

Feature Extraction from Finger Pulse Profile for High Pitta Detection

*Thesis submitted in partial fulfillment of the requirement for
the award of degree of*

**Master of Engineering
in
Electronic Instrumentation and Control**



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CERTIFICATE

I hereby certify that the work being presented in this thesis entitled “**Feature Extraction from Finger Pulse Profile for High Pitta Detection**” in partial fulfillment of award of degree of **Master of Engineering in Electronics Instrumentation and Control**, submitted in Electrical and Instrumentation Engineering department, Thapar University, Patiala, is an authentic record of my own work carried under the supervision of **Dr. Mandeep Singh**, Associate Professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, Punjab.

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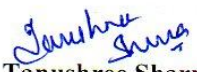
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ABSTRACT

Ancient Indian system of medicine popularly known as Ayurveda was heavily dependent on diagnosis through nadi parikshan i.e. pulse diagnosis. Through nadi parikshan, the tridosha (vata, pitta and kapha) level of body was studied and checked for imbalances, and the latter if present, was considered the very root of the ailment or illness in the body. This analysis required no sophisticated instrument and was totally dependent on the expertise of the expert. In the modern times we have highly sophisticated instruments but the expertise available earlier for diagnosis is missing. Pulse Plethysmograph is one modern instrument which can be used to overcome this lacking expertise and hence to revive this dying art of nadi parikshan. According to Ayurveda, the level of pitta increases immediately after lunch. In this thesis it has been proposed that a substantial relation may lie between the finger pulse features and high pitta level in human body.

In this work the finger PPG waveform has been studied and some prominent features have been extracted from the pulse wave. The data has been recorded using BIOPAC MP System and AcqKnowledge software. The features thus extracted from the finger pulse plethysmogram have been used to find a relation between increased pitta and the peripheral finger pulse. For this pilot study data was acquired from three subjects and three parameters were extracted from both right and left hands, before and immediately after lunch. On calculating and comparing the mean and variance of these parameters, it has been found that the variance of $A2/A1$ in middle finger, and $TP2/TPT$ in ring finger, decreases consistently for all the three subjects, in both left and right hand. This result may be further validated used as an indication of high pitta level in human body.

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Chapter 1

Introduction to Ayurveda

1.1 Ayurveda

Ayurveda (Sanskrit Ayus, “life” and Veda, “knowledge”), is the ancient Indian system of traditional medicine, writings about which date from about 2500 BC. It is still widely practiced in India, and is becoming increasingly known outside Asia [2]. The theory that informs ayurveda is wide-ranging, involving philosophy and spirituality, as well as science and medicine, based on the Samkhya philosophy of creation. (The roots of the term Samkhya are two Sanskrit words: Sat, meaning “truth”, and Khya, meaning “to know”).

1.2 Basic Elements of Universe

The rishi Kapila, who realized the Samkhya philosophy of creation, discovered twenty-four principles or elements of the universe, of which Prakruti and Purusha are the most basic. Purusha is the male, while Prakruti is the female energy. Purusha is formless, colorless and beyond attributes and takes no active part in the manifestation of the universe. This energy is choice less, passive awareness. Prakruti has form, color and attributes: it is awareness with choice. It is Divine Will, the One who desires to become many.

The universe is the child born out of the womb of Prakruti, the Divine Mother. Prakruti creates all forms in the universe, while Purusha is the witness to this creation. It is primordial physical energy containing the three attributes, or gunas, found in all nature, the evolving cosmos. The three gunas which are the foundation for all existence are satva (essence), rajas (movement) and tamas (inertia). They are contained in balance in Prakruti. When this balance is disturbed, there is an interaction of the gunas which thus engenders the evolution of the universe.

The first manifestation from Prakruti is Cosmic Intellect called Mahad. From Mahad, Ego (Ahamkar) is formed. Ego then manifests into the five senses (tanmatras). (Tan means

“subtle” and Matra means “elements”) The tanmatras, the subtle elements, are the objects of the five senses. The five tanmatras are sound, touch, form, taste, and odor or smell; the five senses are hearing, tactile perception, vision, taste, and smell. The tanmatras are the ways in which the objective world is sensed.

The five motor organs, with the help of satva, thus create the organic universe while the Ego manifests into the five basic elements (bhutas) with the help of tamas, to create the inorganic universe [29].

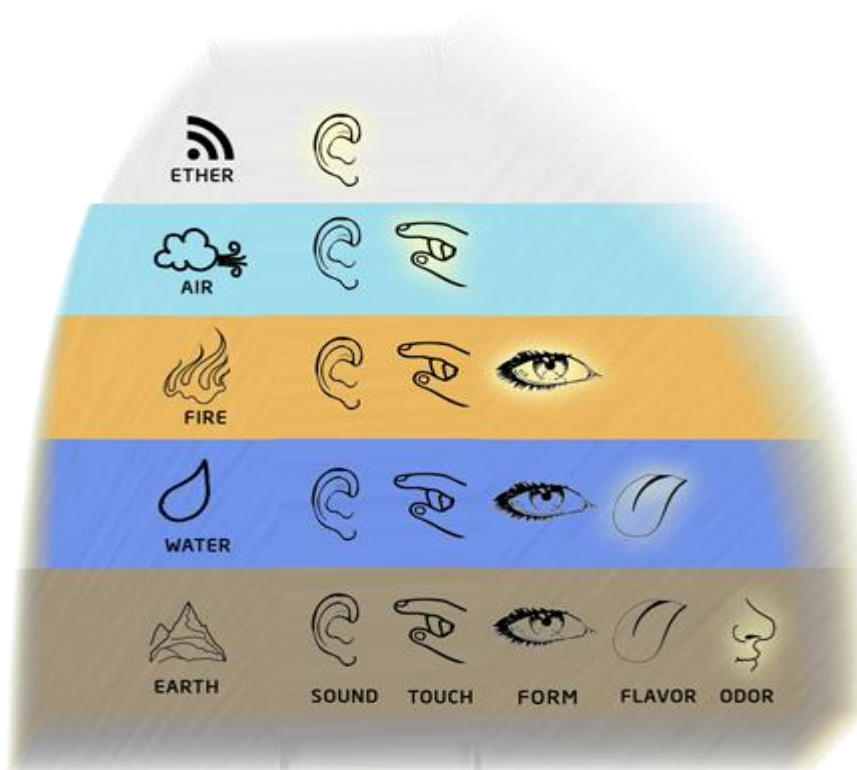


Figure 1.1: The Tanmatras

1.3 Three Gunas

Rajas is the active vital life force in the body which moves both the organic and inorganic universes to satva and tamas respectively. Satva and tamas are inactive, potential energies which need the active, kinetic force of rajas. Satva is creative potential (Brahma), Rajas is a kinetic protective force (Vishnu), and Tamas is a potential destructive force (Mahesh). Creation, Protection and Destruction are the three manifestations of the first cosmic soundless sound, Aum, which is constantly operating in the universe [29].

Chart I – *Samkhya* Philosophy of Creation

Purusha is unmanifested, formless, passive, beyond attributes, beyond cause and effect, space and time. **Purusha** is Pure Existence. **Prakriti** is the creative force of action, the source of form, manifestation, attributes and nature. **Mahad** is the Cosmic intelligence or *Buddhi*. **Ahamkar** is ego, the sense of "I am." **Satva** is stability, pure spect, awakening, essence and light. **Rajas** is dynamic movement. **Tamas** is static. It is potential energy, inertia, darkness, ignorance and matter.

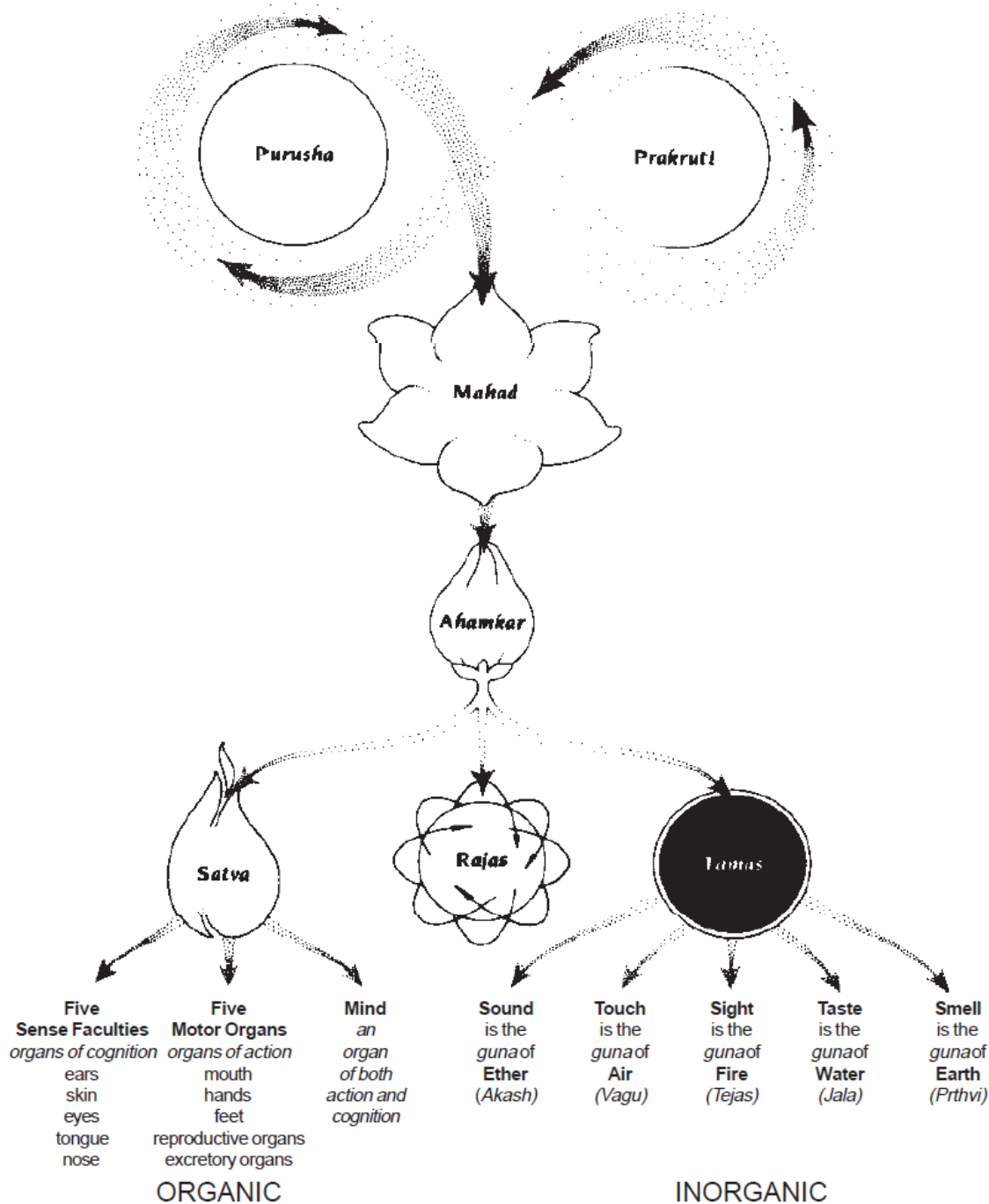


Figure 1.2: Samkhya Philosophy of Creation

1.4 Tridosha: Vata, Pitta and Kapha

Ayurveda is based on the idea that the mind, body, and environment are part of an all-encompassing field of energy and intelligence that creates and sustains life. According to ayurveda, Ether, Air, Fire, Water and Earth the five basic elements, manifest in the human body as three basic principles, or humors, known as the tridosha. From the Ether and Air elements, the bodily air principal called vata is manifested. The Fire and Water elements manifest together in the body as the fire principle called pitta. The Earth and Water elements manifest as the bodily water humor known as kapha. These three elements vata-pitta-kapha govern all the biological, psychological and physiopathological functions of the body, mind and consciousness. They act as basic constituents and protective barriers for the body in its normal physiological condition. But when out of balance, they contribute to disease processes.

Elements of the Tri-dosha

VATA	AIR + ETHER
PITTA	FIRE + WATER
KAPHA	EARTH + WATER

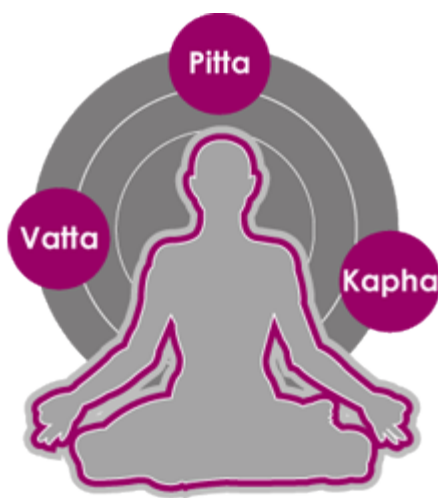


Figure 1.3: Tridoshas: The Constituents of Human Body

According to ayurveda, the predominance of vata dosha makes a person slender, intuitive, energetic, and prone to mood disorders and constipation. Pitta dosha promotes a medium build, reddish hair and ruddy skin, and proneness to anger, acne, heartburn, and ulcers. Those predominant in kapha dosha are more pale and relaxed, and prone to obesity and allergies. Moreover the tridosha are responsible for the arising of natural urges and for individual preferences in foods, their flavors, temperatures and so on. They govern the creation, maintenance and destruction of bodily tissue, and the elimination of waste products from the body. They are also responsible for psychological phenomena, including such emotions as fear, anger, greed, understanding, compassion and love. Thus, the tridosha are the foundation of the psychosomatic existence of man.

The detection of imbalances in our doshas is one of ayurvedic medicine's main ways of diagnosing ill health. It is claimed that, while all three doshas are found in everyone, their relative proportions vary from person to person [2].

Chapter 2

Diagnosis by Pulse Prediction

2.1 Nadi or Pulse

Nadi in traditional medical language means channels. These channels exist within the body in the form of blood vessels, nerves, lymphatic channels, nodes etc. According to ayurveda each cell in our body possesses its own intelligence. Communication of this intelligence takes place in the form of vibrations through these channels [25].

Ayurveda defines diagnosis as a moment-to-moment monitoring of the interactions between order (health) and disorder (disease) in the body. The disease process is a reaction between the bodily humors and the tissues. The symptoms of disease are always related to derangement of the balance of the tridosha. Ayurveda teaches very precise methods for understanding the disease process before any overt signs of the disease have manifested. By detecting early symptoms of imbalance and disease reaction in the body, one can determine the nature of future bodily reactions. Nadi parikshan or pulse analysis is one of the prominent methods of diagnosis in ayurveda [29].

2.2 Nadi Parikshan or Pulse Prediction

In nadi parikshan one understands the vibratory frequency of the pulse at various levels on the radial artery. Subtle vibrations are read at seven different levels vertically downward that help in ascertaining various functions in the body. The pulse, when examined, reveals both physical & mental characteristics of the pulse. This is interpreted in the form of symptoms along with their prognosis which helps in understanding the cause.



Figure 2.1: Nadi Parikshan

2.3 Revelations during Nadi Parikshan

Every aspect of the human organism, the body, mind etc. is understood during the Pulse Diagnosis. Apart from understanding the cause of the current ailments, the diagnosis tracks the disease to its root cause. Even subtler levels of causal factors like emotional issues or specific thought patterns of the individual, that manifest into physical ailments subsequently can be predicted. To summarize Nadi Parikshan:

1. Ascertains one's original constitution at the time of conception (Prakruti). This forms the basis of deciding the basis and structure of the individualized healing process.
2. Helps to understand one's current constitution as against the original Constitution (Vikruti). The diagnosis ascertains the deviation that the body and mind have taken as compared to its original constitution. Also, it enables one to understand the prognosis of ailments that have arisen during this transition from Prakruti to Vikruti.
3. Successfully tracks down the altered state of the mind. This is very important as the science of Ayurveda believes that a major part of human ailments are psychosomatic in nature. This is so because the only way the Mind can express

itself is through the body. Therefore, the body works to a very large extent according to the dictates of the mind.

4. Analysis the doshas. Any alteration in the Doshas can lead to understanding of the disease process. The doshas like Vata, Pitta & Kapha and their sub units help in understanding:

- 4.1 The movement of energies and the working of the nervous system, circulation as defined by the pulsation of the heart, and the movement of nutrition to various tissues in the body.

- 4.2 The metabolic process and the process of bio-transformation in the body, which governs the activities of digestion, absorption & assimilation of nutrition.

- 4.3 The assimilating and binding functions through the help of bodily fluids, which includes the proper and healthy formation of muscles, bones, ligaments and tendons etc.[30].

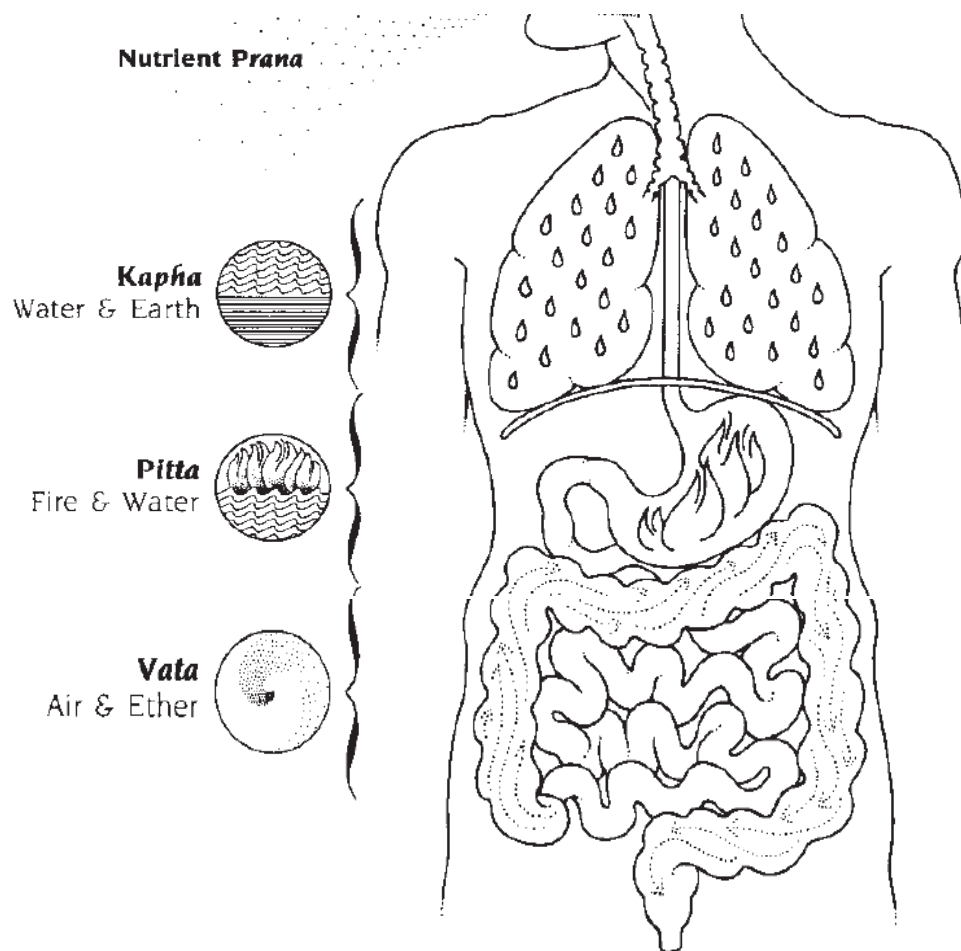


Figure 2.2: Tridosha Composition in Human Body

Chapter 3

Finger Plethysmograph

3.1 Plethysmography

Photoplethysmography (PPG) is a simple, non invasive and inexpensive optical technique that can be used to detect blood volume changes in the micro vascular bed of tissues. The two basic requirements of PPG are: a light source to illuminate the tissue (e.g. skin), and a photo detector to measure the small variations in light intensity associated with changes in perfusion in the catchment volume. PPG is most often operates at red or near infrared wavelength. The peripheral pulse, which is synchronized to each heartbeat, is its most recognizable feature. Despite its simplicity the origins of the different components of the PPG signal are still not fully understood. It is generally accepted, however, that they can provide valuable information about the cardiovascular system [16].

3.2 Optical considerations of origin of PPG waveform

The pulsatile component of the PPG waveform is often called the ‘AC’ component and usually has its fundamental frequency, typically around 1 Hz, depending on heart rate. This AC component is superimposed onto a large quasi-DC component that relates to the tissues and to the average blood volume. This DC component varies slowly due to respiration, vasomotor activity and vasoconstrictor waves and several other factors.

The interaction of light with biological tissue is complex and includes the optical processes of (multiple) scattering, absorption, reflection, transmission and fluorescence [22, 16]. Several researchers have highlighted the key factors that can affect the amount of light received by the photodetector: the blood volume, blood vessel wall movement and the orientation of red blood cells (RBC). The wavelength of optical radiation is also important in light–tissue interactions [31]. There are three main reasons for this: (1) *The optical water window*: The main constituent of tissue is water that absorbs light very strongly in

the ultraviolet and the longer infrared wavelengths. The shorter wavelengths of light are also strongly absorbed by melanin. There is, however, a window in the absorption spectra of water that allows visible (red) and near infrared light to pass more easily, thereby facilitating the measurement of blood flow or volume at these wavelengths. Thus, the red or near infrared wavelengths are often chosen for the PPG light source [9]. (2) *Isobestic wavelength*: There is a significant difference in absorption between oxyhaemoglobin (HbO₂) and reduced haemoglobin (Hb) except at the isobestic wavelengths. For measurements performed at an isobestic wavelength (i.e. close to 805 nm, for near infrared range) the signal should be largely unaffected by changes in blood oxygen saturation and (3) *Tissue penetration depth*: The depth to which light penetrates the tissue for a given intensity of optical radiation depends on the operating wavelength [13]. In PPG the catchment (study) volume, depending on the probe design, can be of the order of 1 cm for transmission mode systems [12].

3.3 The History of PPG

Molitor and Kniazuk of the Merck Institute of Therapeutic Research, New Jersey described recordings made with a reflection mode PPG system from human fingers. Alrick Hertzman from the Department of Physiology at St. Louis University School of Medicine was another pioneer who helped establish the PPG technique. In 1937, Hertzman and his colleagues published their first paper on PPG in which they described the use of a reflection mode system to measure blood volume changes in the fingers induced by the Valsalva manoeuvre, exercise and with exposure to cold. However in 1938, Hertzman undertook a validation of the PPG technique by comparing blood volume changes with those measured simultaneously by mechanical plethysmography. Preliminary observations on the PPG technique were also reported in the same year by Matthes and Hauss. Hertzman and Dillon in 1940 split the AC and DC components with separate electronic amplifiers and monitored vasomotor activity. Hertzman (1938) emphasized that good contact with skin was needed, but without excessive pressure that would result in blanching. He also advised that movement of the measurement probe against the skin should be avoided. These observations led to the development of elaborate positioning devices. Illumination was identified as another important design consideration. Hertzman

also used a battery powered torch bulb which was less than ideal because of its relatively wide spectrum, particularly in the infrared because of local tissue heating, errors due to the effects of oxygen saturation, and the widespread illumination which can mix skin microvascular blood flow with larger vessel signals. Furthermore, constant light intensity could not be guaranteed. In more recent decades the advances in opto-electronics and clinical instrumentation have significantly contributed to the design of modern plethysmography. The developments in semiconductor technology, i.e. light emitting diodes (LED), photodiodes and phototransistors, have made considerable improvements in the size, sensitivity, reliability and reproducibility of PPG probe design. There have also been considerable developments in computer-based digital signal processing and pulse wave analysis [12].

3.5 Photoplethysmography Instrumentation

Modern PPG sensors mostly utilize low cost semiconductor technology with LED and matched photodetector devices working at the red and/or near infrared wavelengths (IR-A near infrared band 0.8 to 1 μm). LEDs convert electrical energy into light energy and have a narrow single bandwidth (typically 50 nm). The main advantage of using LED's as light source is that they are compact, with a long operating life usually greater than 105 hours, operate over a wide temperature range with small shifts in the peak-emitted wavelength, and are mechanically robust and reliable.

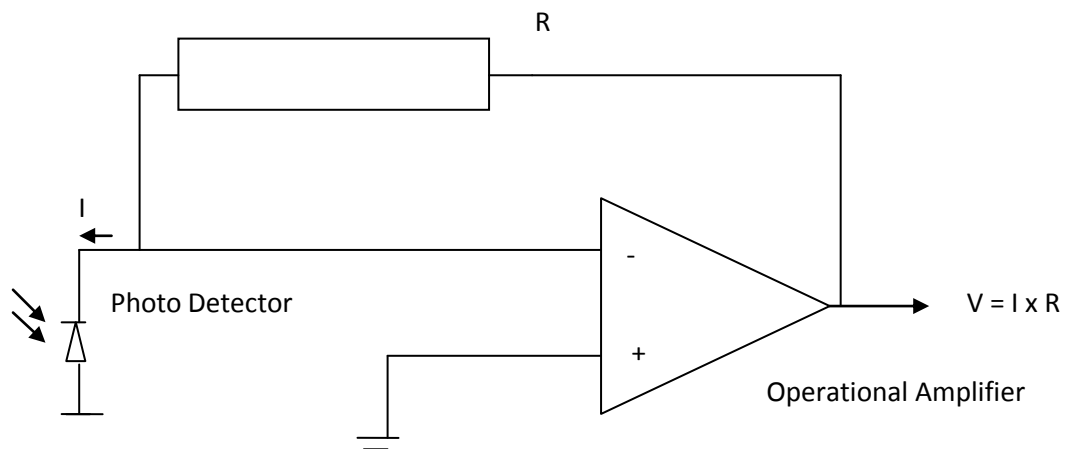


Figure 3.1: Transimpedance Amplifier stage of a PPG Sensor

However it must be taken care of that the average intensity of the LED is constant and preferably sufficiently low to minimize excessive local tissue heating and also to reduce the risk of a non-ionizing radiation hazard. The choice of photodetector depends on its spectral characteristics which are chosen to match that of the light source. A photodetector converts light energy into an electrical current. They are compact, low-cost, sensitive, and have fast response times. Near infrared devices can be encased with daylight filters. The photodetector connects to low noise electronic circuitry that includes a transimpedance amplifier and filtering circuitry.

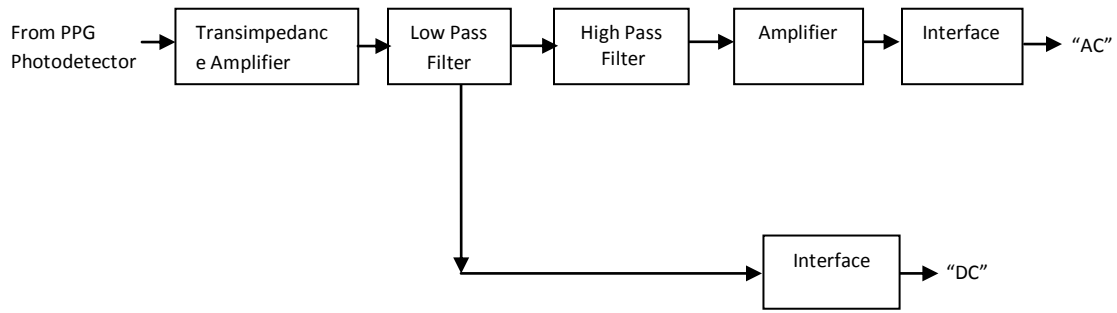


Figure 3.2: Block Diagram of Signal Conditioning Stages of a Standard PPG Sensor

A high pass filter reduces the size of the dominant DC component and enables the pulsatile AC component to be boosted to a nominal 1 V peak-to-peak level. Carefully chosen filtering circuitry is also needed to remove the unwanted higher frequency noise such as electrical pick up from (50 Hz) mains electricity frequency interference. Figure 3.1 shows a transimpedance amplifier design and figure 3.2 shows the signal conditioning stages surrounding this, including low pass filtering, high pass filtering and further amplification, signal inversion and signal interface. The choice of high pass filter cut-off frequency is particularly important because excessive filtering can distort the pulse shape but too little filtering can result in the quasi-DC component dominating over the AC pulse [13].

3.6 Types of PPG configurations and artifacts related to PPG

There are two main PPG operational configurations: transmission (‘trans-illumination’) mode operation where the tissue sample (e.g. fingertip) is placed between the source and detector, and reflection (‘adjacent’) mode operation where the LED and detector are placed side-by-side. The transmission mode PPG imposes more restrictions than the reflection mode PPG on the body locations available for study. The PPG probe should be held securely in place to minimize probe-tissue movement artefact. There are other sources of artifact that need to be considered in the measurement technology. For example, artifact can arise from ambient light interference but can be reduced in several ways: by suitable probe attachment to the skin (e.g. using a dark Velcro wrap-around cuff), by further shading of the study site area and performing measurements in subdued lighting, and by electronic filtering (e.g. light modulation filtering) [14].

