DESIGN AND CONSTRUCTION OF ROBOT HEAD SYSTEM USING SPEECH RECOGNITION TO EXPRESS EMOTIONS

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DECLARATION

I declare that this thesis entitled "DESIGN AND CONSTRUCTION OF ROBOT HEAD SYSTEM USING SPEECH RECOGNITION TO EXPRESS EMOTIONS is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : LIEW QUEK SHIUNG

Date : 24 MAY 2019

APPROVAL

I hereby declare that I have checked this report entitled "DESIGN AND CONSTRUCTION OF ROBOT HEAD SYSTEM USING SPEECH RECOGNITION TO EXPRESS EMOTIONS" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

Humanoid robot is a robot that has the characteristics of a human. It is designed to improve the quality of human life. Humanoid robot is able to have human-like behaviours and engage in effective robot-human synergy. Facial expressions are very important in communication between human. The objectives of this project are to develop a robot head system that is able to express five basic expressions which are happiness, sadness, anger, surprise and fear, to control the robot's expressions using voice commands and to analyse the performance of the robot head system in terms of position, the recognition rate of each facial expression and the speech recognition rate. The control points of the robot head are proposed by combining the action units. The robot head that is able to express various emotions have been provided with 5 DOFs. A survey has been conducted on the design after finished drawing using SolidWorks. Evaluation on the conceptual design of the robot head is done, later, to be implemented on the final product of the robot head. Hardware experiment has been conducted and Arduino Mega is used as the controller for the system. Besides, a microphone with voice recognition module is designed to control the expressions of the robot using speech recognition. This project also focused on the robot head system's ability to function in terms of position of the actuators, recognition rate for facial expressions and speech recognition. The result of the relative position error for the chosen actuator is less than 5%. This increases the ability of the robot head to express the emotions more effectively. Besides, a survey related to the recognition rate for the five facial expressions has been done on 30 subjects. The result obtained for most of the recognition rate is more than 50% except for fear which is 23.34%. The speech recognition rate is repeated for 30 times. The recognition rate for most of the emotions are above 90%. The objectives of this project have been achieved and a robot head system which is able to express emotions using speech recognition has been successfully designed and constructed. However, in the future work, the facial expression recognition rate is expected to be improved by adding more DOFs or improve the hardware integration. The robot head system can also be integrated with other robotic bodies and addition of sensors.

ABSTRAK

Humanoid robot merupakan sejenis robot yang mempunyai ciri-ciri seorang manusia. Tujuan ia direka adalah untuk meningkatkan kualiti kehidupan manusia. Humanoid robot mampu bertingkah laku sebagai seorang manusia dan manjalani interaksi robot-manusia dengan efektif. Ekspresi wajah memainkan peranan yang penting dalam kalangan manusia terutama komunikasi. Objektif projek ini adalah untuk membina satu sistem kepala robot yang dapat mengekspreskan lima emosi asas, iaitu kegembiraan, kesedihan, kemarahan, kejutan, dan ketakutan, mengawasi ekspresi wajah melalui perintah suara, dan menganalisis prestasi sistem kepala robot terutama di atas kedudukan aktuator, kadar pengecaman untuk ekspresi wajah dan suara . Titik kawalan kepala robot adalah dicadangkan dengan menggabungkan unit aksi. Kepala robot yang terbaru ini adalah diberikan 5 darjah kebebasan untuk melaksanakan pelbagai emosi. Satu kajian berkaitan dengan rekabentuk telah dijalankan selepas dilukis menggunakan SolidWorks. Penilaian rekabentuk konsep kepala robot juga telah dijalankan, kemudian, digunakan pada produk terakhir kepala robot. Uji kaji perkakasan telah dijalankan dan Arduino Mega digunakan sebagai kawalan untuk sistem kepala robot. Tambahan pula, satu mikrofon dengan modul pengecaman suara telah direka untuk mengawal emosi robot melalui pengecaman suara. Projek ini memberi tumpuan kepada ujian prestasi sistem kepala robot terutama di atas kedudukan penggerak, kadar pengecaman untuk ekspresi wajah dan suara. Hasil ralat kedudukan relatif bagi penggerak yang terpilih adalah kurang daripada 5%. Oleh hal yang demikian, kepala robot tersebut dapat melakukan emosi dengan efektif. Selain itu, satu tinjauan di atas kadar pengecaman ekspresi wajah telah dijalankan dengan 30 orang responden. Kebanyakan hasil kadar pengesanan emosi yang didapati adalah melebihi 50% kecuali ketakutan, iaitu sebanyak 23.34%. Tinjauan untuk pengecaman suara juga telah diulangi sebanyak 30 kali. Kebanyakan hasil kadar pengesanan bagi pengecaman suara adalah melebihi 90%. Objektif projek ini telah dicapai dan satu kepala robot yang mampu mengekspreskan emosi melalui pengecaman suara telah direka dan dibina. Walau bagaimanapun, pada masa depan, kadar pengesanan emosi dijangka akan bertambah baik dengan menambah darjah kebebasan atau memperbaiki integrasi perkakasan. Kepala robot juga boleh berintegrasi dengan badan robotik lain dan menambah pengesan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AUs	-	action units
DOFs	-	degree of freedoms
mm	-	millimeter
VCC	-	voltage collector to collector
IDCU		Computer and Intelligent Drive & Control Unit

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Autism spectrum disorder (ASD) is a complex developmental condition where it will affect a person's ability to communicate and interact with the others, involve issue with non-verbal communication, and behaviours. The effects of ASD and its severity vary in each individual. Usually, ASD is diagnosed when the individual is around 2 – 3 years with many of the most obvious signs presenting. However, some of the individual with ASD may develop normally until they stop learning or lose previously acquired skills [1].

In [1], it explains that ASD varies from person to person in severity and combination of symptoms. However, the common characteristics of ASD are difficulty in interacting and communicating, having issues relating to things and limited behaviours. Individuals with ASD have issues in a continuous conversation, lessen sharing of interests, challenges in responding to interaction such as eye contact and facial expressions, trouble keeping a relationship, and others.

According to UNICEF's record, there are around 30,000 children registered with disabilities in 2012, and 19,150 of them were having learning disabilities. It is approximated that 1 out of every 600 children in Malaysia is born with ASD based on BERNAMA's report in 2014. The latest statistics also showed that there are about 47,000 Malaysians that are autistic, with roughly 4 out of every 10,000 suffering from severe autism [2]

A child with physical or mental disabilities needs more attention and involvement to assist, and all of these cost money. In 2010, it is estimated that raising a child with disabilities required a total cost of RM96,700 each year. The cost covered diagnosis, therapies, special needs education, and others [2].

Therefore, the end goal here is to build a robot system that is able to help children with autism and special needs. The robot system will be started by constructing its head first. The robot head is designed with the ability to express emotions. Besides, the robot head will be able to communicate with the children so that their social interactions can be improved. Children with autism have issues staring into one's eyes and the ability to remember faces that are unfamiliar. Thus, a robot head system with facial expressions is able to help them because it can help them stay focused and interact with it.

1.2 Problem Statement

There is a theory supported by the research conducted by electric engineering and computer science department at Vanderbilt University and issued in the journal Neural Systems and Rehabilitation Engineering saying that robotic technology works with children with ASD. The research was carried out by testing on six children with ASD and six children in stages of normal development. The result showed that a child with ASD spent more time staring at the robot compared to the normally-developing child. Thus, this study shows that a robot head system could actually help the children with autism in staying focused better [3].

In [4], it mentions that robot-assisted therapies are showing potential in becoming assessment and therapeutic tools. More researches have shown that child with ASD engage better with robots rather than human, because they are simpler and more predictable. In [5], Assoc. Prof. Dr. Hasnah Toran – a leading authority on autism in the country supports the idea of robot-assisted therapies. It is because there is a shortage of healthcare professionals in the field. There are around 300 psychiatrists in the country and only 20 of them are child psychiatrists.

From the above statement, it is believed that a robot capable of showing facial expressions and communicating with the autistic children is able to help them. Autistic children are able to interact more with a robot than a human. This is because the facial expressions, the voice tone and the body movement of the human prevent the autistic child to concentrate more, thus, they are not able to interact well with the human.

There are a few important criteria that have to be considered in designing and constructing the robot head system so that it is effective in helping the autistic children learn to socially adapt:-

1) The design concept and structure of a human-like robot head
2) The degree of freedom of the robot head movement
3) The expression of emotion of the robot head

4) The recognition rate of each emotion expressed by the robot head

5) The ability of the robot head to recognize the speech given by the user

6) The speech recognition rate based on the success rate on expressing correct facial expression

The hardware for the robot head system has been chosen carefully because the selection of hardware components is capable of influencing the performance of the system. Arduino Mega is used as the controller for the system because it has 54 digital I/O pins. The model of the actuators selected are based on its performance in terms of angular position, torque and velocity. The actuators chosen must be capable of high precision for the robot head movement.

1.3 Objectives

The objectives of the research study are:

1) To design and construct a robot head system with five basic expressions.
2) To control the robot's expressions using voice commands.
3) To analyse the performance of the robot head system in terms of position, the recognition rate of each facial expression and the speech recognition rate.

1.4 Scopes

The scopes of the research study are:

1) The construction of the robot head focuses on the human-like movement which consists of the eyebrows, eyelid and mouth. Each part is able to move independently to produce rich facial expressions. The motion of two eyebrows, two eyelids which linked as one, and upper and lower lips are taken into considerations to increase the effectiveness of developing a lifelike robotic face.
2) The robot head system consists of 5 degree of freedoms (DOFs) with 2 DOFs for the eyebrows, 1 DOF for the eyelid, 1 DOF for the upper lip and 1 DOF for the lower lip.
3) The 5 basic expressions are happiness, sadness, anger, fear and surprise.
4) This project covers the position repeatability test by repeating each of the expression for 15 times as it has been done before in [6].

