An Intelligent Hand Gesture Recognition System

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SEP 2017

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A thesis submitted in partial fulfillment of the requirements for the degree of

MS Robotics and Intelligent Machine Engineering

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SEP 2017

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Copyright Statement

Acknowledgements

I would like to acknowledge countless words of thanks and admiration to Allah, the Almighty. Without His Will and Kindness, this accomplishment would not have been possible.

I am grateful to my supervisor, Dr. Yasar Ayaz School of Mechanical and Manufacturing Engineering (SMME) NUST Islamabad for his guidance and motivation given throughout this work. His supervision gave me direction throughout research hand writing of this thesis. I would like to thank him for his encouragement and continuous support. His guidance, enthusiasm and technical expertise and all the way help were pivotal in concluding this research.

I would like to thank all my colleagues and staff of various laboratories for their help. Last but not the least, special thanks to my wife, who provided me with all the support.

Dedicated to my exceptional wife, whose tremendous support and cooperation led me to this wonderful accomplishment.

Abstract

Gesture and emotion recognition plays an important role in the judgement of human behavior. The field of engineering has adopted this science in recent years for development of intelligent and companion systems. Various gesture recognition software aid in medical domain for betterment of human health and general understanding.

This project focuses on the development of a glove for mapping hand gestures and emotions. Four different gestures i.e. thumbs up, pointing finger, fist open and fist close are used. The emotions involved are sad, happy and angry. Emotions are detected by viewing variations in the values of jerk, velocity and acceleration. For this interfacing of flex sensors with myRio for data set collection has been done. A questionnaire has been developed based on five different models including well known categorical as well as dimensional (2D,3D) models to perceive the emotions of observer sitting in front and therefore validating the emotional state based on chosen parameters. The models used were: Paul Ekman's model, Russell's circumplex model of affect, PANAS model, PAD model and Plutchik's Model of Emotions.

In this study, a relationship is developed between the motion of the hand and the perceived emotion. The validity of the perceived emotion by the user is later checked using five different emotional models. The motion characteristics such as velocity and acceleration are changed systematically to observe the change in the perception of affect caused by the robotic motion. The perceived affect is then marked by the user on all three emotional behaviour models.

The novelty of the research lies in two facts: First comparative study of various emotional models used for measuring perceived emotions using Flex sensors.

From the results produced it can be concluded that the emotions perceived by the user is the same on all the five scales, validating the reliability of all the five emotional scale models and also that by changing the motion characteristics parameters i.e. velocity, jerk and acceleration, the emotions perceived by the user also changes.

LIST OF ABBREVIATIONS

PANAS	Positive and Negative Affect Schedule
PAD	Pleasure Arousal Dominance
2D	2 Dimensional
3D	3 Dimensional

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Chapter 1

INTRODUCTION

Any natural calamity, accident or any type of mishap may leave a person handicapped. Loss of a human body part results in inefficient working of an individual and creates much discomfort in everyday work. Our project focuses on helping those who have lost their hand. We aim to make finally a prosthetic hand that is not only used for gripping and grasping but is also useful in conveying emotions in daily life like a normal hand.

1.1 Need

When a person becomes a limb amputee, he or she is faced with staggering emotional and financial lifestyle changes. For living a normal life, the amputee requires a prosthetic device(s) and services which become a life-long event. . Enabling them with a prosthetic hand would make their life easier even after losing their natural hand. Such affected people are our target audience.

According to a survey in US carried out by National Center of Health Statistics, 50,000 new amputations are added every year in USA and ratio of upper limb to lower limb amputation is 1:4. Most common is partial hand amputation with loss of 1 or more fingers.

Existence of 350,000 persons with amputations in USA, 30% have upper limb loss of this, wrist and hand amputations are estimated to make up 10% of upper limb population trans radial amputations make up 60% of total wrist and hand amputations

In US 41,000 persons are registered who had an amputation of hand or complete arm 60% of arm amputations are between ages 21 and 64 years and 10% are under 21 years of age

Although these statistics are only of one country but it gives a view how serious this problem is. Also, it can be imagined that how many people in world actually need help with their lost limb.

1.2 Project Goal

Emotion digitization glove which have been developed so far use flex sensors to change between different emotions and gestures of the hand. Our research aims to provide a prosthetic hand that is more ‘natural’ and provides maximum patterns using the miniaturized EMG sensors as a future goal.

The novelty of the project is that it is first comparative study of various emotional models used for measuring perceived emotions using flex sensors.

1.3 Report Organization

The report is organized into seven chapters.

Chapter 2 *explains the research on the already developed prosthetic hands and how*

Chapter 3 *describes affective expression of machines*

Chapter 4 *talks about the concept of models used for perception*

Chapter 5 *talks about the implementation of the methodology devised for achieving the tasks.*

Chapter 6 *is about what is achieved and results*

Chapter 7 *is about conclusion of the research and future recommendations*

Chapter 2

LITERATURE REVIEW

As biological signal studies have progressed well and new technique for detection of signals have been developed, the surface electromyograms (sEMG) is now a widely applied method in multiple fields, including medicine [1], computer control [2] artificial limb control [3] and so on. Studies have shown that there is no harm on the body with sEMG collection and flexible signal processing, effective bionic control and potential application prospects are now available to us.

Fewer electrodes for artificial limb users are a more convenient option in prosthesis. However, too little of the electrode does not accurately provide the complete information of movements that is required and lacks identification of more types of actions, therefore most researchers use six or four electrodes when the action modes are numerous. The choice of electrodes is a compromise plan between convenience and multi-information. [4] For our research, we will be targeting for three electrodes as bare minimum.

2.1 The Hand Anatomy

To detect the different hand movements, the exact muscles must be identified to where the force exerted by the hand is maximum and placement of electrodes exactly at that muscle can give sharp signals when the hand movements makes that particular posture. The following figures show placement of electrodes for detection of individual fingers.