3.7 Measurement protocol and reproducibility

Reproducibility is very important in clinical physiological measurement, for example in giving confidence in detecting significant responses to therapy. Many factors affect reproducibility, including the method of probe attachment to tissue, probe–tissue interface pressure, pulse amplifier bandwidth, minimization of movement artifact, subject posture and relaxation, breathing, wakefulness, room temperature and acclimatization [32]. As yet, however, there are no internationally recognized standards for clinical PPG measurement. There are a limited number of studies quantifying the repeatability or reproducibility of PPG measurements. Another important study addressed the uncertainty in PPG measurements for a group of healthy adult subjects. They studied the repeatability of PPG pulse transit time (PTT) measurements made from the ear, thumb and toe sites both within session and between sessions held on separate days. Measurements at individual sites and bilateral (right–left) side differences were both assessed. The results showed the importance of controlling for factors such as posture, ambient temperature, relaxation and acclimatization. Bilateral measurements were generally more repeatable than individual site measurements since heart rate, respiration and blood pressure factors tend to affect both sides of the body simultaneously.

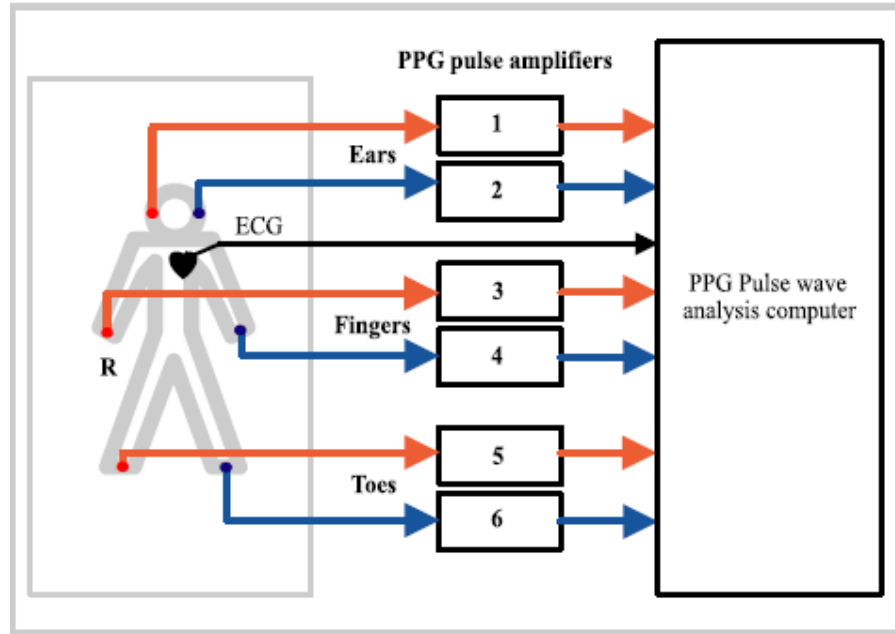


Figure 3.3: An Overview of a Six Channel PPG measurement and Analysis System

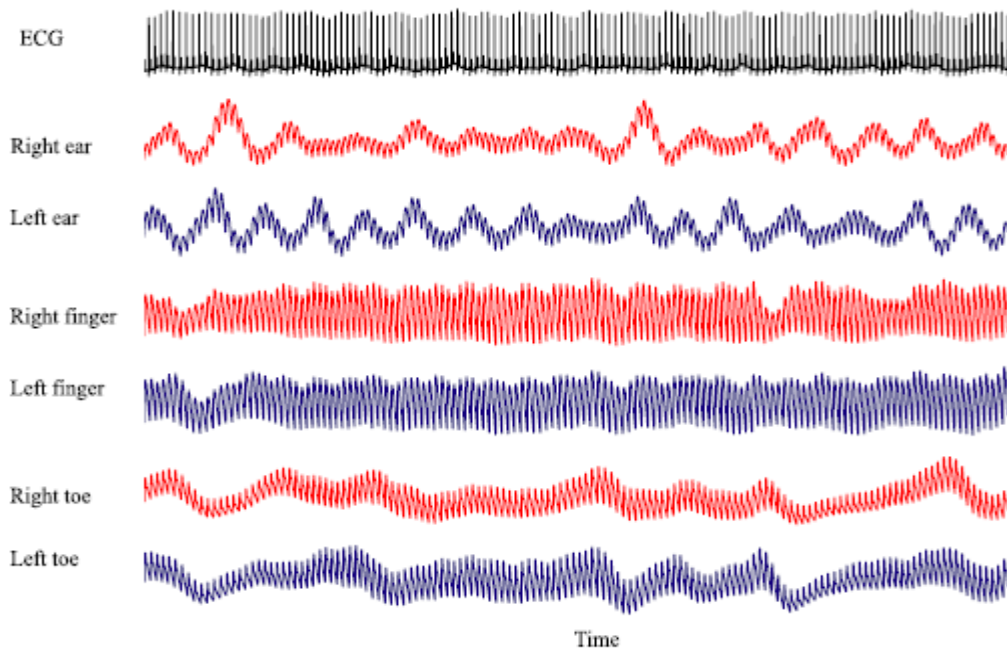


Figure 3.4: An Example Recording Made from the Right and Left Ear Lobes, Index Fingers, and Great Toes of a Healthy Subject

From the two figures we observe a similarity in the pulse characteristics between the right and left body sides but clear differences between the proximal and distal measurement

sites. However, the degree of right to left side similarity in the high and low frequency components of the PPG waveform can be reduced in patients with vascular disease [13].

3.7 Photoplethysmography pulse wave characterization

Two important characteristics of the PPG AC pulse waveform were described by Hertzman and Spealman (1937). The appearance of the pulse was defined as two phases: the anacrotic phase being the rising edge of the pulse, and the catacrotic phase being the falling edge of the pulse. The first phase is primarily concerned with systole, and the second phase with diastole and wave reflections from the periphery. A dicrotic notch is usually seen in catacrotic phase of subjects with healthy compliant arteries. It is useful also to consider the blood pressure pulse and its propagation along individual arteries. The pressure pulse wave is known to change in shape as it moves toward the periphery and undergoes amplification and alterations in its shape and temporal characteristics. These changes are thought to be largely due to reflection of the pulse wave and the tapering down of the arteries towards the periphery. Pulse propagation in arteries is further complicated by frequency dependent phase distortion [12].

Chapter 4

Finger Pulse Profile Features

4.1 Pulse Wave

The pulse wave (PW) is a complex physiological phenomenon observed and detected in blood circulation. In the course of heart systole a certain amount of blood is ejected and it is moved into the arteries because of transformation between kinetic and potential energy of each segment of ejected blood. On each artery or venous section affected by a pulse wave, three coherent phenomena are observed: blood flow (flow pulse), the increase of blood pressure (pressure pulse) and extension of transverse profile (profile or volume pulse).

Several invasive methods are available to detect the PW. The PW contour varies in different parts of the circulation. It depends on physiological or pathophysiological conditions of the organism. The heart rate, the body height and the age, as well as BMI or body fat belong to important physiological phenomena. The pathological events like arteriosclerosis or diabetes have a great primary effect on the arterial elasticity. Hypertension or some heart diseases influence the PW velocity.

The physics of blood circulation in arteries can be demonstrated on the model mechanical system. This system is composed of a piston and elastic hose, which is filled with fluid and terminated by wave resistance. The piston (model of heart) injects a certain volume of fluid (blood) into the hose (model of arteries). If we have a rigid hose, the whole volume of fluid would move, but if we have an elastic-walled-hose, only the fluid at the beginning of the hose moves. The pressure then increases, which causes local widening of the hose and local accumulation of the fluid. Tension of the widened elastic wall causes contraction and pushes the fluid to the next part of the hose. The hose widens there again and the pressure increases. The process continues along the whole length of the hose. The process, which we have just described, runs continuously as a propagating pulse wave along the hose. In

every region where the pulse wave runs, three related effects can be observed: liquid flow (flow wave), a pressure change (pressure wave), and a cross-section change (volume wave). The forward wave spreads to the periphery, where it does not dissipate, but is reflected back to central vascular system. This retrograde propagation causes an increase of blood pressure again. Standing waves arise. The resulting pulse waveform is determined by phase sum of forward and reflected waves. The time differences of reflected pulse wave in each part of circulation are responsible for differences of central and peripheral pulse wave. The pressure in ascending aorta decreases after reaching the maximum and there is a typical incision at the end of diastole. This is caused by short regurgitation at the end of systole. It closes the semi lunar valves and the systole is finished.

These shapes of pressure pulse are typical for the arteries close to the heart, e.g. subclavian artery or carotid artery (figure 4.1). In distal arteries, the pressure changes are different from those in the aorta. The pulse pressure increases there and there is no incision because of attenuation of higher frequencies. Therefore the curves are more rounded.

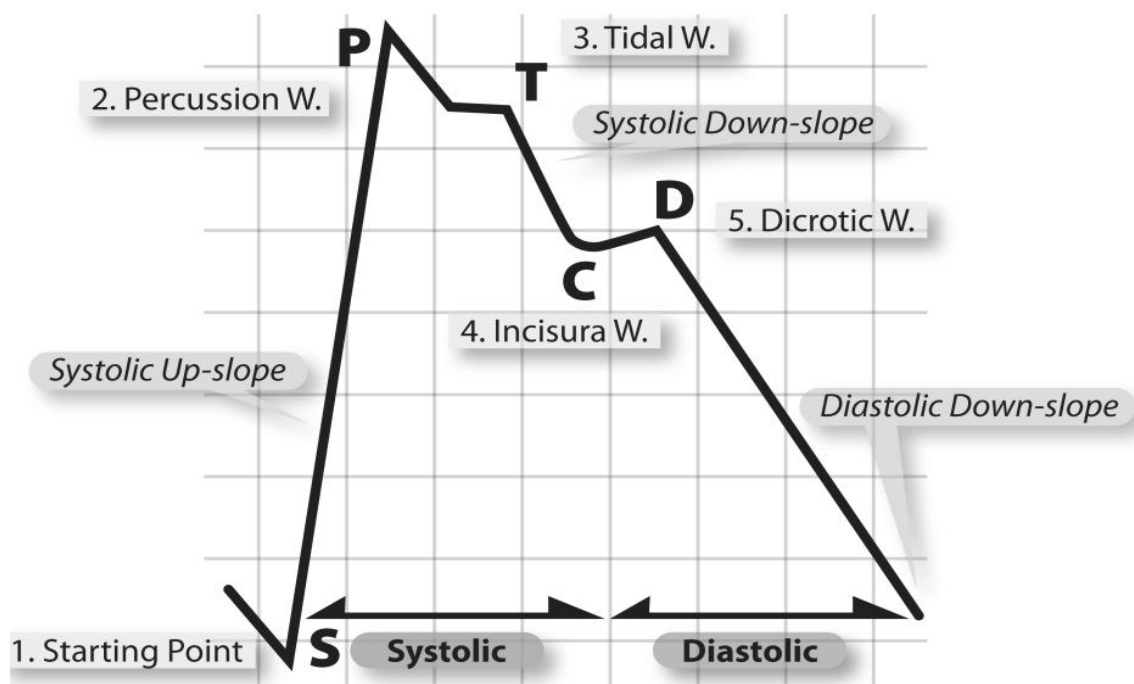


Figure 4.1: Features of a Finger Pulse Wave

Elements of Pulse Wave (Systolic Phase)	
1. S (Starting Point)	Starting point of systolic phase of arterial pulse-wave. Aortic valve opens and the blood of the LV is ejected into aorta.
2. P (Percussion Wave)	Wave caused from LV ejection that increases the blood volume within artery. Higher point means stronger LV ejection and higher compliance of larger artery.
3. T (Tidal Wave)	Reflected wave from the small artery. Higher point means contraction and stiffness of small artery.
4. C (Incisura)	End-point of systolic phase, then aortic valve is closed. Less drop from pulse height (PH) means larger resistance (arterial contraction & tension).

Figure 4.2: Elements of Pulse Wave

The pulse becomes palpated in any place that allows an artery to be compressed against a bone. The common pulse sites on the human body are at the neck (carotid artery), at the wrist (radial artery), behind the knee (popliteal artery), on the inside of the elbow (brachial artery), and near the ankle joint (posterior tibial artery). The peripheral pulse is an extension of the pulse in the radial artery. It can be detected in the fingers. Its wave has two parts: systolic and diastolic (figure 4.2). The beginning flash increase of the pressure is caused by slower drain to capillaries then inflow from the large arteries. Subsequent pressure decrease is caused by lower inflow from the heart then by drain to capillaries. The pulse shape is influenced by the dichrotic wave. This is caused by standing waves between ascending aorta and the distal reflect part at the limb. This standing wave creates maxima and minima, which influences the dichrotic part of the pulse curve. The amplitude of these standing waves is clearer at the distal arteries and the shape of the flow wave differs from the pressure wave and volume wave. Within the superposition of the opposite wave the pressures and volumes are added but the flows are subtracted. The above mentioned should be taken into the consideration to evaluate the pulse wave properly [8].

4.2 Diagnostic Techniques

There are several non-invasive methods of pulse wave measurements based on different principles and depending on the type of the pulse wave. The pulse wave spreading in the surface arteries impact the sensor either directly or implicitly modulate an energetic impulse transmitted to the body. According to the division mentioned above, we can obtain three following waves.

4.2.1 Pressure pulse wave

The shape of pressure pulse wave changes while it moves to the distal arteries. These changes are thought to be largely due to the pulse wave reflection and the tapering. The pressure pulse wave has similarities with volume pulse wave, so similar changes occur in conjunction with vascular diseases, such as damping and a loss of pulsatility because of absorbing the higher frequencies of artery wall movement because of its rigidity. Very famous method of noninvasive pressure pulse wave assessment uses finger pressure cuff in feedback of photoplethysmography sensor to control the constant pressure. There are several commercial devices that can be used for this purpose.

4.2.2 Volume pulse wave

There are two main techniques to measure and record the volume pulse wave. The easiest way is to use the classic brachial cuff surrounding the limb attached to the pressure transducer. This technique is not very sensitive since the addition of the pulse waves of the all arteries under the cuff is also measured. But this still can be used in venous occlusion plethysmography for assessment of the blood volume flowed into the limb after occlusion or for measurement of pulse wave velocity between two cuffs. The second and the most widespread method used is photoplethysmography (figure 4.3). This technique is an optical measurement technique that is used to detect blood volume changes in the micro vascular bed of tissue. This principle is also used in oximeters or blood pressure measurement systems.

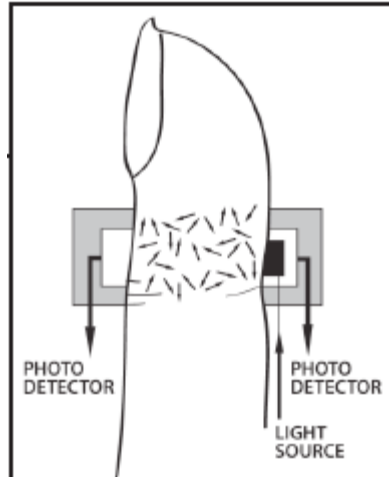


Figure 4.3: Finger PPG

4.2.3 Flow pulse wave

Doppler ultrasound flowmeter is widely used type for measurement of the flow. This can be applied from body surface and has a lot of advantages. Erythrocytes are the basic echo structures and frequencies from 2 MHz to 10 MHz are used. With the color Doppler techniques combined with pulsed emission (to determine the spatial flow location) we can measure the mean flow velocity in selected vessel. However, the flow pulse wave shape does not correlate with the volume and pressure waves. A negative part can also occur here during the regurgitation phase of blood flow [8].

4.3 Measurements on pulse wave in time domain

The typical volume pulse wave shape of the peripheral artery is shown in figure 4.4. On the time course of pulse wave there are following proportions which can be measured: crest time (TP1), dicrotic wave time (TP2), total pulse duration (TPT), interwave time (IWT) measured in two thirds of systolic peak, second forward wave time (T2), systolic amplitude (AP1), dicrotic wave amplitude (AP2).

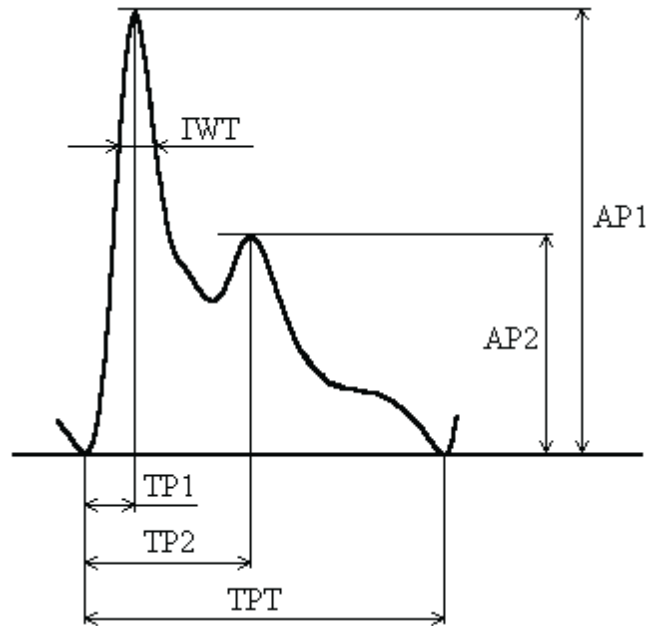


Figure 4.4: Relevant Proportions of Volume or Pressure Pulse Wave Shape of the Peripheral Artery

From the above mentioned proportions, the following parameters can be derived: relative crest time (RCT) = $TP1/TPT$, interwave distance (IWD) = IWT/TPT , relative dirotic wave amplitude (DWA) = $AP2/AP1$ (also called reflection index (RI)) or relative dirotic wave time (DWT) = $TP2/TPT$, all these parameters are dimensionless. In practice the augmentation index is used for the expression of intra-arterial pressure increase caused by reflected wave. The aortic wave curve is calculated from radial curve using the transfer function. Using the body height (h), the index of large artery stiffness (SI) = $h/T2$ can be calculated. SI is related to PWV (pulse wave velocity) in large arteries and closely correlates with carotid-to-femoral PWV. The systolic component of the waveform arises mainly from a forward going pressure wave and the diastolic component from pressure waves reflected back along the aorta from small arteries mainly in the lower body. The time between the systolic and diastolic peaks is related to the transit time of the pressure waves from the root of the aorta to the site of reflection and back. There are some other time-derived parameters like inclination time, elasticity index, descending time, propagation time, which are not used anymore because of difficult evaluation [8].

4.4 Measurements on pulse wave derivatives

Another approach is the evaluation of derivatives of the waveforms. This allows us the precise analysis of sudden changes in the waveform and time shifts. Figure 4.5 shows a real volume pulse waveform of radial artery and its first-order and second-order time derivative.

The first-order derivative parameters have a non acceptable variation and therefore are not used. But, the second-order derivative (called Acceleration Plethysmogram, APG) is more useful. The abbreviations SDFAP (second derivative of finger arterial pressure waveform) or SDPTG (second derivative of finger photoplethysmograph) can also be found. The second-order derivative waveform comprises of five main parts, labeled from A to E: initial positive (A), early negative (B), re-increasing (C), late re-decreasing (D) and diastolic positive (E). From these determinants, the following parameters can be calculated: B/A ratio, C/A ratio, D/A ratio, E/A ratio and aging index $AGI = (B-C-D-E)/A$ [8].

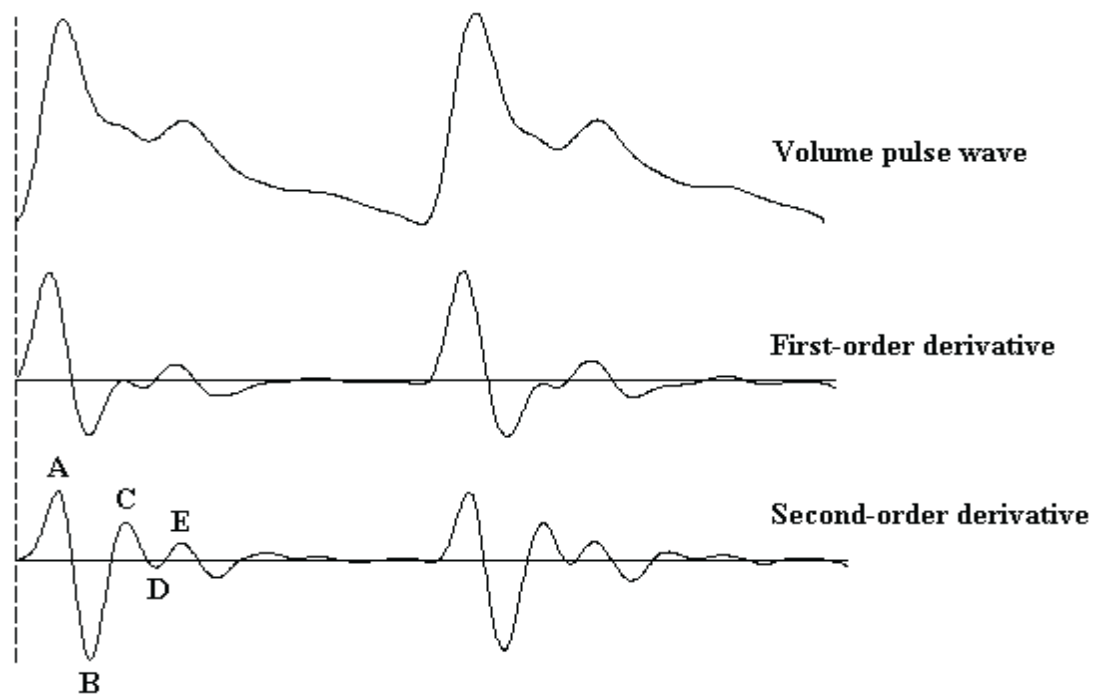


Figure 4.5: Distal real Volume Pulse Waveform and its Derivatives.

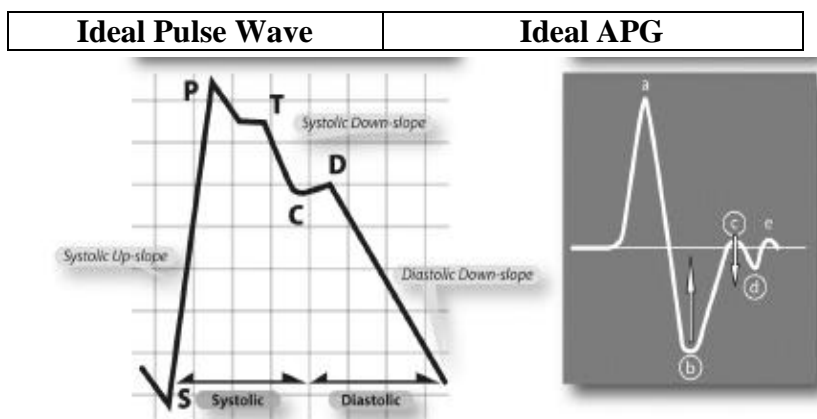


Figure 4.6: Ideal Wave and APG Wave

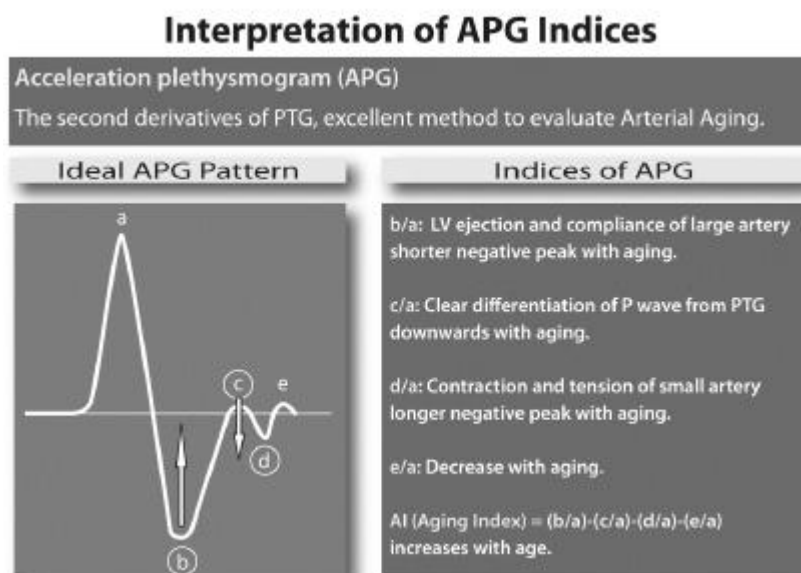


Figure 4.7: Interpretation of APG Indices

4.5 Pulse wave velocity (PWV)

The rate at which aortic pressure waves travel is determined in part by vascular stiffness. As large arteries stiffen with age or disease processes, both PWV and amplitude of the reflected wave increase. The reflected wave then appears in the aorta during systole, augmenting central aortic pressure. The parameter of real spreading of pulse wave in the artery system is pulse wave velocity (PWV) or pulse transit time (PTT), related according

$PWV = L/PTT$, where L is the length distance of two spots between which the velocity is measured. This of course cannot be confused with blood flow velocity, which is much slower and has a different physiological sense. PWV is the most frequently evaluated parameter, because it is very evident and measurable by commercial available devices [8].

4.6 Augmentation Index

Augmentation index (Aix) is defined as the difference of the first systolic and second peak, expressed as a percentage. Numerically $Aix = (AP1 - AP2) / AP1 \times 100 \%$. Aix can be evaluated either for the aorta (central Aix, cAix) or radial or other distal arteries (peripheral Aix, pAix). Since Aix is influenced by heart rate, the corrected index for heart rate 75 bpm (AI@75) is commonly used [8].

Chapter 5

Literature Survey

5.1 The Optics of Human Skin

In 1981, R Rox Anderson and John A Parrish from the Department of Dermatology, Harvard Medical School and Massachusetts General Hospital, Boston, Massachusetts respectively, presented an integrated review of the transfer of optical radiation into human skin, aimed at developing useful models for photo medicine, in the journal of Investigative Dermatology. Epidermal thickness and melanization are important factors for UV wavelengths less than 300 nm, whereas the attenuation of UVA (320-400 nm) and visible radiation is primarily via melanin. Optical properties of the dermis are modeled using the Kubelka-Munk approach, and calculations of scattering and absorption coefficients are presented. This simple approach allows estimates of the penetration of radiation *in vivo* using noninvasive measurements of cutaneous spectral remittance (diffuse reflectance). Although the blood chromophores Hb, HbO₂, and bilirubin determine dermal absorption of wavelengths longer than 320 nm, scattering by collagen fibers largely determines the depths to which these wavelengths penetrate the dermis, and profoundly modifies skin colors. According to this review, an optical "window" exists between 600 and 1300 nm, which offers the possibility of treating large tissue volumes with certain long-wavelength photosensitizers [22].

5.2 Skin photoplethysmography – A Review

In this April 1989 review published in Computer Methods and Programs in Biomedicine, Volume 28, issue 4, A.A.R. Kamal, J.B. Hamess, G. Irving and A.J. Mearns have talked about the photoplethysmograph, its use and the information obtained from it. It concludes that a photoplethysmograph signal from any site on the skin can be separated into an oscillating (a.c.) and a steady-state (d.c.) component, their amplitudes dependent upon the structure and flow in the vascular bed. The d.c. component of the photoplethysmograph

signal is a function of the blood flux beneath the device. It can be used to study skin colour and haemoglobin saturation meters while pulse counters can be obtained from the ac component. It further states that a good emitter for use in a photoplethysmograph of skin blood flow is one in the frequency range 600-700 nm and the best signal for a.c. analysis is obtained from the finger pulp [16].

5.3 In vivo reflectance of blood and tissue as a function of light wavelength

Light reflectance from soft tissue has been utilized in noninvasive clinical measurement devices such as the photoplethysmograph and the reflectance pulse oximeter. Incident light on the skin travels into the underlying layers and is in part reflected back to the surface. In 1990, W.J. Cui, L.E. Ostrander, B.Y. Lee performed an experimental study on 17 subjects to describe the reflectance of light from in vivo tissue for wavelengths in the range from 420 to 940 nm, based on photon diffusion theory. The results showed a minimum reflectance and peak sensitivity to the blood pulsations in the wavelength range from 510 to 590 nm. Skin pigmentation was seen to attenuate reflectance rather than altering the character of the modulation spectra. Based on the model introduced in this paper, the dependence of modulation spectra on mean blood fractional volume as well as wavelength was also described theoretically, and corroborated by further experimental data at 570 and 630 nm [31].

5.4 Frequency Analysis of the Peripheral Pulse Wave Detected in the Finger with a Photoplethysmograph

M. H. Sherebrin and R. Z. Sherebrin, in this paper published in 1990, performed the frequency analysis of the peripheral volume pulse wave obtained by photoelectric plethysmography, using a portable computer. It was used to determine how the pulse shape varied with age using 54 subjects in three age groups, 10-29, 30-59, and 60-89 years. The youngest group had a larger power in the second harmonic, (normalized to the fundamental), with $p < 0.05$ than the older two groups. The decrease of power in the harmonics of the peripheral pulse wave with age may be a useful noninvasive measure of aging and vascular disease [19].