5) This project also covers the facial expression recognition test on 30 subjects by using the final product of the robot head system. To justify using 30 subjects, it has been showed in [11], the recognition test used 27 subjects; in [12], it is repeated with 20 subjects; and in [16], the test is repeated with 32 subjects.
6) The motion of the robot head is being controlled by Arduino Mega which consists of 54 digital I/O pins.
7) A microphone with a voice recognition module is installed in the system to process the speech given by the user. The speech must be the keywords that have been programmed in the system.
8) Since facial expression recognition test is done with 30 subjects, the speech recognition, too is repeated 30 times. The recognition is done with the keywords provided to the subjects. It is counted as success if the robot head is able to express the correct facial expression with the correct keyword.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory

2.1.1 Design and Construction of Robot Head System

The study of humanoid robots has been conducted for many years and the robot head system becomes the main factor in determining the effectiveness of human-robot interaction. Different type of design of the robot head will have distinct interpretation to the user. Therefore, there are a few considerations to be taken into when designing the robot head [7]:

1) The design of a face with understandable expressions, and
2) The design of a friendly face and not react unfavourably to it.

In [8], there is a discussion in if the robot head should be more human-like or more technical optimized. The benefit of a technical head is that, there is no restriction on the design parameters such as size and shape. This particular detail reduces the effort for mechanical construction. Contrarily, if the robot head is used for human-robot interaction, an anthropomorphic head could help increase the performance of the system.

The technical complexity is measured by the number of sensors or actuators in constructing the robot head. The main objective of this project is to construct a robot head with 5 DOFs so that it is able to express the 5 basic expressions in the best recognition rate. The construction of the robot head included the eyebrows, eyelids, and lips.

2.1.2 Facial Action Coding System (FACS)

The Facial Action Coding System (FACS) refers to a set of facial muscle movements that match with a displayed emotion. It is created by Carl-Herman Hjortsjö with 23 facial motion units in 1970. It is later further developed and published by Paul Ekman and Wallace Friesen in 1978. Then, it was substantially updated and published in 2002 by Ekman, Friesen, and Joseph C. Hager [9].

Action units (AUs) are the basic actions used for the expression of emotions by means of facial expression. The AUs are formed by a group of muscles to produce various facial expression. The five basic expressions introduced are happiness, sadness, surprise, anger and fear.

In this project, 4 AUs are used to produce the five facial expressions as shown in Table 2.1. 10 control points and their movements on the facial skin are selected corresponded to the action units as shown in Figure 2.1.

Table 2.1 Action Units and Control Points for Five Facial Expressions

Action Units	Motion Changes	Control Point	
		Right	Left
1	Eyebrow Motion	1, 3	2, 4
2	Eyelid Motion	5, 6	
3	Upper Lip Motion	7, 8	
4	Lower Lip Motion	9, 10	

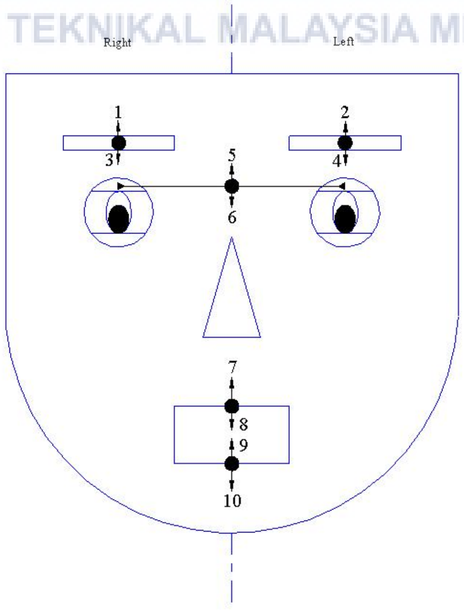


Figure 2.1 Position of Control Points and Their Direction of Movement

2.2 Research and Study

2.2.1 Facial Expressions

Table 2.2 to 2.6 show the review for 6 research papers on facial expressions. The robot names of the 6 research papers are ExpressionBot, KOBIAN-Refined, SAYA, F & H Robot, Flobi and ROMAN respectively. There are a few elements that are compared to help design and construct a robot head system for this project. The elements compared are the type of head used, the propose method of the robot head system, the type of expression, the DOFs of the robot head system, the type of motor used, the type of mechanism used, the dimension of the robot head, the weight of the robot head, the recognition rate of the facial expressions and the design overview of the robot head system.

Table 2.2 Review for 6 Research Papers on Facial Expressions

No.	**Paper 1** [10]	**Paper 2** [11]
Name of Robot	ExpressionBot	KOBIAN-Refined
Type of Head	Human-like	Human-like
Propose Method	1. Neck system controls the projector and mask position. 2. Display system consists of a small projector. 3. Animation application displays a face animation along with speech and emotion.	1. The head should have high facial expression ability. 2. Facial color is suggested in creating computer graphics (CG) images to affect the impression (e.g. sadness – check becomes little blue-tinged, fear – blue forehead color expression).
Type of Expression	6 basic expressions (anger, disgust, fear, joy, sadness, surprise) and neutral	Ekman's 6 basic expressions (anger, sadness, happiness, surprise, disgust, and fear)
Degree of Freedoms (DOFs)	3 DOFs (150º of yaw, 30º of pitch, 30º of roll)	24 DOFs (3 for eyes, 5 for eyelids, 8 for eyebrows, 7 for lips, and 1 for jaw)
Type of Motor	N/A	DC motor and ultrasonic motor

Table 2.3 Review for 6 Research Papers on Facial Expressions (cont.)

Type of Mechanism	1. Dell DLP M110 Portable Projector. 2. Nikon Fisheye Converter FCE8. 3. A mold is designed using the 3D model of the neutral face in Autodesk Maya (as a mask).	1. Eyes are driven by a gimbal structure where metal ring turns around low friction PTFE sleeve. 2. Eyelids are driven by an ultrasonic motor TULA-70. 3. Eyebrows are driven by a magnet through the cover.
Type of Controller	Computer	Computer
Skin Material	N/A	Silicone-like (Dragonskin)
Dimension (mm)	N/A	150 x 214 x 181
Weight (kg)	N/A	1.7
Recognition Rate	Joy – 100% Anger – 85% Sadness – 100% Disgust – 40% Surprise – 100% Fear – 55%	Happiness – 71.5% Anger – 92.3% Sadness – 73.1% Surprise – 96.2% Fear – 19.2% Disgust – 57.7%
Design Overview		

Table 2.4 Review for 6 Research Papers on Facial Expressions (cont.)

No.	**Paper 3** [12]	**Paper 4** [13]
Name of Robot	SAYA	F & H Robot
Type of Head	Human-like	Human-like
Propose Method	1. Generate Action Units (AUs) necessary for producing the various facial expressions. 2. Use McKibben type pneumatic actuator to control displacement of control points on facial skin. 3. Facial skin made from soft urethane resin.	1. Anti-cracking, anti-aging and coloring properties of face film material must be treated. 2. Adopts motor plus guiding tube plus diving mechanism of non-metal rope.
Type of Expression	6 basic expressions (surprise, fear, disgust, anger, happiness, sadness) and calm	Ekman's 6 basic expressions (happy, anger, sad, surprise, fear, disgust), initial (nature), and solemnity
Degree of Freedoms (DOFs)	6 DOFs (2 for eyeballs, 1 for chin, 2 for mechanical frames, and 1 for eyelid)	8 DOFs (3 for neck, 2 for eyeballs, 1 for eyebrow, and 2 for lower jaw)
Type of Motor	DC motor	DC servo motor
Type of Mechanism	1. McKibben type actuators that are attached in a mechanical frame. 2. Oculomotor mechanism on mechanical frame. 3. Human-like motion using coil spring	1. Small-pneumatic-element mechanism 2. Liquid-drive mechanism. 3. Rope-drive mechanism
Type of Controller	Computer	Computer and IDCU
Skin Material	Soft urethan resin	Concave die and metal mould
Dimension (mm)	115 x 200 x 155	N/A
Weight (kg)	1.5	N/A

Table 2.5 Review for 6 Research Papers on Facial Expressions (cont.)

No.	**Paper 3** [12]	**Paper 4** [13]
Recognition Rate	Surprise – 100% Fear – 93% Disgust – 86% Anger – 86% Happiness – 100% Sadness – 93%	Survey for the facial recognition rate was not conducted.
Design Overview		
No.	**Paper 5** [14,15]	**Paper 6** [16,17]
Name of Robot	Flobi	ROMAN (Robot huMan interAction machiNe)
Type of Head	Cartoon-like	Human-like
Propose Method	1. Cartoon-like appearance to trigger a natural interaction. 2. Able to express a variety of emotional states by means of dynamic facial features. 3. Consists of exchangeable modular parts.	1. Kinematics and dynamics of a human neck are considered. 2. Integration of all mechanical and most electronic components inside the robot head. 3. Design and implementation of an emotional architecture.
Type of Expression	5 universal basic expressions (happiness, sadness, fear, surprise, anger) and neutral	6 basic expressions (fear, disgust, joy, anger, surprise, sadness) and neutral
Degree of Freedoms (DOFs)	18 DOFs (3 for eye, 3 for neck, 6 for mouth, 4 for lids, and 2 for brows)	4 DOFs (4 for neck)
Type of Motor	DC motor (Maxon type 203893 with gear ratio 67:1)	DC & servo motor (Faulhaber AM 1524)

Table 2.6 Review for 6 Research Papers on Facial Expressions (cont.)

