, 0.25, \dots, 1\}.$$

J = New image after segmentation

$$A_{i,i+0.1,0,1} = image\ adjustment\ formula, img = converting\ image$$

$$i\ is\ lower\ scale\ ;\ i + 0.1 = \max scale\ ; 0,1 = \max contrast$$

Also, the higher segment consist the element to lower segment.

$$J_n \subset J_{n+1} \;\;,\;\; 1 < n < 9$$

J1 is subset of J2 and J9 is subset of J10

4.5. Combination of segment with cropping

Table 12: First layer combination of segment

Segmentation	Result
J2 – J1 (K1)	
J3 – J2 (K2)	
J4-J3 (K3)	

J5 – J4 (K4)	
J6 – J5 (K5)	
J7 – J6 (K6)	
J8 – J7 (K7)	

J9 – J8 (K8)	
J10 – J9 (K9)	

Table 12 show double combinations and 5 sets of image have successfully merged.

$$K(m)_{m=1\to 9} = J_{m+1} - (\frac{J_{m+1} - J_m}{2})$$

Table 13: Second layer combination of segment.

Double segmentation	Picture	Double segmentation	Picture
K2 – K1 (L1)		K3 – K2 (L2)	
K4 – K3 (L3)		K5-K4 (L4)	
K6 – K5 (L5)		K7 – K6 (L6)	
K8 – K7 (L7)		K9 – K8 (L8)	

So, Table 13combination formulation as present as below.

$$L(o)_{o=1\rightarrow 8} = K_{o+1} - (\frac{K_{o+1} - K_o}{2})$$

Table 14: Third layer combination of segment

Triple segmentation	Picture	Triple segmentation	Picture
L2 – L1 (X1)		L3 – L2 (X2)	
L4 – L3 (X3)		L5 –L4 (X4)	
L6 – L5 (X5)		L7 – L6 (X6)	
L8 – L7 (X7)			

So, Table 14 ombination formulation as present as below.

$$X(p)_{p=1\to7} = L_{o+1} - (\frac{L_{p+1} - L_p}{2})$$

Table 15: Forth layer combination of segment

Ultimate Segmentation	Picture	Ultimate Segmentation	Picture
X2 – X1 (Y1)		X3 – X2 (Y2)	
X4 – X3 (Y3)*		X5 – X4 (Y4)*	
Y4* – Y3* (Y5)			

So, Table 15 combination formulation as present as below.

$$Y(q)_{q=1\to4} = X_{q+1} - (\frac{X_{q+1} - X_q}{2})$$

$$\mathrm{Y}(5) = Y_4 - (\frac{Y_4 - Y_3}{2})$$

As the result shown, the ending product of hands is Y1, Y2 and Y5 *(combination of Y3and Y4).

Then the image will resize and send to Frangi Filter for processing.

Table 16: Result of Frangi Filter

Name	Result
Z1	
Z2	
Z3	

Table 16 show the beauty of imaging processing, which 3D able to determine with 3 kind of different approach based on 3 kind of 2D image. Z1, Z2 and Z3 showing how the 3D imaging is determine. The final result of FINAL = Z1 + Z2 + Z3 will showing the depth of the blood vessel as clear as Prof. Frangi did on MRI processing or so called 3D processing.

4.6. FINAL image and original image comparison

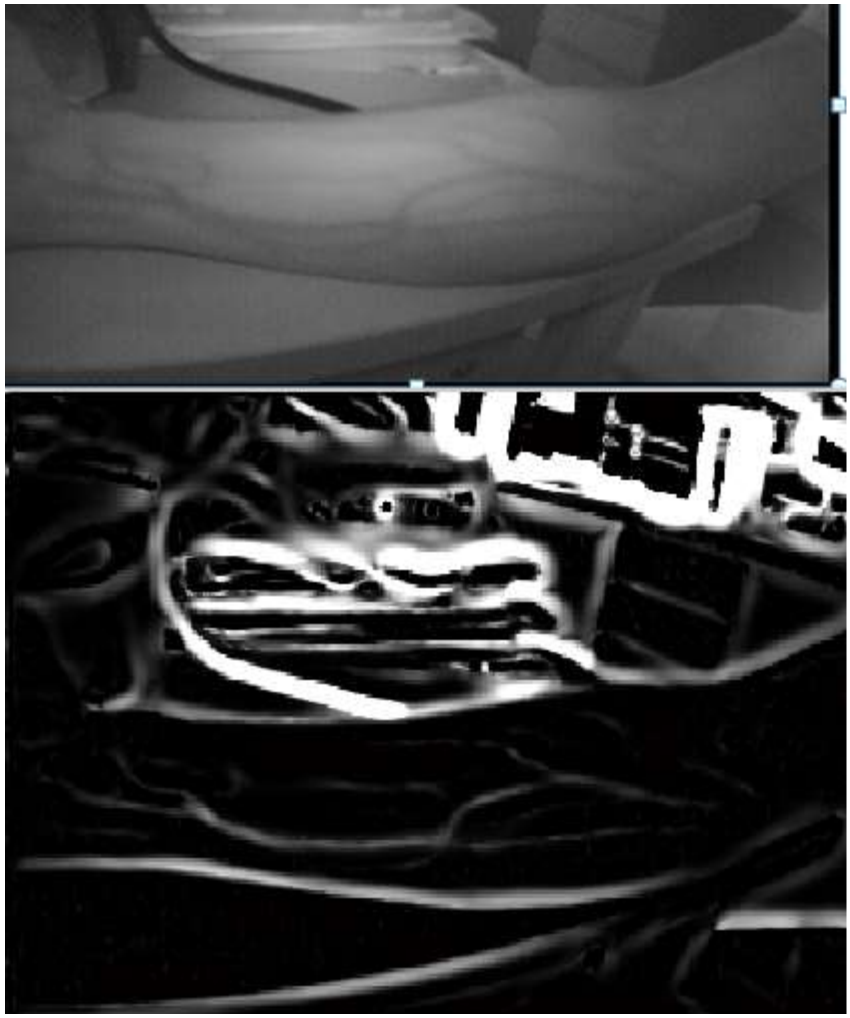


Figure 35: The comparison of original image and 3D image from Frangi filtering system.