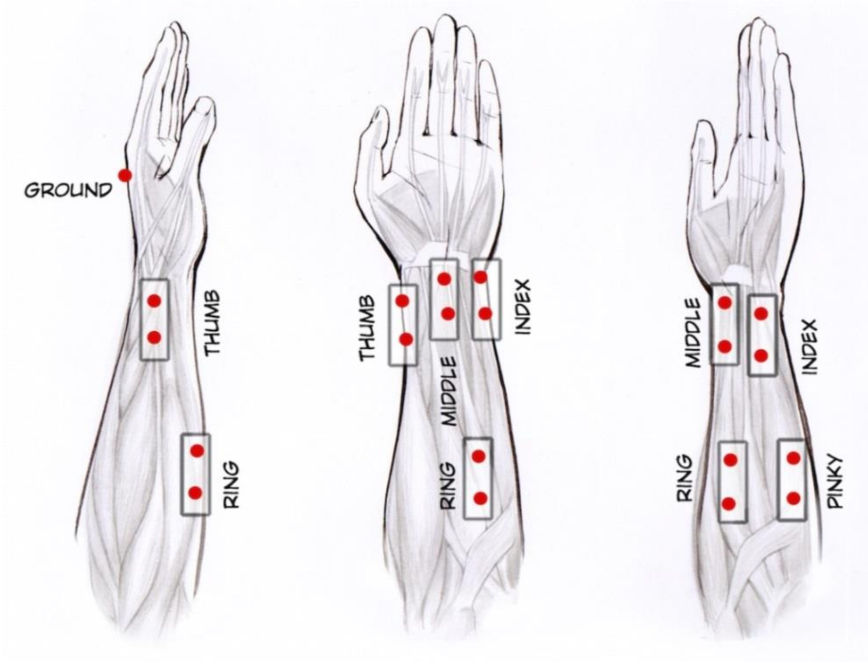


Figure 1: Muscles for each finger

Once identified, such circuitry must be placed that accurately picks up the muscle signals and amplifies them to a detectable range, while also suppressing or nullifying the noise factors. For this purpose the EMG electrode circuits were designed and developed by us.

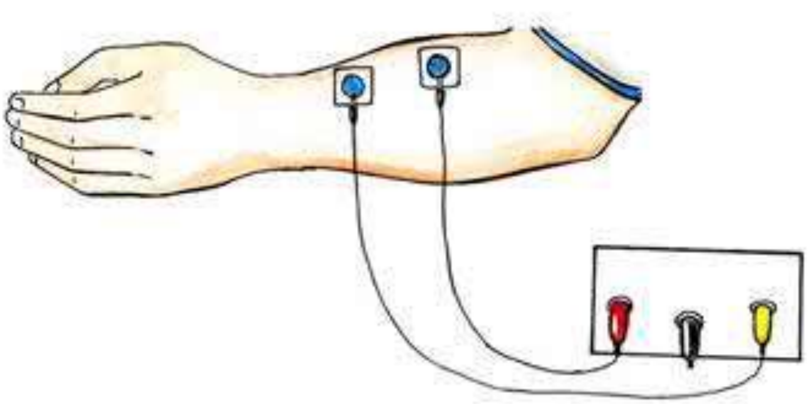


Figure 2: EMG sensor placement on arm

2.2 Prosthetic hands available in market

There has been much work done on the prosthetic hand and different companies have developed artificial limb.

Following hands have been developed until now with brief explanation to their structure and control and how our design will be targeting their short comings.

- Vincent
- Michaelangelo
- BeBionic
- iLimb

2.2.1 Vincent

Physical Structure

The VINCENT evolution 2 features independent myoelectric control of each digit. A thumb that operates in two axes, a powerful grip, anatomically correct size, light weight, and a shell with a natural feel similar to human skin.

Control

Figure 3: Vincent Hand

2.2.4 iLimb

The iLimbs, an active prosthetic hand created by Touch Bionics, is an externally powered prosthesis. This type of prosthetic are electrically powered and use a battery and electric motors to control the hand.

There are several versions of iLimbs which differ in control from one another.

- iLimb Ultra
- iLimb Pulse
- iLimb Ultra Revolution
- iLimb Quantum
- iLimb Digits

Physical structure

The i-Limb has electric motors at the natural joint in a hand so that the prosthetic can bend and move as natural as possible. This prosthetic also has a completely opposable thumb which allows the user to do activities such as picking items up much easier. This device has a 306 degree wrist rotation as well as three wrist positions. The wrist positions are straight, 30 degrees of flexion, and 30 degrees of extension. To change the wrist position the user just has to press a button located on the inside of the wrist and then lightly push the hand in the direction they want it to go.

Control

Control in iLimb Ultra:

- Muscle Control

Control in iLimb Pulse:

- Muscle Control with additional use of pulse varying capability

Control in iLimb Ultra Revolution:

- Muscle Control
- Proximity Control
- App Control

Control in iLimb Quantum:

- Muscle Control
- Proximity Control
- App Control
- Gesture Control

Control in iLimb Digits:

- Muscle Control
- App Control

Figure 6: iLimb Hand

CHAPTER 4

RESEARCH MECHANISM FOR EMOTIONAL PERCEPTION

4.1.1 Paul Ekman's model

A categorical model

Type of emotion (Paul Ekman Model)	Mark an emotion
Anger	
Disgust	
Fear	
Happiness	
Sadness	
Surprise	

Figure 16:Paul Ekman's model

4.1.2 Plutchik's Model of Emotions

A 3D dimensional model

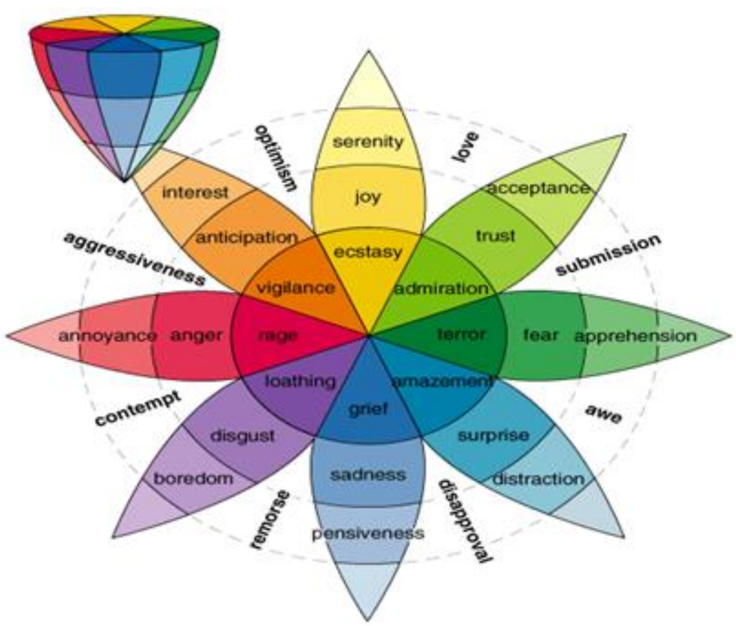


Figure 17:Plutchik's Model

CHAPTER 5

IMPLEMENTATION

The functionality and design section explains in detail the overall concept and course of actions taken to achieve the set goals. This section will explain in detail the exact components used and how they interfaced with each other to achieve the set targets.

