CONTACTLESS HEART RATE MONITOR FOR MULTIPLE PERSONS IN A VIDEO

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A project report submitted in partial fulfilment of the requirements for the award of the degree of Bachelor of Engineering (Hons) Electronic Engineering

Faculty of Engineering and Green Technology
Universiti Tunku Abdul Rahman

September 2015

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **CONTACTLESS HEART RATE MONITORING FOR MULTIPLE PEOPLES IN A VIDEO** was prepared by **WONG TING YI** has met the required standard for submission in partial fulfilment of the requirements for the award of Bachelor of Engineering (Hons) Electronic Engineering at Universiti Tunku Abdul Rahman.

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Specially dedicated to

my beloved mother and father

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ABSTRACT

In this project, we have proposed an algorithm to develop a contactless Heart Rate Monitor using video for multiple people. The video is acquired at a rate of 30 fps with the resolution of 640x480. Firstly, the Viola Jones face detector will be used for face detection purposed. After that, the regions of interest (cheeks) are detected with the coordinate geometry algorithm. Then 3 color traces are obtained for every image by applying mean on every single color plane. Fast Fourier Transform will be applied to these traces and peak frequency will be detected after band pass filtering. The conversion between frequencies to bpm will be done. It has been seen that green channel of RGB color modal given the best result for heart rate. The accuracy of heart rate detection for single person is 7.5% and the multiple persons is 11.3%.

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CHAPTER 1

INTRODUCTION

1.1 Background

Heat rate is measured by the number of heartbeats per unit of time, and is expressed as beat per minute (bpm). Heart rate is an important indicator of a person's physiological state and significantly represents its vital signs which are used for basic functionality measurement of the body. According to Richard Stein, M.D., Professor of medicine and cardiology at New York University School of Medicine in New York City, "As you age, the rate and regularity of your pulse can change and may signify a heart condition or other condition that need to be addressed."

Heart Rate Monitor plays huge role in order to show human's fitness level and cardiovascular health. The heart rate measurements are usually used in clinically examination to determine status of the patient. Normally, the heart rates are determined by wrists, inside elbow, side of the neck and top of the foot. In 1902, Einthoven published the first electrocardiogram recorded on a string galvanometer, it opened the way of Electrocardiography (ECG) era which is still using the primary instrument of heart rate monitor for measure beat. These instruments sometime makes patient more uncomfortable since the probe is needed to attach on patient's skin and it will restrict the movement of patient. Another technique is pulse oxymetry or sphygmology which provides low accuracy as compared to ECG and the pulse oxymetry will completely malfunction when the patient has cold hands or a circulatory disorder.

Contactless heart rate monitor would also be useful to measure the Heart Rate of patient whose conditions maybe worsened by contact sensors such as burn victims and infants. Contactless heart rate monitor have different working principles such as Electromagnetic based monitoring system, Laser-based monitoring system, Image based monitoring system and other methods. Image based heart rate monitoring is actually more focused on human's face to capture the phyotoplethysmography (PPG). The PPG can sense cardiovascular blood volume pulse through variation in transmitted or reflection light. It's the principle of absorb light more than surrounding tissue so the variation in blood volume affect the transmission and reflectance correspondingly. Thus, the image based heart rate can provide an accurate heart rate with this principle.

1.2 Problem Statements

The traditional heart rate examining method requires physical contact with human being's in order to display the heart rate reading precisely but eventually this will make them more uncomfortable and inconvenient. This is because some of the patients feel allergy and itchiness when a device is attached on their skin. Besides, contact heart rate device will restrict patient's movement since it needs to be attached and wired. For example, the contact heart rate monitor is hard to apply on children and babies since the babies always roll on the bed while the children are hard to settle down themselves. In addition, infants at risk of sudden infant death syndrome and burn victims more perturbed and worsened by contact sensors (Clifford, Spring 2007). Hence, the contactless heart rate monitor was then introduced for those conditions and this project is focusing on this contactless heart rate monitor.

1.3 Aims and Objectives

This project aims:

- To segment multiple faces in an image
- To measure Heart Rate for single person and multiple persons
- To measure heart rate under different distances and illuminations.

CHAPTER 2

LITERATURE REVIEW

2.1 Photoplethysmography

Photoplethysmography (PPG) is one of the useful methods which is used in contactless heart rate monitoring. The blood volume of blood capillary is actually simultaneously changed with the cardiac pulse (Xiaobai Li, 2014). Thus, the PPG is applied to detect Heart Rate Variability. PPG is an inexpensive method and capable to sensing the Blood Volume Pulse (BVP) by changing in the amount of light reflected or transmitted that can penetrate in depth in skin. According to Hamed Monkaresi (2013), the PPG was actually using the principle of blood that absorbed light more than the surrounding tissues. Besides, the PPG method is measured with implementing the illumination source such as infrared, daylight or other dedicated light sources. The light intensity that reflected from the skin is corresponding to the volume of the tissue blood perfusion (Magdalena Lewandowska, 2011). Therefore, human heart rate can be determined from plethysmographic signal which is captured in the video since the human heart rate is similar to the frequency of cardiac cycle.

2.2 Region of Interest Detection

Detecting and tracking on human bodies is a difficult and challenging part due to different skin color which is one of the issues. Therefore, the contact free Heart Rate detection is needed to use Region of Interest (ROI) as face detection for image analysis. According to Xiaobai Li (2014), they usually detected the region of interest using Viola-Jones face detector and calculate the mean pixel value of ROI for each frame from RGB channels. For first step, the ROI includes the raw pulse signal from face video. Discriminative Response Map Fitting (DRMF) technique was used to detect the face and find the ROI in the first frame, the Kanade-Lucas-Tomasi (KLT) was then performed to track the coordinates of ROI. After that, the background region was uses the Distance Regularized Level Set Evolution (DRLSE) technique to reduce the interference of illumination variation.

Normalized Least Mean Squares (NLMS) filter was used as next step to avoid the interference caused by the flexible motions. There are two rules to define the ROI. First, the eye must be excluded on the ROI due to the blinking might interfere the reading of Heart Rate frequency. For the next rule, the ROI boundary must indent from face boundary to avoid the incident of including the non-face pixels from the background during tracking process. From this tracked ROI, it contains pixels of facial skin which is capable to observe the cardiac pulse with change in color value. From figure 2.1, the yellow line shows the face rectangle and the features inside the ROI are detected and tracked. The red points indicated 66 landmarks and light blue region define to ROI.

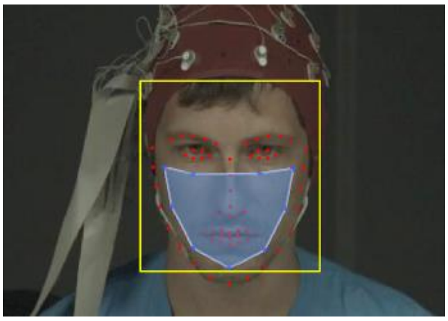

Figure 2.1 ROI detection and tracking during video process.

Another conference paper proposed by Magdalena Lewandowska (2011), rwo different ROI sizes had been made in this analysis. The first ROI are indicating the rectangular region that contains the face region which is selected at first frame in video recording where the second ROI includes the forehead rectangular shaped area. The second ROI follows the rules referring to the calculated coordinate and distance. In addition, it requires the examiner to sit with supine position to improve the accuracy of the algorithm for proper experiment conditions. Moreover, the size or number of channels of ROI is inversely proportional to the noise which means increase in ROI's size or number channels will drop the level of noise. The purpose of performed two different ROI size in this conference paper are to improve the accuracy of heart rate when compared with Electrocardiography (ECG).

Mean heart rate [bpm](measurement time = 30s)				
Patient Id	Web camera			ECG
	zero crossing		fft	
	face ROI	forehead ROI	face/forehead ROI	
1.	87.56	100.67	91.41	87.89
2.	59.32	59.18	58.01	58.59
3.	94.84	104.35	98.44	99.61
4.	60.07	76.85	59.76	58.66

Table 2.1 Heart Rate of Four selected patients

2.3 Elimination of Non-Rigid Movement

An unsolved problem in ROI system is non-rigid movement. For example, facial expressions can create noise and the previous two processes cannot remove it. From figure 2.2, it is shown that the face is still in neutral when at phase 1; the subject started to smile in phase 2 which leads dramatic fluctuation of the signal; then the face started to become stable in phase 2. If the noise segment at phase 2 did not remove, this will lead them to have a big sharp peaks after all temporal filtering process in the next step. This huge peak will significantly affect the power spectral density (PSD) when the signal transfers to frequency domain thus, impede the detection of true pulse frequency and it remaining part of the signal with smoother changes that contributes to the Heart Rate related spectrum. The more stable result was achieved with discarding the largest standard deviation. This process only excludes the noisiest segment which is distorted by sudden non-rigid movement but not all pulse signals (Xiaobai Li, 2014). From figure 2.2, the top curve shows that the noisy signal where the face was smiling in phase 2; the standard deviation of each segment of top curve divided by vertical lines as shown at middle bar chart; the last curve shows that the shearer which discard three segments of phase 2 and re-concatenated signal.

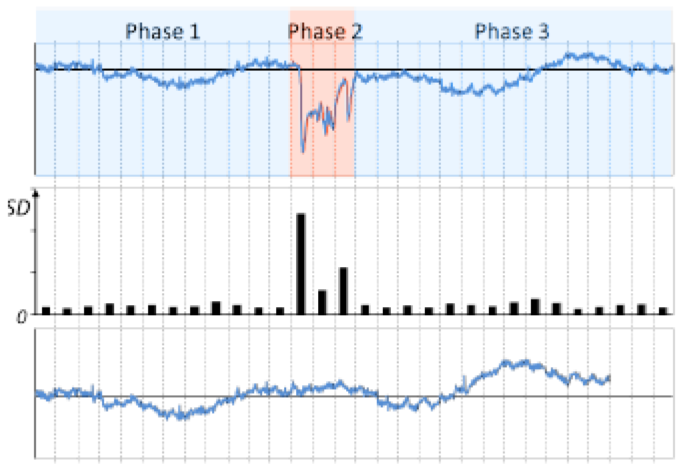

Figure 2.2 Motion elimination of pulse signal distort by sudden non-rigid motions.

2.4 Temporal Filtering

Xiaobai Li (2014) have applied several temporal filters to remove the frequencies that are out of the range of interest. They have used three filters which are found to be helpful for previous research in Heart Rate measurement. The first filter they use is detrending filter which is based on smoothness priors approach. This is useful for reducing the slow and non-stationary trend of the signal. The second useful filter in this research is moving average filter which is capable to remove random noise using temporal average of adjacent frames. The last filter they used is Hamming window based finite impulse response band pass filter with the cutoff frequency of [0.7,4] Hz. The pulse signal will be converted to the frequency domain after filtering and the power spectral density distribution is estimated by using Welch's method.

2.5 Noise Reduction

According to Hamed Monkaresi (2013), motion artifacts or change in illumination source is one of the issues that influences the ICA analysis and accuracy of frequency computations. In order to overcome these issues, threshold for maximum change (12bpm) in pulse rate between successive measurements was introduced to reject the artifacts. These algorithms will reject it and searched in the range of operational frequency for frequency corresponding to next highest power to meet the constraints. The algorithms will retained the last computed pulse frequency once there're no frequency

2.6 Skin Pixels Detection

According to Kual-Zheng Lee (2012) skin color detection is quite effective in segmentation human body and thus they used it as face detection, hand gesture analysis and objectionable image filtering to reduce the search space. To make it more precise, more than 200 images were collected and manually labeled skin/non-skin pixel for training. The skin pixels was differentiated by using threshold function T_{skin}. Higher skin threshold value will decrease the shadow effect but eventually will also reject some useful pixel on skin. Skin color detection will process a pixel that is similar to skin color with their pattern information and convert it into binary image. In another paper by Qi Zhang (2014), the accuracy of heart rate signal was depend on how precise of facial contour tracking, identification and extraction. Firstly, they convert the image from RGB format to YCbCr and the conversion formula was shown as below:

$$\begin{aligned} Y &= 0.257R + 0.504G + 0.098B + 16 \\ Cb &= 0.148R - 0.291G + 0.478B + 128 \\ Cr &= 0478R - 0.368G - 0.071B + 128 \end{aligned} \tag{2.1}$$

The skin color was then threshold with value below:

$$\begin{aligned} V_p &= 1 \; 120 \le Cr \le 170, \;\; 100 \le Cb \le 150 \\ V_p &= 0 \qquad else \end{aligned} \tag{2.2}$$

Based on this paper and researches, the region of face was covered at center with 70% of width and full height of the facial region for easier their subsequent calculations.

2.7 Blind Source Separation

The lossless Principle Component Analysis (PCA) and Independent Component Analysis (ICA) had projected the data onto set of axes which are determined by nature of data. Due to the axes of projection, the BSS was then created and the sources are determined through the application of internal measure without using any prior knowledge of data structure (Clifford, Spring 2007). Ming-Zher Poh (2010) mentioned that the Blind Source Separation (BSS) is a technique used to remove the noise from the physiological signal. To improve the contactless Heart Rate measurement, the BSS technique had applied to recover unobserved signals or sources from a set of mixed signals without prior information about mixing process (Hamed Monkaresi, 2013).

2.8 Independent Component Analysis

The Independent Component Analysis (ICA) is statistical and computational technique for revealing the independent signal from a set of observations that underlie set of random variable measurements, or signals. By applying ICA, the PPG signal can separate from three color (RGB) traces and transferred it's into frequency domain in order to find the maximum power spectrum under the range of Heart Rate frequency (Xiaobai Li, 2014).

According to Xiaobai Li (2014), green channel trace contains the strongest plethysmographic signal among RGB color channels. In fact, green light is better than red light absorbed by hemoglobin. Besides, the green channel trace can penetrate deeper into the skin as compared to the blue light to probe the vasculature. By applying only green channel trace; the ICA can separate the source with more accuracy for measuring Heart Rate. As observed figure 2.3, the output of green channel trace is more significant to obtain as compared to output of other color channel traces. Figure 2.3 shows the region of interest (ROI) is automatically detected using a face tracker. Then, the ROI is decomposed into RGB channels and spatially average to obtain the raw RGB traces. The ICA is applied on normalized RGB trace to recover the 3 independent source signals.

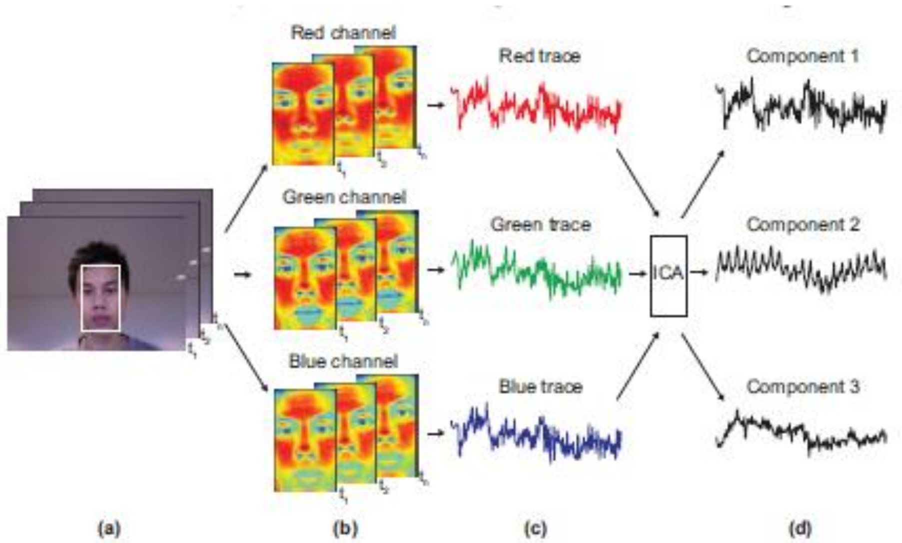

Figure 2.3 Cardiac Pulse Recoveries.