No.	**Paper 5** [14,15]	**Paper 6** [16,17]
Type of Mechanism	1. Actuators to move eyes, eyelids, neck and lips. 2. LEDs to indicate shame or healthiness. 3. Magnetic actuation system.	1. Neck's kinematic chain detects motion 2. Two Dragonfly cameras installed in a stereo-vision system 3. Servo and DC motors are connected via CAN-bus to an embedded PC.
Type of Controller	Atmel XMega64 microprocessor and host computer	Computer
Skin Material	Plastic	Silicone
Dimension (mm)	220 x 280 x 190	N/A
Weight (kg)	2.4	N/A
Recognition Rate	Happiness – 83.3% Sadness – 99.2% Anger – 81.2% Surprise – 54.5% Fear – 33.4%	1 means weak and 5 means strong correlation Anger – 4.5 Disgust – 2.6 Fear – 3.6 Joy – 4.3 Sadness – 3.9 Surprise – 4.2
Design Overview		

The comparison made are then discussed later as shown in Section 2.3.1 in terms of advantages and disadvantages of each paper. More detailed explanations are made to help design and construct the robot head system in this project.

2.2.2 Speech Recognition System

Table 2.7 to 2.9 show the review for 6 research papers on speech recognition system. The elements used to compare each research paper are the propose method, the type of expression, the recognition method, the hardware module, the type of controller, the frequency of speech signal, the commands and the recognition rate.

Table 2.7 Review for 6 Research Papers on Speech Recognition System

No.	**Paper 1** [18]	**Paper 2** [19]
Propose Method	1. Perform categorized recognition by means of algorithm with the combination of HMM and SOFMNN models. 2. Integration of HMM/SOFMN model applied on voice emotion recognition method	1. Embedded speaker-independent speech recognition system
Type of Expression	5 expressions (happy, sad, anger, fear, and surprise)	N/A
Recognition Method	HMM/SOFMNN Hybrid	HMM
Hardware Module	1. Upper PC is composed of industrial PC 2. Lower PC is distributed control module based on field bus	1. 16-bit chip with built-in microphone amplifier and AGC function 2. Memory capacity includes 4K-byte working SRAM plus a 64K-byte flash memory
Type of Controller	Computer	Chip integrated circuit
Frequency of Speech Signal	11 kHz	N/A
Commands	150 recorded speech materials	Forward, Backward, Turn Left, Turn Right, Fire and Dance
Recognition Rate	Joy – 67.5% Grief – 85.0% Anger – 77.5% Fear – 60.0% Surprise – 62.5%	Average accuracy: Normal environment – 100% Noisy environment – 91.7%

Table 2.8 Review for 6 Research Papers on Speech Recognition System (cont.)

No.	**Paper 3** [20]	**Paper 4** [21]
Propose Method	1. Recognize word in a speech signal 2. Speech recognition implemented on a microcontroller	1. Face recognition and emotion recognition 2. Robot will grasp the target of communication
Type of Expression	N/A	5 expressions (happy, sad, angry, shy and wink)
Recognition Method	LPC and HMM	Visual Studio and C#
Hardware Module	1. ATmega162 microcontroller	1. USB microphone (CrispMic) 2. Image sensing Okao Vision of OMRON (OMRON HVC-P B5T-001001 s) 3. Servo motor (BTX032 Dynamixel AX-18A)
Type of Controller	Microcontroller	Computer
Frequency of Speech Signal	8 kHz	N/A
Commands	Maju, Mundur, Kanan, Kiri, Stop	Conversations on greeting, self-introduction, information of date, time and weather, news and smart house function
Recognition Rate	Sample size 5 – 87.0% 10 – 70.0% 15 – 61.0% 20 – 65.0%	N/A

Table 2.9 Review for 6 Research Papers on Speech Recognition System (cont.)

No.	**Paper 5** [22]		**Paper 6** [23]
Propose Method	1. Speech will be recognized on the commands given 2. Implement user's voice to control the motion of the robot wheels		1. The ability of the robot to avoid obstacle, seek light, chase light, and other functions using speech recognition and controller
Type of Expression	N/A		N/A
Recognition Method	Evaluation of Microsoft speech recognition and analytical engine		C language
Hardware Module	1. Servo motor (LM629) 2. Microphone		1. 32K built-in Flash on a 16-bit chip (SPCE061A SCM) 2. 8K built-in Flash on a 8-bit chip (AT89S52) 3. Servo motor (AT89C2051)
Type of Controller	Computer		Computer
Frequency of Speech Signal	N/A		N/A
Commands	Forward, Reverse, Right, Left, Stop		Forward, backward, turn around and head around to aim
Recognition Rate	Silent Condition Forward – 100% Reverse – 80% Right – 100% Left – 100% Stop – 100%	Noisy Condition Forward – 80% Reverse – 100% Right – 80% Left – 60% Stop – 80%	N/A

The comparison made are then discussed later as shown in Section 2.3.2 in terms of advantages and disadvantages of each paper. More detailed explanations are made to help develop a robot head system capable of recognizing voice commands.

2.3 Review Summary

2.3.1 Facial Expressions

Table 2.10 shows the advantages and disadvantages from the 6 research papers on facial expressions that have been done previously. Each research paper is discussed in detailed to select the better method in implementing in this robot head system.

Table 2.10 Advantages and Disadvantages of Papers on Facial Expressions

	Advantages	**Disadvantages**
Paper 1 [10]	Eye gaze is used to improve the interaction.	Low recognition rate for disgust (40%) and fear (55%).
Paper 2 [11]	It has an improvement in recognition rate by average of 25% compared to the older version, Kobian. This is because the DOFs of Kobian-R has increased from 7 to 24.	The recognition rate of fear (19.2%) and disgust (57.7%) are pretty low.
Paper 3 [12]	The recognition rate for each emotion is high (>85%). Human-like head motion is achieved with the newly developed coil-spring mechanism	The range of head movement is restricted. The sample size for the recognition result is too small, thus the accuracy of the data might be low.
Paper 4 [13]	The face film is supported by an exterior which looks like human face, thus, increasing the accuracy of facial expression.	Lack of characteristic points because the mechanism has only 14 DOFs. Survey for facial recognition rate was not conducted.
Paper 5 [14,15]	An application of friendly face with a ‘hole-free’ design. White and red LEDs are used as secondary emotion to indicate shame. The modular parts of the robot are exchangeable for user’s satisfaction.	Low recognition rate on fear (33.4%). Besides, recognition test on disgust is not conducted.
Paper 6 [16,17]	Stereo-vision system as the main sensor system.	The recognition rate for disgust is pretty low (2.6). The nose’s wing has no action units.

In [10], the method used is a facial animation system, projected onto a robotic mask made by a mold. Although the average recognition rate for each emotion was pretty high, but it is produced using a projector. Thus, this decreases the effectiveness of the human-robot interaction as the expression performed does not look real.

Kobian-Refined in [11] has the most degree of freedoms, which is 24 DOFs for the movement of the robot head among all the other papers. The DOFs for the movement of the robot head is defined as the range for the parts on the robot head to move. Though, it is not necessary that the number of DOFs represent the effectiveness of presenting each facial expression. This has been proven in [15] when the robot head "SAYA" with the total of 6 DOFs can have a better recognition rate in each emotion except anger compared to [11, 14, 16].

It is mentioned in [12] that the mechanisms and materials for expressing facial expressions are different from human face and mechanical parts are seen externally. Thus, facial skin is quite important in making a difference in facial expressions. The robot head "SAYA" uses McKibben-type actuator to control the distance of the control points on facial skin made of soft urethan resin. The mechanism has helped create a facial skin similar to the human's muscle.

The robot head "Flobi" has an advantage over all the robot head in the appearance concept. There are individual parts to be combined to create different characters as introduced in [15]. This provides an edge by creating a suitable and pleasant character that can be accepted by the individual during the interaction.

Size also plays an important role in designing the robot head system. In [11, 12, 13], the size of the robot head is based on the size of the human head. This design allows the robot head to mimic the real human head to increase the effectiveness of robot-human interaction.

In conclusion, this project focuses on the design of the appearance of the robot head system. The appearance is friendly looking to improve the effectiveness of interacting with the autism children. The robot head is able to express 5 basic facial expressions (happiness, sadness, anger, surprise, and fear).

2.3.2 Speech Recognition System

Table 2.11 shows the advantages and disadvantages from the 6 research papers on speech recognition system that have been done previously. Each research paper is discussed in detailed to select the better method in implementing in this robot head system.

Table 2.11 Advantages and Disadvantages of Speech-Recognition Papers

	Advantages	Disadvantages
Paper 1 [18]	The integration of HMM/SOFMNN model help overcome the weakness of HMM and SOFMNN to fill up each other's shortcomings. It also improves the robustness and performance of classifier.	The recognition rate for most emotions are well below 80% except grief.
Paper 2 [19]	The embedded speaker recognition system developed is speaker independent. The recognition accuracy reaches 100% in normal environment.	The memory and processing capability of the chip is limited and it doesn't support the floating-point and other complex mathematical operations.
Paper 3 [20]	The integration of LPC and HMM is implemented. LPC is used as extraction method and HMM is used as the recognition method.	Slow time response caused by the microcontroller or digital signal processor.
Paper 4 [21]	The robot is able to perform speech with the expressive of facial expression.	The expression of mouth is presented using LEDs.
Paper 5 [22]	The system is capable of creating a speech profile for the individual speaker.	The noise filtering system is weak, thus, the accuracy in noisy environment is lower than in silent environment.
Paper 6 [23]	Multi-processor control technology is used to execute voice acquisition of the robot, analyse the situation, make judgment and carry out tasks.	The overall look of the structure of the robot and the control functions has to be improved.