5.5 Extraction of photoplethysmographic waveform variability by lowpass filtering

In 2005, G. S. H. Chan, P. M. Middleton, N. H. Lovell and B. G. Celler, proposed the lowpass filtering method as an alternative means to extract the variability signal. The similarities between the lowpass filtered spectrum and the spectra produced by other representation methods were assessed quantitatively via the computation of normalized cross-correlations. Results showed that the lowpass filtered signal produced a variability spectrum which was nearly identical to that of the pulse waveform mean value (correlation = 0.996), and was highly correlated with the trough and the peak variability spectra (correlation > 0.9) [11].

5.6 Contour analysis of the photoplethysmographic pulse measured at the finger

In 2006, Sandrine C. Millasseau, James M. Rittera, Kenji Takazawa and Philip J. Chowienczyka discussed the application of volume pulse in pulse wave analysis. Volume pulse may conveniently be acquired optically from a finger (digital volume pulse). Although less widely used, this technique deserves further consideration because of its simplicity and ease of use. As with the pressure pulse, the contour of the digital volume pulse is sensitive to changes in arterial tone induced by vasoactive drugs and is influenced by ageing and large artery stiffness. Measurements taken directly from the digital volume pulse or from its second derivative can be used to assess these properties. This review describes the background to digital volume pulse contour analysis, how the technique relates to contour analysis of the pressure pulse, and current and future [24].

5.7 Photoplethysmography and its application in clinical physiological measurement

This 2007 topical review by John Allen, (Regional Medical Physics Department, Freeman Hospital, Newcastle upon Tyne NE7 7DN, UK), describes the basic principle of operation of photoplethysmograph and the interaction of light with tissue, early and recent history of PPG, instrumentation, measurement protocol, and pulse wave analysis. The review then focuses on the applications of PPG in clinical physiological measurements, including clinical physiological monitoring, vascular assessment and autonomic function. It has demonstrated its great potential for use in a wide range of clinical measurements [12].

5.8 Nadi Tarangini: A Pulse Based Diagnostic System

In august 2007, Aniruddha Joshi, Anand Kulkarni, Sharat Chandran, V. K. Jayaraman and B. D. Kulkarni, presented details of their procedure for obtaining the complete spectrum of the *nadi* pulses as a time series. A system, Nadi Tarangini was introduced which contains a diaphragm element equipped with strain gauge, a transmitter cum amplifier, and a digitizer for quantifying analog signal. The system acquires the data with 16-bit accuracy with practically no external electronic or interfering noise. In the paper the pulse waveform is also shown to have the desirable variations with respect to age of patients, and the pressure applied at the sensing element [4].

5.9 Predicting Arterial Stiffness from the Digital Volume Pulse Waveform

In 2007, Stephen R. Alty, Natalia Angarita-Jaimes, Sandrine C. Millasseau, and Philip J. Chowienczyk, presented a paper explaining a method for estimating PWV from the digital volume pulse (DVP), a waveform that can be rapidly and simply acquired by measuring the transmission of infra-red light through the finger pulp. PWV and DVP were measured on 461 subjects. Techniques for extracting features from the DVP contour based on physiology and information theory were compared. This technique could be usefully employed as a cheap and effective CVD screening technique for use in general practice clinics [26].

5.10 Parameters Describing the Pulse Wave

In July 25, 2008, D. Korpas, J. Hálek, L. Doležal from the Department of Medical Biophysics, Faculty of Medicine, Palacký University Olomouc, Czech Republic respectively have presented a review article which offers an overview of pulse wave measurement parameters and main results obtained. The principles of pulse wave measurement and current experience in clinical practice is also discussed in brief. It shows the potential utilization and inaccuracy of clinical measurements. It establishes that the Pulse waveform is a real physiological signal. The measurement is sensitive to body motion as influenced by other physiological rhythms. Despite limitations, this technology

represents a promising noninvasive tool for reflecting the status of cardiovascular system both experimental and in a clinical setting [8].

5.11 Wrist Pulse Waveform Feature Extraction and Dimension Reduction with Feature Variability Analysis

Time-domain feature analysis on wrist pulse waveform is common in Traditional Chinese Medical (TCM) engineering and diagnosis modernization. In this 2008 paper, a derivative-based method on the automated time domain feature extraction of wrist pulse waveform is proposed with the consideration of some practical issues. Variability analysis is performed on the features extracted from the pulse waveform trends. A comparison case study of classification between healthy persons and persons with cardiovascular diseases, by using both reduced features and arbitrarily feature combinations, is given to show that feature reduction is proper, reduction rate is sufficient, and the classification performance by dimension-reduced pattern is acceptable [7].

5.12 Finger and ear photoplethysmogram waveform analysis by fitting with Gaussians

This paper was presented by Uldis Rubins in October 2008. It describes a novel algorithm for analyzing simultaneously measured ear and finger photoplethysmography (PPG) signals. More detailed analysis of the PPG waveform showed that the VP consists of four peaks, which cannot always be distinguished by sight. Not all peak positions of the VP can be extracted by the use of first or higher derivatives. More sensitive methods are needed to extract the VP peak positions. The algorithm separates the systolic wave and the diastolic wave of the VP and fits each of them with the sum of two Gaussian functions. The VP was obtained from PP signals taken from 40 healthy subjects at each heartbeat cycle. From the evaluated VP, time values of the direct wave and three reflected waves were calculated, as well as the augmentation index (AI) and the reflection index (RI). The evaluated parameters were compared with those that were obtained by the derivative method, and it was demonstrated that the new method can be used to analyze VP waveforms [28].

5.13 The shape and dimensions of Photoplethysmographic Pulse Waves: A Measurement Repeatability Study

Zbignevs Marcinkevics, Signe Kusnere, Juris Imants Aivars, Uldis Rubins, Aram Hussain Zehtabi, in 2009, recorded two PPG signals (from the radial artery and from the finger) several times in resting conditions to evaluate the individual repeatability of PPG wave shape. Arbitrary amplitudes of incisura and maximum of diastolic notch and time from foot to anacrotic maximum had the greatest repeatability among PPG wave shape parameters in both radial artery and finger. Maximum of the first derivative in the anacrotic phase in the PPG waveform showed the highest variability. A possible explanation for the existing individual variability of PPG parameters might be temporal and spatial summation of fluctuations of heart cycle length and changes of peripheral resistance in magistral artery and microcirculatory vessels [33].

5.14 Frequency Domain Analysis of Radial Pulse in Abnormal Health Conditions

In this 2010 paper Bhaskar Thakker and Anoop Lal Vyas have performed the frequency domain analysis of the radial pulse. The radial pulse signal in abnormal health conditions shows variations in its morphology in comparison to that of the healthy subjects, resulting in changes in the pulse power spectrum. A frequency domain feature “Band Energy Ratio (BER)” has been defined to identify the band of frequencies carrying significant difference between subjects suffering from gastrointestinal disorders and healthy subjects. It is observed that the pulse signal is a low frequency signal and carries information about pulse morphologies in the frequency band of 0 to 20 Hz. The power spectrum analysis of pulse in healthy subjects shows that the energy in 0 to 4 Hz band is quite higher compared to the rest of the bands. The results show importance of 4 to 10 Hz band as an abnormal band. Further investigation of these abnormal bands can help in correlating the pulse spectrum for specific group of subjects [5].

5.15 Breakthrough in Clinical Cardiology: In-Office Assessment with Pulse Wave Velocity (PWV) and Digital Pulse Analysis (DPA)

This article by Brian Scott Peskin and Robert Jay Rowen came out in May 2010. It explores pulse wave velocity as an important indicator regarding the cardiovascular (CV) condition of the patient, backed by more than 25 years of advanced research in medical physics. It discusses the importance of pulse wave and second derivative (APG) of the pulse wave in studying its features helpful in diagnosis of several CV conditions [6].

5.16 Mental Stress Assessment Based on Pulse Photoplethysmography

In this 2011 paper, Kil-sang Yoo and Won-hyung Lee described a method of stress assessment based on pulse photoplethysmography (PPG). Mental stress is accompanied by dynamic changes in autonomic nervous system activity and Heart rate variability (HRV) has often been used for assessing cardiac and autonomic nervous system function. In this paper the possibility of using the pulse rate variability (PRV) extracted from the PPG signal as an alternative measurement of the HRV signal is assessed. Further, to demonstrate the accuracy and feasibility of HRV extraction from PPG signal, finger-tip PPG and standard lead II ECG signals are simultaneously measured. A comparative analysis of time domain and frequency domain measures of PRV was carried out. The results suggest that PRV based on PPG could be used as a surrogate of HRV for the purpose of stress assessment [17].

5.17 Analysis of Reflectance Photoplethysmograph Sensors

In 2011, Fu-Hsuan Huang, Po-Jung Yuan, Kang-Ping Lin, Hen-Hong Chang, and Cheng-Lun Tsai, analyzed the reflectance type PPG sensor, with its advantages and applications. The transmission type measurement is limited to only a few specific positions for example the index finger that has a short path length for light. However the reflectance type measurement can be conveniently applied on most parts of the body surface. This study analyzed the factors that determine the quality of reflectance photoplethysmograph signal including the emitter-detector distance, wavelength, light intensity, and optical properties of skin tissue. Light emitting diodes (LEDs) with four different visible wavelengths were used as the light emitters. A yellowish green (571nm) light with a proper emitter-detection distance of 2mm is the most suitable for obtaining a steady and reliable reflectance photoplethysmograph signal [10].

5.18 Noi Kanppaan: Nadi diagnosing system

It is an automated system to find the disease and its related information about the human body. This paper published in 2011, by M. Sharmila Begum & R. Poonguzhali provides detailed information and reports on patients by obtaining their nadi as a time series. Noi kanappaan, the nadi diagnosing system acquires the data with 32 bit accuracy and practically minimizes the external noise. The readings sent to the noi kanappaan programmatic application are received and plotted per unit time into (vata, pitta, and kapha) pulse waveform graphs. The application shows the probable disease results according to the pulse waveform and pressure applied at the sensing element per unit time [21].

5.19 Correlation studies of finger pulse profiles for detecting ayurvedic doshas

Dr. Mandeep Singh and Spiti Gupta in this paper in 2011 have explored the detection of tridoshas using modern PhotoPlethysmoGraphy (PPG). As per the ancient science of Ayurveda human beings suffer primarily on account of imbalance in the three basic human constituents called doshas. These doshas are normally detected by the skilled masters simply by pressing the radial artery in the wrist with their three fingers. In this study the pulse profiles of all 10 fingers in 7 healthy subjects is acquired using Biopac MP150 data acquisition system. In all 70 cases without exception the autocorrelation for a given finger of subject is always higher than correlation with corresponding finger of any other subject [18].

5.20 Nadi Aridhal: A Pulse Based Automated Diagnostic System

In 2011, T.Thamarai Selvan and M.Sharmila Begum, have developed Nadi Aridhal (finding any disease using nadi pulse), an automated system to find and dictate the disease and its related information of the human body. In this paper they have provided the detailed information and reports by obtaining nadi pulse from the patients as a time series. By reading the signal from the sensors that are send to transmitters and amplifier and a DC (digitizer) for quantifying analog signal. The system acquires the data with 32-bit accuracy with practically external noise can be minimized of our application .The reading are send

to Nadi Aridhal programmatic application receives it and plot the reading into (vata, pitta, kapha) pulse waveform graphs per time. It shows the probable disease results according to the pulse waveform and pressure applied at the sensing element per time [27].

5.21 Applications of Finger Photoplethysmography

Optical sensors that use photons as sensing elements are increasingly becoming important and relevant in the field of non-invasive diagnostics. The reason is that they have simple construction, easy to use and relatively inexpensive in comparison with tools such as EEG, MRI and FMRI that can be used for research with much investment. Among the many optical sensors available, the PPG (photoplethysmography) sensors are capable of measuring blood volumetric changes in the subcutaneous vessels. In Jan- Feb 2012, Rutuja Laulkar and Nivedita Daimiwal in this paper have discussed applications of PPG. The objective is to diagnose parameters like heart rate, respiratory rate. Real time PPG signal is obtained from sensor and heart rate is calculated from it. .Reflectance type of PPG sensor has been used to diagnose the parameters. Detailed analysis of frequency spectrum (FFT) of PPG signal shows a cardiac peak around 1Hz corresponding to 60 pulsations a minute and respiratory peak around 0.25 Hz corresponding to 15 inspiration/expiration cycles per minute [23].

Chapter 6

Problem Definition

According to Ayurveda, Ether, Air, Fire, Water and Earth, manifest in the human body as three basic principles, known as the tridosha. The tridoshas namely, vata-pitta-kapha govern all the biological, psychological and physiopathological functions of the body, mind and consciousness. They act as basic constituents and protective barriers for the body in its normal physiological condition. But when out of balance, they contribute to disease processes. Pitta, one of the tridoshas, which is a combination of fire and water, is responsible for digestion and transformation in our bodies. The state of pitta dosha determines whether we are digesting food properly. Ayurveda also states that the level of pitta in body increases soon after we take our meals [15].

In the ancient times radial pulse analysis or nadi parikshan was a very commonly and accurately practiced technique employed for pitta detection. Expert practitioners, called vaidyas used to detect the nadi or radial pulse with their fingertips placed accurately on the site of radial artery and thus used to predict a number of ailments and conditions dependent on the imbalance of tridoshas in the body.

Similarly in modern times, finger pulse or the peripheral pulse which is an extension of the radial pulse has been studied by researchers for different applications in medical science.. Using PhotoPlethysmoGraphy it is quite possible that specific diagnosis of pitta level in human body may be reached by studying the finger pulse profile features. A set of features can be extracted from the time domain analysis of the finger pulse PPG. The aim of this thesis is to detect the high pitta level in human body with the help of the features derived from finger PPG.

Chapter 7

Proposed Solution

In this thesis work the finger waveform pulse of both left and right hands of three subjects has been acquired for over a minute, with the help of BIOPAC MP System and AcqKnowledge software. This data has been acquired well before lunch and immediately after lunch for all the three subjects. Then a set of 25 pulses has been selected from the acquired data, while pulses with undesired shape or pulse segments with more noise, have been discarded. From the selected 25 pulses, five features have been manually extracted. These features are the amplitude of the peaks (A1 & A2), the total time duration of a pulse (TPT), time taken for the occurrence of first and second peak (TP1 & TP2) as shown in figure 7.1. These features have then been normalized and hence a set of parameters has been considered for high pitta level detection, namely $A2/A1$, $TP1/TPT$, and $TP2/TPT$. Next the mean and variance of these features has been calculated and compared for the set of data collected before and after lunch by arranging them into column graphs. The process described above has been implemented and the results have been discussed in the proceeding chapters of this thesis.

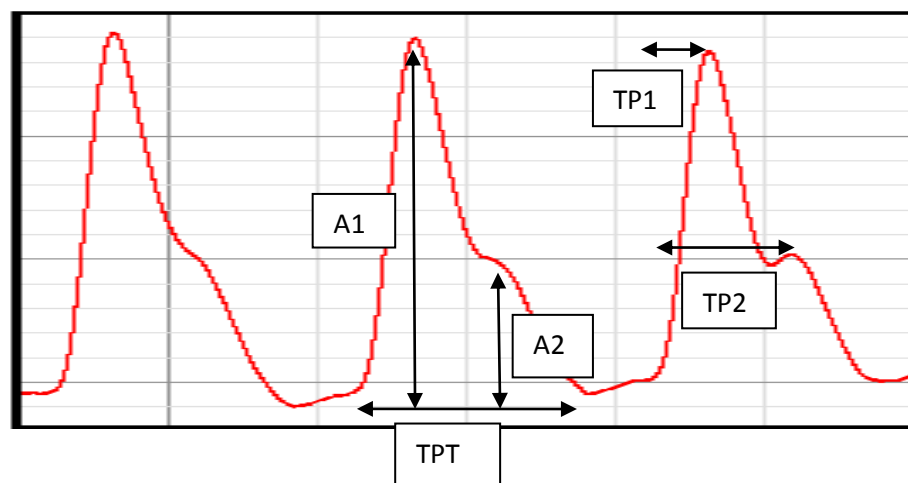


Figure 7.1: Features to be extracted from Finger PPG.

Chapter 8

Methodology

8.1 MP System

MP System is a complete and expandable data acquisition system. Functions of this system are like an on-screen chart recorder, oscilloscope, and X/Y plotter, allowing to record, view, save, and print data (Figure 8.1). It includes all the hardware and software required to turn any computer into a powerful data acquisition workstation specifically designed for life science applications. MP System is as powerful as larger and more expensive data acquisition systems, but has a familiar, easy to use graphical interface. This System will reduce your equipment setup time and increase the quality of your results. By harnessing the power of your computer, the MP System gives you publication-quality results with minimum effort. The MP data acquisition unit (MP150 or MP100) is the heart of the MP System. The MP unit takes incoming signals and converts them into digital signals that can be processed with your computer. Data collection generally involves taking incoming signals (usually analog) and sending them to the computer, where they are (a) displayed on the screen and (b) stored in the computer's memory (or on the hard disk). These signals can then be stored for future examination, much as a word processor stores a document or a Statistics program saves a data file. Graphical and numerical representations of the data can also be produced for use with other programs [20].



Figure 8.1: BIOPAC MP150 System and its Probes

8.2 MP100 Starter System

The MP100 system offers USB-ready data acquisition and analysis. Record multiple channels with differing sample rates. Record at speeds up to 70 kHz or 16 kHz (aggregate to disk).

MP100 System includes:

1. Data acquisition unit: MP100A-CE
2. Transformer: AC100A
3. Universal interface module: UIM100C
4. Cables: CBLSERA cable, CBLS100 cable set
5. USB adapter: USB1W (PC) *or* USB1M (Macintosh)
6. AcqKnowledge® software CD

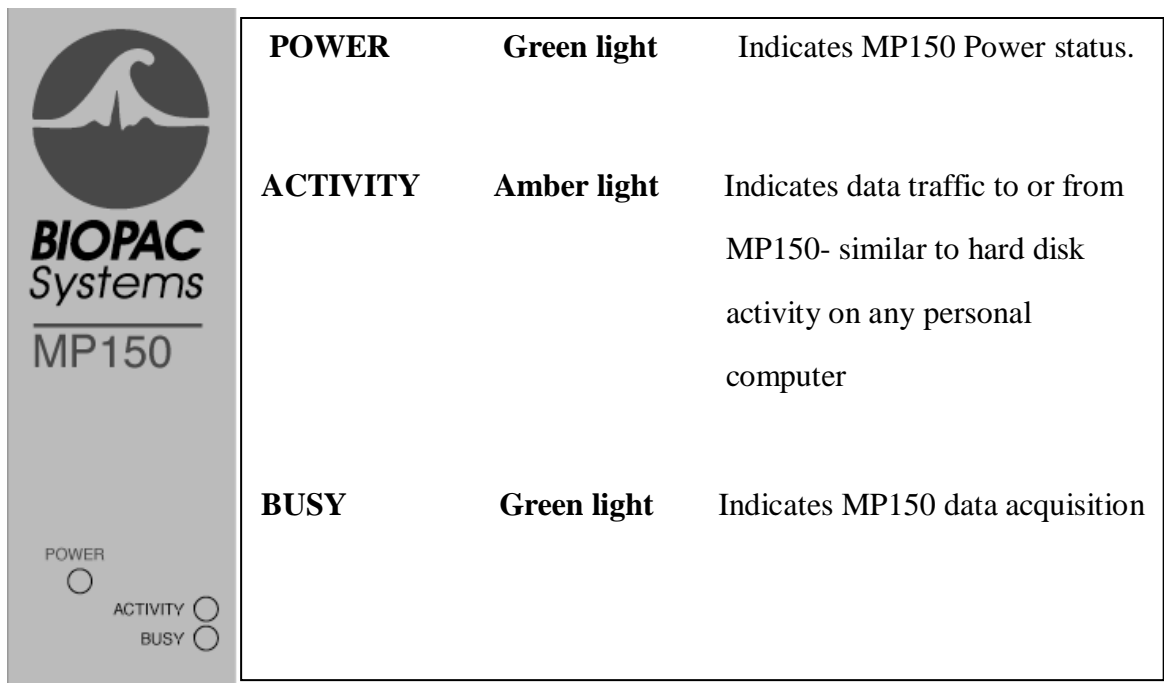


Figure 8.2: Front Panel

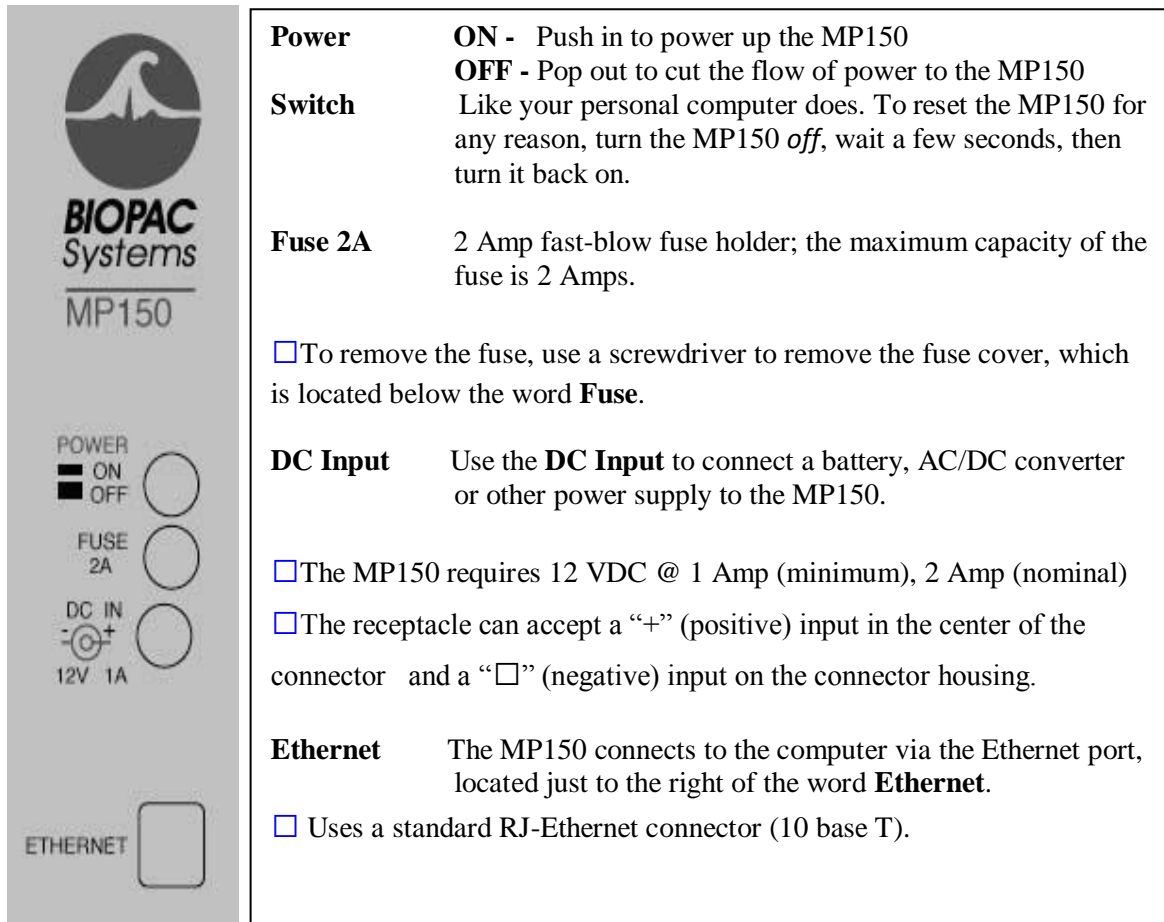


Figure 8.3: Back Panel

Module connections: The two connector inputs are designed to connect directly to the UIM100C.

Analog signals are transmitted through the 37-pin connector (upper right side)

Digital signals are transmitted through the 25-pin connector (lower-right side)

Figure 8.4: Side Panel

Firmware Rollback Switch

The Firmware Rollback Switch is located on the bottom of the MP150 unit and is recessed to prevent accidental activation—it is NOT A RESET for the MP150 unit.

Figure 8.5: Bottom

8.3 Interface Module

When connecting the analog output sourcing from external devices to the MP100 or MP150, channel contention must be considered. If an analog channel is used on the UIM100C or HLT100C, make certain that two external devices do not use the same analog channel. If amplifier modules are connected to the MP System then those amplifier modules must be set to a channel which is not used by external devices plugged into the UIM100C or HLT100C. The UIM100C Universal Interface Module is the interface between the MP150/100 and external devices.

Typically, the UIM100C is used to input pre-amplified signals (usually greater than +/- 0.1 volt peak-peak) and/or digital signals to the MP150/100 acquisition unit. Other signals (e.g., those from electrodes or transducers) connect to various signal-conditioning modules. The Universal Interface Module (UIM100C) is designed to serve as a general-purpose interface to most types of laboratory equipment. The UIM100C consists of sixteen 3.5 mm mini-phone jack connectors for analog inputs, two 3.5 mm mini-phone jack connectors for analog outputs, and screw terminals for the 16 digital lines, external trigger, and supply voltages. The UIM100C is typically used alone to connect polygraph and chart recorder analog outputs to the MP System. BIOPAC Systems, Inc. offers a series of cables that permit the UIM100C to connect directly to a number of standard analog signal connectors. Most chart recorders 59 or polygraphs have analog signal outputs, which can be connected directly to the UIM100C. The UIM100C allows access to 16 analog inputs and 2 analog outputs on one side, and 16 digital Input/output lines, an external trigger, and supply voltages on the other side. The UIM100C is design to be compatible with a variety of different input devices [20].

8.3.1 IPS100C Isolated Power Supply Module

The IPS100C is used to operate 100-series amplifier modules independent of an MP data acquisition unit. The IPS100C module couples the 100-series amplifier outputs directly to any other data acquisition system, oscilloscope or chart recorder. Amplifier modules snap onto the side of the IPS100C to receive the necessary isolated power and to direct the

modules' output to the front panel of the IPS100C. The IPS100C allows users to operate up to 16 amplifiers on a stand-alone basis. The analog channel outputs are provided via 3.5mm phone jacks on the front panel. The IPS100C is generally used with animal or tissue preparations. When collecting data from electrodes attached to humans, use the HLT100C module with INISO and OUTISO adapters to couple signals to external equipment [20].



Figure 8.6: Isolated Power Supply Module

8.4 TSD200 Photoplethysmogram Transducer



Figure 8.7: Plethysmogram Transducer

The TSD200 shown in figure 8.7 consists of a matched infrared emitter and photo diode, which transmits changes in blood density (caused by varying blood pressure), in specific body locations. When the TSD200 is attached to the skin, the infrared light is modulated by blood pulsing through the tissue below. The modulated, reflected light results in small changes in the resistance of the photo resistor, which yields a proportional change in voltage output.

The TSD200 includes a shielded 2-meter cable and a stretchable Velcro® strap for easy attachment to the fingers, or it can be taped to other body parts. The TSD200 can also be placed on other body locations by employing ADD208 adhesive disks to hold the TSD200 in place. Use the TSD200C ear clip transducer for easy attachment to the ear. Place the transducer around the finger and adjust the Velcro® closure to provide only slight tension. Blood density readings can vary considerably depending on transducer location and tension changes [20]. The TSD200 connects to the PPG100C as follows:

<u>TSD200 Lead</u>	<u>PPG100C</u>
Red lead	+ VSUP
Black lead	GND
Purple or Blue lead	INPUT

8.5 PPG100C – Photoplethysmogram Amplifier Module



Figure 8.8: Photoplethysmogram Amplifier Module

The photoplethysmogram amplifier module (PPG100C) is a single channel amplifier designed for indirect measurement of blood pressure or density. The PPG100C is designed for use in the applications like general pulse rate determination, blood pressure analysis, exercise physiology studies, and psycho physiological investigations. The PPG100C works with the TSD200 photoplethysmogram transducer (figure8.9). The peak measurement recorded by the PPG100C indicates the point of maximal blood density in the respective location [20].