2.9 Fast Fourier Transform

Fast Fourier Transform (FFT) was applied to obtain the power spectrum of selected source signal. After calculating power spectrum of all selected components, the maximum spectrum among all the spectra was picked in order to find the cardiovascular pulse frequency. The frequency of the maximum spectrum was known as the operational range from 0.75Hz to 4.0Hz which corresponds to the heart rate measurement between 45bpm and 240bpm (Hamed Monkaresi, 2013). According to T. Pursche (2012), they found that the reference measurement had much higher correlation than peak detection algorithms by analysing the computed power spectrum of the data.

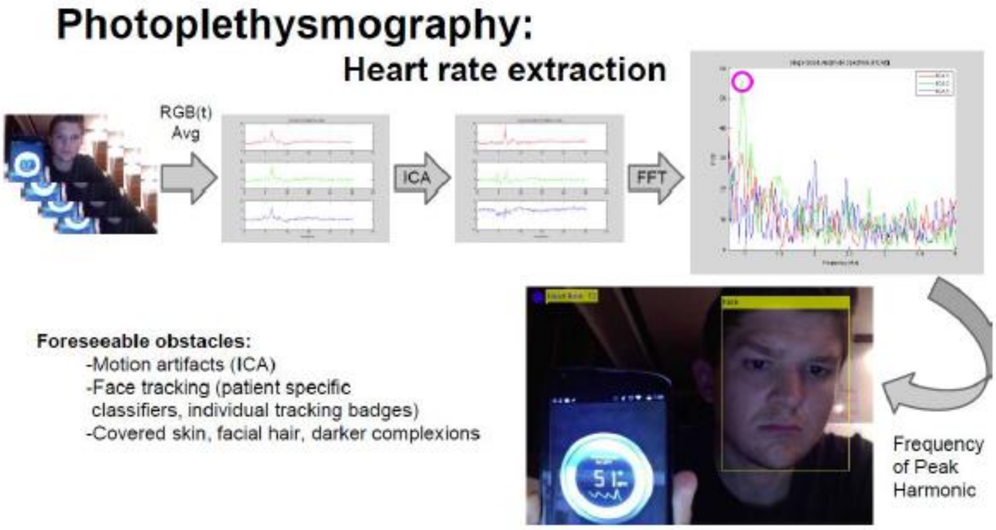

Figure 2.4 Method for Heart Rate monitoring by using Blind Signal Decomposition and spectral analysis. The spectral analysis was done by using Fast Fourier Transform

2.10 Previous Research

In Heart Rate Monitoring with camera, most of the researches have more than 90% of accuracy which made a huge contribution on this field. For the research conducted by Hamed Monkaresi(2013), 10 volunteers participants involved in their research in both studies. The mean age of the participants were about 26.7 years old (8 males, 2 females) with 80% of Caucasians and 20% of Asians. This research was approved by the University of Sydney's Human Ethnics Research Committee for collecting the data.

The computer with window XP installed was located in front of participant.. The Video was record by using Logitech Webcam Pro 9000 with applying 24-bits RGB at 30 Frame per Seconds (fps) with pixels resolutions of 640 x 480 pixels which mounted on the monitor. The Electrocardiogram (ECG) was applied to determine the accuracy of this system. There are three different environment study conducted in this experiment. The first study was conducted in a normal room with illumination source which combination of sunlight and fluorescent ceiling light. The environment of second study was actually applying the environment of first study but the participants were allowed to use internet and other resources. The third study was conducted inside the gymnasium with a female participant and the illumination source was only fluorescent ceiling light and the participant was requested to cycle, there are 7 different levels of experiment. As conclusion, the heart rate reading is more precise as compared to applying the Independent Component Analysis (ICA) and K-Nearest Neighbor (KNN) technique where the Mean Absolute Error are less than 3%.

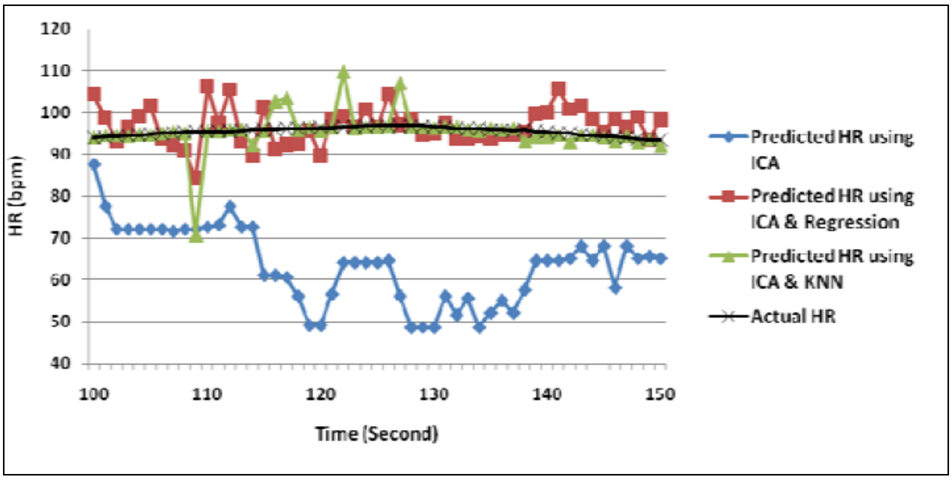

Figure 2.5 Actual Heart Rate and Predicted Heart Rate reading during 3rd study which extracted from Electrocardiogram (ECG)

Another research which conducted by Ming-Zher Poh (2010), 12 volunteers (10 males and 2 females) participated in study, around 18-31 years old. Video recording was using the webcam embedded in MacBook Pro. The video were able to record up to 640 x 480 resolutions with 24 bits RGB colors at 15 frame per seconds. This research was approved by the Massachusetts Institute of Technology Committee on use of human. To make the statistics more precise, varying skin color volunteers were recruited, involving Asians, Africans and Caucasians. The finger probe with 256Hz was applied to measure the Blood Volume Pulse (BVP) for validation purposed. This research was applied by the illumination source of sunlight. The participants were seated in front of laptop with a distance of around 0.5m. Two videos with duration of 1 minute were recorded for every participant. The first video requested the participant to sit properly in front of laptop whereas the second video encouraged the participant to interact naturally with the laptop but not for large and rapid motion. As conclude for this research, the accuracy was successfully more than 95% and capable to measure multiple participants in simultaneously.

Table 2.2 Summary of Heart Rate Detection System

Author/Year	Technique Used for data collection	Advantage	Disadvantage	Accuracy	Algorithms Used
Xiaobai Li, 2014	Face Detection, ROI is whole face	Outperformed as compared to other four methods.	Head rotation in huge angle.	Average error rate about 6.87%	ICA, KLT, Fast Fourier Transform
Ming-Zher Poh, 2010	Face Detection , ROI is whole face	Capable to detect in Different skin color, can make slow and small movement , able to detect heart rate in multiple people	Can’t make a huge movement	About 5% error	ICA, trace normalization, Fourier transform
Hamed Monkaresi, 2013	Face Detection, ROI is whole face	Low mean absolute error with applying ICA and KNN	Participant was restriction for turning and titling their head (>45^{o}) while	Mean Absolute Error (MAE) with less than 2%	ICA, JADE, Fourier Transform, KNN

			recording		
Magdalena Lewandowska, 2011	Face Detection, ROI is forehead	Didn't mentioned	Participant must be motionless and the ROI size must be bigger	>95%	ICA, PCA, Fourier transform, Blind source separation
Qi Zhang, 2014	Skin Color detection, ROI is whole face	Didn't mentioned	Make sure participant head must be in full height of facial region	1-5% error	ICA, Normalized Processing, Band pass Filter, Fast Fourier Transform
Sungjun Kwon, 2012	Face detection, ROI is whole face	Portable, application installable in any smartphone	Inconsistent result with varying the smartphone	Error of raw trace and independent source are 1.04% and 1.47%	ICA, trace normalization, Fourier Transform
Kual-Zheng Lee, 2012	Skin color detection, ROI are various body part such as Head/neck, inner arm, outer	Capable apply at various body parts but the best result is at head/neck region	Illumination effects and body movement	Average error 3.22%	ICA ,Fourier transform, peak detection using local extreme values

	arm and palm				
Yong-Poh Yu, 2013	Face detection, ROI are eye and the upper lip of the mouth	Didn’t mentioned	Didn’t mentioned	Root mean square errors less than 2.4%	STFT, ICA, Blind source separation
T. Pursche, 2012	Face detection, ROI are forehead, area around the eye and nose and mouth	Didn’t mentioned	Change in illumination	Didn’t mentioned	Peak detection, ICA, Fourier transform
Lonneke A.M. Aarts, 2013	Face detection, ROI are uncovered body parts like head, arm and thorax	Didn’t mentioned	Capable apply at various body parts	Poor result with less than 50%, median result in 50 up to 90% and good result is more than 90%	Fourier analysis, JTFDs

CHAPTER 3

METHODOLOGY

3.1 Cost Analysis

To verify and determine the mean error of our contactless heart rate monitor, it needs low variation and high accuracy heart rate monitor equipment. Table 3.1 provides a comparison of different heart rate monitor used in different paper.

Table 3.1 Comparison of Heart Rate Monitor

Author / Year	**Product Description**	**Cost (MYR)**
K. Z. Lee, P. C Hung, 2012	Pulse Oximeter Product Rossmax SA310	1182.55
M. Lewandowska, J. Rumiński, T. Kocejko, J. Nowak, 2011	AsCARD electrocardiograph (AsCARD MrGrey V 201 Aspel)	76742.69
Y.P Yu, B.H. Kwan, C.L. Lim, S.L. Wong, P. Raveendran, 2013.	Polar Heart Rate Monitor	Didn’t mentioned about model

For our study, we have chosen two heart rate monitor Polar FT1 with chest strap and OMRON automatic blood pressure monitor (HEM-7120). It can been seen that the Polar Heart Rate Monitor is the cheapest among them and POLAR brand has been rank as Top 5 brands for Fitness purpose heart rate monitoring. Hence, we choose FT2 Polar Heart Rate Monitor as our heart rate monitor equipment. The OMRON Automatic Blood Pressure was recommended as the second heart rate monitor for 2nd user, this device is convenient as it only determines the blood pressure and heart rate attached on user arm region. Besides, this OMRON Automatic Blood Pressure Monitor's accurate as referred to reading of the Polar FT2 Heart Rate Monitor. The percentage difference between these 2 heart rate devices is about 1% or 2%. For Polar FT2 Heart Rate Monitor, it can determine the heart rate continuously as the user has to attach chest strap on the body and the monitor are not far away from chest strap within specified range while the OMRON Automatic Blood Pressure Monitor determines the average heart rate and blood pressure within the time user pressed start on it.

Table 3.2 Percentage difference in Heart Rate

	Polar FT 2 HRM (Bpm)	OMRON BPM (Bpm)	Percentage difference (%)
1	87	87	0
2	84	83	1.19
3	84	82	2.38
4	84	83	1.19
5	85	84	1.18
Average	84.8	83.8	1.18

Table 3.3 Cost of the experiment equipment

Equipment Description	Cost (RM)
OSRAM Automated Blood Pressure Monitor (HEM-7120)	148.80
Polar FT1 with chest strap	259.00

3.2 Project Management

Project flow is quite important in order to manage our project schedule. Firstly, the literature must are viewed to understand the algorithms and methods. The Gantt chart in table 3.4 is quite important to schedule our project and make sure our progress is keep on the track.

Table 3.4 Gantt Chart of FYP 1 schedule

Activities / Progress	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selecting project title														
Project proposal														
Project title selected														
Literature Review														
review MATLAB code														
Conduct experimental study:														
Face Detection and Tracking														
Image Processing														
Fast Fourier Transform														
Result analysis														
Write FYP thesis														
Hardcopy Submission														

Table 3.5 Gantt Chart of FYP 2 schedule

Activities / Progress	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Selecting project title														
Project proposal														
Project title selected														
Literature Review														
review MATLAB code														
Conduct experimental study:														
Face Detection and Tracking														
Image Processing														
Fast Fourier Transform														
Result analysis														
Write FYP thesis														
Hardcopy Submission														

3.3 Methodology

The experiment setup consists of web camera, OMRON Blood Pressure Monitor and POLAR hear rate monitor with chest strap. The duration of video was about 2 minutes recorded by TOSHIBA webcam. The resolution of this video is 640 x 480 pixels and the frame rate is about 30fps. The sequences of frames will saved in AVI format without any compression. The Polar Heart Rate Monitoring was collecting the heart rate reading while the video is in recording and process the heart rate. Face detection and tracking still got weaknesses because it needs participants to sit closer to webcam within 1m to ensure the webcam capable of collecting the PPG signal.

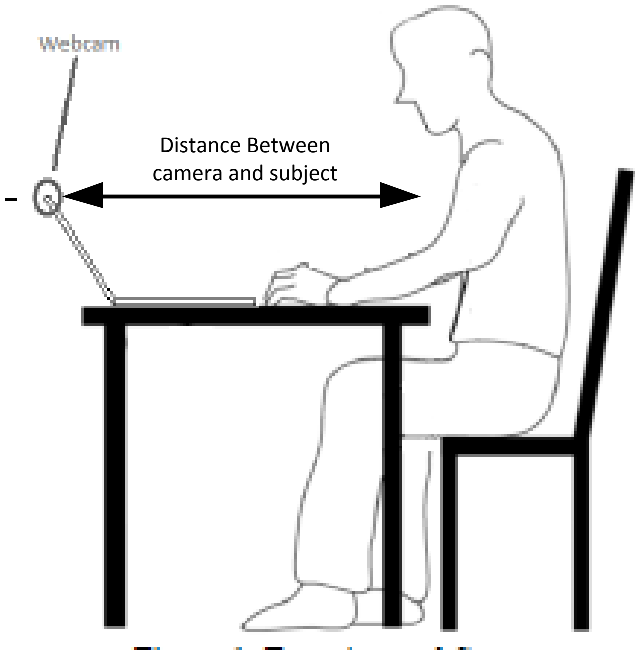

Figure 3.1 Experimental Setup

The experiment was conducted with 3 volunteers for 3 cases. Each case was conducted by 2 different subjects. During the measurement, they were sitting in front of the webcam with variable distances in order to see the effect of distance on measurement. The measurements were performed indoor and have some illumination source such as fluorescent light and sunlight.