In [18], self-organizing feature map neural network (SOFMNN) is integrated with Hidden Markov Model (HMM) to produce a speech emotion recognition. The purpose of the hybrid model is to improve the robustness and performance of classifier through combination of high categorized recognition capability of SOFMNN with capability in describing uncertain information as well as feature of HMM as represented by extensive processing of input speech transient characteristic sequence. However, this project will not implement this model because of the voice recognition module used is for Arduino.

There are two types of speech recognition, which are speaker-dependent system and speaker-independent system. The user does not need to conduct training if the system used is speaker independent, mentioned in [19]. However, in [22], in order for the engine to understand a user's voice, the user has to train the speech recognition engine. The engine will look for certain patterns in a saved sample of speech. Then, it will create a speech profile for each speaker. Thus, this project will focus on the speaker-independent system.

In [21], the robot is able to express facial expressions during conversation. The facial expression is expressed by the movement of the eyebrows, eyelids, eyes, and mouth. However, the number of expressions is limited because the facial expressions have only a few patterns. Hence, in this project, the robot head consists of 5 DOFs to produce rich facial expressions.

In conclusion, this project concentrates on developing a speaker-independent system other than developing a robot head with five facial expressions. The voice recognition module used is attached with a microphone control voice board for Arduino.

CHAPTER 3

METHODOLOGY

3.1 Project Overview

The flow chart of the overall project is as shown in Figure 3.1. It is a one-way flow chart except the software simulation and hardware development of the project will be repeated with different experiments until results are obtained and analysed.

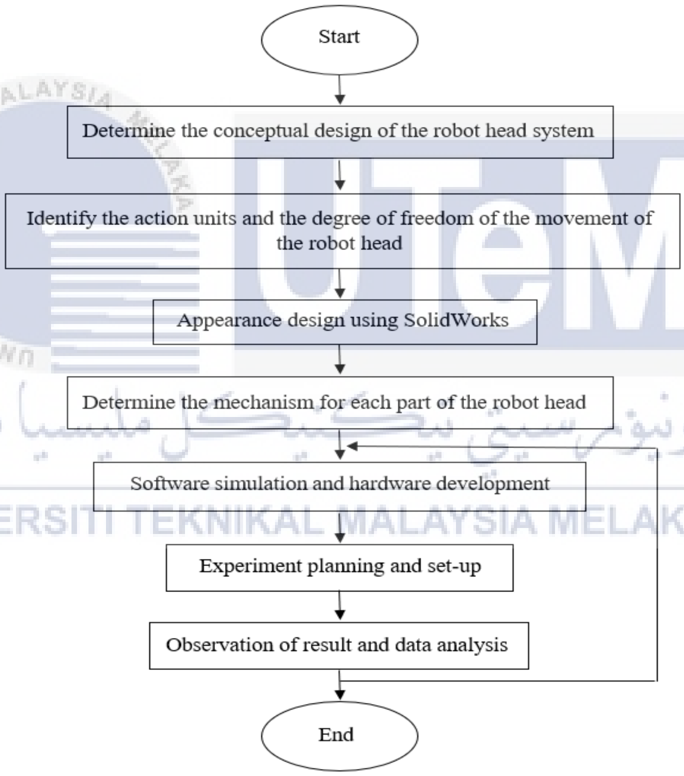


Figure 3.1 Flow Chart of the Project

The project starts by determining the conceptual design of the robot head system. Then, the action units and the DOFs of the movement of the robot head are identified. The appearance of the robot head is designed using SolidWorks. After that, the mechanism for each part of the robot head is determined. Software simulation and hardware development are done, following with experiment planning and set-up. The project ends by observing the results and analyzing the data.

The 3 main objectives of this project are mapped to a few tasks and experiments to provide a brief on how to achieve the objectives. They are summed up as shown in Table 3.1.

Table 3.1 Summary of Objectives to Tasks and Experiments

	Objectives		
	1: Robot head system with five basic expressions	**2: Robot controlled by voice commands**	**3: Analysis of performance of the robot head system**
Task 1: Conceptual Design	✓		
Task 2: Mechanical Configuration	✓		
Task 3: Speech Recognition		✓	
Experiment 1: Servo Accuracy Test			✓
Experiment 2: Position Repeatability			✓
Experiment 3A: Facial Recognition Rate	✓		✓
Experiment 3B: Speech Recognition Rate		✓	✓

Objective 1 is achieved by carrying out task 1, task 2 and experiment 3A. Objective 2 is achieved by carrying out task 3 and experiment 3B. Objective 3 is achieved by carrying out all the experiments, which are servo accuracy test, position repeatability, facial recognition rate and speech recognition rate.

3.2 Task 1: Conceptual Design

A survey on 30 subjects has been done using Google form to identify the suitable design for the robot head. The design of the robot head chosen is to improve the effectiveness in robot-human interaction to help the autism children. There are three choices of head design to be chosen as shown in Figure 3.2.

Figure 3.2 Type of Robot Head

There are three designs for the robot head system, from the most left, human-like robot head, cartoon-like robot head and technical head. Insect-like robot head is not chosen as it does not suit the theme of this project which is user-friendly.

3.2.1 Design Consideration

The design of the robot head is based on the actual head. It consists of eyebrows, eyelids, eyeballs, nose, lips and jaw. The effectiveness of the facial expressions in the robot head system will be improved by having the similar action units as the actual head. The action units can be achieved by identifying the degree of freedoms (DOFs) for the movement of the parts. The motion function and the DOFs of each part are listed in Table 3.2.

Table 3.2 Motion Function and the Degree of Freedom of Robot Head

Part	Motion Function	DOFs	Joint
Eyebrows	There is 1 control point in each eyebrow for the up and down movement	2	Roll
Eyelid	The eyelid is able to rotate up and down	1	Roll
Lips	Lips consist of two parts: upper and lower. The lips can be raised and lowered to form different shape for different emotions. There is 1 control point for each upper and lower lip.	2	Yaw

3.2.2 Appearance Design

The design of the appearance of the robot head has been carried out based on the conceptual design and design consideration. The design of the appearance is done by using SolidWorks. The design is drawn based on the DOFs configuration as shown in the design consideration.

A survey has been conducted on 30 subjects with the design drawn based on the facial expression. The result of the survey is used to obtain the best representation of certain facial expression, which has been implemented on the robot head.

3.3 Task 2: Mechanical Configuration

This robot head system consists of 5 DOFs to express the five basic emotions. The configuration of the construction of the robot head is the most difficult task. In order for the facial expressions to be understandable, it is important to emphasize on the combination of each mechanism. Details of the robot head mechanisms are explained below:

3.3.1 Eyelids

There is only one part of eyelid: the upper part. The details of the eyelids' mechanism are determined and tabulated as shown in Table 3.3.

Table 3.3 Details of Eyelids' Mechanism

Part	Axis	Upwards Distance/ degree	Downwards Distance/ degree	Speed (deg/s)	Type of Actuator	Type of Mechanism
Eyelid	Roll	15	35	500	1 RC Micro Servo Motor HD1160A	Link Mechanism

3.3.2 Eyebrows

The eyebrows of a human are able to arch upwards and downwards. Therefore, the details of the eyebrows' mechanism are determined to mimic human-like. It is tabulated in Table 3.4.

Table 3.4 Details of Eyebrows' Mechanism

Part	Axis	Upwards Distance/ degree	Downwards Distance/ degree	Type of Actuator	Type of Mechanism
Eyebrow	Roll	180	180	2 RC Micro Servo Motor HD1160A	Joint Mechanism

3.3.3 Nose and Mouth

There is only one part for the nose and 2 parts for the mouth, which consists of upper lip, lower lip. The details of the nose's and mouth's mechanisms are determined and tabulated as shown in Table 3.5.

Table 3.5 Details of Nose's and Mouth's Mechanisms

Part	Position	Up/Right (mm)	Down/Left (mm)	Type of Actuator	Type of Mechanism
Nose	-	-	-	-	SolidWorks Design
Mouth	Upper Lip	5	5	2 RC Micro Servo Motor HD1160A	L-Link Mechanism
	Lower Lip	5	5		

3.3.4 Whole Structure

The whole structure of the robot head is as shown in Figure 3.3. The dimension of the head is 140mm x 160mm x 65mm. The weight of the head is 0.8kg. The face structure is manufactured using rapid prototyping technique.

Figure 3.3 Overview of Robot Head

3.4 Task 3: Speech Recognition

Before using the Geeetech voice recognition module, the module's manual is read. The module is able to store up to 15 commands, divided into 3 groups, with 5 in each group. Therefore, this project can only support up to 5 expressions only. The module is able to recognize voice and it receives the voice command through serial port interface.

The module is then connected to the laptop using a Universal Serial Bus (USB) to Time-to-live (TTL) module. There are 4 wires connecting both modules. VCC is connected to 5V, ground to ground, Receive Data (RxD) to Transmit Data (TxD) and TxD to RxD from Geeetech module to the other module respectively as shown in Figure 3.4.