5.1 Glove with embedded flex sensors

The flex sensors purchased are better than typical flex sensors as they have no mechanical components that may wear over time; they are compact, durable and provide precise measurements.

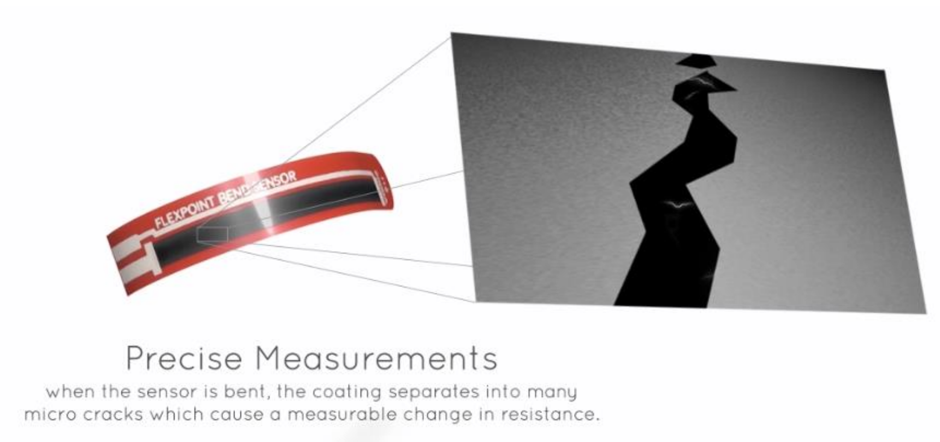


Figure 18: Flex Sensors used for glove design

The PCB with size 2.7cm x 2.4cm designed along-side included a voltage divider component to bring the input voltage (i.e. 5V) to a maximum of 3V that could be fed into the STM32-Controllers ADC channels. Five flex were used for four fingers and thumb. The resistance increased as the fingers started to bend and vice versa.

The glove was hand stitched to hold the flex sensors inside it and to mount the PCB on top of the glove. The circuit consisted of two input power signals (i.e. VCC and Ground) and five output signals to ADC. And two wires each to be sent to the sensors as VCC and ground.

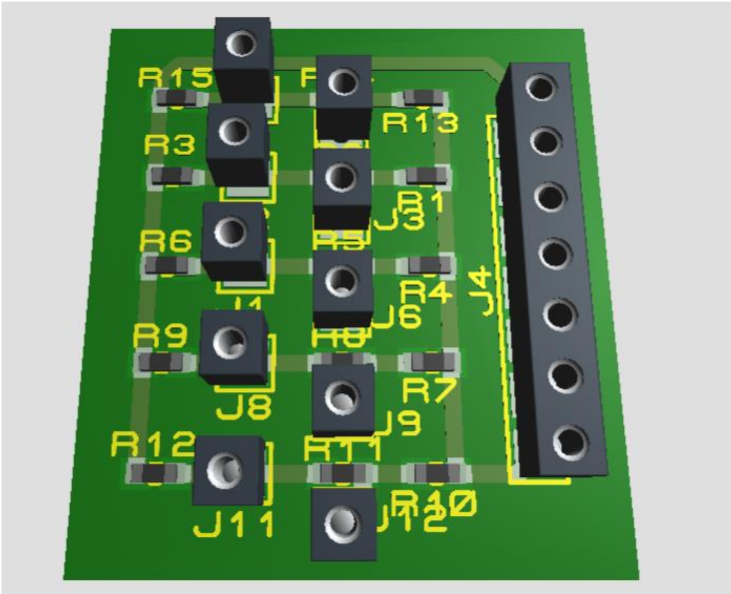


Figure 19: Glove circuit outlook in Proteus simulation 3-D visualizer

5.2 Design of flex sensor glove for accurate hand position determination

Following were the steps involved to develop the flex sensor glove.

- Literature review of the best flex sensors commercially available
- Purchase of flex sensors from abroad (i.e. The United States)
- Design of a PCB for acquiring flex sensor readings
- Fabrication of the PCB on the LPKF machine
- Soldering of the required components and mounting PCB on glove
- Taking Sensor readings through controllers ADC channels

Figure 20: Flex Sensor Glove for accurate hand postures determination

5.3 Questionnaires for measuring perception of emotions

The questionnaires for five different scales and gestures presented to the participants are shown below.

GESTURES	EMOTIONS	Features
Fist open	Sad	Velocity
Fist close	Happy	Acceleration
Thumbs up	Excited	Jerk
Finger pointing		

Figure 21: Selected gestures, emotions and features

The complete data was collected from 17 participants including males and females. The experiment took approximately 20 minutes. Each session was started with a brief introduction of the project and an explanation of how the participant would have to mark the perceived emotions on the given scale. After this introductory session, the participants were given the consent form to sign before they start observing the glove.

A real time experiment was conducted to verify the claims of literature review and the results obtained from gesture digitization system.

Each gesture was displayed in three varying intensities

- L - low
- M - medium
- H – high

For first two gestures, the order of intensities was uniform whereas for the latter two, the order was random. Based on these, questionnaires were filled by subjects, the data of which has been displayed in the table 2

Questionnaire for recognizing emotions/non-verbal communication using Flex sensor and EMG based glove

In this questionnaire, you have to mark different emotions corresponding to each gesture represented by a person wearing a glove with sensors. Carefully read the each emotion and refer to its dictionary meaning if required:

Category	Emotion	Meaning
Arousal	Angry	having a strong feeling of or showing annoyance
	Alarmed	feel frightened, disturbed, or in danger
	Tense	become tense, typically through anxiety or nervousness
	Aroused	evoke or awaken (a feeling, emotion, or response)
	Astonished	greatly surprised or impressed; amazed
Excitement	Excited	cause strong feelings of enthusiasm and eagerness
	Delighted	feeling or showing great pleasure
Pleasure	Happy	feeling or showing pleasure or contentment
	Pleased	feeling or showing pleasure and satisfaction
	Glad	Delighted
Contentment	Serene	peaceful, and untroubled; tranquil
	Content	in a state of peaceful happiness
	At ease	free from worry, awkwardness, or problems
	Satisfied	meet the expectations, needs, or desires of (someone)
	Relaxed	free from tension and anxiety
	Calm	not showing or feeling nervousness, anger, or other emotions
Sleepiness	Sleepy	showing the effects of sleep
	Tired	feel or cause to feel in need of rest
	Droopy	lacking strength or spirit
	Bored	feeling weary because one is unoccupied or lacks interest in one's current activity
Depression	Depressed	in a state of general unhappiness or despondency
	Gloomy	feeling distressed or pessimistic
	Sad	feeling or showing sorrow; unhappy
Misery	Miserable	Wretchedly unhappy or uncomfortable. Pitiably small or inadequate
Distress	Frustrated	to feel upset, typically as a result of being unable to change or

		achieve something
	Distressed	suffering from anxiety, sorrow, or pain
	Annoyed	slightly angry; irritated
	Afraid	feeling fear

DISCRETE EMOTIONAL MODELS

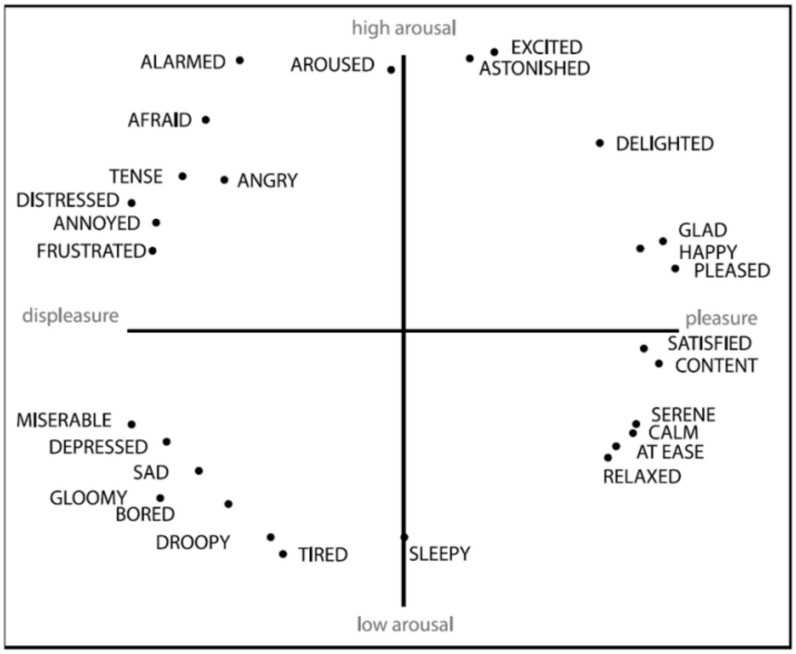
1. Mark the particular observed emotion for a gesture using **Paul Ekman's model** for discrete emotions given below. Mark the emotion on scale as 1a, 1b, 1c for first gesture, similarly for second and third gesture on a separate table given

Type of emotion (Paul Ekman Model)	**Mark an emotion**
Anger	
Disgust	
Fear	
Happiness	
Sadness	
Surprise	

4x copies of this table*

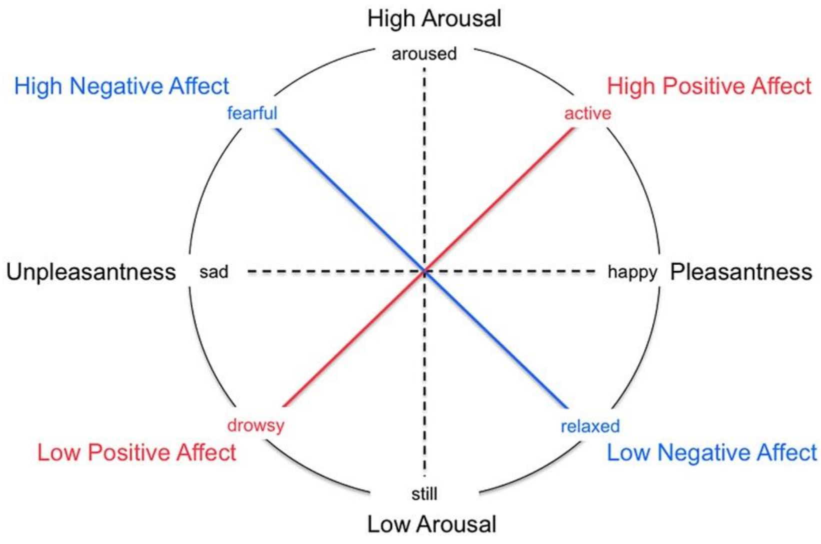
DIMENSIONAL EMOTIONAL MODELS (2D)

1. Mark the particular observed emotion for a gesture using a two dimensional model: **Russell's circumplex model of affect**. Mark the emotion on scale as 1a, 1b, 1c for first gesture, similarly for second and third gesture on a separate model given



4x copies of this model*

2. Mark the particular observed emotion for a gesture using a two dimensional model: **PANAS model**



4x copies of this model*

DIMENSIONAL EMOTIONAL MODELS (3D)

1. Mark the particular observed emotion for a gesture using a three dimensional model: **PAD** model. Terms used are explained as follow:

Pleasure: A measure of happiness
Arousal: The level of activation
Dominance: A measure of power or control
'+': high
'-': low

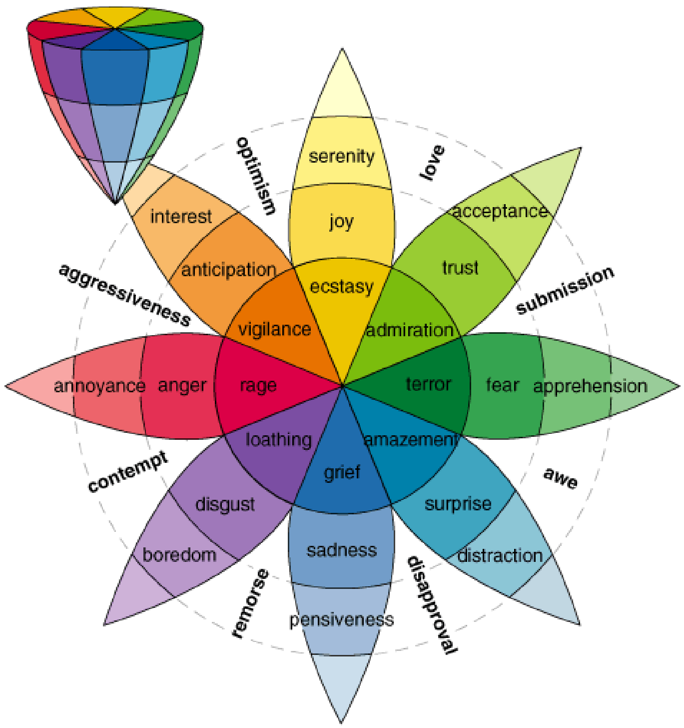
Gesture 1(a)	+/-	Gesture 1(b)	+/-	Gesture 1(c)	+/-
Pleasure		Pleasure		Pleasure	
Arousal		Arousal		Arousal	
Dominance		Dominance		Dominance	