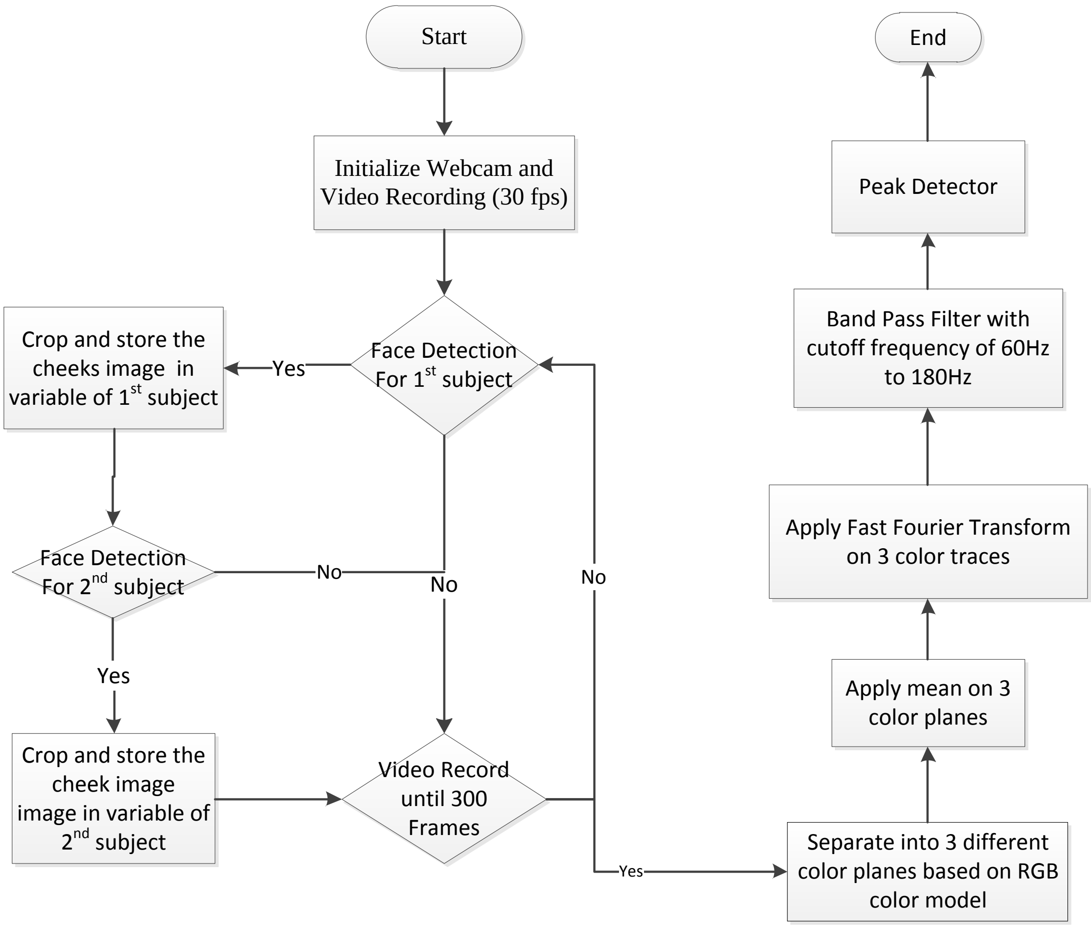

Figure 3.2 Flow Chart of Heart Rate Detection System

3.4 Face Detection and Tracking

This analysis was performed for two Regions of Interest (ROI) sizes and this face detection and tracking was done by Viola Jones techniques using MATLAB function. The first ROI was focused on whole face whereas the next ROI was focused on the cheek. The second ROI was actually segmented according to the coordinates of the cheeks. Thus, this might create another problem where it does not sallow participant to turn his/her head so that the PPG signal can be obtained from the participant's cheeks. Since this heart rate monitor is done continuously so the face detection must be done at every single frame of video. The duration of video is an unknown as according to the illuminant. The video will take about 10 seconds but sometime the video will take about 1 minute. This all about how long the Viola Jones scan all the image.

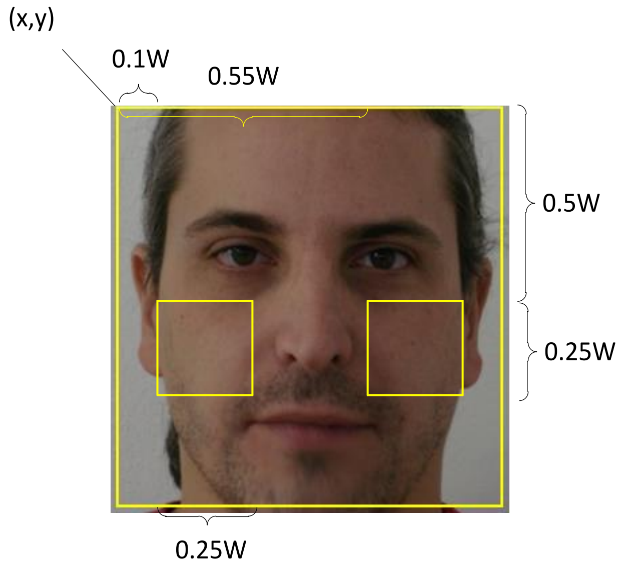

Figure 3.3 The dimension and coordinate of boxes to segment the cheeks region for heart rate processing purpose

To segment the region of cheeks, the coordinate and region of cheeks must identify by studying the boxes that are created by viola jones face detector. The first two coordinates actually represent the coordinates of the origin which are located at the top left of the big box as shown in figure 3.3. The last two coordinate indicate size of the width for x and y axis. The scaling was actually identified by placing the box into the Microsoft Visio. From the information above, it can form an equation to create the box for cheeks to segment it as well.

The equation to find the box of Left Cheek:

$$(X_L, Y_L, W_L, W_L) = (X+0.1w, Y+0.5W, 0.25W, 0.25W) \qquad (3.1)$$

The equation to find the box of Right Cheek:

$$(X_R, Y_R, W_R, W_R) = (X+0.55W, Y+0.5W, 0.25W, 0.25W) \qquad (3.2)$$

The boxes of segmented cheeks were only containing value instead of information of pixels. To obtain the information of user's cheeks, the crop technique is needed to crop and store the cheeks region into a specified variable from an image per frame. The system will also clear the boxes itself once the face was disappeared in order to delete the previous yellow box.

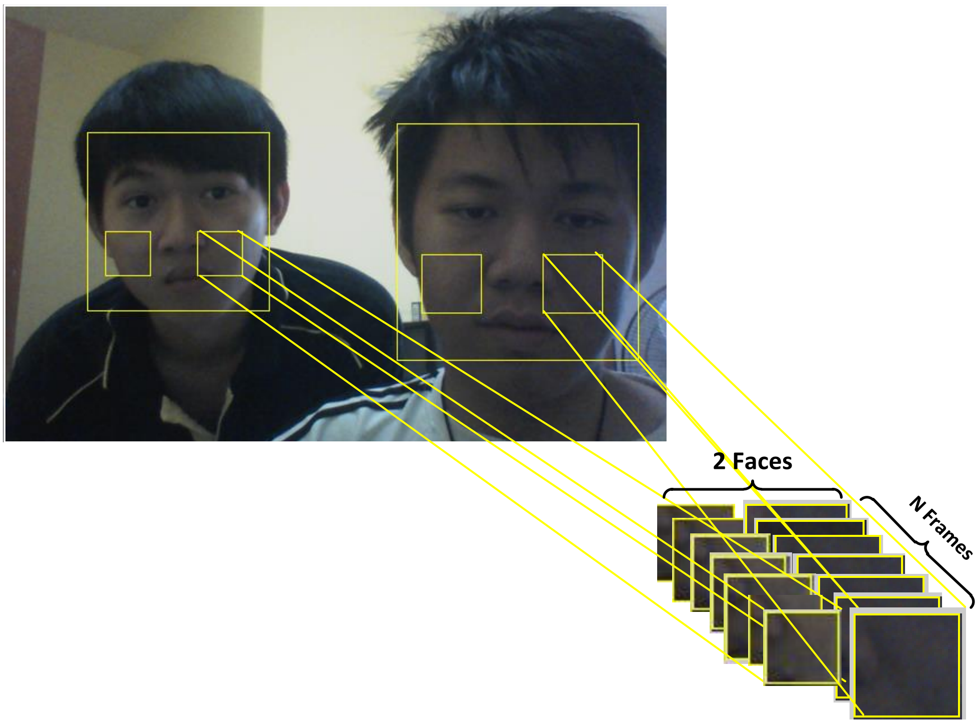

Figure 3.4 Cheeks were cropped and stored inside a specific variable in array type.

3.5 Image Processing

The cropped image was processed frame by frame. Each frame contains random number of pixels; the mean function was then applied in every single color channel to find a single value. Traces of RGB color model were formed and it normalized. The normalization equation is shown as below:

$$x_n(f) = \frac{x_m(f) - \mu_m}{\sigma_m}$$

$x_n(f)$ Is value after normalization in term of frame, where the $x_m(f)$ is an information in term of frame. μ_m is the mean of the series of data along the frames. σ_m is the standard deviation of the series of data along the frames.

3.6 Fast Fourier Transform

Fast Fourier Transform was then applied on the signal of varies color model in order to convert it from time domain into frequency domain. According to X. B. Li, J. Chen, G. Y. Zhao, and M. Pietikäinen (2014), they using frequency with maximal power response as the HR frequency f_{HR}, and the average HR measured from the input video is computed as $HR_{video} = 60f_{HR}$ bpm. With this information, the frame size is needed to multiple 60 to apply the Fourier Transform within specified range of frequency. As referring to the literature review, the operational range is from 0.75Hz to 4.0Hz which corresponds to the heart rate measurement between 45bpm and 240bpm. Hence, the 45bpm and 240bpm will be applied on the equation to find out the useful frequency for heart rate detection. The following equation finds out the range of heart rate detection.

$$f_{bpm} = \frac{HR_{bpm}(t_{on})}{2} \qquad (3.3)$$

HR_{bpm} is value of 45bpm and 240bpm which known as the heart rate measurement range in heart rate detection system. t_{on} is the time taken of video recording where f_{bpm} is known as the useful frequency in order to capturing the heart rate of user.

3.7 Band Pass Filter

Due to the interference from the low frequency and high frequency components, the peak detector detects very low frequency or very high frequency as human heart beat. Band Pass Filter was needed to remove the low frequency and high frequency components. The Band Pass Filter has removed 40% amplitude of high frequency and low frequency components. To determine the frequency of 60bpm and 180bpm, it requires identifying the size of signal within the range of 45bpm to 240bpm. From the figure 3.2, the high frequency component was removed after went through the band pass filter.

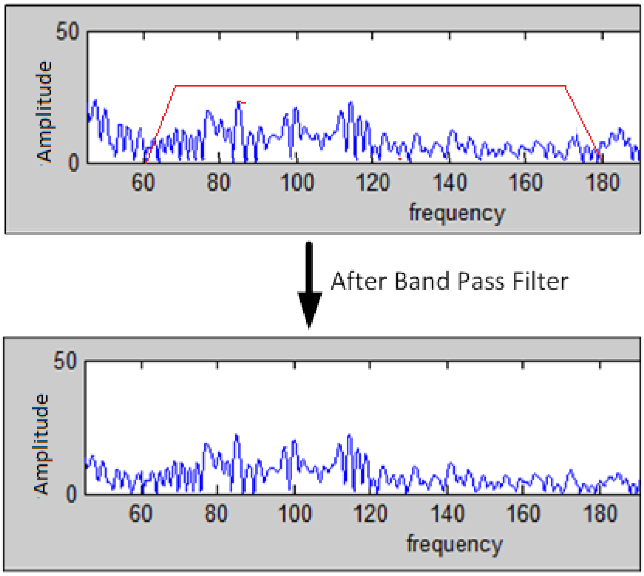

Figure 3.5 PPG signal before and after band pass filter to enhance the accuracy of the system

3.8 Peak Detector

The system will detect the peak of the PPG waveform to calculate the heart rate when on the end of the system. The peak detector is actually a simple algorithm; a variable will store the peak value and will compare the amplitude of every single frequency component within the frequency range of interest. As the peak value (Bpm) was detected, the system will look for the frequency of the peak value itself. Therefore, the heartbeat was detected followed by the value of frequency component. Figure 3.6 shows the graph obtained from Heart Rate Monitor system.

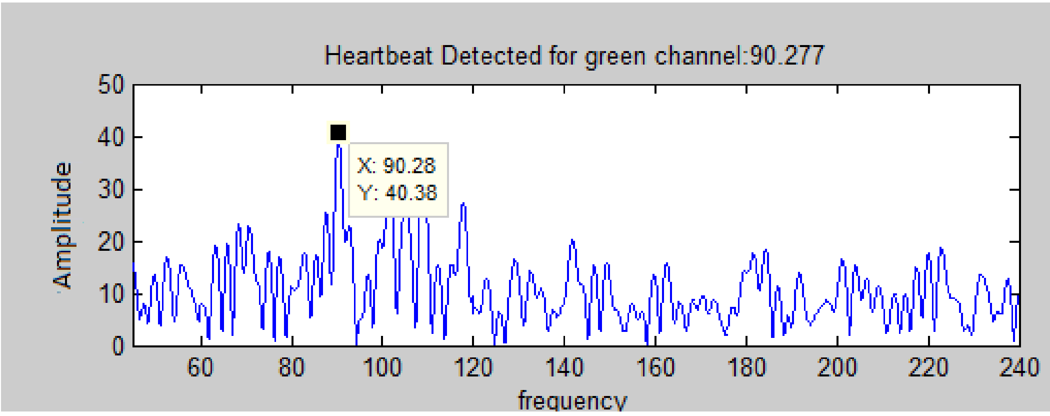

Figure 3.6 Peak detector, the peak was found when X was at amplitude of 40.38 and Y at 90.25.

3.9 Video Record

The video was stored inside the specific location set by user and save in avi format. Therefore, the image sequences will arrange and process together into an aviobj file and the image sequences are in uint8 format.

3.10 Graphic User Interface

The GUI was created to make the system more easy to use. The GUI function was actually created with MATLAB software and it is built-in system in MATLAB. For this system, the GUI is able to display the graph for both users again as the users close the graphs accidently. It is necessary to make sure that the user is always inside the camera when initialize and testing the camera. The image resolution is 640x480 and the colors are in RGB format. Besides, the Frame rate is set to 30fps. This system will start and end with the flag function which means the camera will only initialize when the flag is equal to 1, whereas the camera will close itself when the flag is in zero. Moreover, the GUI is capable to determine the percentage error of system with key in the heart rate measured in the GUI.