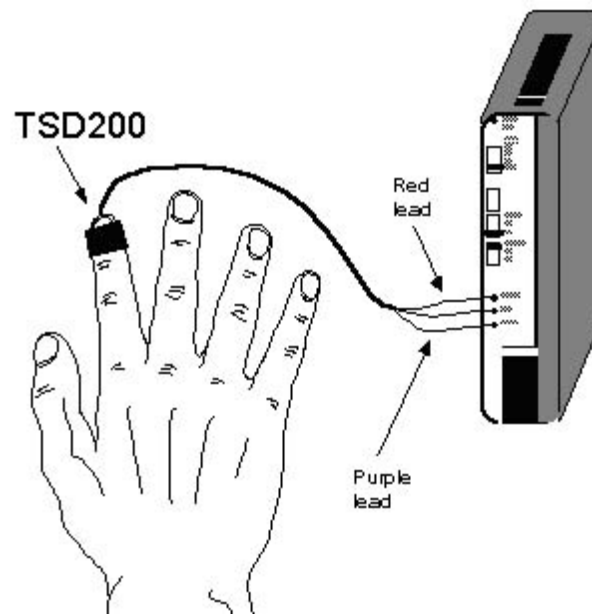


Figure 8.9: Finger Pulse Measurement using the PPG100C and TSD200

8.6 AcqKnowledge Overview

The MP System (MP150 or MP36R) software is called *AcqKnowledge*. It performs two basic functions: acquisition and analysis. All of the acquisition parameters can be found under the MP150 menu. The other menus have commands related to analysis functions such as viewing, editing, and transforming data. Assuming everything is properly connected and there are no conflicts, *AcqKnowledge* opens graph window. A “window” is the term used for the area on the computer’s screen where data is displayed and/or manipulated. The graph window on the screen is designed to provide you with a powerful yet easy-to-use interface for working with data [1].

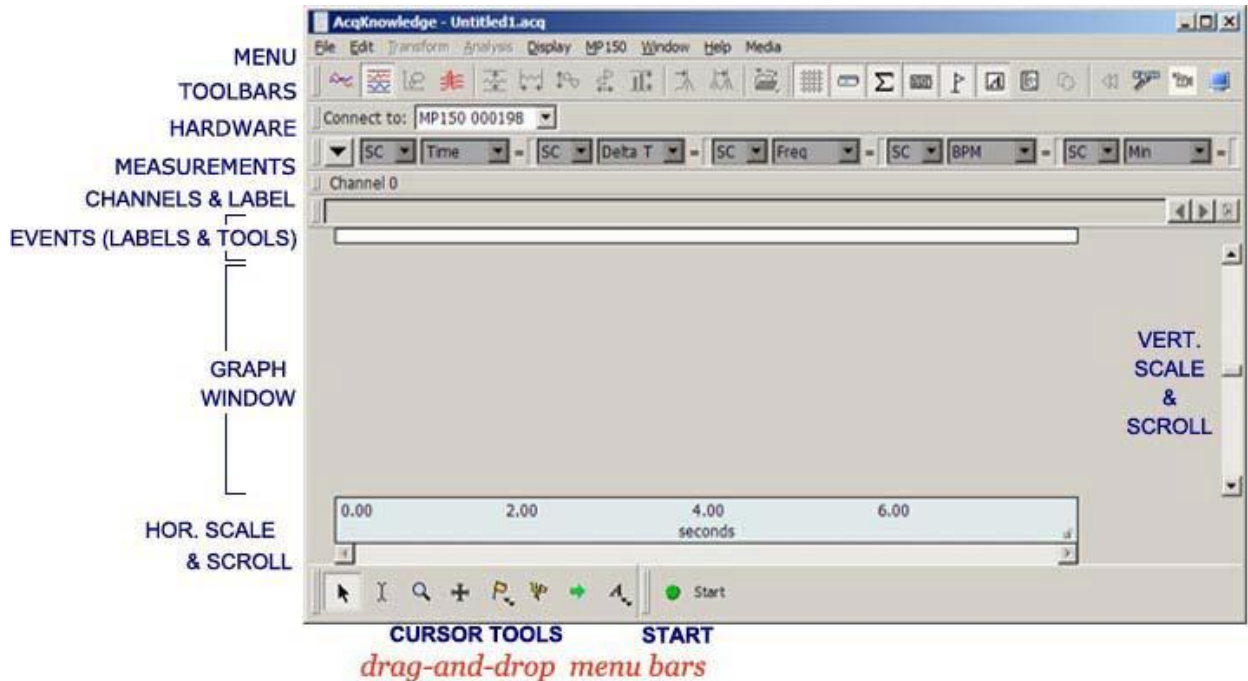


Figure 8.10: Drag and Drop Menu Bars

8.7 Data Acquisition

The equipment is assembled and made ready to take the measurements. The sensor is placed on the tip of each finger one by one. The first step for data acquisition is to set up the channels, the sampling rate, and the acquisition length. ‘Set up channels’ under the MP150 menu has the option for channel selection. In our study we selected one analog channel A1, for acquire, plot & value with sampling rate set at 10 kHz. Acquisition length can be set up in the ‘set up acquisition’ tab under the same drop down menu. Alternatively it can be handled stopped by clicking on stop button at the bottom of the waveform window. We carried on our acquisition for almost a minute (long enough to get 25 pulses for each waveform).

The next step was to start the acquisition. In the lower bar of the screen, next to the Start button, is the circular status light. Green status light indicates that the MP data acquisition unit is properly connected to the computer and is turned on while a solid gray light or no light at all indicates that the MP data acquisition unit is not properly connected or not communicating with the computer. Next we positioned the cursor over the start button and

clicked the mouse button. When start button is pressed the pulse starts appearing in the graph. Sometimes the pulse is not sensed properly which results in distorted pulse with lots of noise. By changing the position of sensor we can get the required results. A waveform was recorded till stop button was clicked. In our study, we recorded the finger pulse waveform of three subjects, after breakfast and before lunch, for index, middle & ring finger, for both hands respectively. The same procedure was repeated immediately after lunch for all the three subjects and a set of 25 pulses was recorded in each case. Once the data was collected it was time for its processing for feature extraction.

8.8 Feature Extraction

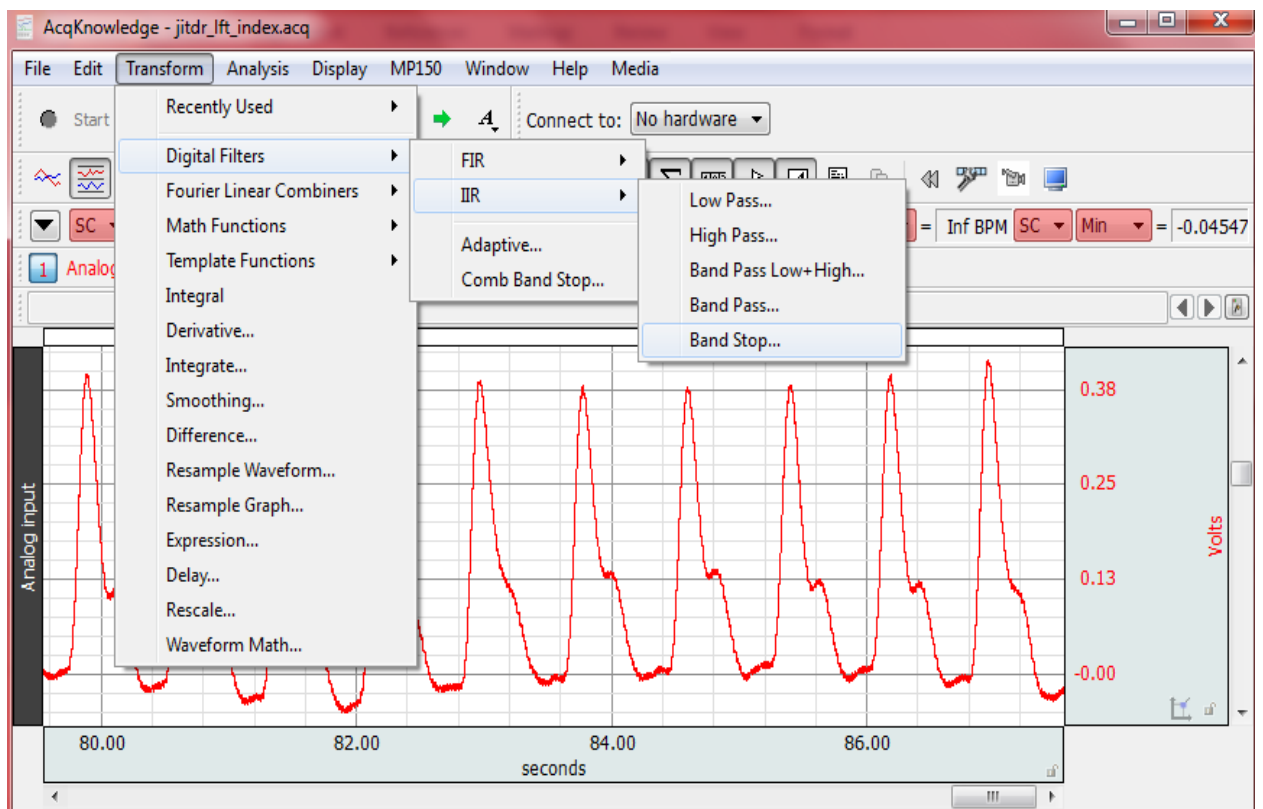


Figure 8.11: Drop down Menu for IIR Filter

Before feature extraction a band stop IIR filter for initial noise removal with its line frequency as default (50 Hz) and quality factor as 5, was applied to the pulse waveform. The IIR digital filter is available in the transform menu as shown in figure 8.11. After applying the IIR filter the initial pulse waveform is transformed. The two graph windows

below in figure 8.12, clearly show the difference in quality of waveforms before and after filtering.

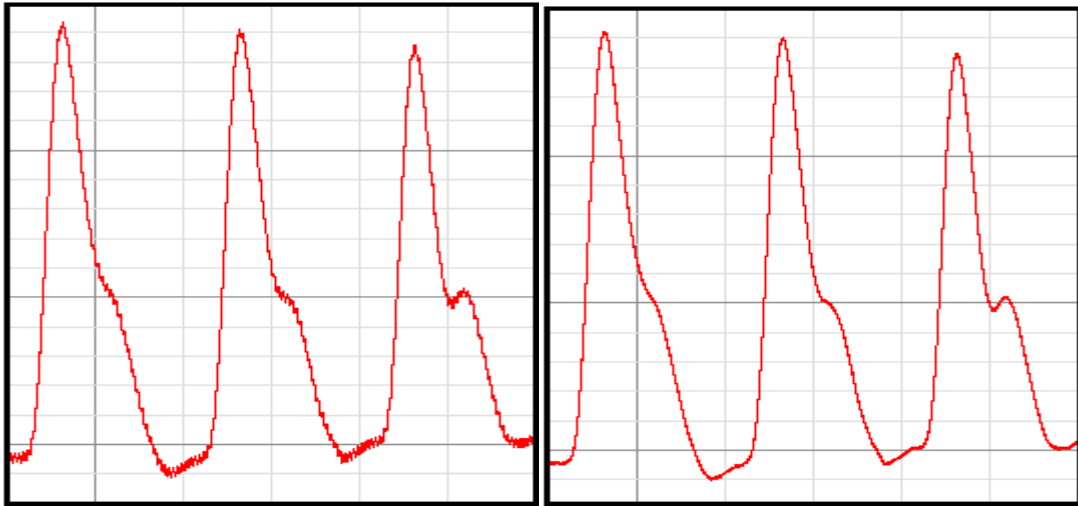


Figure 8.12: Difference between original and filtered pulse waveform

The pull-down measurement menu on the graph window, allows us to select from different types of values for measurement and recording. For our study we choose ‘value’ (in place of bpm), to obtain amplitudes at different point in the waveform (fig.). After this a set of 5 features was extracted from the pulses which include the amplitude of the peaks (A1 & A2), the total time duration of a pulse (TPT), time taken for the occurrence of first and second peak (TP1 & TP2). These features were then normalized and hence we had a set of parameters to be considered, namely $A2/A1$, $TP1/TPT$, and $TP2/TPT$.

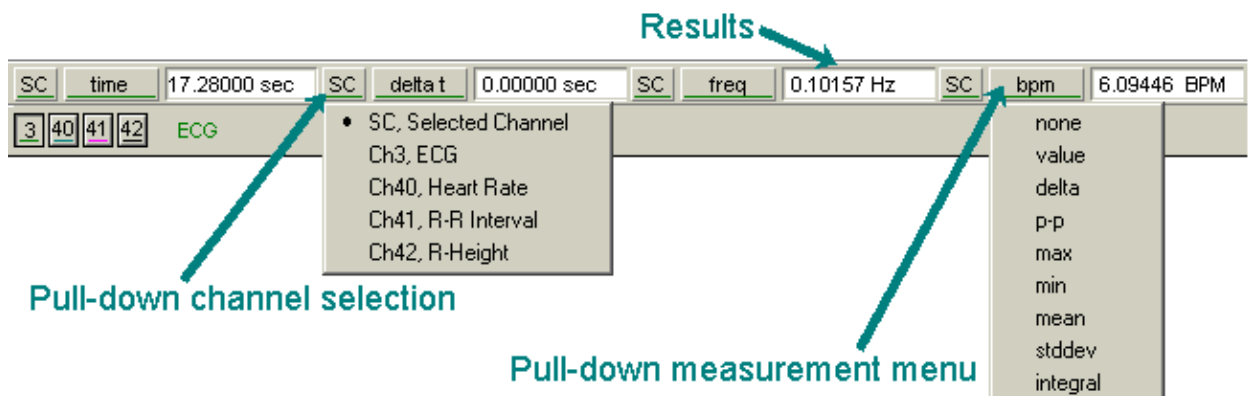


Figure 8.13: Measurement Bar on the Graph Window

Chapter 9

Results and Discussions

After acquiring the waveform of finger pulse with the aid of MP150 system and AcqKnowledge software, the already discussed features were manually extracted and arranged in the form of datasheets as shown below.

9.1 Subject 1 – Right Hand (Before Lunch)

Table 9.1: Index Finger features of subject 1 for right hand before lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1319	0.337	0.6447	0.2698	0.1511	0.2045	0.5227	0.560044
0.1612	0.3809	0.652	0.2455	0.1126	0.2472	0.5842	0.458656
0.1465	0.3516	0.674	0.2409	0.1132	0.2174	0.5217	0.469905
0.1465	0.3883	0.6667	0.2716	0.1182	0.2197	0.5824	0.435199
0.1538	0.3736	0.7619	0.2577	0.1293	0.2028	0.4904	0.501746
0.1685	0.3882	0.7326	0.2785	0.1456	0.23	0.5299	0.522801
0.1611	0.3809	0.6886	0.2574	0.1258	0.2339	0.5532	0.488733
0.1465	0.3663	0.652	0.2665	0.1307	0.2246	0.5618	0.490432
0.1466	0.3663	0.6594	0.2712	0.1243	0.2223	0.5555	0.458333
0.1611	0.3809	0.7326	0.3062	0.1732	0.2199	0.5199	0.565643
0.1611	0.3883	0.674	0.3045	0.1625	0.2392	0.5761	0.533662
0.1465	0.359	0.63	0.284	0.1388	0.2325	0.5698	0.488732
0.1235	0.3457	0.6584	0.3882	0.1741	0.187576	0.525061	0.44848
0.1235	0.3621	0.6996	0.3759	0.1741	0.176529	0.517581	0.463155
0.1235	0.3622	0.6667	0.3984	0.1842	0.185241	0.543273	0.462349
0.1235	0.3457	0.6914	0.3495	0.1459	0.178623	0.5	0.417454
0.1399	0.3457	0.6996	0.311	0.1409	0.199971	0.49414	0.453055
0.1317	0.3539	0.6914	0.3546	0.1563	0.190483	0.51186	0.440778
0.1563	0.3703	0.7242	0.3682	0.1923	0.215824	0.511323	0.522271
0.1399	0.3539	0.716	0.3418	0.1801	0.195391	0.494274	0.526916
0.1399	0.3539	0.716	0.358	0.1871	0.195391	0.494274	0.522626
0.1317	0.3621	0.6996	0.3636	0.1783	0.18825	0.517581	0.490374

0.1317	0.3539	0.7078	0.3687	0.18	0.18607	0.5	0.488202
0.1317	0.3621	0.6831	0.3652	0.1643	0.192798	0.530083	0.44989
0.1317	0.3457	0.6914	0.392	0.2161	0.190483	0.5	0.551276
Mean =					0.207065	0.528282	0.488428
Variance=					0.00042	0.000877	0.001674

Table 9.2: Middle Finger features of subject 1 for right hand before lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.2007	0.4158	0.7527	0.322	0.1632	0.26664	0.552411	0.506832
0.1792	0.4086	0.681	0.3184	0.137	0.263142	0.6	0.430276
0.1577	0.38	0.6094	0.309	0.1311	0.258779	0.623564	0.424272
0.1649	0.4014	0.7097	0.5401	0.2092	0.232352	0.565591	0.387336
0.1505	0.3942	0.6379	0.5113	0.1681	0.23593	0.617965	0.32877
0.1577	0.4014	0.6165	0.5111	0.1597	0.255799	0.651095	0.312463
0.1505	0.3942	0.6165	0.4996	0.1586	0.24412	0.639416	0.317454
0.129	0.3655	0.6093	0.4881	0.1338	0.211718	0.599869	0.274124
0.1362	0.3799	0.5878	0.4712	0.1267	0.231711	0.646308	0.268888
0.1362	0.4014	0.6236	0.526	0.1519	0.218409	0.643682	0.288783
0.172	0.4299	0.6666	0.7185	0.2465	0.258026	0.644914	0.343076
0.1433	0.387	0.6021	0.5493	0.1678	0.238	0.64275	0.30548
0.1362	0.3943	0.6308	0.5599	0.156	0.215916	0.625079	0.278621
0.1219	0.3871	0.595	0.5848	0.154	0.204874	0.650588	0.263338
0.1362	0.3943	0.638	0.6088	0.1842	0.21348	0.618025	0.302562
0.1434	0.3943	0.6739	0.5709	0.1608	0.212791	0.585102	0.281661
0.1362	0.3799	0.6882	0.6244	0.169	0.197908	0.55202	0.27066
0.1291	0.3656	0.7025	0.6268	0.1765	0.183772	0.520427	0.281589
0.1505	0.3799	0.7097	0.6484	0.2011	0.212061	0.535297	0.310148
0.1578	0.4158	0.7241	0.6419	0.1631	0.217926	0.57423	0.254089
0.1578	0.4158	0.7025	0.6657	0.1941	0.224626	0.591886	0.291573
0.1649	0.4086	0.7097	0.6725	0.2022	0.232352	0.575736	0.300669
0.1362	0.4086	0.7957	0.3251	0.1931	0.17117	0.51351	0.593971
0.1792	0.3584	0.6666	0.2639	0.1774	0.268827	0.537654	0.672224
0.1792	0.3656	0.7025	0.2768	0.1587	0.255089	0.520427	0.573338
Mean=					0.229017	0.593102	0.354488
Variance=					0.000672	0.002116	0.013285

Table 9.3: Ring Finger features of subject 1 for right hand before lunch

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1297	0.3601	0.6913	0.4134	0.1693	0.187618	0.520903	0.409531
0.144	0.3961	0.7201	0.4388	0.1711	0.199972	0.550062	0.389927
0.1296	0.36	0.6769	0.429	0.1871	0.191461	0.531836	0.436131
0.1225	0.3457	0.6913	0.4144	0.1898	0.177202	0.500072	0.458012
0.1296	0.3816	0.6913	0.4284	0.1724	0.187473	0.552003	0.402428
0.1368	0.3816	0.6841	0.4358	0.1648	0.199971	0.557813	0.378155
0.1224	0.3528	0.6624	0.4312	0.2176	0.184783	0.532609	0.504638
0.1224	0.3457	0.5329	0.3548	0.1141	0.229687	0.648715	0.32159
0.1296	0.3672	0.5976	0.3964	0.1383	0.216867	0.614458	0.34889
0.1224	0.36	0.6121	0.4046	0.1287	0.199967	0.588139	0.318092
0.1318	0.402	0.6524	0.3424	0.1004	0.202023	0.616186	0.293224
0.1518	0.402	0.6919	0.3146	0.1279	0.219396	0.581009	0.406548
0.1518	0.3888	0.6985	0.2728	0.1169	0.217323	0.556621	0.428519
0.1383	0.3953	0.6853	0.2725	0.126	0.201809	0.576828	0.462385
0.1318	0.3822	0.6524	0.2737	0.108	0.202023	0.585837	0.394593
0.1318	0.3822	0.6524	0.3085	0.1321	0.202023	0.585837	0.428201
0.1318	0.3822	0.6524	0.31	0.1053	0.202023	0.585837	0.339677
0.1318	0.3822	0.6524	0.3524	0.1504	0.202023	0.585837	0.426788
0.1318	0.3822	0.6656	0.3682	0.1568	0.198017	0.574219	0.425856
0.1318	0.3822	0.6788	0.3689	0.1569	0.194166	0.563052	0.425319
0.1318	0.3822	0.6392	0.3567	0.1382	0.206195	0.597935	0.38744
0.1318	0.369	0.6326	0.3772	0.1429	0.208347	0.583307	0.378844
0.1186	0.3624	0.6128	0.3967	0.1629	0.193538	0.591384	0.410638
0.1186	0.3559	0.5865	0.3714	0.1401	0.202217	0.60682	0.377221
Mean=					0.201089	0.574472	0.398027
Variance=					0.000138	0.001103	0.002415

9.2 Subject 1 – Right Hand (After Lunch)

Table 9.4: Index Finger features of subject 1 for right hand after lunch

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.137	0.3391	0.6204	0.2646	0.1313	0.220825	0.546583	0.496221
0.137	0.3391	0.6492	0.2887	0.1348	0.211029	0.522335	0.466921

0.1227	0.3247	0.6492	0.2908	0.1309	0.189002	0.500154	0.450138
0.1155	0.3247	0.6348	0.2787	0.1267	0.181947	0.5115	0.454611
0.1298	0.3318	0.6204	0.3053	0.1358	0.20922	0.534816	0.444808
0.1226	0.3535	0.6131	0.3083	0.129	0.199967	0.576578	0.418424
0.137	0.3606	0.6059	0.3248	0.1354	0.22611	0.595148	0.416872
0.1226	0.3535	0.5987	0.3212	0.1369	0.204777	0.590446	0.426214
0.137	0.3535	0.5987	0.3327	0.1381	0.228829	0.590446	0.415089
0.1226	0.3391	0.5699	0.3197	0.1283	0.215125	0.595017	0.401314
0.1155	0.3535	0.5771	0.3089	0.1248	0.200139	0.612545	0.404014
0.1155	0.3463	0.5699	0.3388	0.1439	0.202667	0.60765	0.424734
0.1155	0.3463	0.5482	0.3449	0.1255	0.21069	0.631704	0.363874
0.1083	0.3391	0.5339	0.3517	0.1337	0.202847	0.635138	0.380154
0.1155	0.3535	0.5627	0.3249	0.1382	0.20526	0.628221	0.425362
0.1155	0.3463	0.5411	0.351	0.1374	0.213454	0.639993	0.391453
0.1155	0.3391	0.5482	0.3531	0.1208	0.21069	0.61857	0.342113
0.1227	0.3463	0.5411	0.3496	0.1236	0.22676	0.639993	0.353547
0.1227	0.3463	0.5555	0.3397	0.1199	0.220882	0.623402	0.352958
0.1298	0.3463	0.5555	0.3508	0.1202	0.233663	0.623402	0.342645
0.1154	0.3463	0.541	0.3349	0.1176	0.213309	0.640111	0.35115
0.1227	0.3534	0.5698	0.3525	0.1288	0.215339	0.620218	0.36539
0.137	0.3607	0.5698	0.3354	0.1241	0.240435	0.633029	0.370006
0.1298	0.3463	0.5411	0.3466	0.1142	0.239882	0.639993	0.329486
0.1227	0.3391	0.5482	0.35	0.1139	0.223823	0.61857	0.325429
Mean=					0.213867	0.599022	0.396517
Variance=					0.000208	0.00186	0.002148

Table 9.5: Middle Finger features of subject 1 for right hand after lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1302	0.3545	0.5715	0.477	0.196	0.227822	0.620297	0.410901
0.123	0.3545	0.5787	0.4761	0.1571	0.212545	0.61258	0.329973
0.1375	0.3617	0.6003	0.498	0.1642	0.229052	0.602532	0.329719
0.1375	0.3762	0.6003	0.4995	0.1479	0.229052	0.626687	0.296096
0.1302	0.3689	0.6003	0.528	0.1647	0.216892	0.614526	0.311932
0.123	0.3689	0.5642	0.5177	0.1724	0.218008	0.653846	0.333011
0.1302	0.3617	0.6076	0.5174	0.1632	0.214286	0.595293	0.315423
0.123	0.3545	0.5787	0.5435	0.1654	0.212545	0.61258	0.304324
0.1375	0.3689	0.6003	0.5538	0.1651	0.229052	0.614526	0.298122
0.1302	0.3689	0.5859	0.5459	0.1641	0.222222	0.62963	0.300605

0.1302	0.3545	0.5859	0.5446	0.154	0.222222	0.605052	0.282776
0.123	0.3617	0.5787	0.5801	0.1693	0.212545	0.625022	0.291846
0.123	0.3617	0.5859	0.5881	0.1686	0.209933	0.617341	0.286686
0.123	0.3689	0.6003	0.5751	0.1957	0.204898	0.614526	0.340289
0.123	0.3545	0.5715	0.5871	0.1583	0.215223	0.620297	0.26963
0.1302	0.3689	0.5787	0.5824	0.1683	0.224987	0.637463	0.288977
0.123	0.3617	0.5715	0.5845	0.1712	0.215223	0.632896	0.2929
0.1375	0.3762	0.5787	0.5857	0.1902	0.237602	0.650078	0.32474
0.1157	0.3617	0.5787	0.5864	0.2006	0.199931	0.625022	0.342087
0.1302	0.3617	0.5715	0.5852	0.2272	0.227822	0.632896	0.388243
0.1157	0.3689	0.5787	0.5786	0.1733	0.199931	0.637463	0.299516
0.1157	0.3617	0.5715	0.5986	0.1642	0.20245	0.632896	0.274307
0.1157	0.3617	0.5642	0.5696	0.1647	0.205069	0.641085	0.28915
0.123	0.3617	0.6003	0.597	0.1674	0.204898	0.602532	0.280402
0.1157	0.3545	0.5642	0.5345	0.142	0.205069	0.628323	0.265669
Mean=					0.215971	0.623416	0.309893
Variance=					0.000112	0.000218	0.001205

Table 9.6: Ring Finger features of subject 1 for right hand after lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.121	0.3559	0.5694	0.4707	0.1259	0.212504	0.625044	0.267474
0.1281	0.3701	0.5765	0.4773	0.1166	0.222203	0.641977	0.244291
0.1565	0.3895	0.6405	0.5084	0.1225	0.24434	0.608119	0.240952
0.1352	0.3843	0.5979	0.5006	0.125	0.226125	0.64275	0.2497
0.1281	0.3843	0.6192	0.5073	0.1347	0.20688	0.62064	0.265523
0.1281	0.3773	0.5979	0.5021	0.1372	0.21425	0.631042	0.273252
0.121	0.3843	0.5907	0.5011	0.1293	0.204842	0.650584	0.258032
0.121	0.3843	0.5979	0.5081	0.1375	0.202375	0.64275	0.270616
0.1353	0.3986	0.5907	0.5021	0.1359	0.22905	0.674793	0.270663
0.121	0.3701	0.6121	0.4968	0.1499	0.19768	0.60464	0.301731
0.121	0.3701	0.5765	0.4922	0.1267	0.209887	0.641977	0.257416
0.1281	0.3772	0.5694	0.5033	0.1326	0.224974	0.662452	0.263461
0.121	0.363	0.5694	0.4911	0.125	0.212504	0.637513	0.254531
0.1281	0.3914	0.5765	0.489	0.1327	0.222203	0.678925	0.27137
0.1281	0.3701	0.5765	0.495	0.1329	0.222203	0.641977	0.268485
0.1139	0.363	0.5694	0.4814	0.1478	0.200035	0.637513	0.307021
0.1281	0.3701	0.5694	0.4699	0.1221	0.224974	0.649982	0.259843
0.1281	0.3701	0.5765	0.4616	0.12	0.222203	0.641977	0.259965

0.1352	0.3701	0.5907	0.5266	0.1571	0.228881	0.626545	0.298329
0.121	0.3701	0.5623	0.4647	0.1119	0.215188	0.65819	0.240801
0.1353	0.3701	0.5694	0.4774	0.1111	0.237619	0.649982	0.232719
0.1353	0.3986	0.6335	0.4684	0.153	0.213575	0.629203	0.326644
0.1353	0.3772	0.5836	0.4799	0.1447	0.231837	0.646333	0.301521
0.1139	0.3701	0.548	0.3876	0.1059	0.207847	0.675365	0.27322
0.121	0.3772	0.5907	0.4365	0.1347	0.204842	0.638564	0.308591
Mean=					0.217561	0.642353	0.270646
Variance=					0.000144	0.000346	0.000578

