DESIGN OF ROBOT HEAD FOR EXPRESSION OF HUMAN EMOTION

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SUPERVISOR ENDORSEMENT

" I hereby declare that I have read through this report entitle "Design of Robot Head for Expression of Human Emotion" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechatronics Engineering (Hons)"

Signature :

Supervisor's Name :

Date :

STUDENT DECLARATION

I declare that this report entitle “Design of Robot Head for Expression of Human Emotion” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Student's Name :

Date :

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ABSTRACT

Humanoid robot is a type of robot which is designed in human-form with the purpose to increase the quality of human life. The key features of humanoid robot are to perform human-like behaviours and to undergo effective interaction with human-operator. The purpose of this project is to develop an interactive robot head that able to express six basic human emotions based on Ekman's model. These six expressions are joy, sadness, anger, disgust, surprise and fear. The combination of action units based on different control points on robot head was proposed in this study. The new robot head is equipped with 11 degree of freedom for the movement of robot head in human like-way. Two surveys have been conducted to evaluate the suitability of robot head and facial expression designs in order to implement on the robot head. Arduino Mega has been used as the controller for the robot head system and it is integrated with IR remote keypad and LCD display. The remote keypad controller is designed for user to control the expression of robot head. It is synchronised with LCD display where the LCD able to display the name of emotion when particular button activated. This project focuses on the performance test of robot head in term of position accuracy and the result shows that the relative percentage error for each robot head parts is less than 20%. The survey that had been conducted for the facial expression recognition test obtained more than 70% recognition rate for each expression shown by the robot head. It can be concluded that this robot head system, is capable to improve the effectiveness of human-robot communication and possible for more advanced interaction development in the future.

ABSTRAK

Robot humanoid direkabentuk merupai bentuk manusia dengan tujuan untuk meningkatkan kualiti kehidupan manusia. Ciri-ciri utama robot humanoid adalah ia mampu mejalankan tingkahlaku seperti manusia dan menjalani interaksi yang berkesan dengan manusia. Tujuan projek ini adalah untuk membina kepala robot interaktif yang mampu memaparkan 6 emosi asas manusia berdasarkan model Ekman. Enam emosi ini adalah terdiri daripada kegembiraan, kesedihan, kemarahan, perasaan meluat, terkejut dan ketakutan. Gabungan unit tindakan berdasarkan kawalan unit yang berbeza pada kepala robot bagi setiap ekspresi muka telah dicadangkan dalam projek ini. Kepala robot ini dilengkapi dengan 11 darjah kebebasan untuk melaksanakan emosi yang berbeza seperti manusia. Dua kajian telah dijalankan dan penilaian telah dibuat untuk memilih reka bentuk kepala robot serta emosi muka yang paling sesuai untuk dibina pada kepala robot. Arduino Mega digunakan sebagai pengawal bagi sistem kepala robot ini dan ia berintegrasi dengan pengawal papan kekunci dan paparan LCD. Pengawal papan kekunci direka untuk mengawal pergerakan kepala robot berdasarkan kawalan pengguna. Pengawal papan kekunci ini disambung dengan paparan LCD untuk menunjukkan jenis ekspresi wajah. Projek ini menitikberatkan ujian prestasi robot dari segi ketepatan pergerakan dan keputusan menunjukkan ralat peratusan relatif untuk setiap bahagian kepala robot adalah kurang daripada 20%. Tinjauan pada kadar pengiktirafan untuk setiap pernyataan emosi menunjukkan lebih daripada 70% kadar pengiktirafan dapat diperolehi bagi setiap emosi yang ditunjukkan oleh kapala robot. Dengan menggunakan sistem robot ini, ia mampu meningkatkan keberkesanan komunikasi antara manusia dengan robot dan menambahkan kemungkinan pembangunan interaksi yang lebih maju pada masa akan datang.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Autism spectrum disorder (ASD) is a life long developmental disability and it affects a person in multiple ways, where it can range from very mild to severe. Children with autism are characterized by impairments in three crucial areas of development which is communication, social and limited imagination. Autism spectrum disorder is reported to occur in all racial, ethnic, and socioeconomic background peoples.