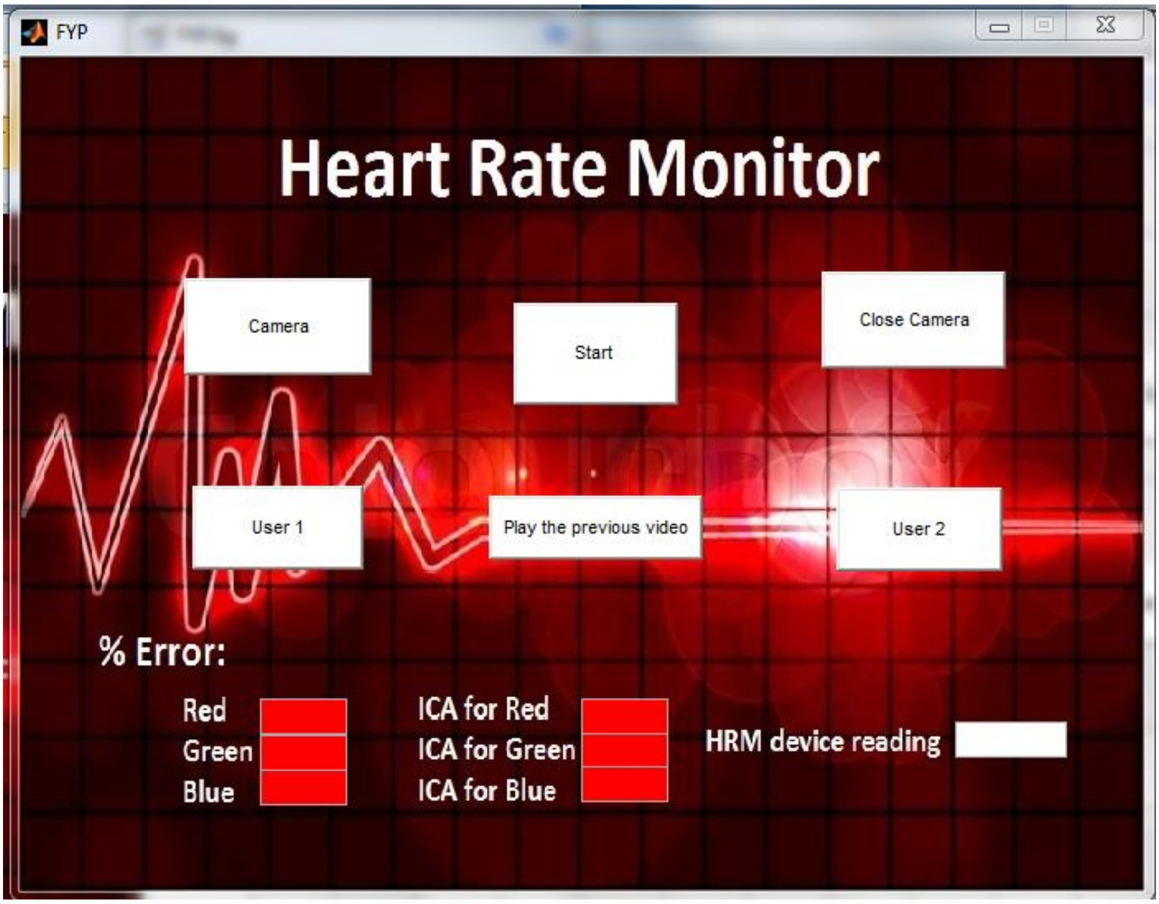

Figure 3.7 GUI of heart rate monitor

CHAPTER 4

RESULTS AND DISCUSSIONS

In this chapter, we will measure the experimental results and a discussion on results. There’re some limitations in order to obtain the result precisely.

4.1 Constraints of the System

4.1.1 Limitation of Viola Jones

In Viola Jones method, the face will not be detected if the subjects turn their head for more than 45 degree. If more head then the image sequence will fill with empty face once the subjects are not following the constraint of the system and it will lead to the error. Besides, the face detector is only allows the subject at a maximum distance of 100cm from the web camera. This constraint was set to enhance the speed of video recording since it may make the system slow as the Viola Jones face detector is needs to scan an image to find out where the face is. Thus, the resolution of every image in the video is rescaled and resized as 3 times smaller than the original image to speed up the video’s frame per second. The detected image will resize back to original image once the image was scanned by the Viola Jones Face Detector.

4.1.2 Insufficient Illumination

This experiment must run inside the room that has sufficient luminance to ensure this system can perceive sufficient Photoplethysmography. The luminance can be from artificial light source or sunlight, but be sure that the luminance does not saturate the system. For instance, the subject's face will became darker as the background luminance is from sunlight and it may lead to distort the images.

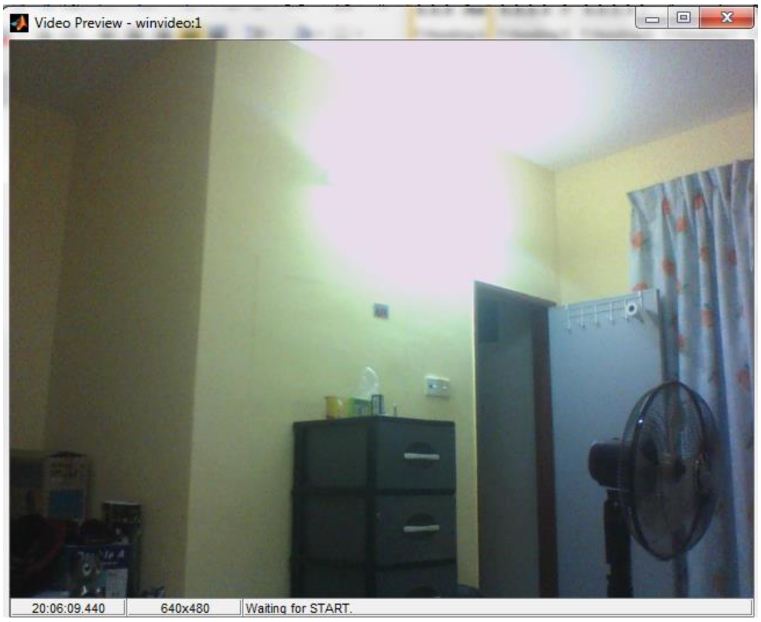

Figure 4.1 uneven illumination

4.1.3 Slow Movement While Recording

Due to the camera issue, the subject can only make slow movement to make sure the image is not distorted as long as the camera can capture enough information to enhance the accuracy. For instance, subject's face will become unclear and blurred as the subject is moving fast while video recording.

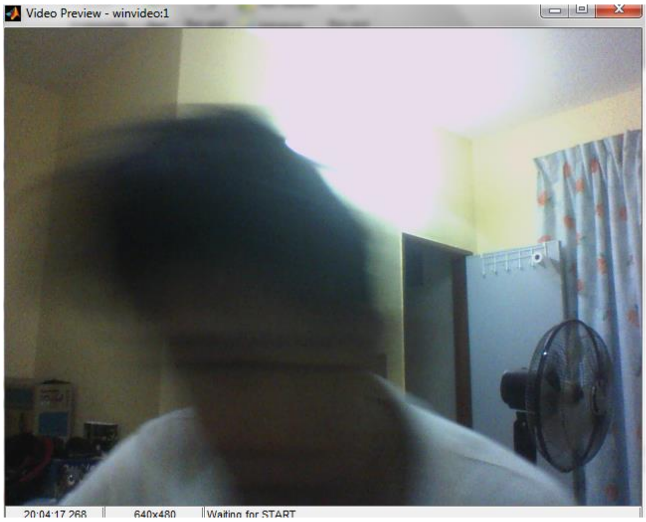

Figure 4.2 Fast motion while recording

4.1.4 Position while Recording for Multiple Persons

In this system, it is not allowed for the subject to cross over the border which aligns at the middle of the image. This constraint was set due to make sure the subject 1 will always detect as subject 1; while subject 2 will always detect as subject 2 as well. Previously, the images were mixed between both subjects due to this issue since the frame of image sequences is independent to each other.

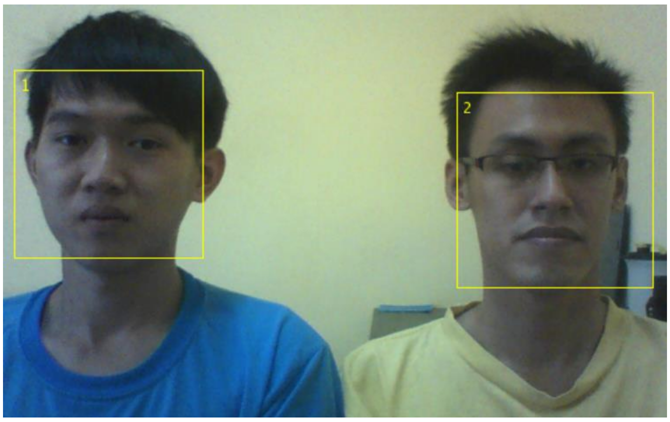

Figure 4.3 Subjects sit in a straight line

4.2 Experiment Result and Discussion

The experimental results were obtained with 3 participation volunteers to measure the heart rate in multiple persons. When video recording in multiple persons, both volunteers will substitute to each other after doing the measurement and created 3 cases. The results were actually obtained by varying the distance between webcam and the subject's face. The distance between webcam and subjects was categorized into 3 case; 50cm, 70cm and 100cm.

4.2.1 Single Person at night time

Table 4.1 Heart rate measurement for single person at night time

	Range											
	50 cm				70cm				100cm			
	M	R	G	B	M	R	G	B	M	R	G	B
1st	83	70.2	70.3	90.3	80	115	69.9	90.7	89	90.4	90.1	90.2
2nd	86	73.2	73.3	73.3	81	109	69.5	89.4	89	74.3	82.2	85.8
3rd	88	83.7	84	84.2	83	62.8	80.7	92.9	85	95.5	95.3	62.9
4th	78	73.2	76.8	62.1	77	79.7	75.2	81.7	86	86.8	99.7	78.1
5th	86	82.5	82.8	109	83	86	80.5	78.2	82	67.3	81.8	67.4
Ave	***84.2***	***76.6***	***77.4***	***83.8***	***80.8***	***90.7***	***75.2***	***86.6***	***86.2***	***82.8***	***89.8***	***76.9***

Table 4.2 Percentage error in heart rate measurement for single person at night time.

	Range								
	50cm			70cm			100cm		
	R	G	B	R	G	B	R	G	B
1st	15.373	15.325	8.819	44.325	12.650	13.350	1.517	1.270	1.326
2nd	14.884	14.826	14.826	35.012	14.222	10.333	16.494	7.663	3.629
3rd	4.852	4.591	4.375	24.301	2.807	11.976	12.329	12.165	26.000
4th	6.154	1.500	20.333	3.468	2.364	6.104	0.872	15.895	9.174
5th	4.058	3.756	27.012	3.666	2.964	5.843	17.878	0.232	17.866
Ave	***9.064***	***8.000***	***15.073***	***22.154***	***7.001***	***9.521***	***9.818***	***7.445***	***11.599***

This measurement was done at night time when the luminance source was from fluorescent light. In table 4.2, the accuracy of green traces is about 90%. As compared the percentage error between three colours traces, the green colour trace is more. Hence, we can conclude that distance will not distort the accuracy of this system since the average of percentage errors was only around 8%.

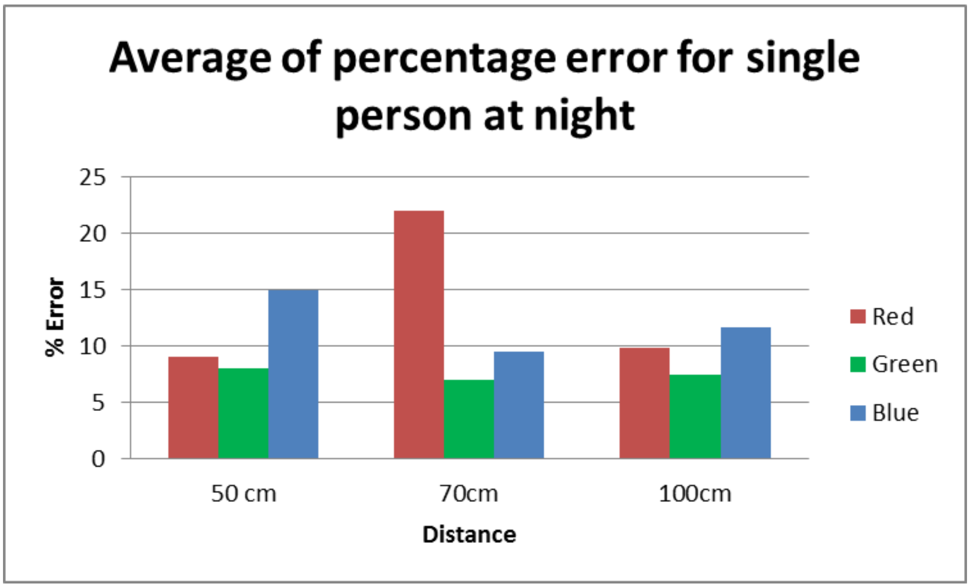

Figure 4.4 Average percentage error between heart rate monitor and proposed system for single person at night

4.2.2 Single Person at Noon

Table 4.3 Heart rate measurement for single person at noon.

	50 cm				70cm				100cm			
	HRD	R	G	B	HRD	R	G	B	HRD	R	G	B
1st	77	86.7	86.7	86.7	82.0	72.4	81.1	87.1	92.0	84.1	84.2	84.2
2nd	74	68.8	69.0	68.8	81.0	77.3	77.5	79.4	87.0	105.4	105.4	60.0
3rd	82	63.9	74.8	92.4	80.0	61.7	61.7	61.5	90.0	96.9	96.8	83.1
4th	83	91.8	74.0	74.0	79.0	64.0	80.7	70.1	82.0	59.9	94.6	69.3
5th	74	107.8	68.4	68.6	73.0	71.0	71.1	81.9	79.0	78.6	78.5	78.4
Ave	78	83.8	***74.6***	78.1	79.0	69.3	***74.4***	76.0	86.0	85.0	***91.9***	75.0

R = Red, G= Green, B=Blue, HRD = Heart Rate Device

Table 4.4 Percentage error in heart rate measurement for single person at noon.

	Range								
	50cm			70cm			100cm		
	R	G	B	R	G	B	R	G	B
1st	12.65	12.65	12.65	11.74	1.06	6.17	8.59	8.51	8.51
2nd	7.07	6.78	7.07	4.59	4.33	2.04	21.16	21.16	31.06
3rd	22.07	8.73	12.62	22.93	22.93	23.18	7.64	7.57	7.63
4th	10.57	10.90	10.84	19.01	2.18	11.30	26.98	15.33	15.55
5th	45.72	7.62	7.30	2.75	2.56	12.14	0.54	0.63	0.72
Ave	19.61	***9.34***	10.10	12.21	***6.61***	10.96	12.98	***10.64***	12.69

R = Red, G= Green, B=Blue

The measurement above shows that the accuracy of green trace is still about 92.39%. As compared to other colour traces, the green trace is the best trace to detect the Heart Rate. The distance of 70cm between webcam and subject has obtained best result as compared to other results.