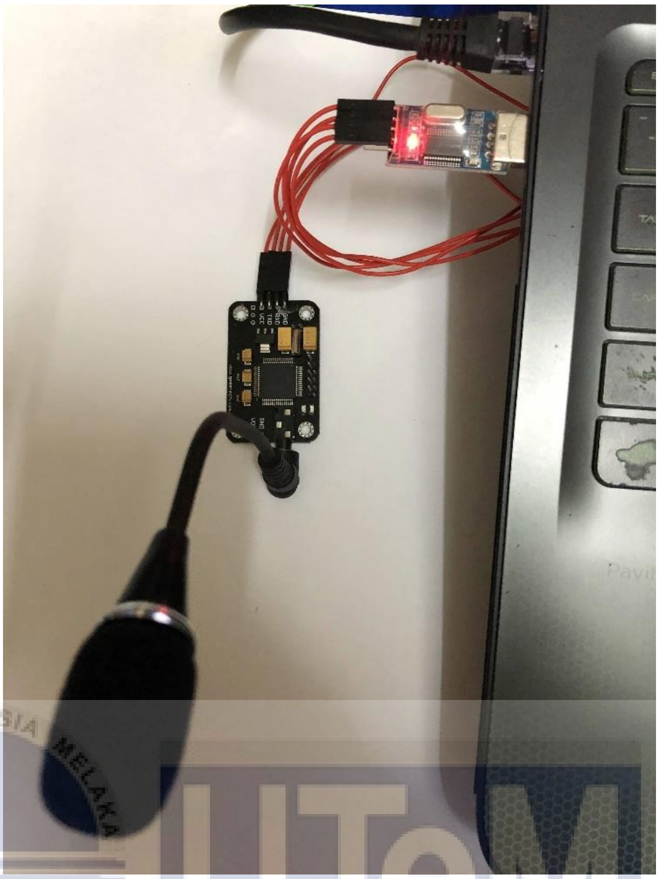


Figure 3.4 Connection of Geeetech Voice Recognition Module

Geeetech voice recognition module works together with AccessPort. Basically, AccessPort is a serial port monitoring tool to design or debug serial port related projects. The serial port setting in AccessPort is as shown in Figure 3.5.

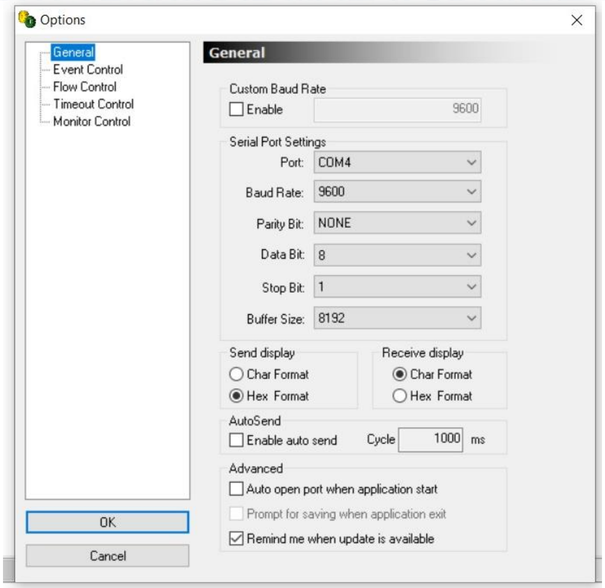


Figure 3.5 Serial Port Setting

Then, the required voice commands are recorded using the microphone attached to the Geeetech module. Most words are recorded as shown in Figure 3.6 because each voice command has the maximum length of 1300ms. After recording 5 commands, they are imported to the module, which is then connected to the Arduino Mega to control the servo motors.

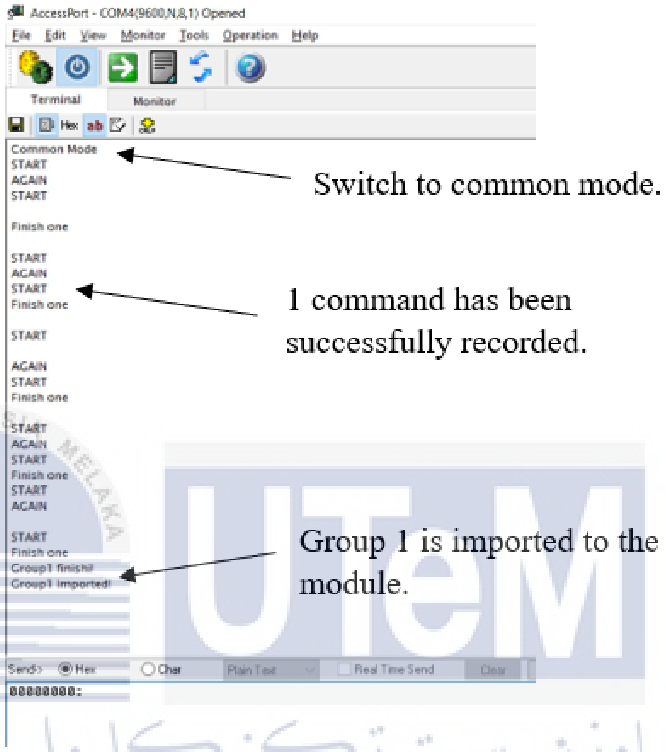


Figure 3.6 Recording Instructions

AccessPort has 2 modes which are common mode and compact mode. The main reason common mode is used in this case is because of the returning message. Common mode response is long string but compact mode response is a byte.

3.5 Hardware Experiment

Hardware included:

1) Arduino Mega with ATmega2560 processor
2) A few different models of servo motor
3) Geeetech voice recognition module with microphone control voice board
4) USB to TTL Module

3.5.1 Experiment 1: Servo Motor Selection and Accuracy Test

An experiment on a few different models of servo motor as shown in Table 3.6 are tested. The objective of the experiment is to analyse the performance of each servo motor and decide on which servo motor is best suited for the project in terms of reliable and accurate angle value.

Table 3.6 Specification of Different Model of Servo Motor

Specifications	SG90 Micro Servo	HD1160A Micro Servo
Dimension, L x W x H (mm)	23 x 12.2 x 29.0	29 x 11 x 30.2
Weight (g)	9	16
Torque (kgcm)	1.8	2.7
Operation Speed (s/deg)	0.12/60	0.12/60

3.5.2 Experiment 2: Position Repeatability

There are a lot of unknown factors such as the arrangement of actuators or the type of mechanism used to support the actuators that will affect the performance of the robot head especially during the construction phase. Thus, to obtain the best performance of the robot head, an experiment on analysing the position repeatability has been carried out.

In the experiment, the position distance and the angle value of each actuator is observed and recorded for each facial expression. The experiment is repeated for 15 times [6]. The mean and the standard deviation are calculated to compare the output with the desired result.

The approach to this experiment is important to obtain a reliable value. A red dot is marked on the robot head on every control point (location of each actuator is placed) when it is in initial position (neutral expression). Measuring equipment such as protractor and ruler are used to obtain the position distance and angle value of the actuator. Parallax error is avoided during the data recording process.

The data recorded are tabulated as shown in Table 4.6 to 4.15.

3.6 Recognition Rate

3.6.1 Experiment 3A: Facial Recognition

The recognition rate for each facial expression on the final product of the robot head has been done on 30 subjects. However, the 30 subjects do not include those who have done the previous survey on the appearance design. This is to eliminate the possibility of the subject of having the knowledge beforehand. The result is tabulated as shown in 4.5.

3.6.2 Experiment 3B: Speech

The speech recognition rate is repeated 30 times using the final product of the robot head. The speech recognition rate is used to test on how the robot head respond once certain word is being said by the user. If the word said is the keyword for certain facial expression, then, the robot will show the emotion. The result is tabulated as shown in Table 4.16

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Conceptual Design

A survey on the suitable design for the robot head system has been answered online by 30 random subjects (22 male and 8 female) with average age of 23 using Google Form. The result of the survey is as shown in Figure 4.1. 19 out of 30 of them have selected human-like robot head as the main design of the robot head system for this project. Most of them agreed that a human-like robot head can perform more pleasant facial expressions to the autism children than the cartoon-like and technical head. Thus, the design of the robot head system is based on the specification of a human-like robot head. The design is drawn using SolidWorks.

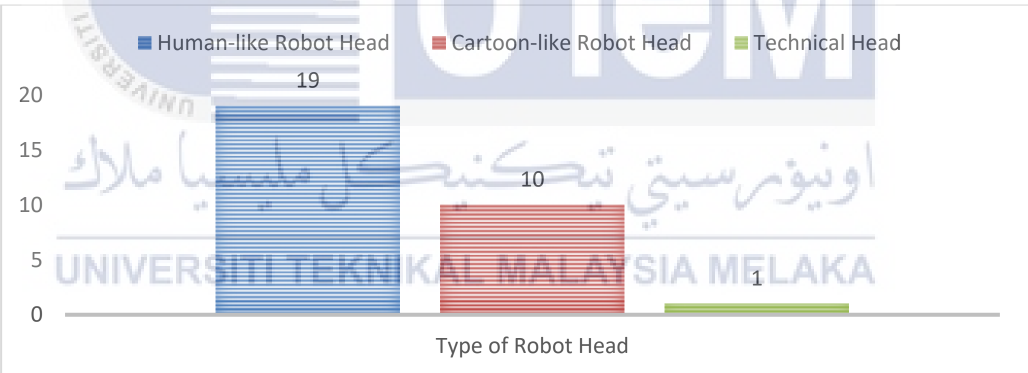


Figure 4.1 Survey on Design of Robot Head

4.2 Action Units (AUs)

There are total of 4 AUs to perform the five basic expressions on the robot head. Besides, 10 control points have been defined and each correspond AUs of the control point is as shown in Table 2.1. The combination of different control point is used to perform the five basic expressions. The result of the combination is tabulated in Table 4.1 and the symbol of the direction of movement for AUs is as shown in Table 4.2.