There is no actual total number of autism children in Malaysia but the statistic showed by Department of Statistic Malaysia (2011), the total number of children aged from 0-14 was 7,784,600 [1]. According to Health Ministry statistics, it shows that one in every 600 children in Malaysia is autistic [2]. It is estimated that today there are 12,975 children in Malaysia are believed to have some form of autism spectrum disorders.

ASD has the fastest growing developmental disability rate with 10-17% annually [3]. The motivation for this project is to reduce the rates of autism with early therapies and intervention. Children with autism have face recognition deficits that cannot be attributed to overall cognitive abilities or task demands [4]. These children have difficulty with face identity after-effect and the ability to fix in memory faces that are unfamiliar. Thus, humanoid robot head with emotion express ability able to assist the children with ASD by continuously update on precise characteristic of human expression during the learning process.

1.2 Problem Statement

Through Mehrabian survey, 7% of information is transferred through spoken language while 38% transferred by paralanguage and 55% of transfer is due to facial expression [5]. This statistic indicates that facial expression is the major element in transferring information and this proposed robot head act as the mediator or the deliverer of the facial information to autism children.

Children with severe autism have significant difficulty to communicate or interact with other people. Most of the autism children are visual oriented and they need patient practice in the learning process. Humanoid robot head with emotion express ability able to solve this issue by provides autism children a learning platform on facial expression recognition. The ability of humanoid robot to perform a repetitive task to modelling human communication provides an effective and better therapy compared to human aided learning system. A report had stated that autism children paid more attention to the robot and followed its instruction to develop on their social skills [6]. Thus, the robot head proposed able to provide a proper learning system which are needed for autism children to recognize facial emotion so that they able to express their own feelings during interaction.

The effectiveness of a robot head to deliver the emotion is highly based on following criteria:

i. Type of robot head design and structure
ii. Degree of freedom of the robot head movement
iii. Amount and position of control point on the robot head
iv. Combination of action units on the robot head for each emotion
v. Recognition rate for each emotion express by robot head

For the robot head system, the selection of hardware components can influence the performance of the system. Arduino Mega has been chosen as the controller for the robot head system and it provides 54 digital I/O pins for connection.

The model of actuators are selected based on the specification of the robot head mechanisms which include the torque and speed needed for moving the mechanisms of robot head parts. The actuator chosen need to be high precision on positioning capabilities for the motion of the robot head. The measurement in term of angle and position distance for the robot head parts will be taken for accuracy performance test for each facial expression. The position of actuators in neutral expression has been taken as the reference point for the series of performance test.

1.3 Objectives

i. To design and construct a robot head that able to express human six basic emotions based on Ekman's model
ii. To design a keypad controller system for controlling robot head emotion expression and implement LCD display to show the name of emotion express by the robot head
iii. To analyze the performance of the robot head in term of position accuracy and obtain the recognition rate of each facial expression

1.4 Scopes

i. The construction of the robot head focuses on human head motion that consists of eyebrows, eyelid, eyeballs and lips. Each of this part able to move independently to express different emotion. Neck construction is not cover in this project.
ii. Appropriate control point on the robot head is determined to control the direction of movement of actuators. The actions units (AUs) are form by the combination of control point. The 6 basic emotion of Ekman's model covered in this project are joy, sadness, anger, disgust, fear and surprise. Working space of robot head is fixed (X-axis = 0.17m, Y-axis = 0.18m, Z-axis = 0.06m).

iii. This project covers the position accuracy test by repeating the motion of robot head parts which include eyeballs, eyebrows and lips.

iv. This project covers the facial expression recognition survey on 100 respondents through actual demonstration of the complete robot head structure. The expression of emotion on robot head appears randomly.

v. The motion of robot head is controlled by using Arduino Mega controller.

vi. A keypad controller is designed for user to control the emotion express on the robot head. The robot head shows the expression when a particular button on keypad controller is activate. Seven buttons are set up for six basic emotions while another one is for neutral emotion.

vii. A LCD display is designed to show the name of emotion on the robot head.