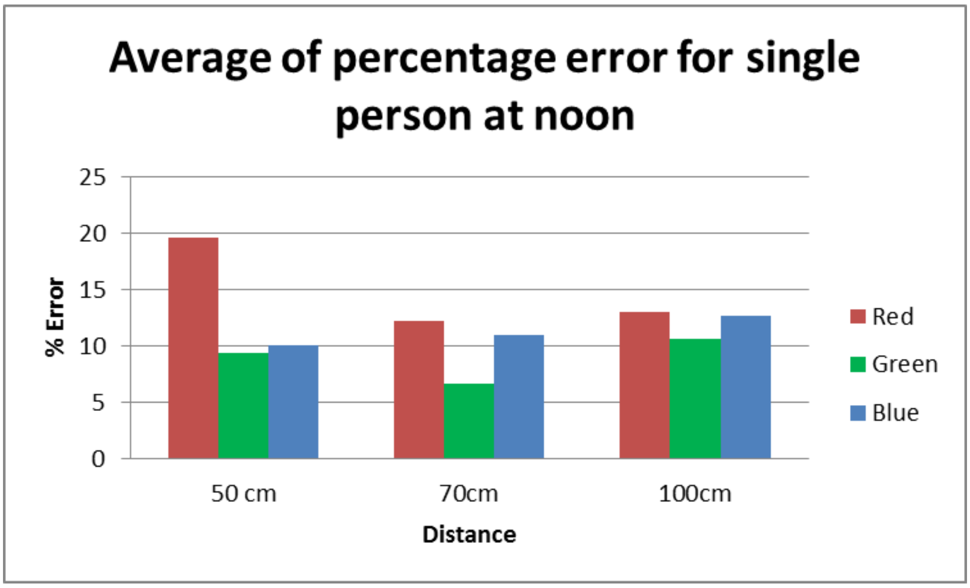

Figure 4.5 Average percentage error for single person at noon

4.2.3 Multiple Persons at Night time

Table 4.5 Heart rate measurement for multiple persons at night time

	Range																							
	50cm								70cm								100cm							
	S1				S2				S1				S2				S1				S2			
	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B
sample 1	74	86	73	117	81	67	105	105	71	68	68	101	85	63	73	99	88	80	80	88	82	118	118	97
	77	77	64	84	79	71	70	76	79	84	84	76	90	101	101	75	71	65	65	71	82	72	72	71
	73	78	62	94	81	78	78	92	75	66	100	107	78	116	74	89	75	66	93	93	78	81	79	101
	71	102	69	119	84	92	81	64	81	84	84	95	83	75	69	111	69	65	65	110	80	71	69	104
	70	112	64	62	76	110	76	108	80	98	98	63	83	95	92	115	69	104	76	119	80	64	79	66
Ave	***73***	***91***	***66***	***95***	***80***	***84***	***82***	***89***	***77***	***80***	***87***	***88***	***84***	***90***	***82***	***98***	***74***	***76***	***76***	***96***	***80***	***81***	***83***	***88***
sample 2	72	110	71	71	80	83	68	82	74	61	62	60	69	69	69	75	73	101	70	84	64	101	64	71
	71	92	81	103	74	99	68	73	80	65	70	64	71	90	72	110	75	70	70	70	65	73	61	73
	75	61	61	68	71	64	64	80	69	101	61	71	68	61	71	66	78	106	64	74	74	70	70	72
	75	94	94	68	73	79	65	65	65	90	63	62	65	89	89	62	70	93	66	94	70	66	61	72
	72	82	82	71	69	72	66	98	67	90	64	99	72	64	64	85	73	75	60	80	73	65	65	100
Ave	***73***	***88***	***78***	***76***	***73***	***79***	***66***	***80***	***71***	***81***	***64***	***71***	***69***	***74***	***73***	***80***	***74***	***89***	***66***	***80***	***69***	***75***	***64***	***77***
sample 3	78	97	63	96	68	78	77	90	79	63	64	65	74	87	84	100	68	89	81	79	76	92	86	105
	81	90	86	66	72	64	77	85	72	84	77	80	68	76	75	87	75	90	94	84	82	67	69	71
	68	80	78	78	70	82	77	79	75	91	85	93	75	69	84	83	75	94	83	85	81	60	77	77
	73	65	79	84	67	74	74	80	77	91	84	96	73	87	88	85	71	79	80	83	78	88	85	98
	75	83	86	83	81	74	87	65	83	107	100	99	72	87	74	82	73	96	77	77	77	87	80	114
Ave	***75***	***83***	***84***	***81***	***72***	***74***	***78***	***80***	***77***	***87***	***82***	***87***	***72***	***81***	***81***	***87***	***72***	***90***	***83***	***81***	***79***	***79***	***79***	***93***

R = Red, G= Green, B=Blue, HR = Heart rate device, S1 = Subject 1, S2 = Subject 2, Ave = Average

Table 4.6 Percentage error for multiple persons at night time.

	Range																	
	50cm						70cm						100cm					
	S1			S2			S1			S2			S1			S2		
	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
Sample 1	16.7	1.57	58.2	16.9	29.3	29.3	4.41	4.54	41.7	25.7	14.7	16.1	9.65	9.65	0.19	43.5	43.6	18.5
	0.06	16.6	8.75	10.8	10.9	4.33	6.76	6.82	3.46	11.7	11.7	16.7	8.42	8.3	0.62	12.4	12	13.1
	7.45	15.8	29.1	3.28	3.42	13.5	11.7	33	42.1	48.1	5.37	14.5	11.9	23.9	23.8	4.44	1.13	29.3
	43.1	3.21	68.3	9.08	3.04	23.8	4.15	4.21	16.7	9.39	16.7	33.6	6.25	6.25	59.8	10.9	14.3	29.6
	59.9	8.91	11.7	45.1	0.08	42.7	22.9	22.7	20.9	14.9	10.5	38.6	50.9	10.6	71.8	20.5	1.81	17.1
Ave	***25.4***	***9.22***	***35.2***	***17***	***9.35***	***22.7***	***9.98***	***14.2***	***25***	***22***	***11.8***	***23.9***	***17.4***	***11.7***	***31.2***	***18.3***	***14.6***	***21.5***
Sample 2	52.8	1.11	1.29	4.24	14.9	2.46	17.5	15.7	18.9	0.06	0.19	8.57	38.5	3.82	14.8	57.1	0.42	11.4
	30.1	14.5	45.4	33.6	7.58	0.86	18.3	11.9	20.6	26.6	1.87	55	6.68	6.44	6.68	12.2	5.97	12
	19.1	19.2	9.89	10.5	10.4	12.8	46.3	11.8	3.13	9.97	4.84	2.82	35.8	18.1	4.67	5.7	5.51	2.42
	25.1	25	9.27	7.63	10.9	10.5	38.3	2.8	5.14	36.5	36.6	4.45	32.9	5.47	34.6	5.27	13.4	2.14
	14.5	14	1.75	3.74	4.97	42.1	33.7	4.76	48.3	11.7	11.6	18.6	2.71	17.4	9.14	10.9	11	36.4
Ave	***28.3***	***14.8***	***13.5***	***12***	***9.76***	***13.7***	***30.8***	***9.4***	***19.2***	***17***	***11***	***17.9***	***23.3***	***10.2***	***14***	***18.2***	***7.26***	***12.9***
sample 3	24.1	18.9	23.1	15.4	12.8	32.5	20.8	18.5	18.2	18.2	13.3	35.3	31.5	18.5	15.7	21.5	12.8	38.5
	10.8	6.5	18.9	11.8	7.5	18.4	16.5	6.7	11.4	11.5	10.8	28.4	20.4	25.9	11.8	18.5	15.6	13.8
	17.6	15.2	14.3	16.5	9.8	12.5	21.9	12.8	23.5	7.8	11.5	10.5	25.9	10.8	12.8	25.7	5.4	5.1
	11.5	8.4	14.8	10.9	10.6	19.5	18.4	9.5	25	19.5	20	15.8	10.8	12.5	16.2	12.8	8.9	25.7
	11	14.5	10.9	8.4	7.6	19.6	29.4	20	19.4	21	3.4	13.5	31.9	5.3	6	13.5	4.3	48.4
Ave	***15***	***12.7***	***16.4***	***12.6***	***9.66***	***20.5***	***21.4***	***13.5***	***19.5***	***15.6***	***11.8***	***20.7***	***24.1***	***14.6***	***12.5***	***18.4***	***9.4***	***26.3***

R = Red, G= Green, B=Blue

S1 = Subject 1, S2 = Subject 2, Ave = Average

This experiment was done by multiple persons which subject 1 was attached the Blood Pressure Monitor and another subject was attached the Polar FT1 heart rate monitor with chest strap. As referring to the methodology, both devices only have percentage difference of 2%. Thus, these both devices can be used in this experiment as reference. From the table above, the results of green trace are more consistent and the percentage error of green trace was less than 15%. Although the blue trace has better result for the 2nd subject when the distance was about 100cm, but the result of blue trace fluctuates as the percentage error of blue trace is 17.9%. This concludes that the green trace has better result as compare to other colour traces. The result above shows that the distance between the webcam and subject facial wasn't affecting the percentage error. The experiment was only encouraged to complete within 100cm distance between webcam and subject face. Sample 1 and sample 2 were actually performed with different subject.

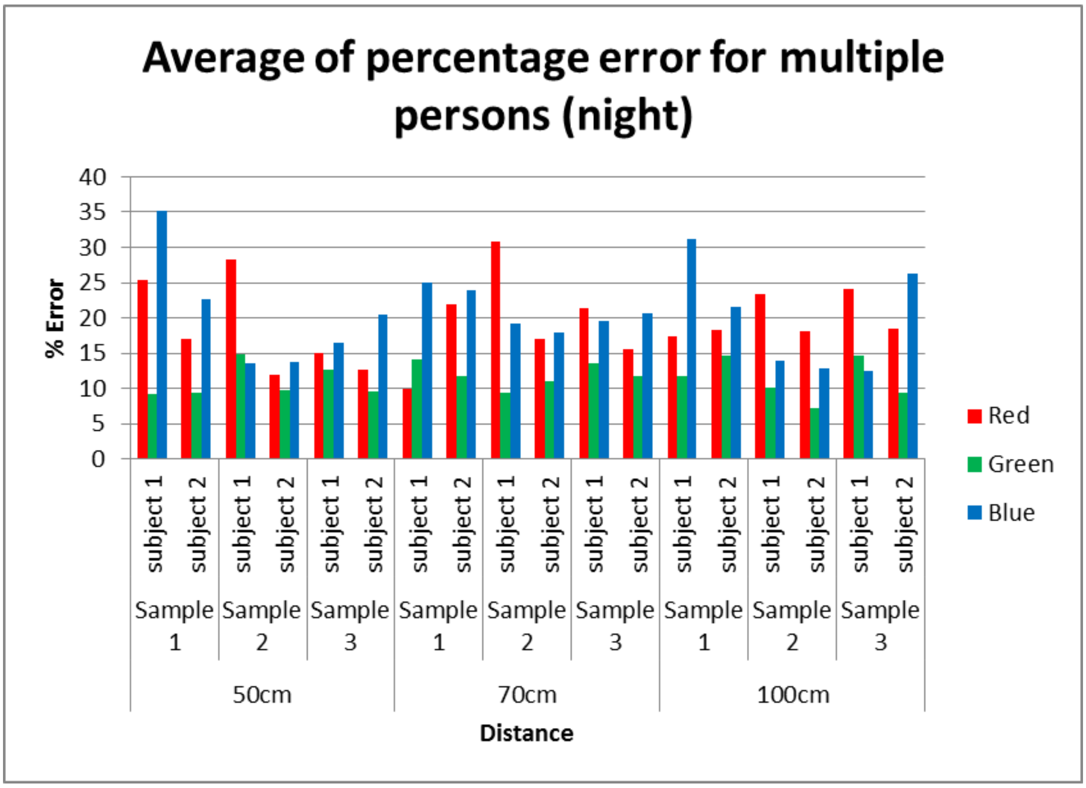

Figure 4.6 Average percentage for multiple persons at night

4.2.4 Multiple Persons at Noon

Table 4.7 Heart rate measurement for multiple persons at noon

	Range																							
	50cm								70cm								100cm							
	S1				S2				S1				S2				S1				S2			
	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B
sample 1	97	95	95	118	72	109	69	69	93	118	118	92	69	66	66	70	87	62	87	62	93	63	63	69
	91	111	111	98	76	71	91	120	92	110	92	64	68	88	88	90	86	81	76	62	95	65	65	65
	97	100	100	72	70	78	78	77	98	93	93	64	78	91	91	63	71	74	61	64	97	61	92	61
	91	112	112	65	76	83	70	81	91	97	97	97	68	78	64	105	87	80	80	113	91	63	70	61
Ave	***94***	***105***	***105***	***88***	***74***	***85***	***77***	***87***	***94***	***105***	***100***	***79***	***71***	***81***	***77***	***82***	***83***	***74***	***76***	***76***	***94***	***63***	***73***	***64***
sample 2	79	82	82	82	72	78	63	73	73	105	105	105	71	63	73	74	78	116	65	103	74	83	63	100
	71	88	81	61	74	100	65	93	78	83	76	98	80	104	68	119	75	77	77	108	69	88	62	62
	75	73	73	73	75	113	73	98	78	76	75	79	76	103	71	99	74	80	80	117	76	71	71	119
	80	98	95	85	74	107	71	62	79	68	70	106	77	83	83	102	79	105	100	75	71	99	64	113
Ave	***76***	***85***	***83***	***75***	***74***	***99***	***68***	***82***	***77***	***83***	***82***	***97***	***76***	***88***	***74***	***98***	***77***	***95***	***81***	***100***	***73***	***85***	***65***	***98***

R = Red, G= Green, B=Blue, HR = Heart rate device

S1 = Subject 1, S2 = Subject 2, Ave = Average

Table 4.8 Percentage error for multiple persons at noon

	Range																	
	50cm						70cm						100cm					
	S1			S2			S1			S2			S1			S2		
	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
Sample 1	1.60	1.64	21.60	50.92	3.85	3.85	26.63	26.69	1.23	3.97	4.03	1.58	28.57	0.18	28.23	32.10	32.31	25.91
	21.95	21.89	7.56	6.68	19.84	57.74	19.53	0.34	30.20	29.78	29.84	32.24	6.29	12.06	27.41	31.20	31.25	31.09
	3.42	3.42	25.67	11.99	12.06	9.30	5.01	5.01	34.78	16.69	16.76	19.35	4.14	14.14	9.28	37.57	5.12	37.41
	22.66	22.66	28.14	9.75	7.72	5.92	6.87	6.71	6.45	14.90	6.50	53.85	8.56	8.51	30.36	30.80	23.24	33.35
Ave	***12.41***	***12.40***	***20.74***	***19.83***	***10.87***	***19.20***	***14.51***	***9.69***	***18.16***	***16.33***	***14.28***	***26.75***	***11.89***	***8.72***	***23.82***	***32.92***	***22.98***	***31.94***
sample 2	3.87	4.05	3.87	8.69	13.14	1.24	43.55	43.48	43.22	11.65	2.13	4.44	49.06	16.73	31.45	11.81	15.34	34.46
	24.20	13.54	13.82	34.51	12.68	26.18	6.54	2.49	25.12	30.54	15.56	48.84	2.32	2.25	43.37	27.90	9.88	10.32
	2.16	2.16	2.09	50.32	2.28	30.77	3.09	3.22	0.86	35.14	6.28	29.87	8.32	8.32	58.07	7.03	6.96	56.11
	22.69	19.15	6.36	44.99	4.24	15.68	13.30	10.78	34.77	7.55	7.43	32.17	33.11	27.04	5.68	39.49	9.39	59.00
Ave	***13.23***	***9.72***	***6.54***	***34.63***	***8.08***	***18.47***	***16.62***	***14.99***	***25.99***	***21.22***	***7.85***	***28.83***	***23.21***	***13.59***	***34.64***	***21.56***	***10.39***	***39.97***