9.3 Subject 1 – Left Hand (Before Lunch)

Table 9.7: Index Finger features of subject 1 for left hand before lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1354	0.3704	0.6269	0.2694	0.0766	0.215983	0.590844	0.284336
0.1354	0.3704	0.6269	0.2752	0.072	0.215983	0.590844	0.261628
0.1425	0.3918	0.6654	0.3024	0.0817	0.214157	0.588819	0.270172
0.1354	0.399	0.7124	0.3354	0.1005	0.190062	0.560079	0.299642
0.1354	0.3918	0.6198	0.2919	0.0831	0.218458	0.632139	0.284687
0.1425	0.4274	0.691	0.3062	0.0909	0.206223	0.618524	0.296865
0.1425	0.4061	0.6554	0.2909	0.0793	0.217424	0.619622	0.272602
0.1282	0.4132	0.5912	0.2883	0.0474	0.216847	0.698917	0.164412
0.1354	0.4061	0.6269	0.3176	0.0845	0.215983	0.647791	0.266058
0.1425	0.3918	0.6554	0.3138	0.0914	0.217424	0.597803	0.291268
0.1354	0.3918	0.6554	0.2971	0.0793	0.206591	0.597803	0.266913
0.1425	0.406	0.6767	0.3161	0.0844	0.210581	0.59997	0.267004
0.1496	0.4132	0.6625	0.3178	0.084	0.225811	0.623698	0.264317
0.1354	0.4132	0.6767	0.3074	0.0755	0.200089	0.61061	0.245608
0.1638	0.4345	0.7195	0.3521	0.0995	0.227658	0.603892	0.28259
0.1354	0.399	0.6554	0.3187	0.0853	0.206591	0.608789	0.26765
0.1568	0.4061	0.6982	0.3207	0.0793	0.224577	0.581638	0.247272
0.1496	0.3918	0.6911	0.3294	0.0999	0.216467	0.566922	0.303279
0.1425	0.3918	0.6483	0.3231	0.0846	0.219806	0.60435	0.261838
0.1568	0.4061	0.6697	0.2968	0.0847	0.234135	0.606391	0.285377
0.1496	0.4132	0.6482	0.3008	0.07786	0.230793	0.637458	0.258843
0.1425	0.3989	0.6625	0.2953	0.085	0.215094	0.602113	0.287843
0.1567	0.4345	0.6269	0.2843	0.076	0.24996	0.693093	0.267323

0.1425	0.4132	0.6411	0.3067	0.0922	0.222274	0.644517	0.300619
0.1345	0.4061	0.6198	0.2812	0.0796	0.217005	0.655211	0.283073
Mean=					0.217439	0.615273	0.271249
Variance=					0.000136	0.001136	0.000749

Table 9.8: Middle Finger features of subject 1 for left hand before lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1354	0.3708	0.6916	0.2433	0.1182	0.195778	0.536148	0.48582
0.1498	0.3636	0.6488	0.1973	0.086	0.230888	0.560419	0.435884
0.1498	0.3636	0.6917	0.2092	0.1139	0.216568	0.525661	0.544455
0.1354	0.3708	0.6987	0.2051	0.1094	0.193788	0.5307	0.533398
0.1569	0.3815	0.6489	0.1846	0.0924	0.241794	0.587918	0.500542
0.1354	0.3494	0.6417	0.1995	0.1186	0.211002	0.544491	0.594486
0.1498	0.3494	0.6204	0.1843	0.0978	0.241457	0.563185	0.530657
0.1498	0.3636	0.6132	0.1664	0.0834	0.244292	0.592955	0.501202
0.1568	0.3992	0.6631	0.1787	0.0897	0.236465	0.602021	0.501959
0.1498	0.3851	0.6275	0.1844	0.0812	0.238725	0.613705	0.440347
0.1355	0.3636	0.6275	0.1749	0.0825	0.215936	0.579442	0.471698
0.1355	0.3636	0.6061	0.2208	0.0865	0.22356	0.599901	0.391757
0.1355	0.3636	0.5633	0.2158	0.0802	0.240547	0.645482	0.37164
0.1498	0.3636	0.6631	0.2134	0.0961	0.225909	0.548334	0.450328
0.1426	0.3779	0.6703	0.1927	0.0683	0.212741	0.563777	0.354437
0.1498	0.3636	0.6845	0.2093	0.1041	0.218846	0.531191	0.497372
0.1426	0.3779	0.6631	0.2551	0.0935	0.215051	0.569899	0.366523
0.1498	0.3779	0.6631	0.2926	0.123	0.225909	0.569899	0.420369
0.1498	0.3922	0.6917	0.265	0.1119	0.216568	0.567009	0.422264
0.1498	0.3855	0.6845	0.2611	0.1109	0.218846	0.563185	0.424741
0.1569	0.3993	0.6845	0.2673	0.1198	0.229218	0.583346	0.448186
0.164	0.3921	0.6559	0.2706	0.1234	0.250038	0.597805	0.456024
0.1354	0.3779	0.6773	0.2545	0.1	0.199911	0.557951	0.392927
0.1426	0.3707	0.6631	0.2611	0.1097	0.215051	0.559041	0.420146
0.164	0.3851	0.6917	0.2566	0.1083	0.237097	0.556744	0.422058
Mean=					0.223839	0.570008	0.455169
Variance=					0.000233	0.000807	0.003652

Table 9.9: Ring Finger features of subject 1 for left hand before lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1287	0.386	0.6005	0.2386	0.1218	0.214321	0.642798	0.510478
0.1215	0.3503	0.7006	0.2463	0.131	0.173423	0.5	0.531872
0.1144	0.3574	0.7221	0.2384	0.1223	0.158427	0.494945	0.513003
0.1215	0.3574	0.7435	0.2467	0.1296	0.163416	0.480699	0.525334
0.1287	0.3574	0.6792	0.2458	0.1339	0.189488	0.526207	0.544752
0.1287	0.3646	0.6953	0.3971	0.2017	0.1851	0.524378	0.507933
0.1358	0.3574	0.7292	0.3987	0.2081	0.186231	0.490126	0.521946
0.143	0.3718	0.715	0.3954	0.2071	0.2	0.52	0.523773
0.1358	0.3574	0.715	0.3961	0.2126	0.18993	0.49986	0.536733
0.1358	0.3646	0.7506	0.3953	0.1992	0.180922	0.485745	0.503921
0.1358	0.3646	0.715	0.3831	0.2071	0.18993	0.50993	0.54059
0.1358	0.3547	0.7006	0.3722	0.2008	0.193834	0.50628	0.539495
0.1215	0.3575	0.715	0.3886	0.2032	0.16993	0.5	0.522903
0.1278	0.3646	0.7078	0.3758	0.1954	0.180559	0.515117	0.519957
0.1287	0.3575	0.7006	0.3867	0.198	0.1837	0.510277	0.512025
0.1215	0.3575	0.7649	0.3967	0.2103	0.158844	0.467381	0.530124
0.1358	0.3503	0.8293	0.3925	0.2286	0.163753	0.422404	0.58242
0.1358	0.3575	0.7364	0.3969	0.2182	0.184411	0.48547	0.549761
0.143	0.3789	0.7221	0.4172	0.2165	0.198034	0.52472	0.518936
0.1358	0.3646	0.7292	0.4146	0.2199	0.186231	0.5	0.530391
0.1358	0.3789	0.7578	0.4057	0.2053	0.179203	0.5	0.506039
0.143	0.3789	0.7578	0.4269	0.2617	0.188704	0.5	0.613024
0.1358	0.3646	0.7506	0.3835	0.2019	0.180922	0.485745	0.526467
0.143	0.3718	0.7436	0.4086	0.2455	0.192308	0.5	0.600832
0.1501	0.3575	0.7436	0.3442	0.1923	0.201856	0.480769	0.558687
Mean=					0.183739	0.502914	0.534856
Variance=					0.000186	0.001313	0.000787

9.4 Subject 1 – Left Hand (After Lunch)

Table 9.10: Index Finger features of subject 1 for left hand after lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1568	0.3705	0.6056	0.4226	0.1208	0.258917	0.61179	0.28585

0.1282	0.3633	0.5699	0.3998	0.1093	0.224952	0.63748	0.273387
0.1425	0.3562	0.6198	0.4202	0.1363	0.229913	0.574702	0.324369
0.1425	0.3847	0.5913	0.425	0.1129	0.240994	0.6506	0.265647
0.1282	0.3491	0.5913	0.4253	0.1099	0.21681	0.590394	0.258406
0.1496	0.3847	0.6198	0.4246	0.1382	0.241368	0.620684	0.325483
0.1496	0.3847	0.6127	0.4176	0.1031	0.244165	0.627877	0.246887
0.1496	0.3633	0.6197	0.4075	0.1135	0.241407	0.586251	0.278528
0.1496	0.3776	0.6056	0.416	0.1181	0.247028	0.623514	0.283894
0.1425	0.3633	0.6127	0.4112	0.1278	0.232577	0.592949	0.310798
0.1496	0.3704	0.5984	0.4134	0.1068	0.25	0.618984	0.258345
0.1496	0.3776	0.6127	0.4082	0.1098	0.244165	0.616289	0.268986
0.1568	0.3918	0.6198	0.403	0.1112	0.252985	0.632139	0.275931
0.1425	0.3633	0.5984	0.4065	0.1072	0.238135	0.607119	0.263715
0.1425	0.3633	0.634	0.4126	0.1051	0.224763	0.573028	0.254726
0.1425	0.3704	0.5984	0.4121	0.0921	0.238135	0.618984	0.223489
0.1639	0.3918	0.5984	0.4084	0.1053	0.273897	0.654746	0.257835
0.1568	0.3562	0.6198	0.4242	0.1337	0.252985	0.574702	0.315182
0.1211	0.3562	0.5699	0.3968	0.0943	0.212493	0.625022	0.237651
0.1353	0.3633	0.577	0.4175	0.1168	0.234489	0.629636	0.27976
0.1568	0.3776	0.6056	0.4228	0.1184	0.258917	0.623514	0.280038
0.1283	0.3422	0.5771	0.4029	0.1104	0.222318	0.592965	0.274013
0.1425	0.3704	0.5771	0.4169	0.1019	0.246924	0.64183	0.244423
0.1425	0.3633	0.5841	0.3901	0.1136	0.243965	0.621983	0.291207
0.1425	0.3633	0.5984	0.4245	0.1227	0.238135	0.607119	0.289046
Mean=					0.240418	0.614172	0.274704
Variance=					0.000196	0.000527	0.000662

Table 9.11: Middle Finger features of subject 1 for left hand after lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1504	0.3653	0.6589	0.4024	0.1515	0.228259	0.554409	0.376491
0.1504	0.3868	0.6589	0.4149	0.1433	0.228259	0.587039	0.345384
0.1361	0.3581	0.6446	0.4157	0.1645	0.211139	0.555538	0.395718
0.1361	0.3868	0.6517	0.4286	0.1256	0.208838	0.593525	0.293047
0.1361	0.3796	0.6875	0.4366	0.1594	0.197964	0.552145	0.365094
0.1432	0.3724	0.6589	0.4673	0.1759	0.217332	0.565184	0.376418
0.1432	0.3796	0.666	0.4536	0.1804	0.215015	0.56997	0.397707
0.1361	0.3724	0.6589	0.4531	0.1591	0.206556	0.565184	0.351137
0.1504	0.3939	0.6947	0.4865	0.1883	0.216496	0.567007	0.38705

0.1361	0.3653	0.6804	0.4568	0.1717	0.200029	0.53689	0.375876
0.1504	0.3939	0.6875	0.4601	0.1622	0.218764	0.572945	0.352532
0.1432	0.3868	0.6875	0.4525	0.1614	0.208291	0.562618	0.356685
0.1289	0.3581	0.6589	0.444	0.1536	0.195629	0.543482	0.345946
0.1432	0.3796	0.6732	0.4576	0.1651	0.212715	0.563874	0.360795
0.1432	0.3796	0.6948	0.4437	0.1654	0.206102	0.546344	0.372774
0.1289	0.3796	0.6875	0.4485	0.1649	0.187491	0.552145	0.36767
0.1361	0.3724	0.6947	0.4603	0.1551	0.195912	0.536059	0.336954
0.1576	0.3939	0.7019	0.4846	0.1814	0.224533	0.561191	0.374329
0.1432	0.3939	0.6733	0.4701	0.1713	0.212684	0.585029	0.364391
0.1648	0.3868	0.7019	0.476	0.1999	0.234791	0.551076	0.419958
0.1504	0.3868	0.6876	0.467	0.1592	0.218732	0.562536	0.340899
0.1361	0.3796	0.6733	0.4798	0.1654	0.202139	0.56379	0.344727
0.1504	0.3868	0.6666	0.4755	0.1917	0.225623	0.580258	0.403155
0.1432	0.3796	0.6519	0.4406	0.1775	0.219666	0.582298	0.40286
0.1504	0.3868	0.6518	0.4406	0.1286	0.230746	0.593434	0.291875
Mean=					0.212948	0.564159	0.363979
Variance=					0.000149	0.000263	0.000933

Table 9.12: Ring Finger features of subject 1 for left hand after lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1216	0.3649	0.6011	0.3111	0.1142	0.202296	0.607054	0.367085
0.1216	0.3649	0.6011	0.3483	0.1248	0.202296	0.607054	0.358312
0.1216	0.3649	0.6154	0.3405	0.1101	0.197595	0.592948	0.323348
0.1216	0.3649	0.6154	0.3463	0.1085	0.197595	0.592948	0.313312
0.1431	0.3721	0.6369	0.3725	0.1165	0.224682	0.584236	0.312752
0.1288	0.365	0.6083	0.3547	0.0965	0.211738	0.600033	0.272061
0.1431	0.3721	0.6297	0.3733	0.1117	0.227251	0.590916	0.299223
0.1502	0.3864	0.6225	0.3455	0.0826	0.241285	0.620723	0.239074
0.1431	0.3792	0.6368	0.3831	0.1234	0.224717	0.595477	0.322109
0.1431	0.3721	0.6297	0.361	0.1197	0.227251	0.590916	0.331579
0.1431	0.3721	0.6297	0.3702	0.112	0.227251	0.590916	0.302539
0.136	0.3649	0.6083	0.3581	0.1245	0.223574	0.599868	0.347668
0.1502	0.3864	0.6511	0.3602	0.1246	0.230687	0.593457	0.345919
0.1502	0.3864	0.6297	0.3416	0.1077	0.238526	0.613626	0.315281
0.136	0.365	0.6512	0.3172	0.0991	0.208845	0.560504	0.312421
0.1431	0.3507	0.6369	0.3127	0.1044	0.224682	0.550636	0.333866
0.1216	0.3435	0.6083	0.3343	0.0996	0.199901	0.564688	0.297936

0.136	0.3507	0.6512	0.3162	0.0886	0.208845	0.538544	0.280202
0.136	0.372	0.6011	0.3113	0.0852	0.226252	0.618865	0.273691
0.1502	0.3864	0.6082	0.3001	0.0822	0.246958	0.635317	0.273909
0.1431	0.3649	0.6082	0.3021	0.0793	0.235284	0.599967	0.262496
0.1349	0.372	0.5939	0.3137	0.0922	0.227143	0.626368	0.293911
0.1288	0.372	0.6011	0.3197	0.1031	0.214274	0.618865	0.32249
0.136	0.372	0.5796	0.3009	0.0729	0.234645	0.641822	0.242273
0.1288	0.3649	0.5796	0.3155	0.0823	0.222222	0.629572	0.260856
Mean=					0.221032	0.598613	0.304173
Variance=					0.000199	0.000651	0.001201

9.5 Subject 2 - Right Hand (Before Lunch)

Table 9.13: Index Finger features of subject 2 for right hand before lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1311	0.3934	0.5683	0.1698	0.0682	0.230688	0.69224	0.401649
0.1311	0.3934	0.5829	0.1729	0.0588	0.224909	0.674901	0.340081
0.1311	0.3861	0.5902	0.2067	0.055	0.222128	0.654185	0.266086
0.1384	0.3934	0.612	0.2402	0.0635	0.226143	0.64281	0.264363
0.1239	0.3861	0.6047	0.2556	0.0661	0.204894	0.638498	0.258607
0.1166	0.3934	0.5974	0.2229	0.052	0.195179	0.65852	0.233288
0.1238	0.3788	0.5974	0.1656	0.0509	0.207231	0.634081	0.307367
0.1311	0.3934	0.5974	0.1272	0.038	0.219450	0.65852	0.298742
0.1311	0.3861	0.5902	0.1387	0.041	0.222128	0.654185	0.295602
0.1166	0.3716	0.5829	0.1599	0.049	0.200034	0.637502	0.306442
0.1239	0.3861	0.5829	0.1889	0.0522	0.212557	0.662378	0.276337
0.1239	0.3716	0.5902	0.2006	0.0532	0.209928	0.629617	0.265204
0.1239	0.3716	0.5611	0.1629	0.0427	0.220816	0.662271	0.262124
0.1384	0.3789	0.5902	0.1269	0.0405	0.234496	0.641986	0.319149
0.1384	0.3934	0.5902	0.1105	0.0367	0.234496	0.666554	0.332127
0.1239	0.3789	0.6047	0.1181	0.0369	0.204894	0.626592	0.312447
0.1239	0.3716	0.5902	0.1404	0.0391	0.209928	0.629617	0.27849
0.1311	0.3934	0.612	0.1609	0.045	0.214215	0.64281	0.279677
0.1239	0.3716	0.612	0.1811	0.0444	0.202450	0.60719	0.245168
0.1311	0.3789	0.5902	0.1772	0.0386	0.222128	0.641986	0.217833
0.1311	0.4007	0.5829	0.1535	0.0413	0.224909	0.687425	0.269055
0.1311	0.3934	0.5756	0.1397	0.0414	0.227762	0.683461	0.296349

0.1093	0.3643	0.5683	0.158	0.0439	0.192327	0.641035	0.277848
0.1166	0.3789	0.561	0.1779	0.0455	0.207843	0.675401	0.255762
0.1348	0.3934	0.5829	0.1626	0.0319	0.231257	0.674901	0.196187
Mean=					0.216112	0.652747	0.282239
Variance=					0.000149	0.000451	0.001764

Table 9.14: Middle Finger features of subject 2 for right hand before lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1236	0.3855	0.6109	0.3644	0.1425	0.202324	0.631036	0.391054
0.1236	0.3855	0.5964	0.358	0.1349	0.207243	0.646378	0.376816
0.1236	0.3855	0.5964	0.3494	0.1345	0.207243	0.646378	0.384946
0.1236	0.3782	0.5964	0.3321	0.1468	0.207243	0.634138	0.442036
0.1236	0.3855	0.5745	0.267	0.1207	0.215143	0.671018	0.45206
0.1163	0.3855	0.5673	0.2385	0.0867	0.205006	0.679535	0.363522
0.1236	0.3855	0.5891	0.2278	0.0786	0.209811	0.654388	0.34504
0.1236	0.3782	0.5745	0.2333	0.0847	0.215143	0.658312	0.363052
0.1236	0.3855	0.5964	0.2591	0.01035	0.207243	0.646378	0.039946
0.1236	0.3636	0.598	0.2808	0.1303	0.206688	0.608027	0.464031
0.1309	0.3782	0.5964	0.3253	0.1382	0.219483	0.634138	0.424839
0.1163	0.3855	0.5891	0.3357	0.159	0.197419	0.654388	0.473637
0.1527	0.4145	0.6036	0.3357	0.1148	0.252982	0.686713	0.341972
0.1309	0.3927	0.5964	0.3153	0.0858	0.219483	0.658451	0.272122
0.1309	0.3855	0.5745	0.3109	0.1239	0.227850	0.671018	0.39852
0.1236	0.3782	0.5891	0.35	0.1422	0.209811	0.641996	0.406286
0.1091	0.3636	0.56	0.3134	0.1474	0.194821	0.649286	0.470325
0.1091	0.3636	0.56	0.325	0.1532	0.194821	0.649286	0.471385
0.1236	0.3855	0.5745	0.3588	0.1327	0.215143	0.671018	0.369844
0.1091	0.3709	0.5818	0.3726	0.13	0.187521	0.637504	0.3489
0.1163	0.3782	0.5891	0.3708	0.1397	0.197419	0.641996	0.376753
0.1236	0.3709	0.5818	0.3454	0.1642	0.212444	0.637504	0.475391
0.1163	0.3782	0.5891	0.35	0.1288	0.197419	0.641996	0.368
0.1309	0.3782	0.5891	0.3436	0.1269	0.222203	0.641996	0.369325
0.1091	0.3782	0.5673	0.3396	0.1318	0.192314	0.666667	0.388104
Mean=					0.208969	0.650382	0.383116
Variance=					0.000184	0.000301	0.007723

Table 9.15: Ring Finger features of subject 2 for right hand before lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1776	0.4478	0.7318	0.2294	0.1009	0.242689	0.611916	0.439843
0.1563	0.3979	0.7389	0.2514	0.1257	0.211530	0.538503	0.5
0.1634	0.3979	0.6892	0.2733	0.1335	0.237086	0.577336	0.488474
0.135	0.3908	0.6679	0.2462	0.1156	0.202126	0.585118	0.469537
0.1421	0.4121	0.6679	0.2242	0.1061	0.212756	0.617009	0.473238
0.135	0.3908	0.6181	0.2168	0.0963	0.218411	0.63226	0.444188
0.1492	0.3979	0.6608	0.2377	0.1059	0.225786	0.602149	0.44552
0.1563	0.4192	0.6679	0.256	0.1098	0.234017	0.627639	0.428906
0.1492	0.3837	0.6395	0.2662	0.112	0.233307	0.6	0.420736
0.1492	0.3907	0.6891	0.269	0.1236	0.216514	0.566971	0.45948
0.1421	0.3907	0.6394	0.257	0.1305	0.222239	0.611042	0.507782
0.135	0.3837	0.6182	0.2504	0.1225	0.218375	0.620673	0.489217
0.135	0.3979	0.5968	0.2657	0.1194	0.226206	0.666723	0.449379
0.135	0.3837	0.6536	0.2805	0.1114	0.206548	0.587056	0.397148
0.1492	0.3908	0.6608	0.3064	0.1385	0.225786	0.591404	0.452023
0.1563	0.3979	0.6891	0.3069	0.1364	0.226817	0.57742	0.444444
0.1563	0.3979	0.6821	0.3145	0.145	0.229145	0.583346	0.461049
0.1492	0.3908	0.6537	0.3071	0.1461	0.228239	0.597828	0.475741
0.135	0.3873	0.6323	0.2902	0.146	0.213506	0.612526	0.503101
0.135	0.3766	0.5968	0.2531	0.1175	0.226206	0.631032	0.464243
0.1492	0.3979	0.6324	0.2613	0.1081	0.235926	0.62919	0.413701
0.1563	0.405	0.6537	0.3083	0.1336	0.239100	0.61955	0.433344
0.1421	0.383	0.6394	0.297	0.1373	0.222239	0.598999	0.46229
0.1421	0.3837	0.6608	0.3047	0.147	0.215042	0.58066	0.482442
0.1421	0.3624	0.6323	0.3005	0.1465	0.224735	0.573146	0.487521
Mean=					0.223773	0.60158	0.459734
Variance=					0.000105	0.00072	0.000825

9.6 Subject 2 – Right Hand (After Lunch)

Table 9.16: Index Finger features of subject 2 for right hand after lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1349	0.3834	0.6602	0.4549	0.1498	0.204332021	0.580733	0.329303

0.1278	0.3834	0.6247	0.4453	0.1695	0.204578198	0.613735	0.380642
0.1349	0.3762	0.6318	0.4473	0.1732	0.213516936	0.595442	0.387212
0.1349	0.3904	0.6389	0.4901	0.1542	0.211144154	0.61105	0.31463
0.1349	0.3904	0.6318	0.4912	0.1628	0.213516936	0.617917	0.331433
0.1349	0.3834	0.6389	0.4253	0.1541	0.211144154	0.600094	0.362332
0.1349	0.3904	0.6034	0.4147	0.1532	0.223566457	0.647	0.369424
0.1349	0.3834	0.6247	0.482	0.15	0.215943653	0.613735	0.311203
0.1207	0.3834	0.6104	0.4361	0.1593	0.197739187	0.628113	0.365283
0.1349	0.3904	0.646	0.4966	0.1405	0.208823529	0.604334	0.282924
0.1278	0.3762	0.646	0.5143	0.1626	0.197832817	0.582353	0.316158
0.1278	0.3904	0.6034	0.4864	0.1713	0.211799801	0.647	0.352179
0.1349	0.3904	0.6318	0.4927	0.1325	0.213516936	0.617917	0.268926
0.1278	0.3904	0.646	0.5401	0.1531	0.197832817	0.604334	0.283466
0.1349	0.3834	0.6318	0.502	0.1532	0.213516936	0.606838	0.305179
0.1278	0.3762	0.6104	0.4485	0.1557	0.209370904	0.616317	0.347157
0.1349	0.3762	0.6318	0.522	0.1682	0.213516936	0.595442	0.322222
0.1349	0.3762	0.6318	0.4736	0.1557	0.213516936	0.595442	0.328758
0.1278	0.3904	0.6104	0.4865	0.1691	0.209370904	0.639581	0.347585
0.1278	0.3904	0.6104	0.4211	0.1572	0.209370904	0.639581	0.373308
0.1349	0.3834	0.6318	0.518	0.1537	0.213516936	0.606838	0.296718
0.1349	0.3904	0.6176	0.4848	0.1602	0.218426166	0.632124	0.330446
0.1207	0.3762	0.6176	0.5066	0.1504	0.195433938	0.609132	0.296881
0.1349	0.3762	0.6176	0.5174	0.1681	0.218426166	0.609132	0.324894
0.1278	0.3762	0.6104	0.4555	0.1541	0.209370904	0.616317	0.33831
Mean=					0.209965009	0.61322	0.330663
Variance=					4.90355E-05	0.000322	0.001021

Table 9.17: Middle Finger features of subject 2 for right hand after lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1841	0.4325	0.6444	0.2823	0.1206	0.285692117	0.671167	0.427205
0.1363	0.3875	0.6314	0.2683	0.1033	0.215869496	0.613716	0.385017
0.1651	0.4162	0.6673	0.2944	0.1083	0.247414956	0.623707	0.367867
0.1651	0.4162	0.6744	0.3274	0.1242	0.244810202	0.617141	0.379352
0.1507	0.409	0.6171	0.291	0.1203	0.244206774	0.662778	0.413402
0.1651	0.4162	0.6529	0.3035	0.1112	0.252871803	0.637464	0.366392
0.1507	0.3588	0.6314	0.3184	0.1302	0.238675958	0.568261	0.40892
0.1507	0.3946	0.6457	0.2849	0.1153	0.233390119	0.61112	0.404703
0.1435	0.3731	0.6457	0.3168	0.1289	0.22223943	0.577823	0.406881

0.1363	0.3659	0.6424	0.2972	0.1232	0.212173101	0.569583	0.414536
0.1507	0.4018	0.6314	0.3121	0.1172	0.238675958	0.636364	0.375521
0.1507	0.3803	0.6673	0.3407	0.1264	0.225835456	0.569909	0.371001
0.1435	0.4018	0.6314	0.3044	0.1105	0.227272727	0.636364	0.363009
0.1507	0.409	0.6386	0.3272	0.1213	0.235984967	0.640464	0.370721
0.1435	0.3874	0.6457	0.3015	0.1077	0.22223943	0.599969	0.357214
0.1292	0.3803	0.6027	0.2823	0.1173	0.214368674	0.630994	0.415515
0.1435	0.3731	0.6099	0.2751	0.1044	0.235284473	0.611174	0.379498
0.1507	0.3946	0.6242	0.2739	0.1035	0.241429029	0.632169	0.377875
0.1292	0.3731	0.6171	0.2696	0.1169	0.209366391	0.604602	0.433605
0.1363	0.3731	0.6242	0.2719	0.1206	0.2183595	0.597725	0.443545
0.1363	0.3731	0.6242	0.2916	0.1225	0.2183595	0.597725	0.420096
0.1363	0.3731	0.6242	0.2967	0.1284	0.2183595	0.597725	0.43276
0.1363	0.3659	0.6314	0.3138	0.1273	0.215869496	0.579506	0.405672
0.1363	0.3802	0.6242	0.282	0.1124	0.2183595	0.6091	0.398582
0.1363	0.3659	0.6171	0.3163	0.1299	0.22087182	0.592935	0.410686
0.1292	0.3588	0.6171	0.2978	0.1283	0.209366391	0.581429	0.430826
Mean=					0.229513337	0.610441	0.398477
Variance=					0.000291319	0.000777	0.000651