Gesture 2(a)	+/-	Gesture 2(b)	+/-	Gesture 2(c)	+/-
Pleasure		Pleasure		Pleasure	
Arousal		Arousal		Arousal	
Dominance		Dominance		Dominance	

Gesture 3(a)	+/-	Gesture 3(b)	+/-	Gesture 3(c)	+/-
Pleasure		Pleasure		Pleasure	
Arousal		Arousal		Arousal	
Dominance		Dominance		Dominance	
Gesture 3(a)	+/-	Gesture 3(b)	+/-	Gesture 3(c)	+/-
Pleasure		Pleasure		Pleasure	
Arousal		Arousal		Arousal	
Dominance		Dominance		Dominance	

2. Mark the particular observed emotion for a gesture using a three dimensional model: **Plutchik's Model of Emotions**.

Explanation of Model: In this model, eight basic emotions are used. They are organized into opposite pairs: rage–terror, vigilance–amazement, ecstasy–grief and admiration–loathing. On the third, depth dimension intensity of the emotion is represented, resulting in a three dimensional cone mapping of emotions.



4x copies of this model*

5.4 Hardware architecture

Figure 22 shows the hardware connection of myRIO and emotion digitization glove.

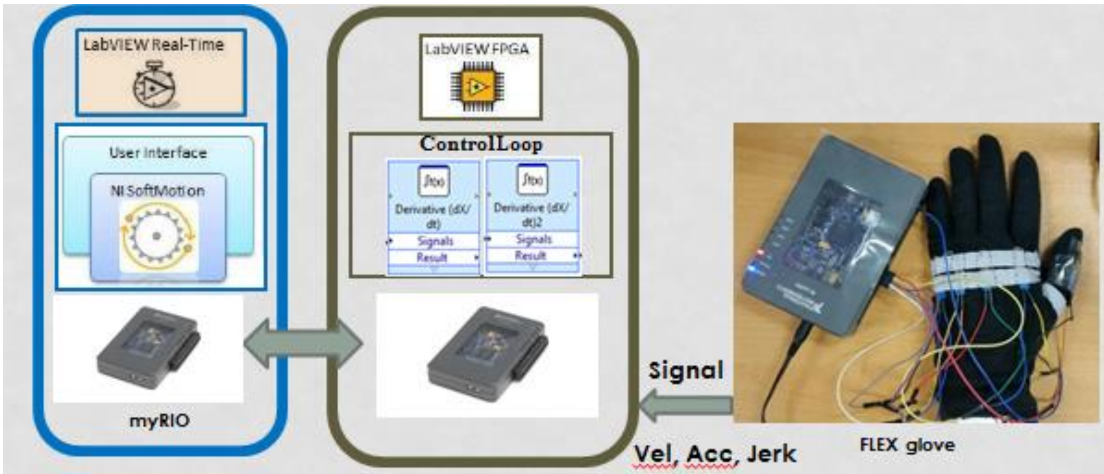


Figure 22: Hardware and software connection

There are a number of ways of gesture digitization. The task can be achieved using various image processing techniques which increase the cost of overall system.

In this research, a system has been modelled for gesture digitization. From the incoming data to the system, various parameters are calculated which help in emotion estimation. It can also be further utilized cost effectively in recognition software and other research fields. The system comprises of following components

- Flex sensors
- NI myRIO

Figure 23: Gesture digitizing glove assembly

5.5 Emotion detection

According to literature review, emotions are directly influenced by three key factors in gestures that are Jerk, Velocity and Acceleration. By observing the variations in these parameters, a person's emotion can be estimated.