R = Red, G= Green, B=Blue

S1 = Subject 1, S2 = Subject 2, Ave = Average

Table 4.9 Heart rate measurement and the result for ICA algorithm for multiple persons at noon

	Range																							
	50 cm								70 cm								100 cm							
	S1				S2				S1				S2				S1				S2			
	HR	IR	IG	IB	HR	IR	IG	IB	HR	IR	IG	IB	HR	IR	IG	IB	HR	IR	IG	IB	HR	IR	IG	IB
Sample	97	60	71	91	72	60	114	75	93	81	72	78	69	62	100	62	87	87	89	66	93	94	81	111
1	91	65	60	120	76	68	107	72	92	69	90	68	68	64	67	66	86	91	93	95	95	76	78	93
	97	65	94	64	70	80	66	63	98	67	88	88	78	81	115	102	71	66	73	73	97	82	82	103
	91	65	71	97	76	61	64	71	91	52	79	75	68	64	105	111	87	77	104	68	91	60	88	61
Ave	***94***	***64***	***74***	***93***	***74***	***67***	***88***	***70***	***94***	***67***	***82***	***78***	***71***	***68***	***97***	***85***	***83***	***80***	***90***	***76***	***94***	***78***	***82***	***92***
Sample	79	68	62	110	72	86	83	73	73	64	62	59	71	60	74	105	78	61	76	114	74	100	100	63
2	71	75	80	80	74	64	93	87	78	76	76	74	80	64	88	119	75	63	67	88	69	63	63	66
	75	73	73	73	75	74	67	109	78	67	64	75	76	83	64	78	74	60	110	93	76	61	99	63
	80	63	63	116	74	78	63	101	79	60	56	52	77	60	94	102	79	62	88	78	71	73	69	99
Ave	***76***	***70***	***70***	***95***	***74***	***75***	***77***	***93***	***77***	***67***	***64***	***65***	***76***	***67***	***80***	***101***	***77***	***62***	***85***	***93***	***73***	***74***	***83***	***73***

IR = ICA applied after Red trace, IG= ICA applied after Green trace, IB= ICA applied after Blue trace,

HR = Heart rate device

S1 = Subject 1, S2 = Subject 2, Ave = Average

Table 4.10 Percentage error of ICA algorithm in this system for multiple persons when at noon.

	Range																	
	50cm						70cm						100cm					
	IR	IG	IB	IR	IG	IB	IR	IG	IB	IR	IG	IB	IR	IG	IB	IR	IG	IB
Sample 1	38.0	27.3	6.2	16.4	58.5	4.2	12.4	23.1	15.6	10.3	44.2	9.5	0.3	2.5	24.1	0.7	12.7	35.3
	28.1	34.1	31.7	10.0	41.0	5.0	25.1	2.5	25.6	5.8	1.0	3.3	6.2	8.3	10.2	19.6	18.1	31.1
	33.5	2.8	34.5	14.1	6.2	10.4	32.1	10.4	10.2	4.4	46.9	30.6	7.1	3.1	2.5	15.3	15.7	33.5
	28.1	22.1	6.2	19.3	16.0	7.2	42.5	13.4	17.4	5.5	54.1	63.5	11.4	19.0	21.3	34.1	2.8	28.1
Ave	***31.9***	***21.6***	***19.7***	***15.0***	***30.4***	***6.7***	***28.0***	***12.3***	***17.2***	***6.5***	***36.6***	***26.7***	***6.3***	***8.2***	***14.5***	***17.5***	***12.3***	***32.0***
Sample 2	13.6	21.5	38.9	19.2	15.6	1.7	12.1	15.6	19.4	15.5	4.0	47.2	22.0	2.5	46.3	35.6	34.8	7.7
	5.7	13.0	13.0	13.2	25.6	17.6	2.4	2.6	5.7	20.1	10.3	49.0	16.3	10.7	17.3	9.0	8.9	8.7
	2.2	2.2	2.1	1.1	10.1	44.9	14.3	17.8	4.2	9.4	16.2	2.5	19.0	49.0	25.7	19.4	30.9	3.4
	21.4	21.3	45.5	4.9	15.3	36.9	24.3	29.4	34.1	21.8	22.6	32.2	20.9	11.2	1.3	2.5	2.2	11.5
Ave	***10.7***	***14.5***	***24.9***	***9.6***	***16.7***	***25.3***	***13.3***	***16.3***	***15.9***	***16.7***	***13.3***	***32.7***	***19.6***	***18.3***	***22.7***	***16.6***	***19.2***	***7.8***

IR = ICA applied after Red trace, IG= ICA applied after Green trace, IB= ICA applied after Blue trace

S1 = Subject 1, S2 = Subject 2, Ave = Average

From figure 4.6, the green colour trace is still a good colour trace to display our heartbeat as compared to other colour traces. The accuracy of Subject 2 is quite low when the distance was about 100cm from webcam. The level of brightness will also affect the result since different distances will be perceived different luminance level. The accuracy of blue colour has improved when the distance was about 50cm. But the blue colour traces are not consistent, sometimes it will display out the percentage error of 40%. Besides, this result includes the ICA algorithm, the ICA algorithm was applied for RGB traces after performing FFT algorithm. As referring to the table above, the result of all colour models were not consistent and high percentage errors as compare to the Green trace before applying ICA algorithm.

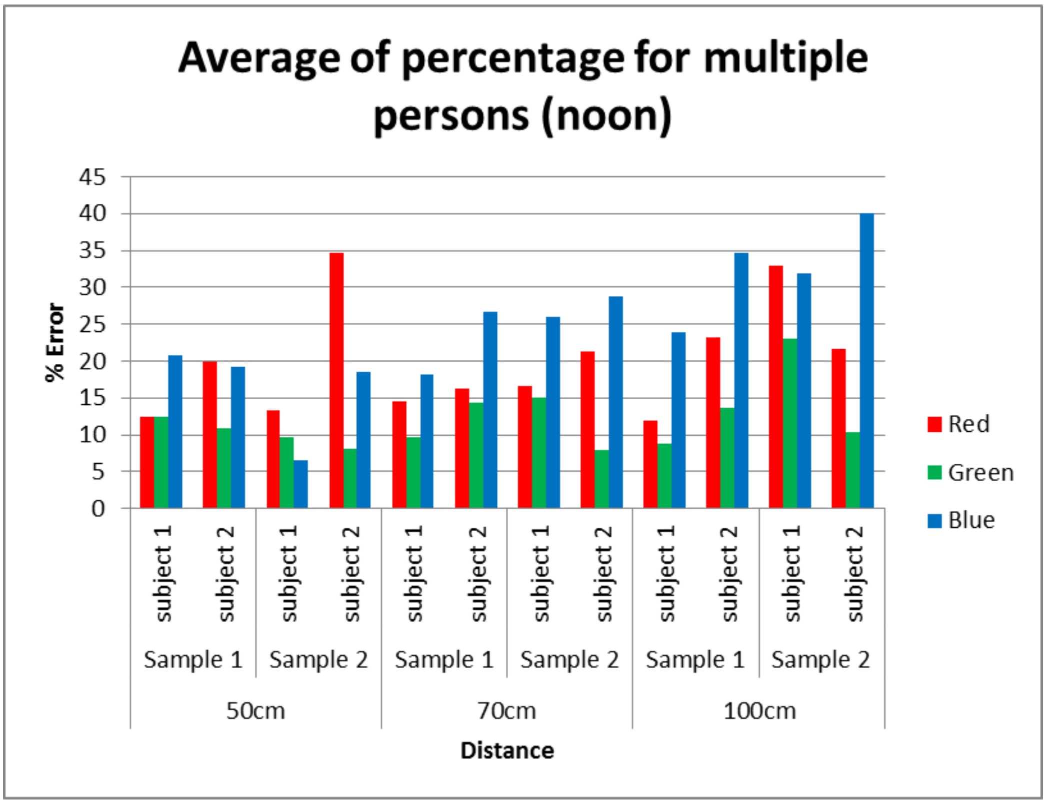

Figure 4.7 percentage error for multiple persons at noon

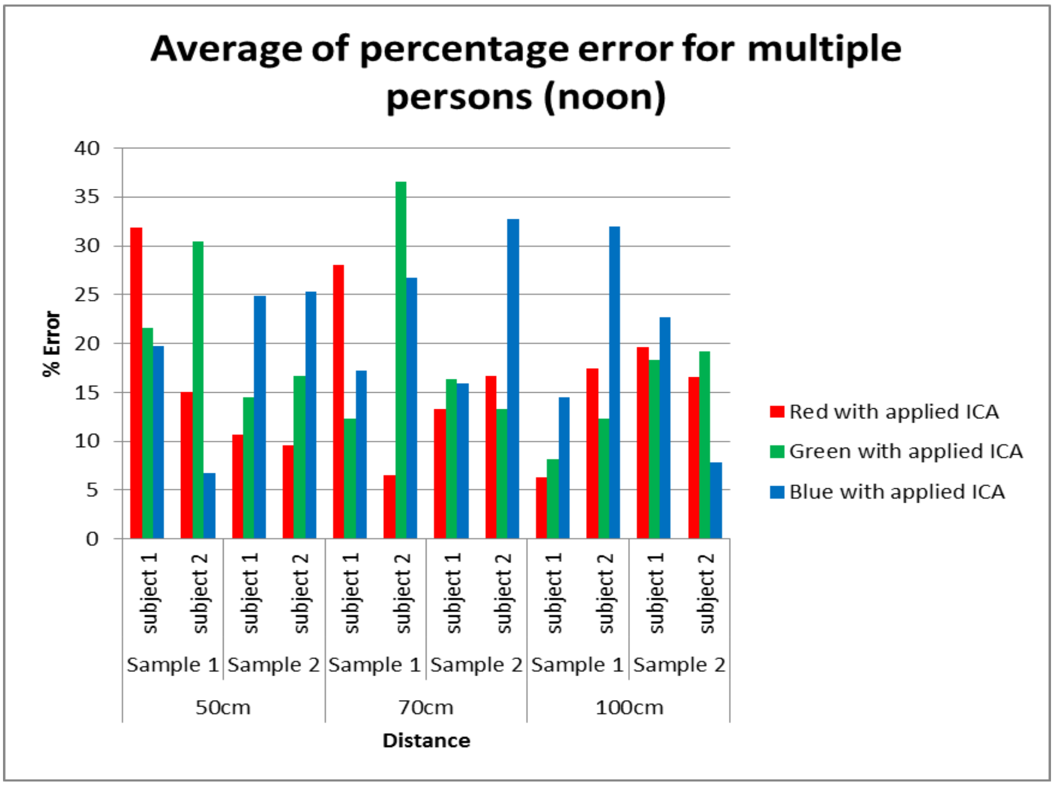

Figure 4.8 Average percentage error in HR measurement for multiple persons at noon

4.2.5 Multiple Persons with no movement

Table 4.11 Heart rate measurement in multiple persons with no movement.

	Range																							
	50cm								70cm								100cm							
	subject 1				subject 2				subject 1				subject 2				subject 1				subject 2			
	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B
Sample 1	84	76	76	72	90	63	80	96	67	60	65	60	74	66	63	74	68	90	64	90	100	69	71	96
Sample 2	73	76	81	71	83	106	69	78	73	70	68	70	74	91	63	63	70	62	68	64	83	91	98	98
Sample 3	75	86	69	97	70	71	71	76	67	64	64	64	81	72	72	76	73	102	67	83	86	90	91	82
Average	***77***	***79***	***75***	***80***	***81***	***80***	***73***	***83***	***69***	***65***	***65***	***65***	***76***	***76***	***66***	***71***	***70***	***85***	***66***	***79***	***90***	***83***	***86***	***92***

Table 4.12 Percentage error for multiple persons with no movement

	50cm						70cm						100cm					
	S1			S2			S1			S2			S1			S2		
	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
Sample 1	9.9	*3.7*	11	10	*15*	0.2	33	*5.5*	33	31	*29*	3.5	33	*5.5*	33	31	*29*	3.5
Sample 2	3.8	*6.5*	3.9	22	*15*	18	12	*3.3*	8.3	9.2	*18*	18	12	*3.3*	8.3	9.2	*18*	18
Sample 3	5	*5.2*	5.5	11	*11*	6.2	39	*8.4*	14	5.1	*5.3*	5.2	39	*8.4*	14	5.1	*5.3*	5.2
Average	***6.2***	***5.1***	***6.7***	***15***	***14***	***8.2***	***28***	***5.7***	***19***	***15***	***17***	***8.9***	***28***	***5.7***	***19***	***15***	***17***	***8.9***

R = Red, G= Green, B=Blue, HR = heart rate device, S1 = Subject 1, S2 = Subject 2

The result with the subjects without movement, It shows that the percentage different is quite low. Among all the traces, green trace is still the best result and the percentage error of green trace is about 10.75% Both of the subjects are require to sit in proper way in front of webcam in order to ensure the PPG is able to capture by the webcam.

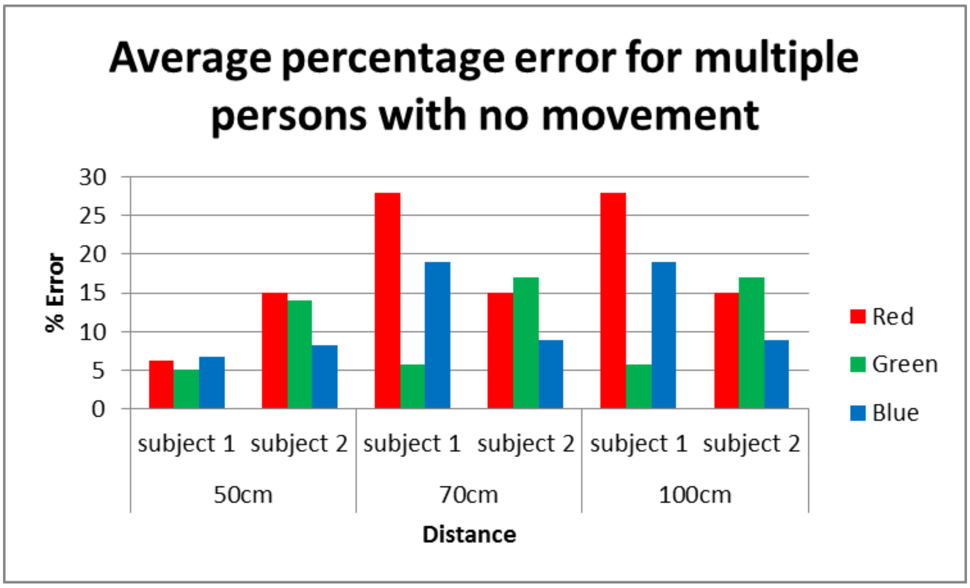

Figure 4.9 Average percentage error for multiple persons with no movement

4.2.6 Multiple Persons with slow movement

Table 4.13 heart rate measurement for multiple persons with slow movement.