Table 9.18: Ring Finger features of subject 2 for right hand after lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1281	0.3772	0.5694	0.4137	0.0991	0.224973656	0.662452	0.239546
0.1352	0.3772	0.5836	0.4089	0.1022	0.231665524	0.646333	0.249939
0.1352	0.3772	0.5694	0.4279	0.1026	0.237442922	0.662452	0.239776
0.1432	0.3915	0.5907	0.42	0.1142	0.242424242	0.662773	0.271905
0.1352	0.3772	0.5907	0.4125	0.1041	0.228880989	0.638564	0.252364
0.1432	0.3772	0.5907	0.4268	0.1048	0.242424242	0.638564	0.245548
0.1352	0.3915	0.5623	0.3908	0.1151	0.240441046	0.696248	0.294524
0.1352	0.3772	0.5907	0.4175	0.0976	0.228880989	0.638564	0.233772
0.1352	0.3772	0.5907	0.4082	0.0996	0.228880989	0.638564	0.243998
0.1352	0.3772	0.5694	0.4142	0.1173	0.237442922	0.662452	0.283197
0.1352	0.3772	0.5907	0.4117	0.1069	0.228880989	0.638564	0.259655
0.1281	0.3772	0.5836	0.4329	0.1046	0.219499657	0.646333	0.241626
0.1352	0.3772	0.5836	0.435	0.1	0.231665524	0.646333	0.229885
0.1281	0.3772	0.5907	0.4242	0.1129	0.216861351	0.638564	0.266148
0.1281	0.3772	0.5694	0.4311	0.1132	0.224973656	0.662452	0.262584
0.1432	0.3843	0.5907	0.4478	0.1094	0.242424242	0.650584	0.244305

0.1281	0.3701	0.5694	0.4437	0.11	0.224973656	0.649982	0.247915
0.1432	0.3843	0.5836	0.4472	0.1105	0.245373544	0.658499	0.247093
0.1352	0.3772	0.5694	0.4415	0.1111	0.237442922	0.662452	0.251642
0.1281	0.3772	0.5907	0.4522	0.1256	0.216861351	0.638564	0.277753
0.1281	0.3772	0.5836	0.4571	0.1067	0.219499657	0.646333	0.233428
0.1352	0.3915	0.5907	0.4517	0.1098	0.228880989	0.662773	0.243082
0.1281	0.3772	0.5694	0.4664	0.1243	0.224973656	0.662452	0.266509
0.1281	0.3772	0.5694	0.4535	0.1091	0.224973656	0.662452	0.240573
0.1352	0.3772	0.5694	0.4594	0.1024	0.237442922	0.662452	0.222899
Mean=					0.230727412	0.65343	0.251587
Variance=					7.16958E-05	0.000186	0.000303

9.7 Subject 2 – Left Hand (Before Lunch)

Table 9.19: Index Finger features of subject 2 for left hand before lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1468	0.3744	0.6312	0.4073	0.1092	0.232572877	0.593156	0.268107
0.1761	0.4037	0.6459	0.3911	0.1179	0.272642824	0.625019	0.301457
0.1615	0.3963	0.6312	0.3776	0.1211	0.25586185	0.627852	0.32071
0.1689	0.3744	0.6312	0.374	0.1337	0.267585551	0.593156	0.357487
0.1468	0.367	0.6239	0.3719	0.1311	0.235294118	0.588235	0.352514
0.1468	0.3669	0.6459	0.3824	0.118	0.227279765	0.568045	0.308577
0.1615	0.4036	0.6312	0.3921	0.1105	0.25586185	0.639417	0.281816
0.1615	0.3963	0.6239	0.3933	0.1217	0.258855586	0.635198	0.309433
0.1615	0.3963	0.6459	0.4062	0.1318	0.250038706	0.613562	0.324471
0.1541	0.389	0.6239	0.3566	0.104	0.246994711	0.623497	0.291643
0.1541	0.389	0.6239	0.35	0.1153	0.246994711	0.623497	0.329429
0.1614	0.3743	0.6239	0.3426	0.1254	0.258695304	0.599936	0.366025
0.1614	0.3743	0.6312	0.334	0.1293	0.255703422	0.592997	0.387126
0.1541	0.3596	0.6312	0.347	0.1258	0.24413815	0.569708	0.362536
0.1541	0.3596	0.6459	0.3546	0.1299	0.238581824	0.556743	0.366328
0.1614	0.3889	0.6678	0.338	0.1262	0.241689128	0.58236	0.373373
0.1834	0.411	0.6972	0.3378	0.1277	0.263052209	0.589501	0.378034
0.1761	0.3963	0.6386	0.3219	0.1198	0.275759474	0.620576	0.372165
0.1761	0.3963	0.6386	0.3085	0.1164	0.275759474	0.620576	0.37731
0.1761	0.3963	0.6825	0.3023	0.1298	0.258021978	0.580659	0.429375
0.1615	0.3816	0.6532	0.28	0.1007	0.247244336	0.584201	0.359643

0.1615	0.3816	0.6238	0.3079	0.1214	0.258897082	0.611735	0.394284
0.1615	0.3596	0.6459	0.3006	0.1407	0.250038706	0.556743	0.468064
0.1761	0.367	0.6459	0.2896	0.1374	0.272642824	0.568199	0.474448
0.1541	0.3743	0.6459	0.2798	0.1283	0.238581824	0.579501	0.458542
Mean=					0.253151531	0.597763	0.360516
Variance=					0.000183692	0.000616	0.003079

Table 9.20: Middle Finger features of subject 2 for left hand before lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1516	0.3754	0.6209	0.3862	0.1078	0.244161701	0.604606	0.27913
0.1589	0.3827	0.6137	0.3387	0.1201	0.258921297	0.623595	0.354591
0.1444	0.3827	0.5776	0.3102	0.0994	0.25	0.662569	0.320438
0.1444	0.3754	0.5776	0.3087	0.076	0.25	0.649931	0.246194
0.1444	0.3754	0.5776	0.3036	0.083	0.25	0.649931	0.273386
0.1444	0.3611	0.5776	0.3095	0.1003	0.25	0.625173	0.324071
0.1372	0.3682	0.5776	0.3191	0.1025	0.237534626	0.637465	0.321216
0.1588	0.3899	0.592	0.3149	0.1005	0.268243243	0.658615	0.319149
0.1516	0.3827	0.592	0.228	0.0624	0.256081081	0.646453	0.273684
0.1372	0.3755	0.5704	0.1673	0.0438	0.240532959	0.65831	0.261805
0.1372	0.3827	0.5559	0.1712	0.0462	0.24680698	0.688433	0.26986
0.1516	0.3899	0.5776	0.1917	0.0481	0.262465374	0.675035	0.250913
0.1445	0.3754	0.5848	0.2052	0.049	0.247093023	0.641929	0.238791
0.1516	0.3899	0.592	0.2117	0.0508	0.256081081	0.658615	0.239962
0.1516	0.3899	0.592	0.2233	0.054	0.256081081	0.658615	0.241827
0.1444	0.3971	0.592	0.2243	0.0523	0.243918919	0.670777	0.23317
0.1372	0.3754	0.5704	0.2235	0.0532	0.240532959	0.658135	0.238031
0.1516	0.3899	0.592	0.215	0.0536	0.256081081	0.658615	0.249302
0.1516	0.3754	0.5848	0.159	0.0413	0.259233926	0.641929	0.259748
0.1372	0.3754	0.5848	0.1482	0.0412	0.234610123	0.641929	0.278003
0.1589	0.3971	0.592	0.1673	0.0389	0.268412162	0.670777	0.232516
0.1444	0.3682	0.5776	0.1764	0.0444	0.25	0.637465	0.251701
0.1444	0.3682	0.5776	0.1585	0.0396	0.25	0.637465	0.249842
0.1516	0.3898	0.6137	0.1437	0.0365	0.247026234	0.635164	0.254001
0.1372	0.3827	0.5848	0.1557	0.0405	0.234610123	0.654412	0.260116
Mean=					0.250337119	0.649838	0.268858
Variance=					8.51678E-05	0.000327	0.00112

Table 9.21: Ring Finger features of subject 2 for left hand before lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1679	0.3861	0.7807	0.1521	0.1097	0.215063405	0.494556	0.721236
0.1762	0.3777	0.7051	0.1539	0.1123	0.249893632	0.535669	0.729695
0.1595	0.3442	0.7051	0.153	0.1065	0.226209048	0.488158	0.696078
0.1679	0.3442	0.6884	0.164	0.1138	0.243898896	0.5	0.693902
0.1762	0.3609	0.6884	0.1638	0.1179	0.25595584	0.524259	0.71978
0.1511	0.3358	0.7387	0.1466	0.108	0.204548531	0.454582	0.736698
0.1679	0.3609	0.7387	0.1576	0.1185	0.227291187	0.488561	0.751904
0.1931	0.4029	0.8898	0.1931	0.142	0.21701506	0.452798	0.73537
0.1931	0.3526	0.8311	0.1604	0.1243	0.232342678	0.424257	0.774938
0.1679	0.3442	0.7316	0.2135	0.1446	0.229496993	0.470476	0.677283
0.1679	0.3861	0.7219	0.2284	0.1478	0.23258069	0.534839	0.64711
0.1763	0.3945	0.7387	0.2564	0.1498	0.238662515	0.534046	0.584243
0.1847	0.3861	0.7723	0.1893	0.1235	0.239155768	0.499935	0.652404
0.1595	0.361	0.6968	0.183	0.1127	0.228903559	0.518083	0.615847
0.1679	0.3777	0.7387	0.2414	0.1414	0.227291187	0.511304	0.58575
0.1679	0.3777	0.7387	0.2556	0.1487	0.227291187	0.511304	0.581768
0.1847	0.3861	0.7219	0.2589	0.1484	0.255852611	0.534839	0.573194
0.1763	0.361	0.722	0.2741	0.1661	0.244182825	0.5	0.605983
0.1763	0.3945	0.6967	0.2619	0.1505	0.253050093	0.566241	0.574647
0.1679	0.3693	0.6799	0.2202	0.1292	0.246948081	0.543168	0.586739
0.1763	0.361	0.6968	0.2393	0.1349	0.253013777	0.518083	0.563728
0.1511	0.3693	0.6547	0.2692	0.1467	0.230792729	0.564075	0.544948
0.1679	0.3945	0.6632	0.2795	0.1337	0.253166466	0.594843	0.478354
0.1679	0.3945	0.7639	0.2857	0.1505	0.219793167	0.516429	0.526776
0.1763	0.3694	0.6716	0.2546	0.1491	0.262507445	0.55003	0.585625
Mean=					0.236596295	0.513221	0.63776
Variance=					0.000222463	0.001471	0.006551

9.8 Subject 2 – Left Hand (After Lunch)

Table 9.22: Index Finger features of subject 2 for left hand after lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1507	0.3947	0.7175	0.1462	0.0666	0.210034843	0.550105	0.45554

0.1578	0.4161	0.7103	0.1447	0.0592	0.222159651	0.585809	0.409122
0.1794	0.4018	0.7175	0.1307	0.0651	0.250034843	0.56	0.498087
0.1578	0.3946	0.6888	0.1245	0.0549	0.229094077	0.57288	0.440964
0.1507	0.4089	0.6601	0.1312	0.0481	0.228298743	0.619452	0.366616
0.1793	0.4018	0.6959	0.1409	0.0656	0.257651961	0.577382	0.465578
0.165	0.4089	0.7175	0.1158	0.0477	0.229965157	0.569895	0.411917
0.1507	0.3875	0.6817	0.1354	0.0578	0.221064985	0.568432	0.426883
0.165	0.4161	0.7103	0.1424	0.0544	0.232296213	0.585809	0.382022
0.1578	0.3946	0.6959	0.1523	0.069	0.226756718	0.567035	0.453053
0.1507	0.3875	0.6888	0.1317	0.0537	0.218786295	0.562573	0.407745
0.1507	0.3946	0.6888	0.146	0.0538	0.218786295	0.57288	0.368493
0.1865	0.4376	0.6959	0.1638	0.0639	0.267998276	0.628826	0.39011
0.1578	0.3946	0.7175	0.1665	0.0744	0.219930314	0.549965	0.446847
0.1578	0.3875	0.6744	0.137	0.058	0.233985765	0.574585	0.423358
0.165	0.3875	0.6959	0.1617	0.0681	0.237103032	0.556833	0.42115
0.1578	0.4018	0.6959	0.1806	0.0805	0.226756718	0.577382	0.445736
0.165	0.4089	0.6888	0.1651	0.0676	0.239547038	0.593641	0.409449
0.165	0.4089	0.7103	0.1503	0.0601	0.232296213	0.575672	0.399867
0.1578	0.3946	0.7175	0.1741	0.0735	0.219930314	0.549965	0.422171
0.1794	0.4233	0.7175	0.1865	0.074	0.250034843	0.589965	0.396783
0.165	0.4089	0.6888	0.1779	0.0693	0.239547038	0.593641	0.389545
0.1578	0.4161	0.6959	0.1595	0.0644	0.226756718	0.597931	0.403762
0.1507	0.3731	0.6744	0.1796	0.0744	0.223457888	0.553233	0.414254
0.1605	0.4161	0.6744	0.1866	0.0727	0.237989324	0.616993	0.389603
Mean=					0.23201053	0.578035	0.417546
Variance=					0.000179397	0.000471	0.000985

Table 9.23: Middle Finger features of subject 2 for left hand after lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1295	0.3884	0.6904	0.18	0.0585	0.187572422	0.562572	0.325
0.1381	0.397	0.63	0.1954	0.0538	0.219206349	0.630159	0.275333
0.1467	0.3789	0.6214	0.2046	0.0587	0.23607982	0.609752	0.286901
0.1381	0.3797	0.6472	0.2115	0.0541	0.213380717	0.586681	0.255792
0.1812	0.441	0.699	0.1952	0.0644	0.259227468	0.630901	0.329918
0.1381	0.3884	0.63	0.1962	0.0618	0.219206349	0.616508	0.314985
0.1812	0.397	0.6645	0.2194	0.0671	0.27268623	0.597442	0.305834
0.1467	0.4056	0.6472	0.193	0.0594	0.226668727	0.6267	0.307772
0.1381	0.3884	0.6213	0.1842	0.0632	0.222275873	0.625141	0.343105

0.1467	0.4142	0.6472	0.2008	0.0558	0.226668727	0.639988	0.277888
0.1467	0.397	0.6472	0.2245	0.0677	0.226668727	0.613412	0.301559
0.164	0.441	0.6559	0.2077	0.0568	0.250038116	0.672359	0.273471
0.1467	0.397	0.6213	0.1654	0.0479	0.236117817	0.638983	0.289601
0.1467	0.4056	0.6645	0.1864	0.055	0.220767494	0.610384	0.295064
0.1467	0.4056	0.6559	0.2015	0.0497	0.223662144	0.618387	0.24665
0.1467	0.4056	0.6904	0.2058	0.0547	0.212485516	0.587486	0.265792
0.164	0.4142	0.6214	0.1755	0.0522	0.26392018	0.666559	0.297436
0.1381	0.397	0.6041	0.1631	0.0429	0.228604536	0.657176	0.263029
0.1381	0.397	0.6472	0.168	0.0479	0.213380717	0.613412	0.285119
0.164	0.4142	0.6559	0.1768	0.0497	0.250038116	0.631499	0.281109
0.1381	0.3884	0.6559	0.1613	0.054	0.210550389	0.592163	0.33478
0.164	0.4142	0.6732	0.171	0.0517	0.243612597	0.61527	0.302339
0.164	0.4142	0.6732	0.2047	0.0584	0.243612597	0.61527	0.285296
0.1381	0.4142	0.6559	0.2017	0.0472	0.210550389	0.631499	0.234011
0.164	0.397	0.6559	0.2009	0.0467	0.250038116	0.605275	0.232454
Mean=					0.230680805	0.619799	0.28841
Variance=					0.00038892	0.000622	0.000863

Table 9.24: Ring Finger features of subject 2 for left hand after lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.172	0.3888	0.7402	0.4691	0.2088	0.23236963	0.525263	0.445108
0.1869	0.4112	0.7252	0.4977	0.1995	0.257722008	0.567016	0.400844
0.172	0.4112	0.7178	0.4922	0.2041	0.239621064	0.572862	0.414669
0.172	0.3962	0.7102	0.4798	0.1914	0.2421853	0.557871	0.398916
0.1869	0.4112	0.7102	0.5605	0.211	0.263165306	0.578992	0.37645
0.172	0.4112	0.7178	0.4996	0.1247	0.239621064	0.572862	0.2496
0.186	0.4112	0.7178	0.5375	0.2046	0.259125104	0.572862	0.380651
0.172	0.4262	0.7178	0.5211	0.2165	0.239621064	0.593759	0.415467
0.172	0.4112	0.7102	0.5746	0.1882	0.2421853	0.578992	0.327532
0.1645	0.3962	0.7102	0.4257	0.175	0.231624894	0.557871	0.411088
0.1645	0.3962	0.7102	0.3877	0.1346	0.231624894	0.557871	0.347176
0.172	0.3962	0.6954	0.4558	0.1875	0.247339661	0.569744	0.411365
0.1645	0.3888	0.6792	0.3899	0.1484	0.242196702	0.572438	0.38061
0.1645	0.4112	0.6792	0.368	0.1366	0.242196702	0.605418	0.371196
0.1645	0.3888	0.6792	0.3521	0.1585	0.242196702	0.572438	0.450156
0.1794	0.4112	0.7178	0.3911	0.1908	0.249930343	0.572862	0.487855
0.172	0.3888	0.7102	0.3821	0.188	0.2421853	0.547451	0.492018

0.172	0.3888	0.6792	0.3652	0.1655	0.253239105	0.572438	0.453176
0.1794	0.4112	0.6954	0.5262	0.2042	0.257981018	0.591314	0.388065
0.1645	0.4187	0.7028	0.5588	0.2064	0.234063745	0.59576	0.369363
0.172	0.3963	0.6655	0.5022	0.1902	0.258452292	0.595492	0.378734
0.1645	0.4038	0.6729	0.6222	0.2242	0.244464259	0.600089	0.360334
0.172	0.4112	0.6655	0.5827	0.2036	0.258452292	0.617881	0.349408
0.1645	0.3888	0.643	0.524	0.19	0.255832037	0.604666	0.362595
0.172	0.4038	0.6878	0.625	0.2284	0.250072696	0.587089	0.36544
Mean=					0.246298739	0.577652	0.391513
Variance=					9.13203E-05	0.000416	0.002647

9.9 Subject 3 – Right Hand (Before Lunch)

Table 9.25: Index Finger features of subject 3 for right hand before lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1022	0.4015	0.5475	0.8908	0.129	0.186666667	0.733333	0.144814
0.1094	0.4233	0.541	0.8611	0.1385	0.202218115	0.78244	0.160841
0.1022	0.4088	0.5475	0.8056	0.1333	0.186666667	0.746667	0.165467
0.1168	0.4161	0.5329	0.7845	0.1086	0.219178082	0.780822	0.138432
0.1022	0.4088	0.5329	0.7378	0.1095	0.191780822	0.767123	0.148414
0.1022	0.3942	0.5475	0.7901	0.1232	0.186666667	0.72	0.15593
0.1094	0.4233	0.5329	0.8083	0.1275	0.2052918	0.794333	0.157738
0.1168	0.4161	0.5402	0.8657	0.1266	0.216216216	0.77027	0.14624
0.1094	0.4161	0.5475	0.8519	0.1342	0.199817352	0.76	0.15753
0.1022	0.4088	0.5475	0.804	0.1073	0.186666667	0.746667	0.133458
0.1068	0.3981	0.5534	0.8095	0.1229	0.192988797	0.719371	0.151822
0.1053	0.4129	0.5425	0.8694	0.1379	0.194101382	0.761106	0.158615
0.1053	0.3968	0.5425	0.8956	0.1513	0.194101382	0.731429	0.168937
0.1053	0.3968	0.5263	0.8889	0.1458	0.200076002	0.753943	0.164023
0.1053	0.4049	0.5344	0.9008	0.1495	0.197043413	0.757672	0.165964
0.1053	0.3968	0.5425	0.8813	0.1422	0.194101382	0.731429	0.161353
0.1053	0.3968	0.5587	0.8687	0.1345	0.188473241	0.71022	0.154829
0.1053	0.4049	0.5587	0.8693	0.1333	0.188473241	0.724718	0.153342
0.1053	0.3968	0.5263	0.9017	0.1278	0.200076002	0.753943	0.141732
0.1053	0.4049	0.5425	0.9197	0.151	0.194101382	0.746359	0.164184
0.1053	0.4049	0.5263	0.776	0.1416	0.200076002	0.769333	0.182474
0.1053	0.4049	0.5506	0.7547	0.1397	0.191245914	0.73538	0.185107

0.1053	0.4049	0.5668	0.7217	0.1396	0.185779817	0.714361	0.193432
0.1053	0.3968	0.5506	0.7421	0.1422	0.191245914	0.720668	0.191618
0.1053	0.4049	0.5668	0.7678	0.155	0.185779817	0.714361	0.201875
Mean=					0.19515331	0.745838	0.161927
Variance=					7.81519E-05	0.000567	0.000305

Table 9.26: Middle Finger features of subject 3 for right hand before lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1073	0.3908	0.5287	0.3431	0.0413	0.202950634	0.739172	0.120373
0.1149	0.4138	0.5287	0.3854	0.0316	0.217325515	0.782674	0.081993
0.1149	0.4138	0.536	0.4137	0.0315	0.214365672	0.772015	0.076142
0.1149	0.4138	0.536	0.4036	0.0366	0.214365672	0.772015	0.090684
0.1149	0.4062	0.5288	0.3938	0.0502	0.217284418	0.768154	0.127476
0.1072	0.3831	0.521	0.4074	0.0452	0.205758157	0.735317	0.110947
0.1149	0.4062	0.5364	0.4462	0.035	0.214205817	0.757271	0.07844
0.1226	0.4062	0.5288	0.4796	0.0171	0.231845688	0.768154	0.035655
0.1149	0.4062	0.5594	0.5567	0.0693	0.205398641	0.726135	0.124484
0.1072	0.3908	0.5364	0.5778	0.0641	0.199850858	0.728561	0.110938
0.1149	0.3985	0.5441	0.5849	0.0652	0.211174416	0.732402	0.111472
0.1073	0.3985	0.5441	0.623	0.1127	0.197206396	0.732402	0.180899
0.1149	0.4062	0.5594	0.6969	0.0735	0.205398641	0.726135	0.105467
0.1073	0.4062	0.5747	0.7077	0.0805	0.186706108	0.706804	0.113749
0.1149	0.3985	0.5517	0.6658	0.0582	0.208265362	0.722313	0.087414
0.1226	0.4016	0.5364	0.6435	0.0831	0.228560776	0.748695	0.129138
0.1226	0.4138	0.5517	0.6547	0.0786	0.222222222	0.750045	0.120055
0.1149	0.3985	0.5364	0.7534	0.0945	0.214205817	0.742916	0.125431
0.1072	0.3908	0.5364	0.7858	0.1175	0.199850858	0.728561	0.149529
0.1072	0.3985	0.5517	0.8039	0.135	0.194308501	0.722313	0.167931
0.1226	0.3985	0.5594	0.7815	0.1211	0.219163389	0.71237	0.154958
0.1149	0.3908	0.5594	0.7461	0.1057	0.205398641	0.698606	0.14167
0.1073	0.3813	0.5441	0.7186	0.0882	0.197206396	0.70079	0.122739
0.1302	0.4138	0.5747	0.7868	0.0995	0.226552984	0.720028	0.126462
0.1226	0.4138	0.5824	0.8039	0.1085	0.210508242	0.710508	0.134967
Mean=					0.210003193	0.736174	0.11716
Variance=					0.00012364	0.000557	0.000977

Table 9.27: Ring Finger features of subject 3 for right hand before lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1123	0.3742	0.5463	0.3054	0.0626	0.205564708	0.684972	0.204977
0.1123	0.3667	0.5163	0.3243	0.0582	0.2175092	0.710246	0.179463
0.1123	0.3817	0.5463	0.3269	0.0659	0.205564708	0.6987	0.201591
0.1123	0.3742	0.5538	0.31	0.0684	0.202780787	0.675695	0.220645
0.1123	0.3667	0.5388	0.2842	0.065	0.208426132	0.680586	0.228712
0.1197	0.3667	0.5388	0.3188	0.0709	0.222160356	0.680586	0.222396
0.1272	0.3817	0.5463	0.3183	0.0627	0.232839099	0.6987	0.196984
0.1272	0.3892	0.5613	0.337	0.064	0.226616782	0.69339	0.189911
0.1272	0.3742	0.5463	0.313	0.0552	0.232839099	0.684972	0.176358
0.1197	0.3892	0.5463	0.3181	0.0686	0.219110379	0.712429	0.215655
0.1197	0.3816	0.5538	0.3199	0.0848	0.216143012	0.689057	0.265083
0.1123	0.3742	0.5463	0.3157	0.0775	0.205564708	0.684972	0.245486
0.1123	0.3742	0.5314	0.3349	0.0641	0.211328566	0.704178	0.1914
0.1197	0.3817	0.5239	0.3334	0.0536	0.228478717	0.728574	0.160768
0.1197	0.3667	0.5388	0.3138	0.0573	0.222160356	0.680586	0.1826
0.1123	0.3742	0.5314	0.3247	0.0718	0.211328566	0.704178	0.221127
0.1123	0.3742	0.5089	0.3163	0.0603	0.220672038	0.735311	0.190642
0.1197	0.3742	0.5238	0.3394	0.0621	0.228522337	0.714395	0.18297
0.1272	0.3817	0.5014	0.332	0.0416	0.253689669	0.761268	0.125301
0.1347	0.3817	0.5089	0.314	0.0404	0.264688544	0.750049	0.128662
0.1273	0.3817	0.5613	0.2853	0.0527	0.22679494	0.680029	0.184718
0.1422	0.3817	0.5538	0.2789	0.0773	0.256771398	0.689238	0.27716
0.1123	0.3443	0.5463	0.2791	0.0824	0.205564708	0.63024	0.295235
0.1272	0.3592	0.5762	0.2896	0.0795	0.220756682	0.623395	0.274517
0.1272	0.3742	0.5388	0.2933	0.057	0.236080178	0.694506	0.19434
Mean=					0.223278227	0.69561	0.206268
Variance=					0.000270202	0.000924	0.001779

9.10 Subject 3 – Right Hand (After Lunch)

Table 9.28: Index Finger features of subject 3 for right hand after lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1239	0.4011	0.5761	0.6059	0.0654	0.215066829	0.696233	0.107939

0.1166	0.4011	0.525	0.5948	0.0733	0.222095238	0.764	0.123235
0.1166	0.4011	0.5397	0.5482	0.0614	0.216045951	0.743191	0.112003
0.124	0.4157	0.5907	0.5645	0.0852	0.209920433	0.703741	0.15093
0.1094	0.4011	0.5324	0.5797	0.0726	0.205484598	0.753381	0.125237
0.1166	0.4084	0.547	0.6144	0.0747	0.213162706	0.746618	0.121582
0.1094	0.4011	0.5907	0.5765	0.0817	0.185203995	0.679025	0.141717
0.124	0.4084	0.6198	0.5804	0.0937	0.200064537	0.658922	0.16144
0.124	0.4084	0.5761	0.5568	0.0624	0.21524041	0.708905	0.112069
0.1021	0.4011	0.5834	0.5593	0.0654	0.17500857	0.687521	0.116932
0.1094	0.4084	0.5615	0.5783	0.0689	0.194835263	0.727337	0.119142
0.1094	0.4084	0.5907	0.5787	0.066	0.185203995	0.691383	0.114049
0.1094	0.4084	0.5907	0.5808	0.0779	0.185203995	0.691383	0.134125
0.124	0.4156	0.5907	0.5498	0.0712	0.209920433	0.703572	0.129502
0.1166	0.4011	0.5907	0.5333	0.0788	0.197392924	0.679025	0.147759
0.1094	0.4011	0.5543	0.5496	0.0809	0.197366047	0.723615	0.147198
0.1094	0.4084	0.5543	0.5697	0.0802	0.197366047	0.736785	0.140776
0.1094	0.3793	0.5543	0.5577	0.0922	0.197366047	0.684286	0.165322
0.1094	0.3938	0.5834	0.58	0.0966	0.187521426	0.675009	0.166552
0.124	0.4157	0.598	0.5496	0.0927	0.20735786	0.695151	0.168668
0.124	0.4011	0.598	0.5242	0.0964	0.20735786	0.670736	0.183899
0.1094	0.4011	0.5688	0.545	0.0893	0.19233474	0.705169	0.163853
0.1094	0.4011	0.5469	0.581	0.0818	0.20003657	0.733406	0.140792
0.1313	0.423	0.6272	0.5874	0.0893	0.209343112	0.674426	0.152026
0.1313	0.423	0.6199	0.5536	0.0888	0.211808356	0.682368	0.160405
Mean=					0.201508318	0.704608	0.140286
Variance=					0.000143056	0.000832	0.000464