Table 4.1 Combination of AUs for each expression

Facial Expression	Action Units
Joy	**1Y+2Y+10Y**
Sadness	**1Y+2Y+6Y**
Anger	**5X**
Surprise	**1Y+2Y+5X+7X+10Y**
Fear	**1Y+2Y**

Table 4.2 Symbol of Direction of Movement for AUs

Symbol	Direction
X	**Up**
Y	**Down**

4.3 Servo Motor Accuracy Test

The initial test of the accuracy test of servo motor is set up as shown in Figure 4.2. The selected servo motor is attached to a white paper with protractor drawing. The servo motor is then screwed with a single-sided horn to ensure that the paper did not move.

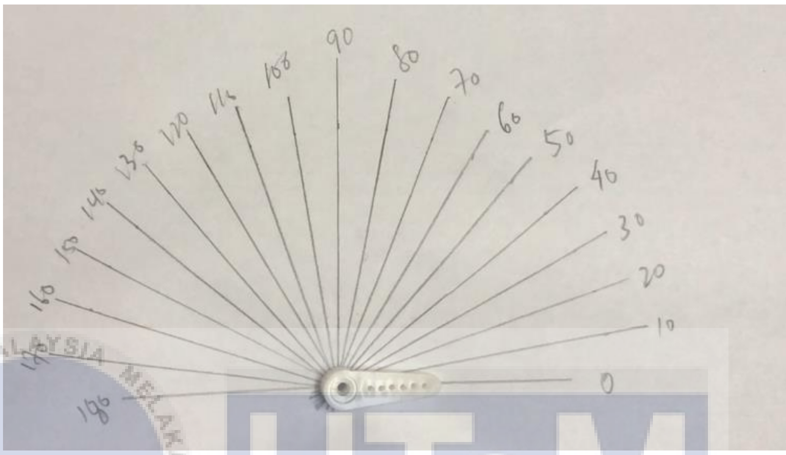


Figure 4.2 Initial Position of Servo Motor

The servo motor is then moved to a particular angle. As shown in Figure 4.3, the servo motor is programmed to move to 100º. An extra line is drawn on the paper to measure the angle of the servo motor rotated to. After that, the result will be tabulated as shown in Table 4.3. The experiment is repeated and tabulated as shown in Table 4.4.

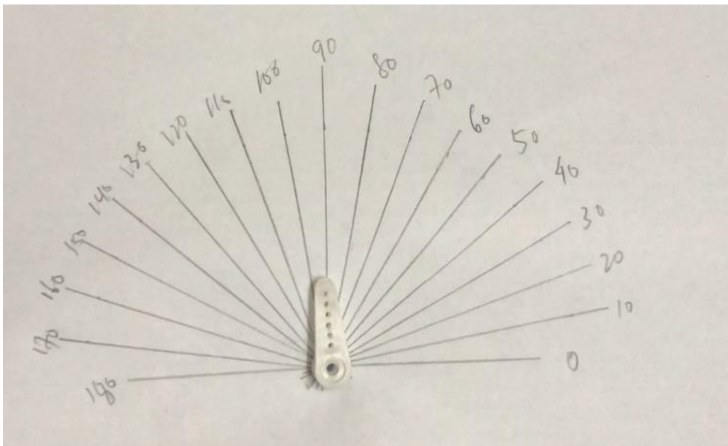


Figure 4.3 Final Position of Servo Motor

Table 4.3 Accuracy Test for SG90 Micro Servo

Angle, °	Sample			Mean	Error	Percentage Relative Error (%) = $\left\lvert \frac{measured\ value - true\ value}{true\ value} x100\% \right\rvert$
	1	2	3			
0	0	0	0	0	0	0
10	10	10	10	10	0	0
20	20	20	20	20	0	0
30	30	30	30	30	0	0
40	40	40	40	40	0	0
50	50	50	50	50	0	0
60	60	60	60	60	0	0
70	70	70	70	70	0	0
80	80	79	79	79.33	0.67	0.84
90	89	89	89	89	1	1.11
100	98	99	98	98.33	1.67	1.67
110	108	107	108	107.67	2.33	2.12
120	117	116	118	117	3	2.50
130	126	125	125	125.33	4.67	3.59
140	134	135	134	134.33	5.67	4.05
150	143	143	143	143	7	4.67
160	152	153	153	152.67	7.33	4.58
170	162	161	162	161.67	8.33	4.90
180	171	171	171	171	9	5.0

Table 4.4 Accuracy Test for HD1160A Micro Servo

Angle, °	Sample			Mean	Error	Percentage Relative Error (%) = $\left\lvert \frac{measured\ value - true\ value}{true\ value} x100\% \right\rvert$
	1	2	3			
0	0	0	0	0	0	0
10	10	10	10	10	0	0
20	20	20	20	20	0	0
30	30	30	30	30	0	0
40	40	40	40	40	0	0
50	50	50	50	50	0	0
60	60	60	60	60	0	0
70	70	70	70	70	0	0
80	80	80	80	80	0	0
90	90	90	90	90	0	0
100	100	99	99	99.33	0.67	0.67
110	109	110	108	109	1	0.91
120	118	119	118	118.33	1.67	1.39
130	127	128	127	127.33	2.67	2.05
140	136	136	138	136.67	3.33	2.38
150	146	144	145	145	5	3.33
160	155	154	154	154.33	5.67	3.54
170	164	163	163	163.33	6.67	3.92
180	171	173	172	172	8	4.44

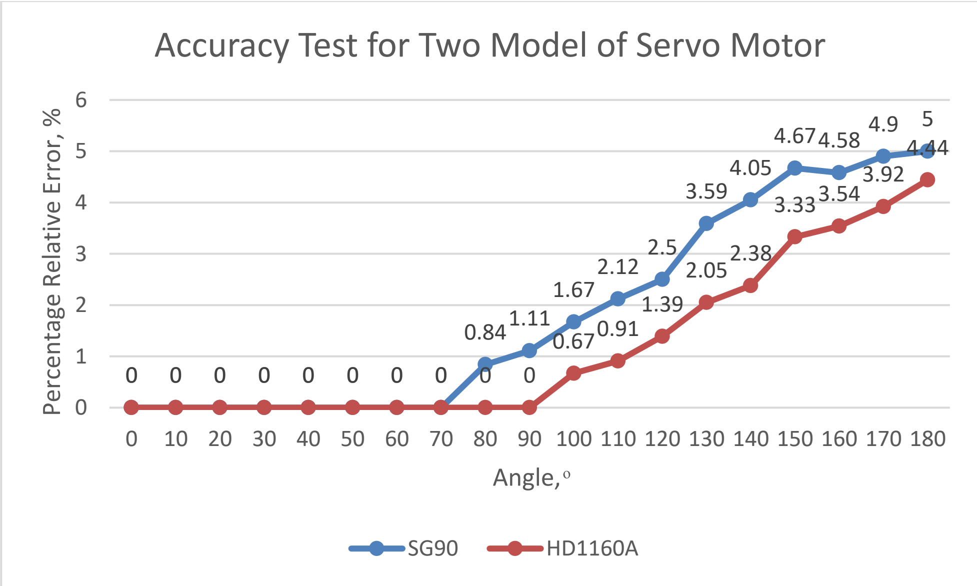
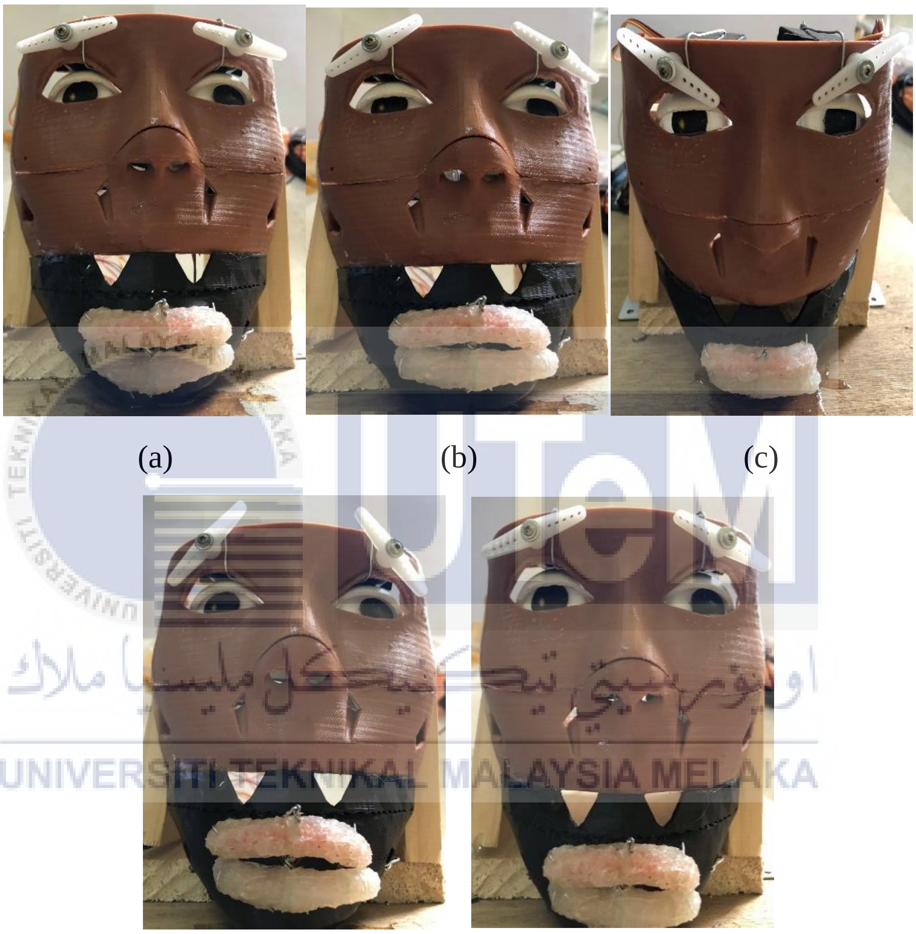


Figure 4.4 Percentage Relative Error for Two Model of Servo Motor

Based on Table 4.3 and 4.4 and Figure 4.4, HD1160A micro servo has a higher accuracy compared to SG90 micro servo. The percentage relative error for HD1160A micro servo is less than 5%, which is 4.44%, is acceptable to be the servo motor for this project to control the expressions of the robot head. Besides, based on Table 3.6, HD1160A micro servo has a higher torque value than SG90 micro servo. Thus, HD1160A is more suitable to be part of the mechanism used on the robot head.