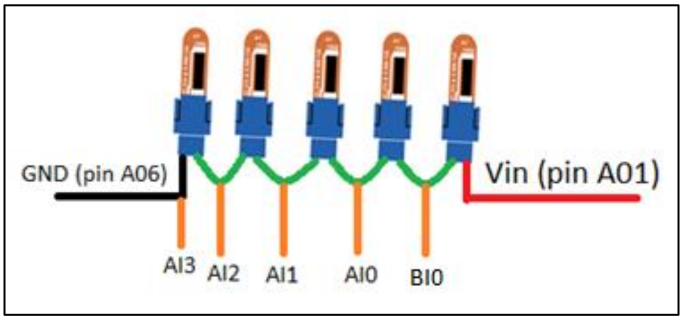


Fig. 24: Flex sensor connection diagram

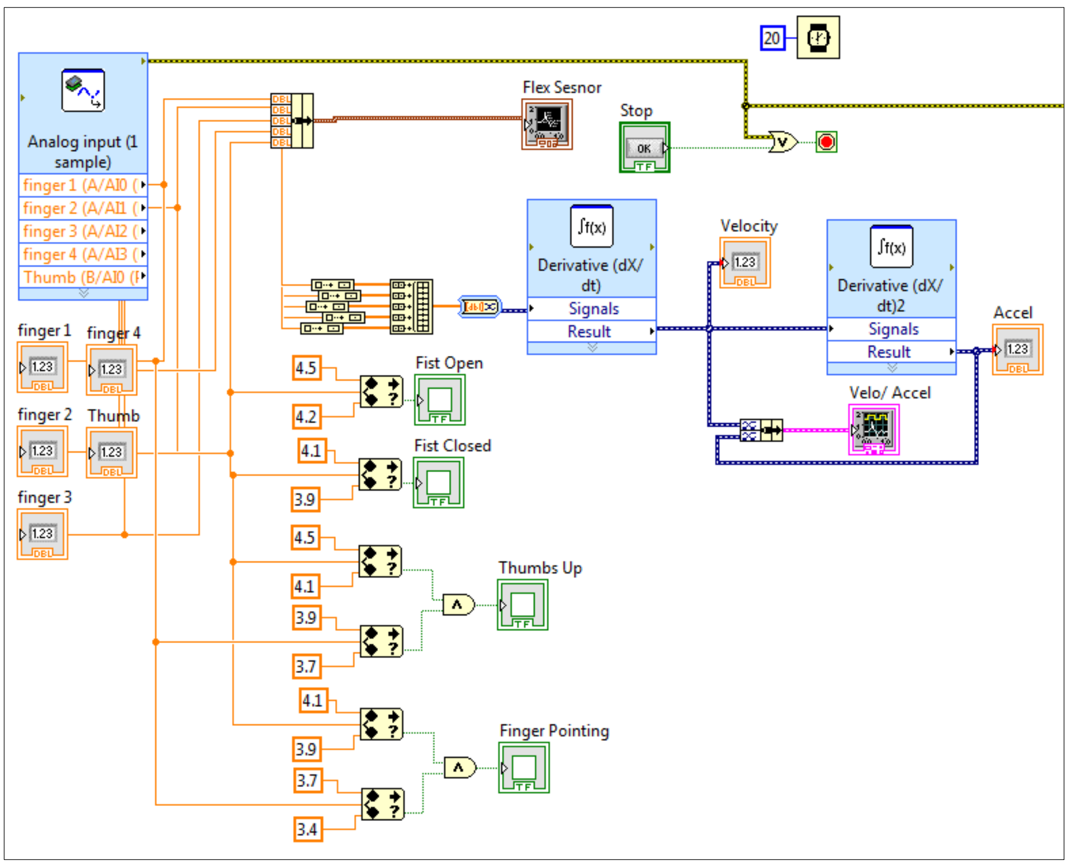


Fig. 25: Programming in LabVIEW

The flex sensors have been fixed on a glove which the user can wear and record various gestures. NI's myRIO is serving as an interface between the computer and flex sensors. Hardware is shown in Fig. 23.

A. HARDWARE ASSEMBLING

The flex sensors have been mounted on glove such that they are positioned over knuckles of each finger of the hand. They are connected in series with a +5V input from myRIO thus forming a voltage divider configuration. Output from each sensor i.e. voltage is being fed into the Analog input pins (BI0, AI0-AI3) of connector A and B in myRIO. Connection diagram of sensors with myRIO is shown in Fig.24.

B. HARDWARE SOFTWARE INTEGRATION

myRIO is connected to the target PC over Wifi . The LabVIEW 2015 is used for building the algorithm. An analog input VI is used to receive data coming from the flex sensors. This data is being displayed as well as plotted at a rate of 20ms. A stop button is placed to halt the while loop at any desired instance. LabVIEW block diagram code is shown in Fig 25.

An analog input VI is used for reading data from flex sensors in the form of voltage. Data from 5 sensors is received and they are named accordingly i.e. finger 1-4 and Thumb. This data is individually displayed by numeric indicators and is also plotted in graphical form. To plot data from all the sensors on one graph, they are clustered and the cluster output is fed into the graph. This graph displays the "JERK". For calculating "VELOCITY", which is rate of change of data, a time domain math VI is used to calculate derivate of sensor data. This VI takes only 'Dynamic Data Type' (DDT) as input.

The data from every individual sensor is recorded in a dynamic array by using 'build array' block. These individual arrays are then concatenated by using the same, 'build array' block again. The block is set to concatenation mode by right clicking on it and selecting the respective option. This concatenated array is then converted in DDT by using 'convert to DDT' block. This data is fed into the VI for derivative calculation. The output is also in DDT and is displayed by numeric indicator.

For calculating "ACCELERATION", which is rate of change of velocity, the time domain math VI is used again. Velocity data is fed into the VI and the output acceleration is displayed on numeric indicator.

Velocity and acceleration data are also plotted on graph. The DDT out from both is clustered and the cluster output is fed into the graph.

For 'GESTURE RECOGNITION FROM BENDING ANGLE', a look-up table has been implemented using 'in range and coerce' block, 'AND logic' block and Boolean indicators. When a specific gesture is recognized by comparison of voltage values from sensors, the indicator lights up.

The user interface is shown in Fig.26. In order to record the incoming data to generate a data set, simulation is stopped at desired point and the data is exported to an excel sheet by simply right clicking on the graph and utilizing the "Export to Excel" command.

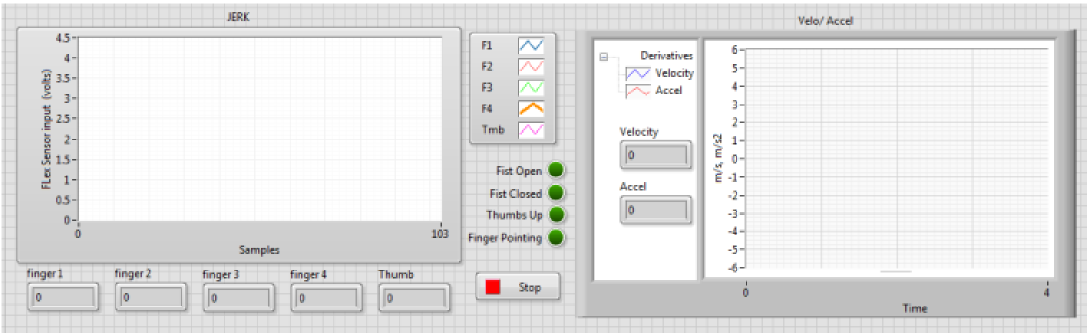


Fig. 26: User interface

CHAPTER 6

EXPERIMENTAL RESULTS

6.1 Gesture Data set

Using the above system, data values, for three different emotions each, for four different gestures have been observed.