Table 9.29: Middle Finger features of subject 3 for right hand after lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.123	0.415	0.5533	0.6823	0.1011	0.222302548	0.750045	0.148175
0.1153	0.3996	0.5226	0.6843	0.0805	0.220627631	0.764638	0.117638
0.1306	0.415	0.584	0.7166	0.0993	0.223630137	0.710616	0.138571
0.1383	0.415	0.584	0.7064	0.1029	0.236815068	0.710616	0.145668
0.1306	0.4227	0.5918	0.6752	0.1104	0.220682663	0.714262	0.163507
0.123	0.415	0.5764	0.659	0.1046	0.213393477	0.719986	0.158725
0.1306	0.3996	0.584	0.679	0.0927	0.223630137	0.684247	0.136524
0.123	0.4227	0.5918	0.6949	0.0975	0.207840487	0.714262	0.140308
0.1306	0.4073	0.5918	0.6922	0.0959	0.220682663	0.688239	0.138544

0.1153	0.4073	0.584	0.6659	0.103	0.197431507	0.697432	0.154678
0.1153	0.4073	0.5687	0.6469	0.1083	0.202743098	0.716195	0.167414
0.123	0.3996	0.561	0.6889	0.1062	0.219251337	0.712299	0.154159
0.1153	0.415	0.5687	0.7029	0.0916	0.202743098	0.729734	0.130317
0.1153	0.4073	0.6148	0.7205	0.0959	0.187540664	0.662492	0.133102
0.1153	0.4073	0.6225	0.7117	0.0979	0.185220884	0.654297	0.137558
0.1306	0.3996	0.5918	0.6921	0.1133	0.220682663	0.675228	0.163705
0.1153	0.3996	0.5918	0.6899	0.1082	0.194829334	0.675228	0.156834
0.123	0.415	0.5995	0.7194	0.0924	0.205170976	0.692244	0.12844
0.123	0.4227	0.6071	0.7097	0.0931	0.202602537	0.696261	0.131182
0.123	0.4227	0.5995	0.6633	0.088	0.205170976	0.705088	0.13267
0.123	0.4073	0.5918	0.6263	0.1001	0.207840487	0.688239	0.159828
0.1306	0.3996	0.5763	0.5866	0.0874	0.226618081	0.693389	0.148994
0.123	0.4073	0.5678	0.5777	0.0511	0.216625572	0.71733	0.088454
0.1383	0.415	0.6071	0.7197	0.0831	0.227804316	0.683578	0.115465
0.1383	0.438	0.5917	0.5744	0.0302	0.233733311	0.74024	0.052577
Mean=					0.213024546	0.703847	0.137722
Variance=					0.000187023	0.000676	0.000633

Table 9.30: Ring Finger features of subject 3 for right hand after lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1314	0.4097	0.5736	0.4471	0.0483	0.229079498	0.714261	0.10803
0.149	0.432	0.6033	0.4249	0.0559	0.246974971	0.716062	0.13156
0.1415	0.4097	0.5885	0.4758	0.0517	0.240441801	0.696177	0.108659
0.1314	0.4023	0.5736	0.4586	0.0472	0.229079498	0.70136	0.102922
0.1267	0.4023	0.5736	0.4361	0.0536	0.220885635	0.70136	0.122908
0.1314	0.4023	0.581	0.4084	0.0442	0.22616179	0.692427	0.108227
0.1341	0.4171	0.581	0.384	0.0477	0.23080895	0.7179	0.124219
0.1341	0.4097	0.581	0.3986	0.0325	0.23080895	0.705164	0.081535
0.1341	0.4097	0.5885	0.3954	0.0284	0.22786746	0.696177	0.071826
0.1266	0.3948	0.5885	0.3807	0.0376	0.215123195	0.670858	0.098765
0.149	0.4023	0.596	0.3751	0.0415	0.25	0.675	0.110637
0.1341	0.4097	0.5885	0.3462	0.0511	0.22786746	0.696177	0.147603
0.1341	0.4023	0.5885	0.3527	0.046	0.22786746	0.683602	0.130422
0.1341	0.4171	0.5959	0.3823	0.0259	0.225037758	0.69995	0.067748
0.1504	0.4171	0.5885	0.3681	0.0513	0.255564996	0.708751	0.139364
0.1564	0.4246	0.5885	0.3725	0.0414	0.265760408	0.721495	0.111141
0.1564	0.4246	0.581	0.3657	0.0421	0.26919105	0.730809	0.115122

0.149	0.432	0.581	0.3494	0.0404	0.256454389	0.743546	0.115627
0.149	0.3948	0.5363	0.3526	0.0338	0.277829573	0.736155	0.095859
0.149	0.4246	0.5885	0.3615	0.0272	0.253186066	0.721495	0.075242
0.1564	0.4321	0.581	0.3786	0.0261	0.26919105	0.743718	0.068938
0.1341	0.4096	0.5563	0.324	0.0595	0.241056984	0.736293	0.183642
0.1341	0.3948	0.5438	0.3299	0.0512	0.246598014	0.726002	0.155199
0.149	0.4022	0.6034	0.3566	0.0629	0.24693404	0.666556	0.176388
0.1415	0.4096	0.5885	0.342	0.0593	0.240441801	0.696007	0.173392
Mean=					0.242008512	0.707892	0.116999
Variance=					0.000286473	0.00047	0.001066

9.11 Subject 3 – Left hand (Before Lunch)

Table 9.31: Index Finger features of subject 3 for left hand before lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1258	0.407	0.5698	0.3645	0.0331	0.220779221	0.714286	0.090809
0.1111	0.3775	0.5477	0.3506	0.0472	0.202848275	0.689246	0.134626
0.1184	0.3775	0.5477	0.3132	0.0468	0.216176739	0.689246	0.149425
0.1184	0.3775	0.5329	0.3363	0.0538	0.222180522	0.708388	0.159976
0.1184	0.3996	0.555	0.3145	0.0373	0.213333333	0.72	0.118601
0.1258	0.407	0.5477	0.3067	0.0335	0.229687785	0.743108	0.109227
0.1258	0.3848	0.5698	0.2987	0.0389	0.220779221	0.675325	0.130231
0.1184	0.3774	0.555	0.2901	0.0462	0.213333333	0.68	0.159255
0.1036	0.3922	0.5772	0.2395	0.0286	0.179487179	0.679487	0.119415
0.1184	0.3977	0.5847	0.2053	0.0216	0.202497007	0.680178	0.105212
0.1111	0.3996	0.555	0.2676	0.051	0.20018018	0.72	0.190583
0.1184	0.3922	0.5403	0.2989	0.0592	0.219137516	0.725893	0.19806
0.1111	0.3848	0.555	0.3086	0.0476	0.20018018	0.693333	0.154245
0.1184	0.3755	0.518	0.3223	0.0476	0.228571429	0.724903	0.147688
0.1111	0.3755	0.5329	0.3257	0.0523	0.208481892	0.704635	0.160577
0.1258	0.3922	0.5698	0.3297	0.0611	0.220779221	0.688312	0.18532
0.1184	0.3774	0.5477	0.3389	0.0555	0.216176739	0.689063	0.163765
0.1184	0.3774	0.5477	0.3524	0.0485	0.216176739	0.689063	0.137628
0.1332	0.407	0.5625	0.3638	0.0414	0.2368	0.723556	0.113799
0.1258	0.3996	0.5625	0.362	0.0385	0.223644444	0.7104	0.106354
0.1332	0.3996	0.5625	0.3518	0.0466	0.2368	0.7104	0.132462
0.1037	0.3701	0.5255	0.3241	0.0425	0.197335871	0.704282	0.131132

0.1258	0.3996	0.5625	0.3181	0.0447	0.223644444	0.7104	0.140522
0.1184	0.3775	0.5403	0.3142	0.0508	0.219137516	0.698686	0.16168
0.1184	0.3775	0.5255	0.307	0.047	0.225309229	0.718363	0.153094
Mean=					0.215738321	0.703622	0.142148
Variance=					0.000172797	0.000318	0.000757

Table 9.32: Middle Finger features of subject 3 for left hand before lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.11	0.3959	0.5573	0.2998	0.0761	0.197380226	0.710389	0.253836
0.1027	0.374	0.5647	0.2987	0.0774	0.181866478	0.662299	0.259123
0.1027	0.3886	0.5647	0.3077	0.0864	0.181866478	0.688153	0.280793
0.1027	0.396	0.55	0.3002	0.0821	0.186727273	0.72	0.273484
0.11	0.396	0.5426	0.3056	0.0805	0.202727608	0.729819	0.263416
0.11	0.374	0.5426	0.3101	0.0696	0.202727608	0.689274	0.224444
0.1174	0.3886	0.5207	0.331	0.0583	0.225465719	0.746303	0.176133
0.1246	0.3886	0.5059	0.3293	0.0474	0.246293734	0.768136	0.143942
0.1174	0.3959	0.5133	0.3618	0.0609	0.22871615	0.771284	0.168325
0.1246	0.3886	0.55	0.3921	0.0689	0.226545455	0.706545	0.17572
0.1174	0.3886	0.5647	0.4152	0.0798	0.207897999	0.688153	0.192197
0.1246	0.3959	0.5792	0.4318	0.0877	0.215124309	0.683529	0.203103
0.11	0.374	0.55	0.4173	0.0855	0.2	0.68	0.204889
0.1174	0.396	0.55	0.4389	0.0853	0.213454545	0.72	0.19435
0.1174	0.3813	0.5573	0.4844	0.0863	0.210658532	0.684192	0.178159
0.11	0.374	0.5426	0.504	0.0863	0.202727608	0.689274	0.17123
0.1246	0.396	0.5719	0.5214	0.0903	0.217870257	0.692429	0.173188
0.1246	0.396	0.5646	0.5268	0.0939	0.220687212	0.701382	0.178246
0.11	0.3813	0.5426	0.5094	0.0821	0.202727608	0.702728	0.16117
0.11	0.3813	0.5426	0.5145	0.0984	0.202727608	0.702728	0.191254
0.1174	0.3813	0.5426	0.541	0.091	0.216365647	0.702728	0.168207
0.1174	0.3886	0.5353	0.5653	0.0816	0.219316271	0.725948	0.144348
0.11	0.3739	0.5353	0.5519	0.0884	0.205492247	0.698487	0.160174
0.11	0.3813	0.5426	0.5407	0.0956	0.202727608	0.702728	0.176808
0.1174	0.3959	0.5426	0.5688	0.0957	0.216365647	0.729635	0.168249
Mean=					0.209378393	0.707846	0.195391
Variance=					0.000219973	0.000694	0.001632

Table 9.33: Ring Finger features of subject 3 for left hand before lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1305	0.4348	0.5725	0.6429	0.0562	0.227947598	0.759476	0.087416
0.1305	0.4348	0.5653	0.5724	0.04	0.230850876	0.769149	0.069881
0.1305	0.4276	0.5653	0.4997	0.0292	0.230850876	0.756413	0.058435
0.116	0.4131	0.558	0.4656	0.0261	0.207885305	0.740323	0.056057
0.1377	0.442	0.5653	0.4921	0.036	0.243587476	0.781886	0.073156
0.1377	0.4348	0.5507	0.4921	0.0289	0.250045397	0.789541	0.058728
0.1377	0.442	0.5362	0.4976	0.0334	0.256807162	0.824319	0.067122
0.1305	0.4348	0.5507	0.4777	0.0331	0.236971128	0.789541	0.06929
0.1449	0.4348	0.5507	0.4773	0.0459	0.263119666	0.789541	0.096166
0.1232	0.4058	0.529	0.4713	0.0453	0.23289225	0.767108	0.096117
0.1377	0.4276	0.5435	0.4971	0.0441	0.253357866	0.786753	0.088715
0.1449	0.442	0.5507	0.5239	0.0462	0.263119666	0.802615	0.088185
0.1377	0.442	0.5652	0.5403	0.0462	0.243630573	0.782024	0.085508
0.1377	0.4348	0.5797	0.522	0.0427	0.237536657	0.750043	0.081801
0.1305	0.4348	0.5507	0.5121	0.0445	0.236971128	0.789541	0.086897
0.1377	0.4348	0.5652	0.4774	0.0403	0.243630573	0.769285	0.084416
0.1232	0.4203	0.5507	0.4789	0.0382	0.223715271	0.76321	0.079766
0.1305	0.4565	0.5652	0.479	0.0324	0.23089172	0.807679	0.067641
0.1377	0.442	0.558	0.4795	0.033	0.246774194	0.792115	0.068822
0.145	0.4276	0.5652	0.4689	0.0299	0.256546355	0.756546	0.063766
0.1232	0.4131	0.5507	0.416	0.0329	0.223715271	0.750136	0.079087
0.1305	0.4275	0.558	0.41	0.0331	0.233870968	0.766129	0.080732
0.1305	0.4275	0.5434	0.4271	0.0233	0.240154582	0.786713	0.054554
0.1377	0.4131	0.5507	0.4037	0.0291	0.250045397	0.750136	0.072083
0.1305	0.4276	0.5435	0.3857	0.0483	0.240110396	0.786753	0.125227
Mean=					0.240201134	0.776279	0.077583
Variance=					0.000173316	0.000425	0.000246

9.12 Subject 3 – Left Hand (After Lunch)

Table 9.34: Index Finger features of subject 3 for left hand after lunch.

INDEX FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1243	0.3948	0.5996	0.3803	0.0756	0.20730487	0.658439	0.19879

0.1316	0.3876	0.5923	0.3807	0.0534	0.222184704	0.654398	0.140268
0.1243	0.3948	0.5996	0.371	0.0535	0.20730487	0.658439	0.144205
0.117	0.3876	0.5996	0.3707	0.0543	0.195130087	0.646431	0.14648
0.1389	0.4022	0.6069	0.358	0.0719	0.228868018	0.662712	0.200838
0.1243	0.373	0.5704	0.351	0.0614	0.217917251	0.653927	0.174929
0.117	0.3876	0.5631	0.3635	0.0645	0.20777837	0.688332	0.177442
0.1243	0.3803	0.5412	0.3659	0.0455	0.229674797	0.702698	0.124351
0.1243	0.3949	0.5192	0.3541	0.046	0.23940678	0.760593	0.129907
0.117	0.3949	0.5192	0.3421	0.0389	0.225346687	0.760593	0.113709
0.117	0.3876	0.5704	0.3424	0.0629	0.205119215	0.679523	0.183703
0.1316	0.3949	0.5777	0.3338	0.0637	0.227799896	0.683573	0.190833
0.1389	0.4022	0.5411	0.364	0.0544	0.256699316	0.743301	0.149451
0.1243	0.3876	0.5411	0.3606	0.0341	0.229717243	0.716319	0.094565
0.117	0.3948	0.5557	0.3568	0.051	0.210545258	0.710455	0.142937
0.1243	0.3876	0.5704	0.348	0.063	0.217917251	0.679523	0.181034
0.117	0.3876	0.5631	0.3484	0.0581	0.20777837	0.688332	0.166762
0.117	0.3876	0.5558	0.3674	0.0548	0.210507377	0.697373	0.149156
0.117	0.3949	0.5338	0.3473	0.0391	0.219183215	0.73979	0.112583
0.117	0.3802	0.5631	0.3238	0.0605	0.20777837	0.675191	0.186844
0.117	0.3729	0.5777	0.3313	0.0666	0.202527263	0.645491	0.201026
0.1243	0.3875	0.5411	0.3481	0.0595	0.229717243	0.716134	0.170928
0.1097	0.3948	0.5703	0.3544	0.0624	0.192354901	0.692267	0.176072
0.1243	0.3948	0.5777	0.3595	0.0546	0.21516358	0.6834	0.151878
0.1097	0.3876	0.5119	0.3572	0.0353	0.214299668	0.757179	0.098824
Mean=					0.217120984	0.694177	0.156301
Variance=					0.000204008	0.001296	0.001006

Table 9.35: Middle Finger features of subject 3 for left hand after lunch.

MIDDLE FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1243	0.4314	0.5996	0.3851	0.0224	0.20730487	0.71948	0.058167
0.1243	0.4242	0.5924	0.3925	0.032	0.209824443	0.71607	0.081529
0.139	0.4242	0.5996	0.383	0.0377	0.231821214	0.707472	0.098433
0.1316	0.4095	0.5777	0.3734	0.0435	0.227799896	0.708845	0.116497
0.1243	0.4168	0.5923	0.3809	0.0514	0.209859868	0.703697	0.134944
0.1243	0.4242	0.5777	0.3973	0.0312	0.21516358	0.734291	0.07853
0.1243	0.4168	0.5923	0.4007	0.0309	0.209859868	0.703697	0.077115
0.1243	0.4095	0.5777	0.4086	0.0357	0.21516358	0.708845	0.087372
0.1243	0.4095	0.5704	0.3895	0.0393	0.217917251	0.717917	0.100899

0.1316	0.4168	0.585	0.3984	0.0445	0.224957265	0.712479	0.111697
0.117	0.4314	0.5777	0.4099	0.0304	0.202527263	0.746754	0.074164
0.1316	0.4168	0.5777	0.4256	0.0247	0.227799896	0.721482	0.058036
0.1243	0.4242	0.5704	0.4302	0.0321	0.217917251	0.743689	0.074616
0.1243	0.4095	0.5923	0.4149	0.0424	0.209859868	0.691373	0.102193
0.1243	0.4095	0.5997	0.4243	0.0442	0.207270302	0.682841	0.104172
0.117	0.4095	0.5997	0.4382	0.0378	0.195097549	0.682841	0.086262
0.1243	0.4095	0.5851	0.4571	0.0221	0.212442318	0.69988	0.048348
0.117	0.4168	0.5411	0.4671	0.0333	0.216226206	0.770283	0.071291
0.117	0.4095	0.5265	0.4429	0.028	0.222222222	0.777778	0.06322
0.117	0.3949	0.5485	0.4243	0.0318	0.213309025	0.719964	0.074947
0.117	0.4241	0.5557	0.4358	0.035	0.210545258	0.763182	0.080312
0.117	0.3949	0.5119	0.4343	0.0304	0.228560266	0.77144	0.069998
0.117	0.3876	0.5265	0.4319	0.0395	0.222222222	0.736182	0.091456
0.1024	0.3949	0.5119	0.4554	0.0277	0.20003907	0.77144	0.060826
0.117	0.3803	0.5192	0.4632	0.0431	0.225346687	0.732473	0.093048
Mean=					0.21524229	0.725776	0.083923
Variance=					8.96627E-05	0.000795	0.000421

Table 9.36: Ring Finger features of subject 3 for left hand after lunch.

RING FINGER							
TP1	TP2	TPT	A1	A2	TP1/TPT	TP2/TPT	A2/A1
0.1294	0.4097	0.5966	1.0649	0.1977	0.216895743	0.686725	0.185651
0.1437	0.4169	0.6038	1.1203	0.2229	0.237992713	0.69046	0.198965
0.1437	0.4169	0.6109	1.1096	0.2328	0.235226715	0.682436	0.209805
0.1437	0.4241	0.6181	1.0904	0.2183	0.232486653	0.686135	0.200202
0.1294	0.4169	0.6038	1.0347	0.1889	0.214309374	0.69046	0.182565
0.1581	0.4169	0.6038	0.9489	0.144	0.261841669	0.69046	0.151755
0.1294	0.4025	0.5894	0.9746	0.1624	0.2195453	0.682898	0.166632
0.1438	0.4169	0.5894	1.0094	0.1857	0.243976926	0.707329	0.183971
0.1365	0.4241	0.5894	1.016	0.2049	0.231591449	0.719545	0.201673
0.1294	0.4025	0.5894	0.9966	0.2022	0.2195453	0.682898	0.20289
0.1294	0.4097	0.5894	0.9536	0.1742	0.2195453	0.695114	0.182676
0.1365	0.4025	0.5606	0.9022	0.1437	0.243489119	0.717981	0.159277
0.1222	0.3954	0.5535	0.9286	0.1628	0.220776874	0.714363	0.175318
0.1294	0.4097	0.5822	1.0014	0.2018	0.222260392	0.70371	0.201518
0.1222	0.3809	0.5606	0.996	0.2197	0.217980735	0.679451	0.220582
0.1294	0.3953	0.5822	0.9875	0.2138	0.222260392	0.678976	0.216506
0.1222	0.3953	0.575	0.9205	0.1522	0.212521739	0.687478	0.165345

0.1366	0.4241	0.5894	0.9406	0.1598	0.231761113	0.719545	0.169892
0.1366	0.4097	0.575	0.9938	0.1906	0.237565217	0.712522	0.191789
0.1509	0.4241	0.5966	0.982	0.1771	0.252933289	0.710862	0.180346
0.1366	0.4241	0.6038	0.9505	0.1625	0.226233852	0.702385	0.170963
0.1581	0.4313	0.5966	0.8603	0.108	0.265001676	0.72293	0.125538
0.1437	0.4168	0.5822	0.8456	0.1075	0.246822398	0.715905	0.127129
0.1222	0.4097	0.5606	0.9263	0.1464	0.217980735	0.730824	0.158048
0.1294	0.4097	0.5678	0.9454	0.1699	0.227897147	0.721557	0.179712
Mean =					0.231137673	0.701318	0.18035
Variance=					0.000213202	0.000265	0.000598

Next the column charts of the values of variance and means of the three parameters namely, A2/A1, TP2/TPT, TP1/TPT for the three subjects were plotted, to compare their values before and after lunch for detection of any consistent change.

9.13 Index finger bar charts for mean and variance

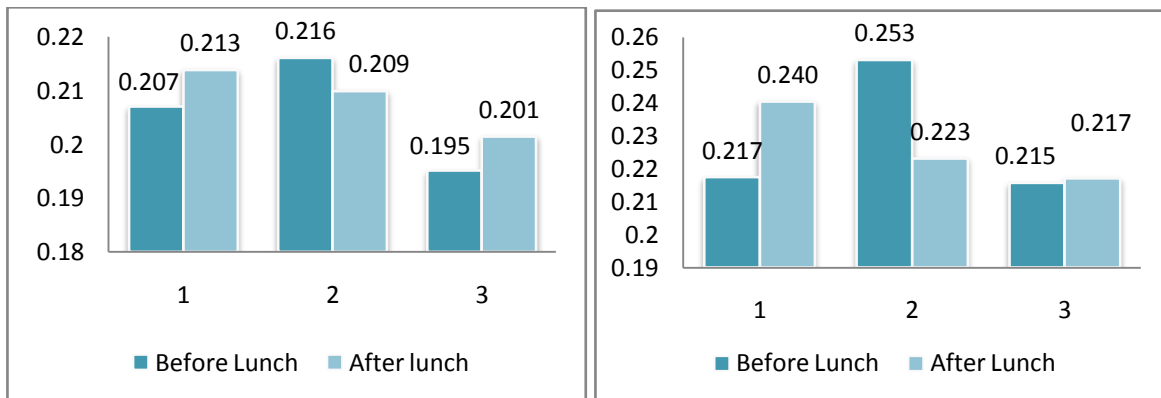


Figure 9.1: Change in mean of TP1/TPT for Index Finger of right and left hand.

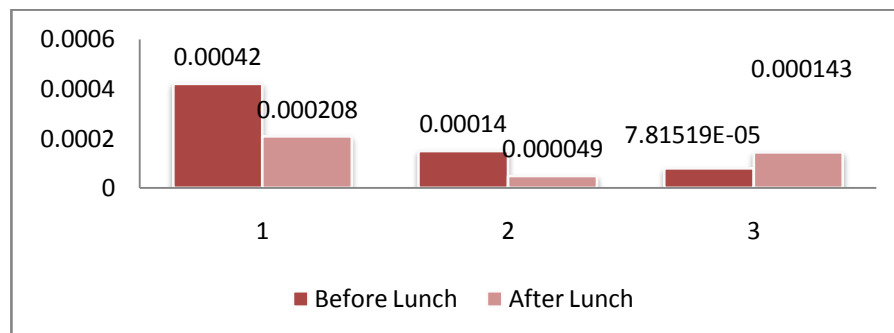


Figure 9.2: Change in variance of TP1/TPT for Index Finger of right hand.

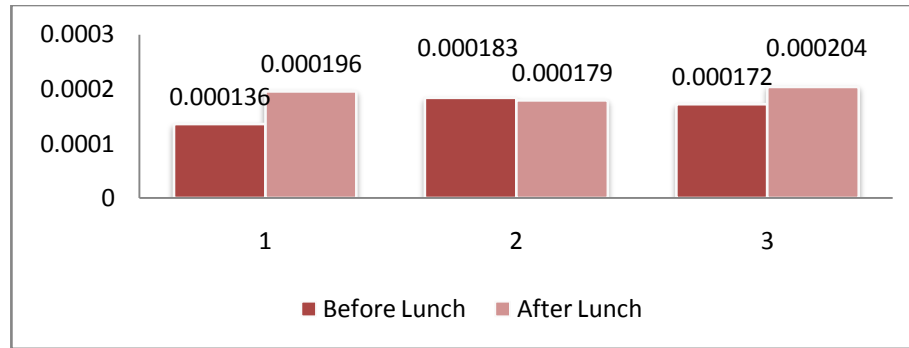


Figure 9.3: Change in variance of TP1/TPT for Index Finger for left hand.



Figure 9.4: Change in mean of TP2/TPT for Index Finger of right and left hand.

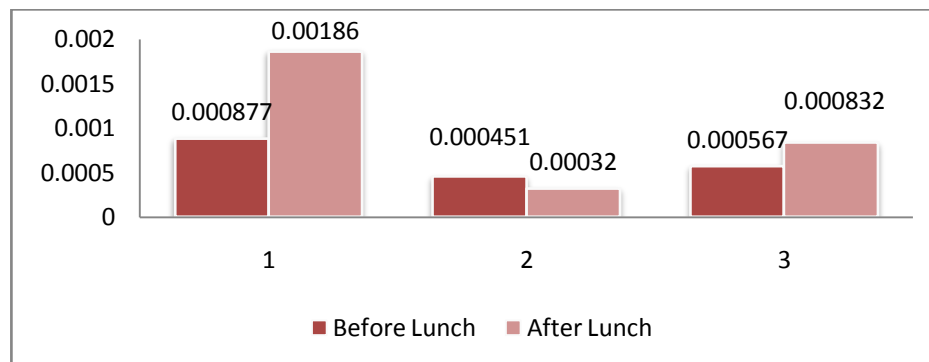


Figure 9.5: Change in variance of TP2/TPT for Index Finger for right hand.

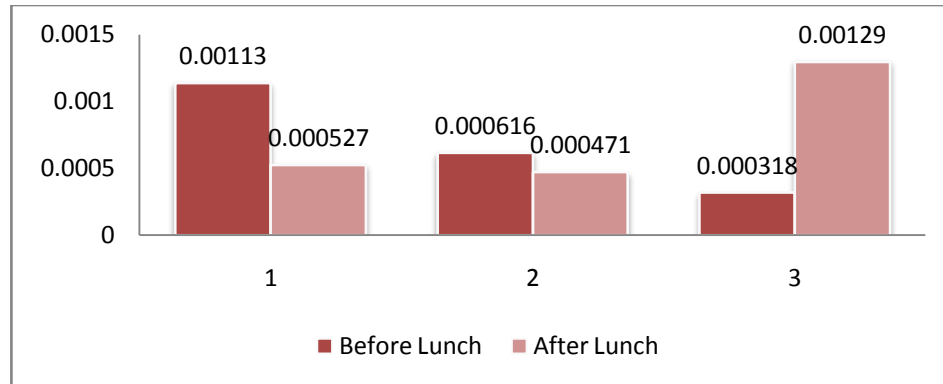


Figure 9.6: Change in variance of TP2/TPT for Index Finger for left hand.

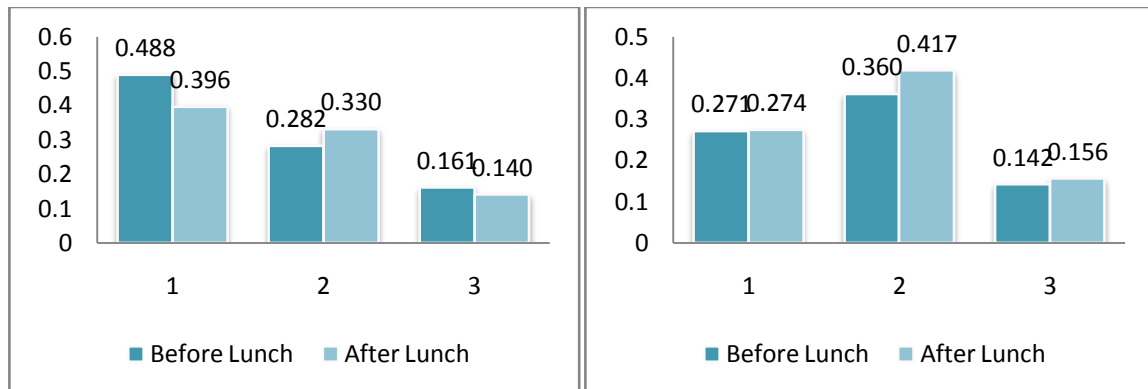


Figure 9.7: Change in mean of A2/A1 for Index Finger of right and left hand.