4.4 Recognition Rate on Facial Expressions

The five expressions expressed by the robot head system are as shown in Figure 4.5. The expressions of the robot head are determined by the position of the eyebrows, eyelid, upper lip and lower lip. The position of each part is different for each expression.



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

Figure 4.5 (a) Happiness (b) Sadness (c) Anger (d) Surprise (e) Fear

A survey has been conducted on 30 random subjects through Google Form on recognizing the expressions expressed by the robot head. The five expressions shown to the subjects are of static images. The results obtained are tabulated as shown in Table 4.5.

Table 4.5 Facial Expression Recognition Rate

Facial Expressions	Recognition Rate (%)				
	Happiness	Sadness	Anger	Surprise	Fear
Happiness	**66.67**	13.34	3.33	13.33	3.33
Sadness	3.33	**53.34**	3.33	13.33	26.67
Anger	0	13.33	**76.67**	0	10.0
Surprise	0	30.0	6.67	**50.0**	13.33.
Fear	0	50.0	13.33	13.33	**23.34**

Based on Table 4.5, 30 of the subjects evaluated the static images and successfully recognized happiness (66.67%), sadness (53.34%), anger (76.67%) and surprise (50.0%). Fear has received a lower score, with only 23.34%, which is a result that will be further invested and improved. One hypothesis fear has failed is that the emotions displayed by the robot head is not human-like enough.

4.5 Position Repeatability

There are total of 5 actuators used in designing this robot head system. Thus, the 5 actuators are tested on their position value and angle value to analyse the performance of the robot head. However, not every emotion uses 5 actuators at the same time. The same approach showed in Figure 4.2 is used to measure the angle value. The position value is measured using a Vernier caliper.

The position value is used to measure the upper or lower extension of the lips (actuator 4 or 5). The maximum extension for both upper and lower is 5mm. The angle value is used to measure the degree of the servo motor (actuator 1, 2 or 3). Each expression has different degrees for different servo motor.

The initial position of each servo motor is fixed. Then, a command for the expression is given by the user to control the robot head. After the voice command, the position of the servo motors or the lips are measured with either a protractor or a Vernier caliper respectively. Parallax is avoided in recording the data. The data collected are tabulated in Table 4.7 to 4.16. The representation of the actuator is as shown in Table 4.6.

Table 4.6 Representation of Each Actuator

Actuator	1	2	3	4	5
Representation	Left Eyebrow	Right Eyebrow	Eyelid	Upper Lip	Lower Lip

Table 4.7 Position Value of 5 Actuators on Robot Head for Happiness

No. of Sample	**Actuator (Position Value, mm)**				
	1	**2**	**3**	**4**	**5**
1	-	-	-	0	4.8
2					4.8
3					4.7
4					4.8
5					4.7
6					4.8
7					4.8
8					4.9
9					4.8
10					4.7
11					4.8
12					4.8
13					4.7
14					4.8
15					4.7
Average					4.773

For happiness, there is movement for actuator 5 only. Actuator 4 is not programmed to extend the upper lip of the robot head. The maximum extension of the lip is 5mm each. Since actuator 4 is not moving, there is no extension. Actuator 5 has an average of 4.773mm extension compared to the maximum extension of 5mm. Thus, it proves that the servo motor has problem rotating to the maximum extension when there is extra load (lower lip) acting on the servo motor.

Table 4.8 Angle Value for 5 Actuators on Robot Head for Happiness

No. of Sample	Actuator (Angle Value, degree)				
	1	**2**	**3**	**4**	**5**
1	58	116	0	-	-
2	57	117			
3	59	117			
4	58	117			
5	58	118			
6	58	116			
7	57	117			
8	58	117			
9	58	116			
10	57	118			
11	59	117			
12	58	118			
13	58	116			
14	57	117			
15	57	116			
Average	57.8	116.87			

For happiness, there are movement for actuator 1 and 2 only. Actuator 3 is not programmed to rotate the eyelid of the robot head. The rotation programmed for actuator 1 and 2 are 60º and 120º respectively. Since actuator 3 is not rotating, there is no rotation. Actuator 1 has an average of 57.8º rotation compared to the maximum rotation of 60º while actuator 2 has an average of 116.87º compared to the maximum rotation of 120º. Thus, it proves that both servo motor has problem rotating to the maximum rotation when there are extra loads (left and right eyebrows) acting on the servo motors.

Table 4.9 Position Value of 5 Actuators on Robot Head for Sadness

<table>
<tr><th rowspan="2">No. of Sample</th><th colspan="5">Actuator (Position Value, mm)</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>1</td><td rowspan="16">-</td><td rowspan="16">-</td><td rowspan="16">-</td><td rowspan="16">0</td><td rowspan="16">0</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td></tr>
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<tr><td>12</td></tr>
<tr><td>13</td></tr>
<tr><td>14</td></tr>
<tr><td>15</td></tr>
<tr><td>Average</td></tr>
</table>

For sadness, there are no movement for both actuator 4 and 5. They are not programmed to extend both lip of the robot head. Since actuator 4 and 5 are not moving, there is no extension.

Table 4.10 Angle Value for 5 Actuators on Robot Head for Sadness

No. of Sample	Actuator (Angle Value, degree)				
	1	2	3	4	5
1	88	143	59	-	-
2	87	142	58		
3	88	143	58		
4	86	144	59		
5	87	143	57		
6	88	142	58		
7	88	142	59		
8	87	143	57		
9	86	143	57		
10	87	143	58		
11	87	144	58		
12	87	142	59		
13	88	143	58		
14	86	144	57		
15	88	142	59		
Average	87.2	142.87	58.07		

For sad, there are movement for actuator 1, 2 and 3. The rotation programmed for actuator 1, 2 and 3 are 90º, 150º and 60º respectively. Actuator 1 has an average of 87.2º rotation compared to the maximum rotation of 90º, actuator 2 has an average of 142.87º compared to the maximum rotation of 150º, while actuator 3 has an average of 58.07º compared to the maximum rotation of 60º. Thus, it proves that all three servo motors have problem rotating to the maximum rotation when there are extra loads (left and right eyebrows and eyelid) acting on the servo motors.

Table 4.11 Position Value of 5 Actuators on Robot Head for Anger

<table>
<tr><th rowspan="2">No. of Sample</th><th colspan="5">Actuator (Position Value, mm)</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>1</td><td rowspan="16">-</td><td rowspan="16">-</td><td rowspan="16">-</td><td rowspan="16">0</td><td rowspan="16">0</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td></tr>
<tr><td>7</td></tr>
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<tr><td>10</td></tr>
<tr><td>11</td></tr>
<tr><td>12</td></tr>
<tr><td>13</td></tr>
<tr><td>14</td></tr>
<tr><td>15</td></tr>
<tr><td>Average</td></tr>
</table>

For anger, there are no movement for both actuator 4 and 5. They are not programmed to extend both lip of the robot head. Since actuator 4 and 5 are not moving, there is no extension.

Table 4.12 Angle Value for 5 Actuators on Robot Head for Anger

No. of Sample	Actuator (Angle Value, degree)				
	1	**2**	**3**	**4**	**5**
1					
2					
3					
4					
5					
6					
7					
8	0	0	0	-	-
9					
10					
11					
12					
13					
14					
15					
Average					

For anger, there are no movement for actuator 1, 2 and 3. All actuators are not programmed to rotate. Since they are not rotating, there is no rotation. The reason all three actuators are not moving because anger is used as the initial expression of the robot head system. This is because the voice recognition module can only store 5 commands and thus anger is used as the initial expression.

Table 4.13 Position Value of 5 Actuators on Robot Head for Surprise

No. of Sample	Actuator (Position Value, mm)				
	1	2	3	4	5
1				4.7	4.8
2				4.8	4.9
3				4.7	4.7
4				4.7	4.8
5				4.8	4.8
6				4.7	4.7
7				4.8	4.7
8	-	-	-	4.9	4.7
9				4.8	4.8
10				4.8	4.7
11				4.7	4.7
12				4.8	4.8
13				4.8	4.7
14				4.8	4.7
15				4.7	4.8
Average				4.767	4.760

For surprise, there are movement for both actuator 4 and 5 to form a shape ‘O’. The maximum extension of the lip is 5mm each. Actuator 4 has an average of 4.767 and actuator 5 has an average of 4.760mm extension compared to the maximum extension of 5mm. Thus, it proves that both servo motor has problem rotating to the maximum extension when there are extra loads (upper and lower lip) acting on the servo motors.

Table 4.14 Angle Value for 5 Actuators on Robot Head for Surprise

No. of Sample	Actuator (Angle Value, degree)				
	1	2	3	4	5
1	118	172	10	-	-
2	117	170	10		
3	118	171	10		
4	116	170	9		
5	117	169	10		
6	117	170	9		
7	116	170	10		
8	117	171	10		
9	117	169	10		
10	118	170	10		
11	117	169	9		
12	116	170	10		
13	117	170	10		
14	117	171	9		
15	117	168	10		
Average	117.0	170.0	9.73		

For surprise, there are movement for actuator 1, 2 and 3. The rotation programmed for actuator 1, 2 and 3 are 120º, 180º and 10º respectively. Actuator 1 has an average of 117.0º rotation compared to the maximum rotation of 120º, actuator 2 has an average of 170.0º compared to the maximum rotation of 180º, while actuator 3 has an average of 9.73º compared to the maximum rotation of 10º. Thus, it proves that all three servo motors have problem rotating to the maximum rotation when there are extra loads (left and right eyebrows and eyelid) acting on the servo motors.