Figure 42 show the comparison of original image of 3D image from Frangi filtering system which about to show the property of blob area of hand. 3D image is the sense of image property of image which allow the system to apply monte carlo algorithm to get the solid image.

4.7. Discussion

1. First, Histogram is not suitable to use in this situation, because the contrast is not sharp enough.

2. Image enhancement have choose imadjust be the formula that using for sharpen the image.

3. Although the NIR filter still haven arrive to Malaysia, but still we able to do the rest of work in order to make sure that no part of work will left behind.

4. IRIS detection is not available in short time.

5. ROI region scale imaging have justify image pixel with 150 to 200 square is the most suitable scale for frangi filtering system.

6. Real Time Imaging have improve 28 times speed than conventional method or 0.07 second per frame.

7. Segmentation filtering system have combined different approach and managed to convert 2D imaging to 3D image.

CHAPTER 5:

CONCLUSION & RECOMMENDATION

As conclusion, the project consider successfully done and compute a self-formulation that makes 2D image to have 3D effect. However, formula that combined all subset formula still required to find lecturer for further discussion. Then, servo angle tuning algorithm successful created for performing with iris movement. In short, this project have proven the possible for detecting depth and locating human vein with invisible method

Recommendation will be;

1. Order the equipment as fast as possible within 2 weeks' time..

2. Compute a complete formula for the algorithm of image enhancement that makes 2D image have 3D effect.

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APPENDICES:

1. Intensity Checking

```
I = imread('go.png');

% im2bw vary from 0.1 to 0.99
a1 = im2bw(I,0.1);
a2 = im2bw(I,0.2);
a3 = im2bw(I,0.3);
a4 = im2bw(I,0.4);
a5 = im2bw(I,0.5);
a6 = im2bw(I,0.6);
a7 = im2bw(I,0.7);
a8 = im2bw(I,0.8);
a9 = im2bw(I,0.9);
a99 = im2bw(I,0.99);

% histogram
hist(double(rgb2gray(I)));

figure, imshow(a1);
figure, imshow(a2);
figure, imshow(a3);
figure, imshow(a4);
figure, imshow(a5);
figure, imshow(a6);
figure, imshow(a7);
figure, imshow(a8);
figure, imshow(a9);
```

2. image collection (gamma correction, histogram equalization, imadjust)

```
I = imread('go.png');

I = rgb2gray(I);

%gamma correction
 hgamma = ...
   vision.GammaCorrector(2.0,'Correction','De-gamma');
gamma = step(hgamma, I);

%histogram equalization
histo = histeq(I);

%image adjust
adj = imadjust(I);

figure, imshow(gamma);
figure, imshow(histo);
figure, imshow(adj);
```

3. Frangi Filtering on im2bw image

```
addpath('bw to rgb');
addpath('frangi_filter_version2a');

I = imread('go.png');

% im2bw vary from 0.1 to 0.99
a1 = im2bw(I,0.1);a2 = im2bw(I,0.2);
a3 = im2bw(I,0.3);a4 = im2bw(I,0.4);
a5 = im2bw(I,0.5);a6 = im2bw(I,0.6);
a7 = im2bw(I,0.7);a8 = im2bw(I,0.8);
a9 = im2bw(I,0.9);a99 = im2bw(I,0.99);

a1 = FrangiFilter2D(a1);a2 = FrangiFilter2D(a2);
a3 = FrangiFilter2D(a3);a4 = FrangiFilter2D(a4);
a5 = FrangiFilter2D(a5);a6 = FrangiFilter2D(a6);
a7 = FrangiFilter2D(a7);a8 = FrangiFilter2D(a8);
a99 = FrangiFilter2D(a99);
% histogram
%hist(double(rgb2gray(I)));

figure, imshow(a1);figure, imshow(a2);
figure, imshow(a3);figure, imshow(a4);
figure, imshow(a5);figure, imshow(a6);
figure, imshow(a7);figure, imshow(a8);
figure, imshow(a9);
```

4. Rescale of image

```
addpath('frangi_filter_version2a');
a1 = imresize(I,0.1);a2 = imresize(I,0.2);
a3 = imresize(I,0.3);a4 = imresize(I,0.4);
a5 = imresize(I,0.5);a6 = imresize(I,0.6);
a7 = imresize(I,0.7);a8 = imresize(I,0.8);
a9 = imresize(I,0.9);a10 = I;

b1= FrangiFilter2D(double(a1));b2= FrangiFilter2D(double(a2));
b3= FrangiFilter2D(double(a3));b4= FrangiFilter2D(double(a4));
b5= FrangiFilter2D(double(a5));b6= FrangiFilter2D(double(a6));
b7= FrangiFilter2D(double(a7));b8= FrangiFilter2D(double(a8));
b9= FrangiFilter2D(double(a9));b10= FrangiFilter2D(double(a10));

figure, imshow(b1);figure, imshow(b2);
figure, imshow(b3);figure, imshow(b4);
figure, imshow(b5);figure, imshow(b6);
figure, imshow(b7);figure, imshow(b8);
figure, imshow(b9);figure, imshow(b10);
```