1. Thumbs up
2. Finger pointing
3. Fist closed
4. Fist open

Observed emotions for each gesture are

1. Sad
2. Happy
3. Excited

6.1.1 Finger pointing

Velocity and acceleration, being instantaneous in nature with respect to this system, only vary for short spans therefore numerical indicators uptil five decimal places prove more useful, than graph. Jerk is the prominent feature

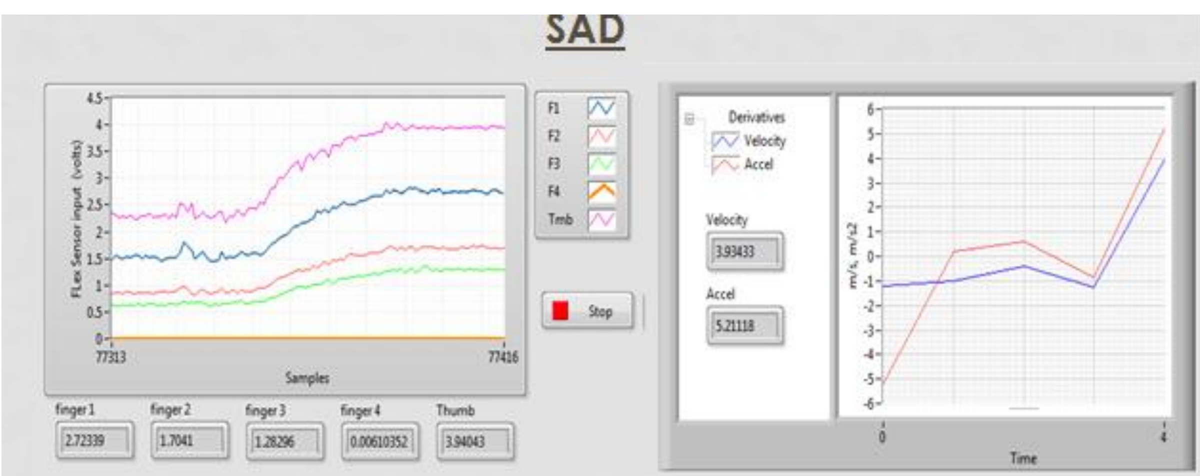


Fig. 27: Finger pointing for sad emotion

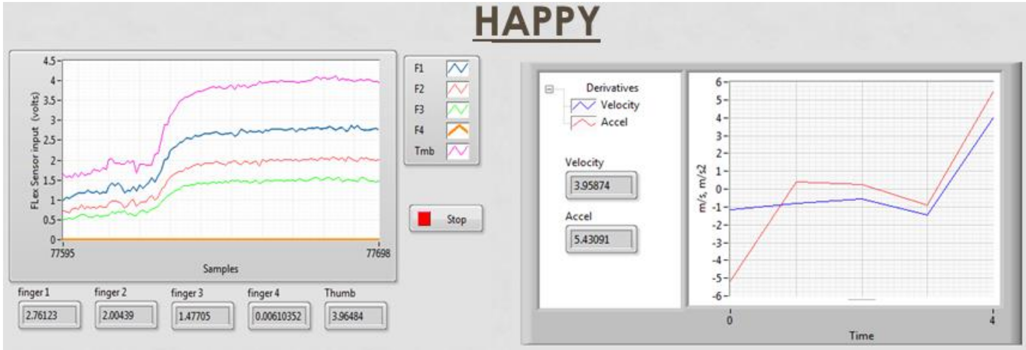


Fig.28: Finger pointing for happy emotion

Fig. 29: Finger pointing for excited emotion

6.1.2 Thumbs Up

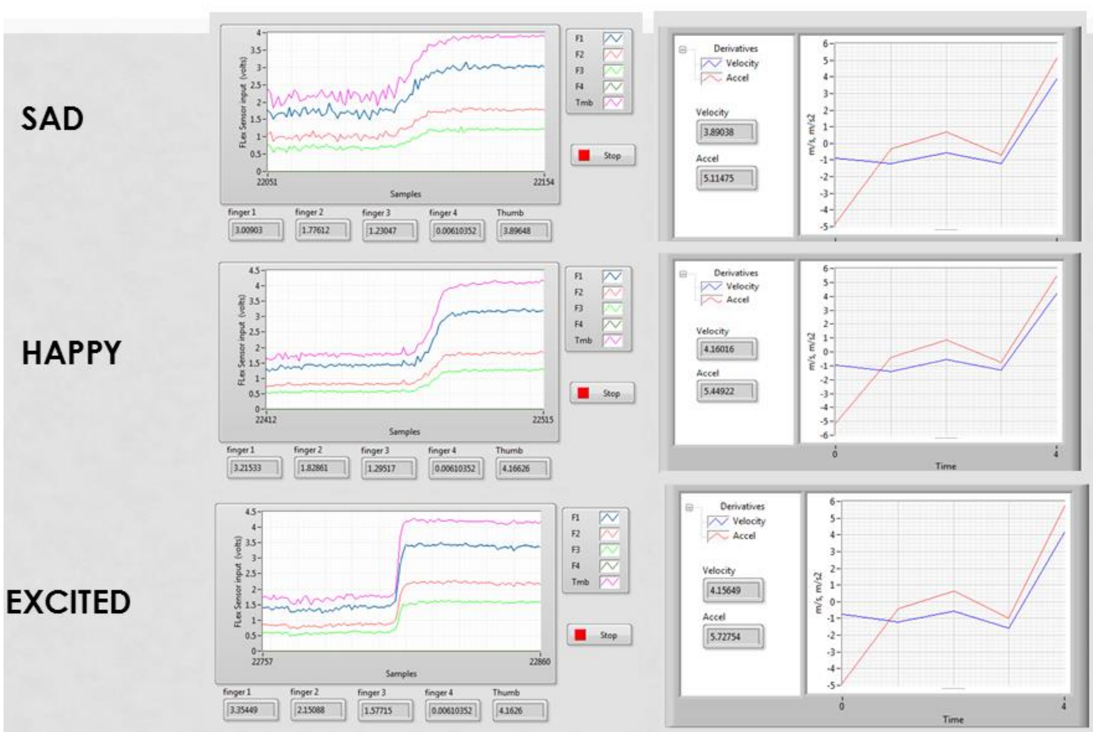


Fig. 30: Thumbs up for sad, happy and excited emotion

6.1.3 Fist open

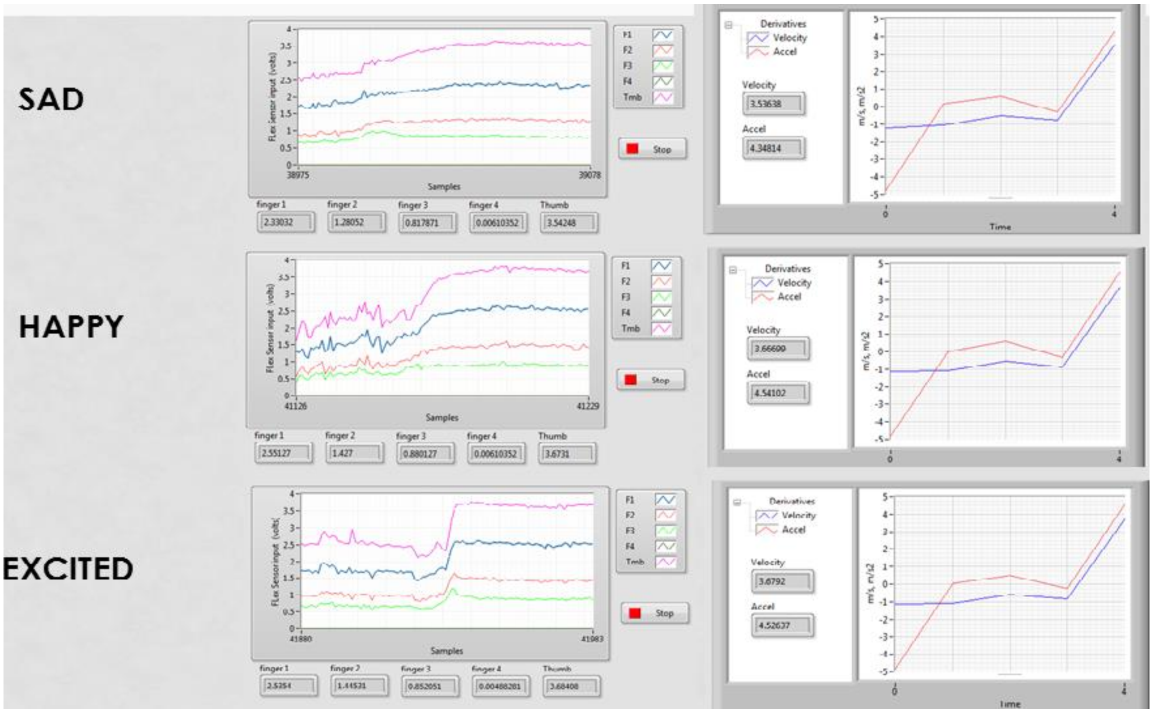


Fig. 31: Fist open for sad, happy and excited emotion

6.1.4 Fist close

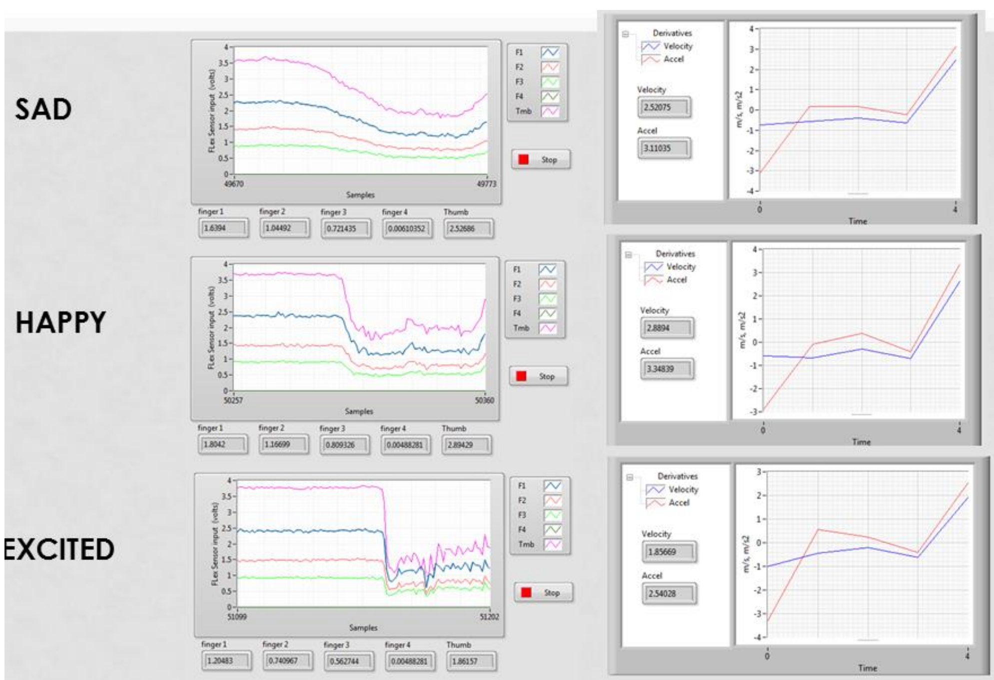


Fig. 32: Fist close for sad, happy and excited emotion

Table 2: Comparison of all four gestures using five different models

TOTAL = 17 (Males:12, Females:5, Age:18-21)																
GESTURE INTENSITY ORDER	GESTURES	MODEL 1			MODEL 2			MODEL 3			MODEL 4			MODEL 5		
Ascending		S	H	E	S	H	E	S	H	E	S	H	E	S	H	E
	Thumbs Up	16	10	12	16	13	16	12	14	15	14	13	14	14	11	14
	Result in%	94%	59%	71%	94%	76%	94%	71%	82%	88%	82%	76%	82%	82%	65%	82%