Table 4.15 Position Value of 5 Actuators on Robot Head for Fear

No. of Sample	Actuator (Position Value, mm)				
	1	2	3	4	5
1				4.8	
2				4.8	
3				4.8	
4				4.9	
5				4.7	
6				4.8	
7				4.8	
8	-	-	-	4.7	0
9				4.7	
10				4.8	
11				4.8	
12				4.7	
13				4.7	
14				4.9	
15				4.8	
Average				4.780	

For fear, there is movement for actuator 4 only. Actuator 5 is not programmed to extend the upper lip of the robot head. The maximum extension of the lip is 5mm each. Since actuator 5 is not moving, there is no extension. Actuator 4 has an average of 4.780mm extension compared to the maximum extension of 5mm. Thus, it proves that the servo motor has problem rotating to the maximum extension when there is extra load (upper lip) acting on the servo motor.

Table 4.16 Angle Value for 5 Actuators on Robot Head for Fear

No. of Sample	Actuator (Angle Value, degree)				
	1	2	3	4	5
1	57	115	0	-	-
2	58	117			
3	57	116			
4	58	117			
5	59	116			
6	57	116			
7	57	116			
8	58	117			
9	57	117			
10	58	115			
11	57	117			
12	59	117			
13	58	117			
14	57	116			
15	58	116			
Average	57.67	116.33			

For fear, there are movement for actuator 1 and 2 only. Actuator 3 is not programmed to rotate the eyelid of the robot head. The rotation programmed for actuator 1 and 2 are 60º and 120º respectively. Since actuator 3 is not rotating, there is no rotation. Actuator 1 has an average of 57.67º rotation compared to the maximum rotation of 60º while actuator 2 has an average of 116.33º compared to the maximum rotation of 120º. Thus, it proves that both servo motor has problem rotating to the maximum rotation when there are extra loads (left and right eyebrows) acting on the servo motors.

Based on the results obtained, the servo motor is unable to rotate to the degree where it is programmed to. The servo motors that acted as the eyebrows may have a larger weight based on the double-sided horn and there is friction caused between the surface of the robot head with the servo motor. Besides, there is some steel wire attached to the single-sided horn of the servo motors for the other parts of the robot head. Therefore, the servo motor is not able to work effectively and accurately like the previous experiment done as shown in Table 4.4.

4.6 Speech Recognition Rate

Same as the previous recognition rate test, speech recognition test has been repeated for 30 times by the user. 5 voice commands to control the robot head are happy, sad, angry, surprise and fear. A successful speech recognition means that the robot head is able to express the emotions commanded by the user. A failed speech recognition means that the robot head failed to express the emotions commanded by the user within 3 seconds. The result obtained is tabulated in Table 4.16 and then transformed into graphical form as shown in Figure 4.10.

Table 4.17 Speech Recognition Rate

Voice Command	Recognition Rate (%)	
	Identified	Failed to identify
Happy	93.33	6.67
Sad	93.33	6.67
Angry	90.0	10.0
Surprise	96.67	3.33
Fear	93.33	6.67

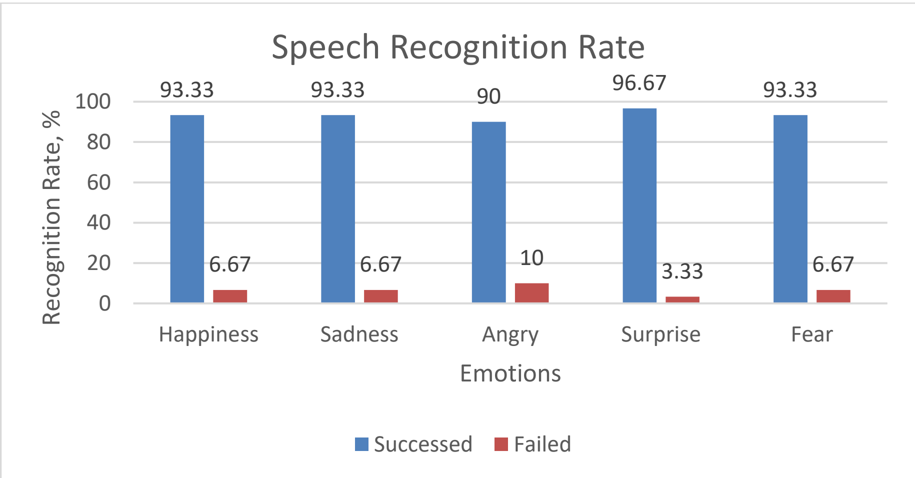

Figure 4.6 Graph of Recognition Rate against Emotions

The results showed that the recognition rate for speech is very successful. All of the recognition rate is above 90% which is a good sign as the robot head can be controlled effectively and successfully by voice command. Those failures might cause by the surrounding noise. The microphone quality is also one of the reasons the failure happened. A better-quality microphone can receive voice commands better than what this project had at the moment as the microphone used in this project is of low quality. The module itself has stated that it has a recognition accuracy of 99% under ideal environment.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The robot head system mimics the human head which consists of eyebrow, eyelids, eyeballs, nose and lips. The robot head is able to perform five basic expressions, which are happiness, sadness, anger, surprise and fear. It consists of 5 DOFs along with 10 action units. Thus, the first objective has been achieved.

The second objective is achieved with the help of Geeetech voice recognition module. The module is capable of storing five commands in one group. The commands are recorded using AccessPort and imported to the Arduino. The robot head system is able to be controlled by the voice command to express the commanded expressions.

The performance of the robot head system is analysed in terms of position, the recognition rate of each facial expression and the speech recognition. Thus, the third objective is achieved with a few experiments carried out. Position repeatability helps in analyzing the performance of the robot head system in terms of the position of the servo motor in expressing the commanded expression.

5.2 Future Works

This project is still considered flawed because of the low recognition rate of each facial expression. The projected recognition rate is above 80%, but after the survey, it was found out that most of the expressions are below 70%.

The project can be improved by adding more DOFs to the robot head system or improving the hardware integration. The utilization of the lips might not be on point as it looks a little bit weird. The design of the robot head system has its shortcomings as well.

Future work of this robot head system can be integrated with other robotic bodies and also the addition of a few sensors. The robustness of the mechanical construction still has space for improvement as well.

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APPENDICES

APPENDIX A Gantt Chart

Year	2018																2019
Month	September				October					November			December				January
Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Title Registration																	
Identify the Problems																	
Project Research																	
Component Selection																	
Software Design																	
Study Arduino Controller										Mid-Sem Break						Revision Week	Final Examination
Study Servo Motor																	
Study Voice Recognition Module																	
Software Simulation																	
Hardware Development																	
Meeting with Supervisor																	

APPENDIX B Gantt Chart (cont.)

Year	2019														
Month	February		March				April					May			June
Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Software Simulation									Mid-Sem Break					Presentation	Revision Week	Final Examination
Hardware Development																
Software & Hardware Integration																
Performance Testing																
Performance Analysis																
Troubleshooting																
Meeting with Supervisor																

APPENDIX C Coding of the Robot Head System

```
//include servo library
#include <Servo.h>

byte com = 0; //reply from voice recognition module

//define servo name
Servo Servo1; //left eyebrow
Servo Servo2; //right eyebrow
Servo Servo3; //eyelid
Servo Servo4; //upper lip
Servo Servo5; //lower lip

void setup() { //run once as the program starts running

//opens serial port, sets data rate to 9600bps
Serial.begin(9600);

//define servo pin
Servo1.attach(9);
Servo2.attach(10);
Servo3.attach(11);
Servo4.attach(12);
Servo5.attach(13);

Serial.write(0xAA); //send hexadecimal value to serial device
Serial.write(0x37); //compact mode

delay(1000); //stops for 1 second

Serial.write(0xAA);
Serial.write(0x21); //import group 1
}

void loop() { //run over and over again

  while(Serial.available()){ //reply when data is received

  com = Serial.read(); //the voice command is received and saved in the com byte

  switch(com) {

      case 0x11:   //command 1 is for HAPPY

      Servo1.write(60);  //servo turns to 60 deg
     Servo2.write(120);  //servo turns to 120 deg
      Servo3.write(25);  //servo turns to 25 deg
```

```
}
```



```
      Servo4.write(0);  //servo turns to 0 deg
      Servo5.write(180); //servo turns to 180 deg
      break; //switch statement

      case 0x12:  //command 2 is for SAD

      Servo1.write(90);
      Servo2.write(150);
      Servo3.write(60);
      Servo4.write(0);
      Servo5.write(0);
      break;

      case 0x13:  //command 3 is for ANGRY

      Servo1.write(0);
      Servo2.write(0);
      Servo3.write(25);
      Servo4.write(0);
      Servo5.write(0);
      break;

      case 0x14:  //command 4 is for SURPRISE

      Servo1.write(120);
      Servo2.write(180);
      Servo3.write(10);
      Servo4.write(90);
      Servo5.write(90);
      break;

      case 0x15:  //command 5 is for FEAR

     Servo1.write(60);
     Servo2.write(120);
     Servo3.write(25);
     Servo4.write(45);
     Servo5.write(45);
      break;

        }
      }
}
```