	Range																							
	50cm								70cm								100cm							
	S1				S2				S1				S2				S1				S2			
	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B	HR	R	G	B
C1	69	47	61	61	104	66	100	69	64	64	64	64	109	62	101	108	71	70	70	79	105	88	75	95
C2	69	62	62	62	72	65	62	62	79	105	78	78	71	72	72	72	68	65	65	46	73	70	70	67
C3	73	81	82	101	84	60	82	71	73	63	68	63	82	91	74	61	70	76	68	76	76	110	66	62
Ave	***70***	***63***	***68***	***75***	***87***	***64***	***81***	***67***	***72***	***77***	***70***	***68***	***87***	***75***	***82***	***80***	***70***	***70***	***67***	***67***	***85***	***90***	***71***	***75***

Table 4.14 Percentage error for multiple persons with slow movement.

	Range																	
	50cm						70cm						100cm					
	S1			S2			S1			S2			S1			S2		
	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B	R	G	B
C1	32	*12*	13	36	*3.8*	34	0.5	*0.4*	0.1	43	*7.4*	1	2.1	*1.8*	11	16	*28*	9.4
C2	10	*10*	12	10	*14*	14	32	*1.8*	1.8	1.4	*1.5*	1.5	4.8	*4.6*	33	3.5	*3.5*	7.7
C3	12	*12*	28	29	*2.5*	15	13	*7.5*	13	11	*10*	26	8.1	*3.4*	8.3	45	*13*	18
Ave	***18.0***	***11.4***	***17.6***	***25.1***	***6.7***	***20.9***	***15.3***	***3.2***	***5.0***	***18.5***	***6.3***	***9.6***	***5.0***	***3.3***	***17.5***	***21.4***	***14.9***	***11.9***

R = Red, G= Green, B=Blue, HR = Heart rate device, S1 = Subject 1, S2 = Subject 2, Ave = Average

From figure 4.9, the green trace is the best trace given an percentage error of 7.63%. The range of the 70cm is the best distance with lowest percentage error. In this experiment, the movement made by the subjects were slow as the webcam is able to capture the PPG signal with no loss of information.

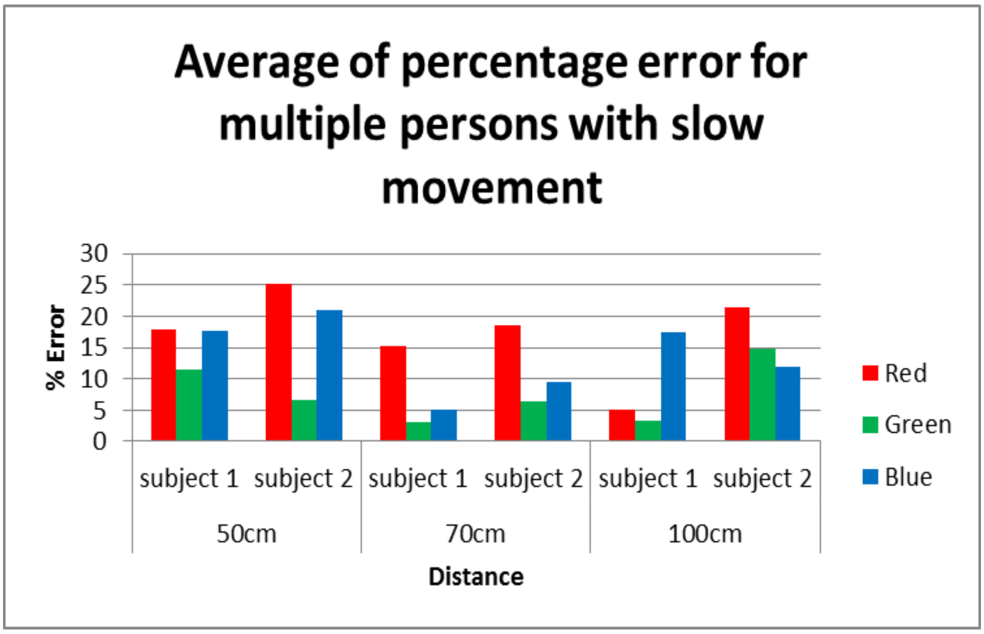

Figure 4.10 Average percentage for multiple persons with slow movement.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this project, we have proposed a contactless heart rate monitor system for single person and multiple persons implemented by video processing. The video is captured at the rate of 30fps and the resolution is about 640 x 480 pixels. The algorithms used in this project are Fast Fourier Transform and Independence Component Analysis. The proposed algorithm is able to obtain the subject's heart rate with cheeks as region of interest. The Green channel of the RGB colour models is the best result and the percentage error of the **single person** and **multiple persons** was about **8.17%** and **10.43%** respectively. Moreover, the percentage error of the multiple persons in **motion** and **non-motion** were about **7.63%** and **10.75%** respectively.

5.2 Recommendation and Further Improvement

Heart rate is an important sign to represent the overall health of human being. The heart attack is often happened nowadays especially people who are driving. This might create an unnecessary accident if driver gets heart attack. Thus, this technique can develop and install in any car to observe the subject. This technique still can improve since the human skin will became unclear as the subject are making a huge or fast movement. Hence, the advance image processing technique might apply in this algorithm to enhance the quality of human skin whenever huge and fast movement performed by the subject. Since this system is required to have sufficient illumination as the system is able to capture the PPG signal. Thus, the technique can be upgrade to night vision mode. Besides, the brake system can be synchronous to this proposed algorithm. The car will slow down and stop as low heart rate was detected.

Moreover, this can be applied in gymnasium to measure their heart rate reading without physical contact with devices while working out. People nowadays are more concerning to healthcare and willing to spend their precious time and money on healthcare. Some of the peoples don’t want to attach heart rate monitor on their skin while working out. The contactless heart rate monitor is the best way to solve this problem.