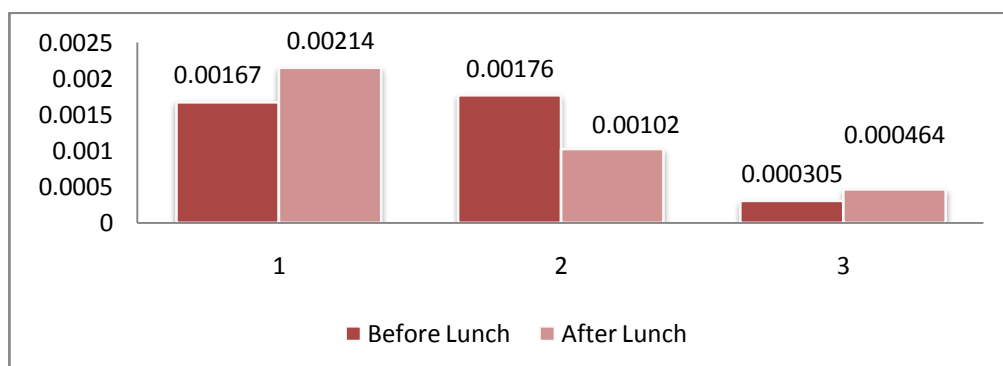


Figure 9.8: Change in variance of A2/A1 for Index Finger for right hand.

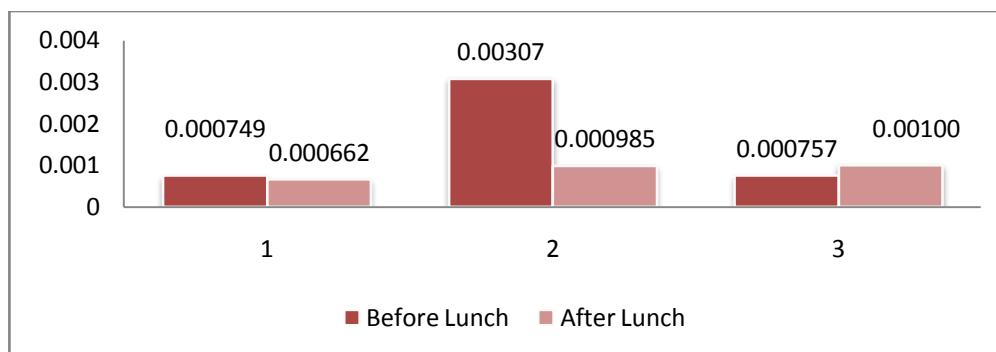


Figure 9.9: Change in variance of A2/A1 for Index Finger for left hand.

9.14 Middle Finger bar charts for mean and variance

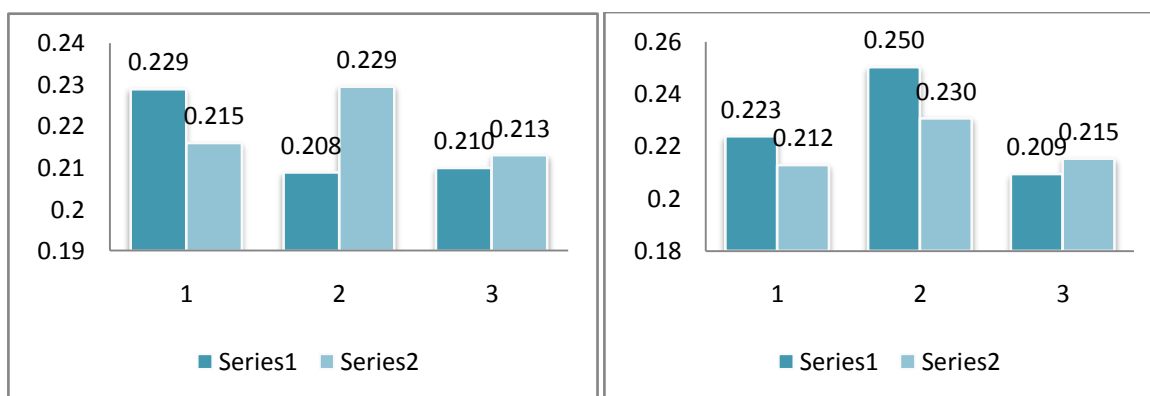


Figure 9.10: Change in mean of TP1/TPT for Middle Finger of right and left hand.

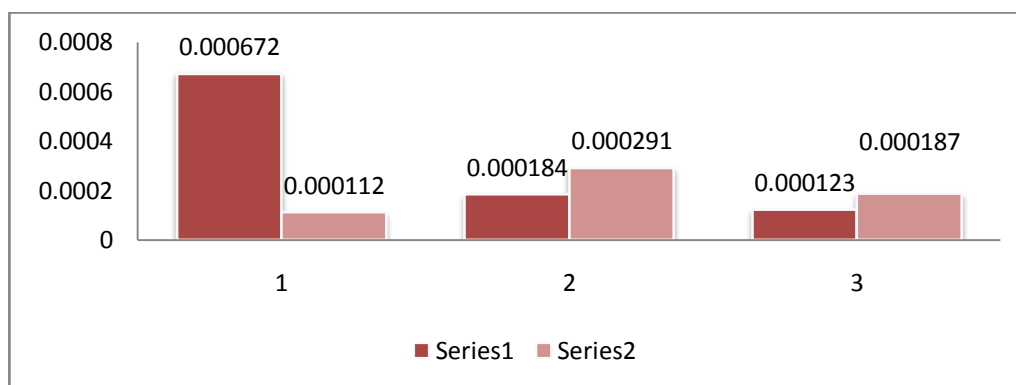


Figure 9.11: Change in variance of TP1/TPT for Middle Finger for right hand.

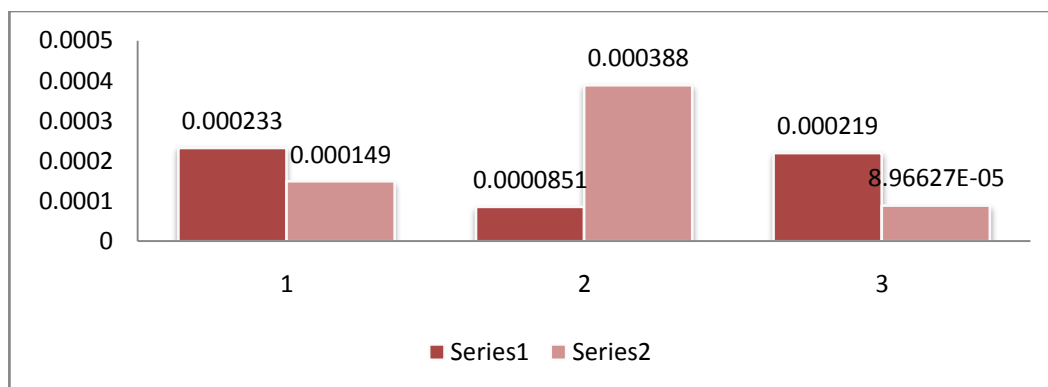


Figure 9.12: Change in variance of TP1/TPT for Middle Finger for left hand.

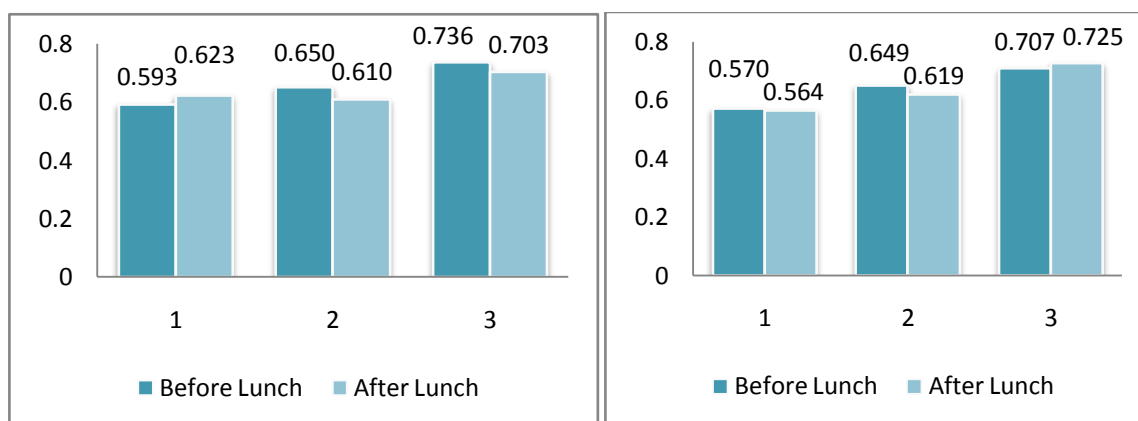


Figure 9.13: Change in mean of TP2/TPT for Middle Finger of right and left hand.

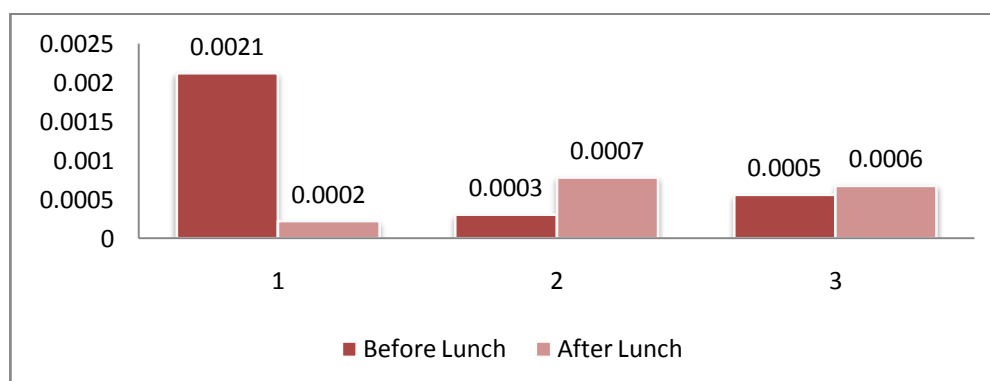


Figure 9.14: Change in variance of TP2/TPT for Middle Finger for right hand.

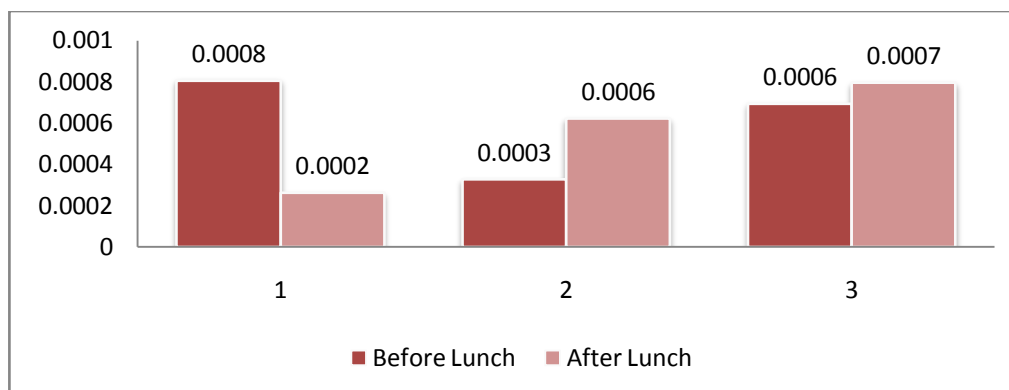


Figure 9.15: Change in variance of TP2/TPT for Middle Finger for left hand.

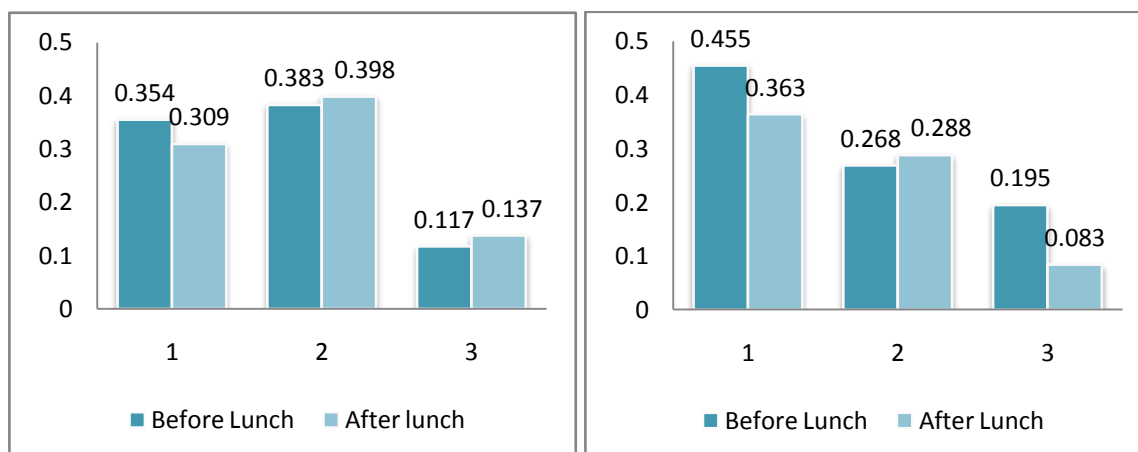


Figure 9.16: Change in mean of A2/A1 for Middle Finger of right and left hand.



Figure 9.17: Change in variance of A2/A1 for Middle Finger for right hand.

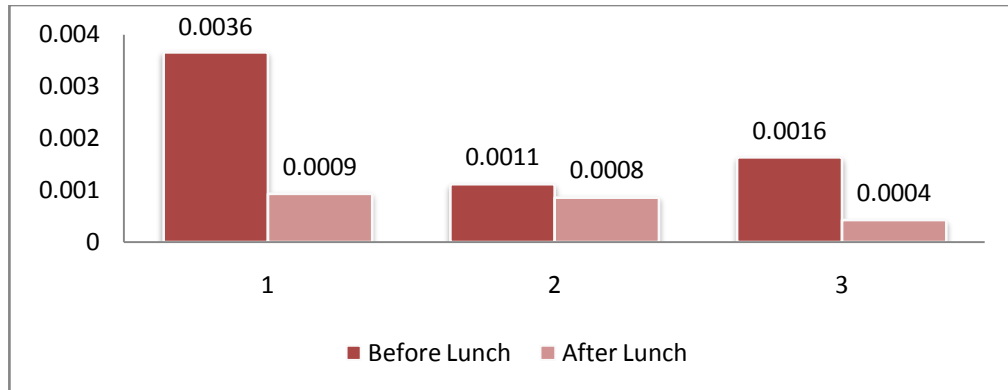


Figure 9.18: Change in variance of A2/A1 for Middle Finger for left hand.

9.15 Ring finger bar charts for mean and variance

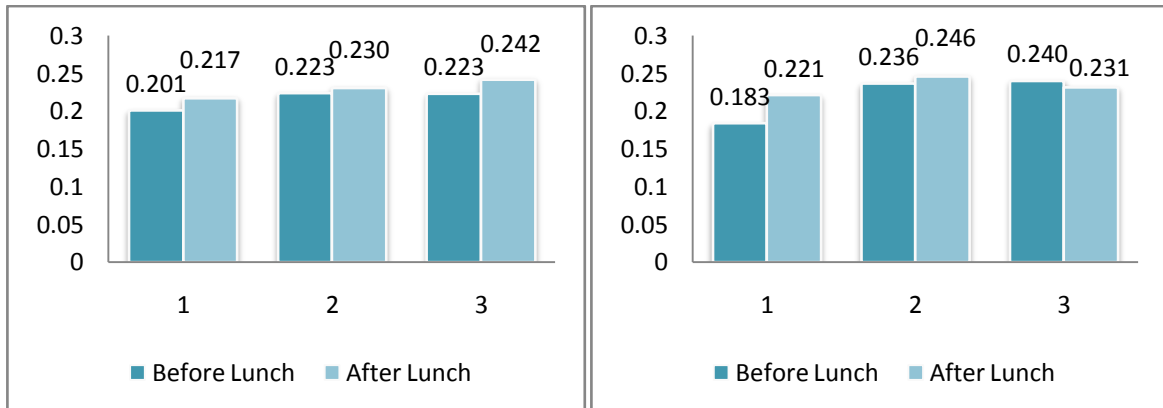


Figure 9.19: Change in mean of TP1/TPT for Ring Finger of right and left hand.

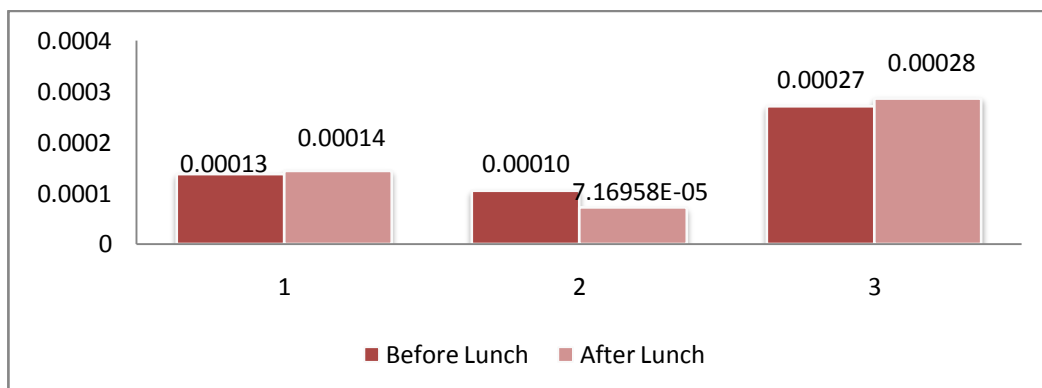


Figure 9.20: Change in variance of TP1/TPT for Ring Finger for right hand.

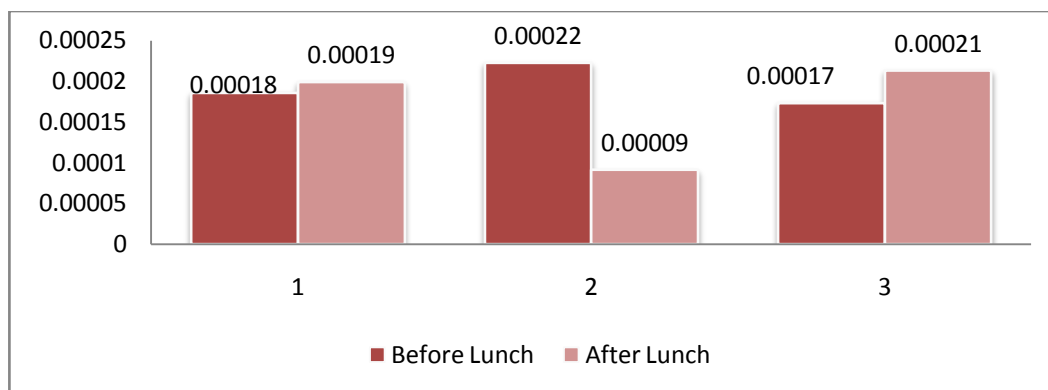


Figure 9.21: Change in variance of TP1/TPT for Ring Finger for left hand.

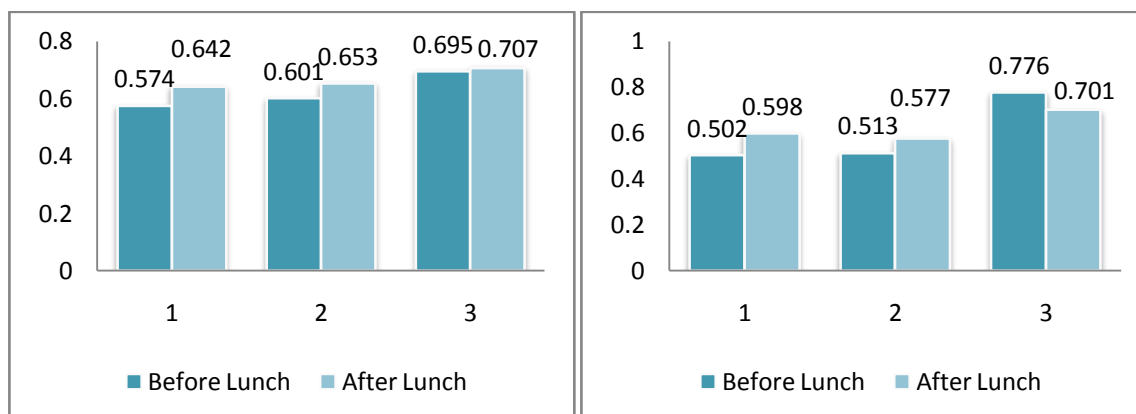


Figure 9.22: Change in mean of TP2/TPT for Ring Finger of right and left hand.

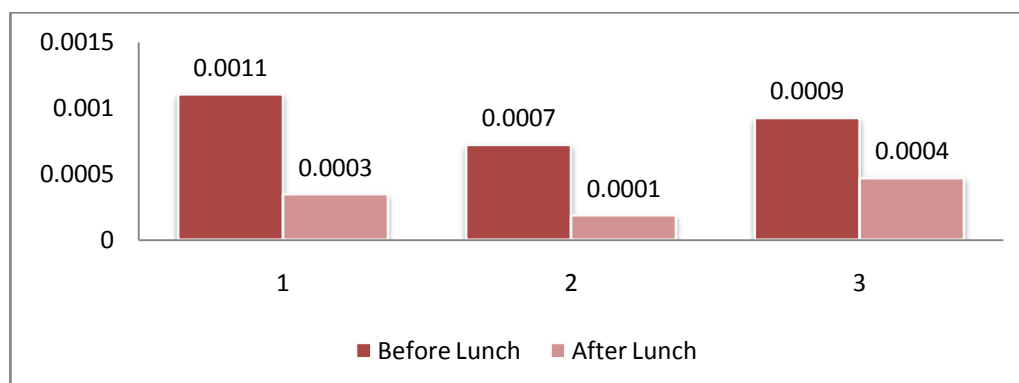


Figure 9.23: Change in variance of TP2/TPT for Ring Finger for right hand.

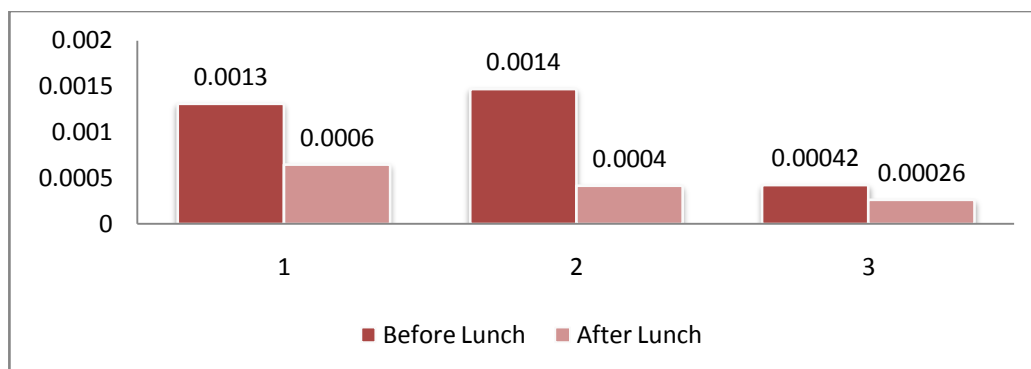


Figure 9.24: Change in variance of TP2/TPT for Ring Finger for left hand.

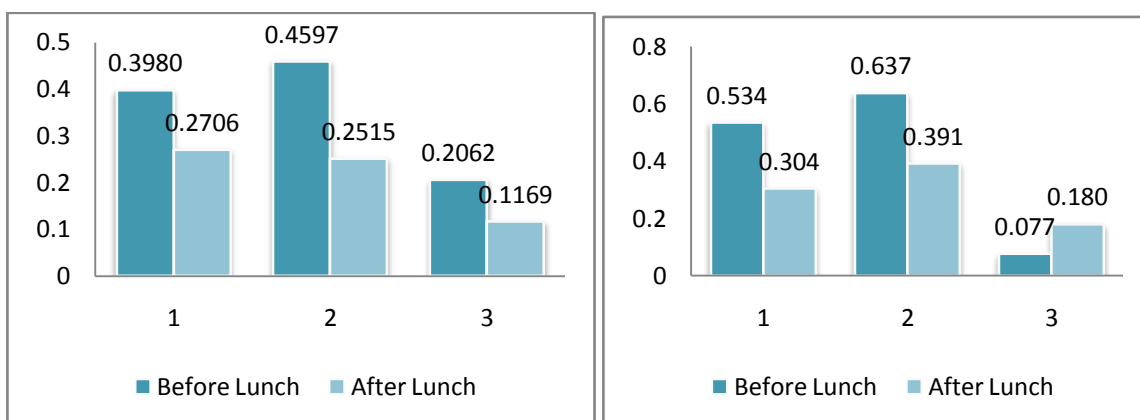


Figure 9.25: Change in mean of A2/A1 for Ring Finger of right and left hand.

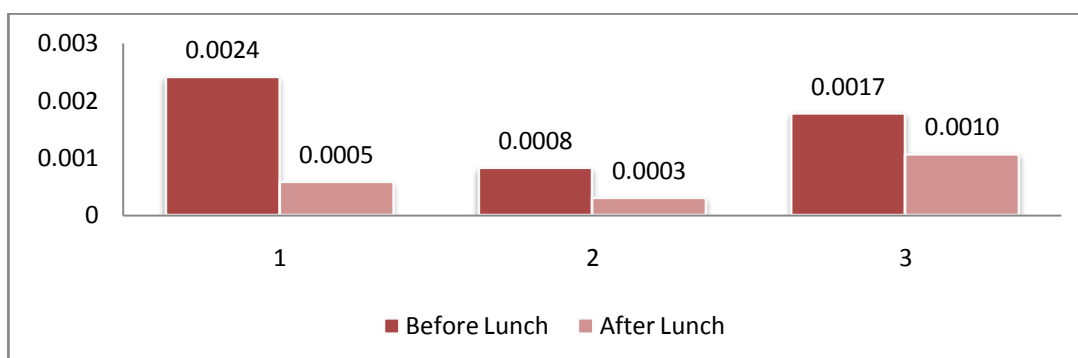


Figure 9.26: Change in variance of A2/A1 for Ring Finger for right hand.



9.27: Change in variance of A2/A1 for Ring Finger for left hand.

From the graphs in figures 9.17, 9.18, 9.23, and 9.24, we can compare the variance of the two features, TP2/TPT for ring finger of right and left hand and A2/A1 for middle finger of right and left hand, in all the three subjects of this study. The graphs show a consistent decrease in the variance values after lunch.

Chapter 10

Conclusion and Future Scope

The results obtained in this pilot study with three subjects may be seen as a possibility but may not be enforced with certainty because of the small number of subjects. The statistical analysis of the results, which is not a part of this study, can add to its validity. Moreover we can also analyze the second derivative parameters [8], as well as features from the frequency domain analysis of the finger PPG to obtain more consistent results. However the fact remains, that we have obtained two parameters (namely variance in $A2/A1$ and $TP2/TPT$), for middle and ring fingers respectively in all the three subjects, for both right and left hands which decrease consistently after lunch. Any parameter decreasing in any finger of any subject after lunch (in this case say variance of $A2/A1$ in middle finger of any hand, left or right), the probability of this occurring by chance is 50% i.e. 0.5. If this happens in both the left and right hand for the same finger the probability of this occurring by chance is 50% of 50% i.e. 25% ($0.5 \times 0.5 = 0.25$). Again if this happens in both the hands of the same finger in all the three subjects consistently, the probability of this occurring by chance is 25% of 25% of 25% i.e. 1.56% ($0.25 \times 0.25 \times 0.25 = 0.015625$). Since the occurrence of this happening by chance is less than 5%, hence a great possibility exists that there is some factor behind it and that factor may be the increased pitta level in the subject's body. The same can be said about decrease in variance of $TP2/TPT$ of ring finger.

The limitations which are cited in this thesis can be worked upon to further strengthen the study and to discover new parameters which may help to detect pitta in human body.

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List of Publications from This Research

PAPERS ACCEPTED

1. Singh Mandeep and Sharma Tanushree, "Proposal for exploring possibilities for Finger Photoplethysmography as a substitute for Pulse Diagnosis in Ayurveda," *International Journal of Computer Science and Communication*, vol. 3, no. 2, 2012 (in press).
2. Singh Mandeep and Sharma Tanushree, "Feature Extraction from Finger Pulse Plethysmography for determining pitta level in human body," *International Journal of Computer Science and Communication*, vol. 3, no.2, 2012 (in press).
3. Singh Mandeep and Sharma Tanushree, "Finger Pulse Plethysmograph Feature Selection for Pitta Detection in Human Body," *International Journal of Computer Science and Communication*, vol. 3, no.2, 2012 (in press).