	Finger Pointing	15	13	16	16	13	14	14	17	15	16	14	14	15	11	15
	Result in %	88%	76%	94%	94%	76%	82%	82%	100 %	88%	94%	82%	82%	88%	65%	88%
Random		M	L	H	M	L	H	M	L	H	M	L	H	M	L	H
	Fist Closed	9	11	16	9	12	15	14	9	16	11	13	13	10	10	13
	Result in %	53%	65%	94%	53%	71%	88%	82%	53%	94%	65%	76%	76%	59%	59%	76%
		M	H	L	M	H	L	M	H	L	M	H	L	M	H	L
	FIST Open	14	16	14	12	14	12	11	12	12	12	14	12	11	11	10
	Result in %	82%	94%	82%	71%	82%	71%	65%	71%	71%	71%	82%	71%	65%	65%	59%

CHAPTER 7

Conclusion and Future Recommendation

A glove for digitizing gestures has been made using flex sensors and myRIO. The system is wireless and communicating with the target PC over WiFi.

Emotions are estimated by viewing variations in the values of jerk, velocity and acceleration. The detection is predominantly governed by jerk variations because they are well defined whereas velocity and acceleration, being instantaneous in nature with respect to this system, only vary for short spans.

For the latter two, numerical indicators prove more useful rather than graph, as they display variations up to five decimal place and thus are sensitive to even the slightest of change.

The results have been verified through questionnaires as well and thus it is evident that emotions do affect gestures in a profound way.

The research should be implemented on prosthetic hand with mre variety of gestures and emotion