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APPENDICES

APPENDIX A: Source Code

```
function varargout = FYP(varargin)
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @FYP_OpeningFcn, ...
                   'gui_OutputFcn',  @FYP_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
   gui_State.gui_Callback = str2func(varargin{1});
end
if nargout
   [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
   gui_mainfcn(gui_State, varargin{:});
end
% --- Executes just before FYP is made visible.
function FYP_OpeningFcn(hObject, eventdata, handles, varargin)
handles.output = hObject;
guidata(hObject, handles);
fprintf('initializing GUI...stay tuned\n');
ah = axes ('unit','normalized','position',[0 0 1 1]);
bg = imread('background.jpg');imagesc(bg);
set(ah,'handlevisibility','off','visible','off');
uistack(ah,'bottom');
% --- Outputs from this function are returned to the command line.
function varargout = FYP_OutputFcn(hObject, eventdata, handles)
varargout{1} = handles.output;

function edit1_Callback(hObject, eventdata, handles)
function edit1_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
   set(hObject,'BackgroundColor','white');
end
```

```
% --- Executes on button press in pushbutton1.
function pushbutton1_Callback(hObject, eventdata, handles)
global flag;
warning('off','all');
vidDevice = imaq.VideoDevice('winvideo', 1, 'YUY2_640x480', ...
                    'ROI', [1 1 640 480], ...
                    'ReturnedColorSpace', 'rgb' );
set(vidDevice.DeviceProperties, 'FrameRate', '30');
flag = 1;
while (flag ==1)
preview(vidDevice);
end

% --- Executes on button press in pushbutton2.
function pushbutton2_Callback(hObject, eventdata, handles)
closepreview;       % terminate camera task
clear;
clc;
clear mex;
warning('off','all');
global flag y1 y2 y3 freq numface ;        %declare variable to enable the
global rft gft bft RCft1 GCft1 BCft1;      %variable worked in any button
global yrc2 ygc2 ybc2;
global yrc1 ygc1 ybc1;
global RCft2 GCft2 BCft2;
flag = 0;
faceDetector = vision.CascadeObjectDetector();  %enable viola jones algorithm
bbox = [100 100 100 100];
bboxx0 = [100 100 100 100];
bboxx1 = [100 100 100 100];
bbox1 = [100 100 100 100];
rmax = [0 0];
gmax = [0 0];
bmax = [0 0];
rcmax1 = 0;
gcmax1 = 0;
bcmax1 = 0;
rcmax2 = 0;
gcmax2 = 0;
bcmax2 = 0;
vidDevice = imaq.VideoDevice('winvideo', 1, 'YUY2_640x480', ...
                    'ROI', [1 1 640 480], ...
                    'ReturnedColorSpace', 'rgb' );
set(vidDevice.DeviceProperties, 'FrameRate', '30');
boxInserter = vision.ShapeInserter('BorderColor','Custom',...
'CustomBorderColor',[255 255 0]);
textInserter = vision.TextInserter('%d','LocationSource','Input port','Color',[255,
255, 0],'FontSize',12);
nFrame =300;
```

```
vidInfo = imaqhwinfo(vidDevice);
vidHeight = vidInfo.MaxHeight;
vidWidth = vidInfo.MaxWidth;
videoPlayer = vision.VideoPlayer('Position',[300 100 640+30 480+30]);
mov(1:nFrame) = ...
   struct('cdata', zeros(vidHeight, vidWidth, 3, 'uint8'),...
        'colormap', []);
mov1(1:nFrame) = ...
   struct('cdata', zeros(vidHeight, vidWidth, 3, 'uint8'),...
        'colormap', []);

aviobj = avifile('C:\Users\User\Documents\MATLAB\sample.avi');   %rename
the code of video file
for k = 1:nFrame        % start recording with 300 frames
tic;                   % timer start
videoFrame = step(vidDevice);      % enable the image capture by webcam
bbox = 4 * faceDetector.step(imresize(videoFrame, 1/4));    % boost video's fps
numface = size(bbox,1);                         % identify number of face
detected
if numface > 1                               % when the 2nd face detected
videoFrame1 = imcrop(videoFrame,[1 1 320 480]);          % crop the image
into half
videoFrame2 = imcrop(videoFrame,[321 1 320 480]);
bbox(1,:)=3 * faceDetector.step(imresize(videoFrame1, 1/3)); % enable the face
detector on
bbox(2,:)=3 * faceDetector.step(imresize(videoFrame2, 1/3)); % cropped images
bbox(2,1)=bbox(2,1)+321;                      % plotted the coordinate of
boxes of face
end                                      % started from half of the image
for m = 1: size(bbox,1)
if ~isempty(bbox)                            % for calculate the dimension of
bboxx0(m,1) =  bbox(m,1)+bbox(m,4)*0.15;                 % 2 faces
bboxx0(m,2) =  bbox(m,2)+bbox(m,4)*0.45;
bboxx0(m,3) = (bbox(m,4)/5);
bboxx0(m,4) = (bbox(m,3)/5);
bboxx1(m,1) = (bbox(m,1)+bbox(m,4)*0.6);
bboxx1(m,2) = (bbox(m,2)+bbox(m,4)*0.45);
bboxx1(m,3) = (bbox(m,4)/5) ;
bboxx1(m,4) = (bbox(m,3)/5) ;
end
end
videoOut = step(boxInserter, videoFrame, bbox);  % highlight the boxes of face
at video
release(boxInserter);
for m = 1:numface
strings =m;                 % identify face 1 as 1 and face 2 as 2
videoOut = step(textInserter,videoOut,int8(strings),[bbox(m,1)+5
bbox(m,2)+5]);
```

```
release(textInserter);
end
picture = im2uint8(videoOut);   % converted image to uint8 file
F = im2frame(picture);                  % Convert I to a movie frame
aviobj = addframe(aviobj,F);    % added frames and formed the video
for m = 1: numface              % store the cropped images inside variable
mov1(m,k).cdata = imcrop(picture,bboxx0(m,:)); % right
mov(m,k).cdata = imcrop(picture,bboxx1(m,:));  % left
end

if (size(bboxx0,1)>numface)  % remove the box highlighted as one of the face
disappear
   for n = 0: size(bboxx0,1)-numface
   bboxx0(size(bboxx0,1)-n,:) = [];
   bboxx1(size(bboxx1,1)-n,:) = [];
   break;
   end
end

videoOut = step(boxInserter, videoOut,bboxx0);  % highlighted the cheeks for
both subjects
release(boxInserter);
videoOut = step(boxInserter, videoOut, bboxx1);
step(videoPlayer, videoOut);                  % display the video live in video player

x1(k) = toc;                          % timer off
end
aviobj = close(aviobj);                    % close the video saved
x = sum(x1);                          % determine the time taken of video recorded
release(videoPlayer);                     % close the video player
release(vidDevice);                       % end task of webcam

for m = 1:numface                         % image processing
for k = 1:nFrame
R(m,k) = mean2(mov(m,k).cdata(:,:,1));        % separate into 3 color model and
G(m,k) = mean2(mov(m,k).cdata(:,:,2));        % mean it to result in color traces
B(m,k) = mean2(mov(m,k).cdata(:,:,3));
end
end
for m = 1:numface
    Gm(m) = mean(G(m,:));%performed the standard
                         deviation mean
    Gs(m) = std(G(m,:)); %filter on every color traces
    Rm(m) = mean(R(m,:));
    Rs(m) = std(R(m,:));
    Bm(m) = mean(B(m,:));
    Bs(m) = std(B(m,:));
end
```

```
for m = 1:numface
    for n = 1:nFrame                   % Normalize the traces
    Green(m,n) = (G(m,n)-Gm(m))/Gs(m);
    Red(m,n) = (R(m,n)-Rm(m))/Rs(m);
    Blue(m,n) = (B(m,n)-Bm(m))/Bs(m);
    end
end
l = nFrame*60;                         % converted frequency to bpm
point1 = round((45*x)/2);
pointl = round((240*x)/2);
% ICA algorithm
combine1 = [R(1,:);G(1,:);B(1,:)];
[traceF11,traceF12] = jade(combine1);
combF11 = traceF12(1,:);
combF12 = traceF12(2,:);
combF13 = traceF12(3,:);
RCfft2F1 =(abs(fft(combF11,l/2)));
GCfft2F1 =(abs(fft(combF12,l/2)));
BCfft2F1 =(abs(fft(combF13,l/2)));
RCfft2F1 = RCfft2F1(point1:pointl);
GCfft2F1= GCfft2F1(point1:pointl);
BCfft2F1 = BCfft2F1(point1:pointl);
RC1 = size(RCfft2F1,2);
GC1 = size(GCfft2F1,2);
BC1 = size(BCfft2F1,2);
rCbplowcut1 = round(0.0769 * RC1);
rCbphicut1 = round(0.3846*RC1) ;
gCbplowcut1 = round(0.0769 * GC1);
gCbphicut1 = round(0.3846*GC1) ;
bCbplowcut1 = round(0.0769 * BC1);
bCbphicut1 = round(0.3846*BC1) ;

for cutoff = 1 : rCbplowcut1                  %Band Pass Filter
    RCfft2F1(cutoff) = RCfft2F1(cutoff)*0.6;
end
for cutoff = rCbphicut1 : RC1
     RCfft2F1 (cutoff) = RCfft2F1 (cutoff)*0.6;
end
for cutoff = 1 : gCbplowcut1
   GCfft2F1(cutoff) = GCfft2F1(cutoff)*0.6;
end
for cutoff = gCbphicut1 : GC1
      GCfft2F1(cutoff) = GCfft2F1(cutoff)*0.6;
end
for cutoff = 1 : bCbplowcut1
    BCfft2F1(cutoff) = BCfft2F1(cutoff)*0.6;
end
for cutoff = bCbphicut1 : BC1
     BCfft2F1(cutoff) = BCfft2F1(cutoff)*0.6;
end
```

```
if numface>1              % if another face detected
combine2 = [R(2,:);G(2,:);B(2,:)];
[traceF21,traceF22] = jade(combine2);
combF21 = traceF22(1,:);
combF22 = traceF22(2,:);
combF23 = traceF22(3,:);
RCfft2F2 =(abs(fft(combF21,l/2)));
GCfft2F2 =(abs(fft(combF22,l/2)));
BCfft2F2 =(abs(fft(combF23,l/2)));
RCfft2F2 = RCfft2F2(point1:pointl);
GCfft2F2= GCfft2F2(point1:pointl);
BCfft2F2 = BCfft2F2(point1:pointl);
RC2 = size(RCfft2F2,2);
GC2 = size(GCfft2F2,2);
BC2 = size(BCfft2F2,2);
rCbplowcut2 = round(0.0769 * RC2);
rCbphicut2 = round(0.3846*RC2) ;
gCbplowcut2 = round(0.0769 * GC2);
gCbphicut2 = round(0.3846*GC2) ;
bCbplowcut2 = round(0.0769 * BC2);
bCbphicut2 = round(0.3846*BC2) ;

for cutoff = 1 : rCbplowcut2
   RCfft2F2(cutoff) = RCfft2F2(cutoff)*0.6;
end
for cutoff = rCbphicut2 : RC2
    RCfft2F2 (cutoff) = RCfft2F2 (cutoff)*0.6;
end
for cutoff = 1 : gCbplowcut2
  GCfft2F2(cutoff) = GCfft2F2(cutoff)*0.6;
end
for cutoff = gCbphicut2 : GC2
     GCfft2F2(cutoff) = GCfft2F2(cutoff)*0.6;
end
for cutoff = 1 : bCbplowcut2
   BCfft2F2(cutoff) = BCfft2F2(cutoff)*0.6;
end
for cutoff = bCbphicut2 : BC2
    BCfft2F2(cutoff) = BCfft2F2(cutoff)*0.6;
end
end


l = nFrame*60;
for m = 1:numface
point1 = round((45*x)/2);
pointl = round((240*x)/2);
rfft2(m,:) = (abs(fft(Red(m,:),l/2)));
rffft2(m,:) = rfft2(m,point1:pointl);
```

```
bfft2(m,:) = (abs(fft(Blue(m,:),l/2)));
bffft2(m,:) = bfft2(m,point1:pointl);
   gfft2(m,:) = (abs(fft(Green(m,:),l/2)));
   gffft2(m,:) = gfft2(m,point1:pointl);
   rk = size(rffft2,2);
   gk = size(gffft2,2);
   bk = size(bffft2,2);
   rbplowcut = round(0.0769 * rk);
   rbphicut = round(0.3846*rk) ;
   gbplowcut = round(0.0769 * gk);
   gbphicut = round(0.3846*gk) ;
   bbplowcut = round(0.0769 * bk);
   bbphicut = round(0.3846*bk) ;

   for cutoff = 1 : rbplowcut
      rffft2(m,cutoff) = rffft2(m,cutoff)*0.6;
   end
   for cutoff = rbphicut : rk
       rffft2(m,cutoff) = rffft2(m,cutoff)*0.6;
   end
   for cutoff = 1 : gbplowcut
      gffft2(m,cutoff) = gffft2(m,cutoff)*0.6;
   end
   for cutoff = gbphicut : gk
       gffft2(m,cutoff) = gffft2(m,cutoff)*0.6;
   end
   for cutoff = 1 : bbplowcut
      bffft2(m,cutoff) = bffft2(m,cutoff)*0.6;
   end
   for cutoff = bbphicut : bk
       bffft2(m,cutoff) = bffft2(m,cutoff)*0.6;
   end
   freq = [point1-1:pointl-1]/(x/2);
   figure;
  subplot(3,2,1),plot((freq),rffft2(m,:));axis([45 240 0 50]);
   xlabel('frequency'),ylabel('Bpm');
   subplot(3,2,2),plot((freq),gffft2(m,:));axis([45 240 0 50]);
   xlabel('frequency'),ylabel('Bpm');
   subplot(3,2,3),plot((freq),bffft2(m,:));axis([45 240 0 50]);
   xlabel('frequency'),ylabel('Bpm');
   if (m ==1)
   subplot(3,2,4),plot((freq),RCfft2F1);axis([45 240 0 50]);
   xlabel('frequency'),ylabel('Bpm');
   subplot(3,2,5),plot((freq),GCfft2F1);axis([45 240 0 50]);
   xlabel('frequency'),ylabel('Bpm');
   subplot(3,2,6),plot((freq),BCfft2F1);axis([45 240 0 50]);
   xlabel('frequency'),ylabel('Bpm');
```

```
else
   subplot(3,2,4),plot((freq),RCfft2F2);axis([45 240 0 50]);
   xlabel('frequency'),ylabel('Bpm');
   subplot(3,2,5),plot((freq),GCfft2F2);axis([45 240 0 50]);
   xlabel('frequency'),ylabel('Bpm');
   subplot(3,2,6),plot((freq),BCfft2F2);axis([45 240 0 50]);
   xlabel('frequency'),ylabel('Bpm');
   end
% Peak Detector
for n = 1:gk
if (gffft2(m,n)>gmax(m))
gmax(m) = gffft2(m,n);
end
end
for n = 1:rk
if (rffft2(m,n)>rmax(m))
rmax(m) = rffft2(m,n);
end
end
for n = 1:bk
if (bffft2(m,n)>bmax(m));
bmax(m) = bffft2(m,n);
end
end
ridx(m) = find(rffft2(m,:)==rmax(m));
gidx(m) = find(gffft2(m,:)==gmax(m));
bidx(m) = find(bffft2(m,:)==bmax(m));
y1(m) = freq(ridx(m));
y2(m) = freq(gidx(m));
y3(m) = freq(bidx(m));
figure(m),subplot(3,2,1),title(['Heartbeat Detected red channel:',num2str(y1(m))]);
figure(m),subplot(3,2,2),title(['Heartbeat Detected green
channel:',num2str(y2(m))]);
figure(m),subplot(3,2,3),title(['Heartbeat Detected blue
channel:',num2str(y3(m))]);
end
rck1=size(RCfft2F1,2);
gck1=size(GCfft2F1,2);
bck1=size(BCfft2F1,2);

for n = 1:rck1
if (RCfft2F1(n)>rcmax1);
rcmax1 = RCfft2F1(n);
end
end
```

```
for n = 1:gck1
if (GCfft2F1(n)>gcmax1);
gcmax1 = GCfft2F1(n);
end
end

for n = 1:bck1
if (BCfft2F1(n)>bcmax1);
bcmax1 = BCfft2F1(n);
end
end

rcidx = find(RCfft2F1==rcmax1);
gcidx = find(GCfft2F1==gcmax1);
bcidx = find(BCfft2F1==bcmax1);
yrc1 = freq(rcidx);
ygc1 = freq(gcidx);
ybc1 = freq(bcidx);
figure(1),subplot(3,2,4),title(['Heartbeat Detected red channel
ICA:',num2str(yrc1)]);
figure(1),subplot(3,2,5),title(['Heartbeat Detected green channel
ICA:',num2str(ygc1)]);
figure(1),subplot(3,2,6),title(['Heartbeat Detected blue channel
ICA:',num2str(ybc1)]);
% Display the title in every single plot
if(numface>1)
rck2=size(RCfft2F2,2);
gck2=size(GCfft2F2,2);
bck2=size(BCfft2F2,2);

for n = 1:rck2
if (RCfft2F2(n)>rcmax2);
rcmax2 = RCfft2F2(n);
end
end

for n = 1:gck2
if (GCfft2F2(n)>gcmax2);
gcmax2 = GCfft2F2(n);
end
end

for n = 1:bck2
if (BCfft2F2(n)>bcmax2);
bcmax2 = BCfft2F2(n);
end
end
```

```
rci1dx = find(RCfft2F2==rcmax2);
gci1dx = find(GCfft2F2==gcmax2);
bci1dx = find(BCfft2F2==bcmax2);
yrc2 = freq(rci1dx);
ygc2 = freq(gci1dx);
ybc2 = freq(bci1dx);
figure(2),subplot(3,2,4),title(['Heartbeat Detected for red channel after
ICA:',num2str(yrc2)]);
figure(2),subplot(3,2,5),title(['Heartbeat Detected for green channel after
ICA:',num2str(ygc2)]);
figure(2),subplot(3,2,6),title(['Heartbeat Detected for blue channel after
ICA:',num2str(ybc2)]);
end
rft = rffft2;
gft = gffft2;
bft = bffft2;
RCft1 =RCfft2F1;
GCft1 = GCfft2F1;
BCft1 =BCfft2F1;
if numface >1
RCft2 =RCfft2F2;
GCft2 = GCfft2F2;
BCft2 =BCfft2F2;
End

% --- Executes on button press in pushbutton5.
function pushbutton3_Callback(hObject, eventdata, handles) % display the graph
of user 1 again as user pressed
global rft gft bft RCft1 GCft1 BCft1;
global y1 y2 y3 freq;
global yrc1 ygc1 ybc1;
global input;
figure(1);
subplot(3,2,1),plot((freq),rft(1,:));axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
subplot(3,2,2),plot((freq),gft(1,:));axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
subplot(3,2,3),plot((freq),bft(1,:));axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
subplot(3,2,4),plot((freq),RCft1);axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
subplot(3,2,5),plot((freq),GCft1);axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
subplot(3,2,6),plot((freq),BCft1);axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
figure(1),subplot(3,2,1),title(['Heartbeat Detected for red
channel:',num2str(y1(1))]);
figure(1),subplot(3,2,2),title(['Heartbeat Detected for green
channel:',num2str(y2(1))]);
```

```
figure(1),subplot(3,2,3),title(['Heartbeat Detected for blue
channel:',num2str(y3(1))]);
figure(1),subplot(3,2,4),title(['Heartbeat Detected for red channel after
ICA:',num2str(yrc1)]);
figure(1),subplot(3,2,5),title(['Heartbeat Detected for green channel after
ICA:',num2str(ygc1)]);
figure(1),subplot(3,2,6),title(['Heartbeat Detected for blue channel after
ICA:',num2str(ybc1)]);
per_red = abs(input - y1(1))/input * 100;
per_green = abs(y2(1)-input)/input * 100;
per_blue = abs(y3(1)-input)/input * 100;
per_Ired = abs(yrc1-input)/input * 100;
per_Igreen = abs(ygc1-input)/input * 100;
per_Iblue = abs(ybc1-input)/input * 100;
set(handles.edit5,'String',per_red);
set(handles.edit7,'String',per_green);
set(handles.edit8,'String',per_blue);
set(handles.edit9,'String',per_Ired);
set(handles.edit10,'String',per_Igreen);
set(handles.edit11,'String',per_Iblue);

% --- Executes on button press in pushbutton4.
function pushbutton4_Callback(hObject, eventdata, handles) % display the graph
of user 2 again as user pressed
global rft gft bft RCft2 GCft2 BCft2;
global y1 y2 y3 freq numface;
global yrc2 ygc2 ybc2;
global input
if (numface > 1)
figure(2);
subplot(3,2,1),plot((freq),rft(1,:));axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
subplot(3,2,2),plot((freq),gft(1,:));axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
subplot(3,2,3),plot((freq),bft(1,:));axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
subplot(3,2,4),plot((freq),RCft2);axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
subplot(3,2,5),plot((freq),GCft2);axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
subplot(3,2,6),plot((freq),BCft2);axis([45 240 0 50]);
xlabel('frequency'),ylabel('Bpm');
figure(2),subplot(3,2,1),title(['Heartbeat Detected for red
channel:',num2str(y1(2))]);
figure(2),subplot(3,2,2),title(['Heartbeat Detected for green
channel:',num2str(y2(2))]);
figure(2),subplot(3,2,3),title(['Heartbeat Detected for blue
channel:',num2str(y3(2))]);
```

```
figure(2),subplot(3,2,4),title(['Heartbeat Detected for red channel after
ICA:',num2str(yrc2)]);
figure(2),subplot(3,2,5),title(['Heartbeat Detected for green channel after
ICA:',num2str(ygc2)]);
figure(2),subplot(3,2,6),title(['Heartbeat Detected for blue channel after
ICA:',num2str(ybc2)]);
per_red2 = abs(y1(2)-input)/input * 100;
per_green2 = abs(y2(2)-input)/input * 100;
per_blue2 = abs(y3(2)-input)/input * 100;
per_Ired2 = abs(yrc2-input)/input * 100;
per_Igreen2 = abs(yrc2-input)/input * 100;
per_Iblue2 = abs(yrc2-input)/input * 100;
set(handles.edit5,'String',per_red2);
set(handles.edit7,'String',per_green2);
set(handles.edit8,'String',per_blue2);
set(handles.edit9,'String',per_Ired2);
set(handles.edit10,'String',per_Igreen2);
set(handles.edit11,'String',per_Iblue2);
set(handles.edit5, 'string', 'percentage error \n');
else
    fprintf('No 2nd User available here\n');
end

% --- Executes on button press in pushbutton5.
function pushbutton5_Callback(hObject, eventdata, handles)
videoFReader = vision.VideoFileReader('sample.avi');
videoPlayer = vision.VideoPlayer;
videoPlayer = vision.VideoPlayer('Position',[300 100 640+30 480+30]);
while ~isDone(videoFReader)
for m = 1:500
end
   frame = step(videoFReader);
   step(videoPlayer,frame);
end

% --- Executes on button press in pushbutton6.
function pushbutton6_Callback(hObject, eventdata, handles)  % close the
camera
global flag;
flag = 0;

function edit5_Callback(hObject, eventdata, handles)
function edit5_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

```
function edit6_Callback(hObject, eventdata, handles)
global input;
input = str2double(get(handles.edit6,'string'));

function edit6_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit7_Callback(hObject, eventdata, handles)
function edit7_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit8_Callback(hObject, eventdata, handles)
function edit8_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit9_Callback(hObject, eventdata, handles)
function edit9_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit10_Callback(hObject, eventdata, handles)
function edit10_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit11_Callback(hObject, eventdata, handles)
function edit11_Callback(hObject, eventdata, handles)
function edit11_CreateFcn(hObject, eventdata, handles)
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```