1.5 Outline of Dissertation

i. Chapter 1 describes the problem designate and goals to be achieved as well as range of this project covers.

ii. Chapter 2 describes the published information related to humanoid robot head in the way to perform human emotions and the performance indices used for expression evaluation.

iii. Chapter 3 describes the method designed to construct robot head parts and mechanism to express different emotion. This chapter also describes the method use to indicate the performance of robot head parts in terms of position accuracy and the facial expression recognition rate.

iv. Chapter 4 describes the findings obtained using statistical technique and also evaluation of the result obtained with proof.

v. Chapter 5 concludes the project findings and suggest on future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory

2.1.1 Robot Head Design and Construction

Currently in the research of humanoid robot, the design and construction of the robot head become one of the determinant factors that will affect the effectiveness of communication between human and a robot. Different design of robot head portrait will produce different understandability for the user. Thus, to design an appearance concept of the robot head, we have to take consideration on two issues [7]:

i. How to design a face that can convey understandable expression, and
ii. How to make a friendly face and will not let user react adversely to it

Human has the best understanding on the expressions of human as this is a natural tendency as a human being. However, the robot head can be design in different form and configuration to achieve different purpose. The design and construction of robot head can be classified based on:

a) human-likeness, and
b) technical complexity of the robot head

The construction of robot head can be designed in human-like way or in a more technical head. The advantage of the human-like robot head (anthropomorphic) is that it can perform more realistic facial expression that would help in effective communication between a person and robot. Thus, it will increase the performance of the robot system and to perform a more adequate interaction to improve quality of human life.

On the other hand, a technical robot head (technomorphic) has no restriction on the design specification such as head size and shape. This robot head can be designed with other additional parts to increase the performance of the head. The time to construct a technical head is shorter as it does not cover the mechanical construction of the head in human manner.

The technical complexity is determined by the amount of sensors or actuators used in the mechanical construction of the robot head. The aim of this project is to develop a robot head with 11-DoFs which able to mimic human facial expression in a more natural way. The robot head parts constructed in this project are eyebrows, eyelid, eyeballs, and lips.

2.1.2 Ekman's Facial Action Coding System

Ekman's Facial Action Coding System (FACS) is a psychological knowledge introduced by Paul Ekman for generating facial expression on robot face [8]. Appropriate control regions are selected to generate adequate facial expression. In FACS psychology, Action Units (AUs) represent the movement of the muscle and it was divided into 44 basic components. The action units are formed by the combination of different control points and it is used for producing various facial expressions. The typical six basic expressions recognize in Ekman’s model are joy, sadness, anger, disgust, surprise and fear.

In this project, there are 10 AUs and two fixed units used to generate the six basic facial expressions as shown in Table 2.1 and Table 2.2. In order to perform the motion of these 10 AUs, 17 control points was selected and its direction of movement empirically on the facial skin are shown in Figure 2.1.

Table 2.1: Action unit on robot head

Action Unit	Appearance Changes	Control Point	
		Right	**Left**
A1	Outer brow raiser	C1	C4
A2	Inner brow raiser	C2	C3
A3	Outer brow lowered	C5	C8
A4	Inner brow lowered	C6	C7
A5	Upper lid raiser	C9	C10
A6	Eyeball left-right motion	C11	C12
A7	Eyeball up-down motion	C13	C14
A8	Upper lip raiser	C15	
A9	Lower lip raiser	C16	
A10	Lower lip lowered	C17	

Table 2.2: Fixed point on robot head

Fixed Unit	Position	Fixed Point	
		Right	**Left**
F1	Upper lip corner	C18	C19
F2	Lower lip corner	C20	C21

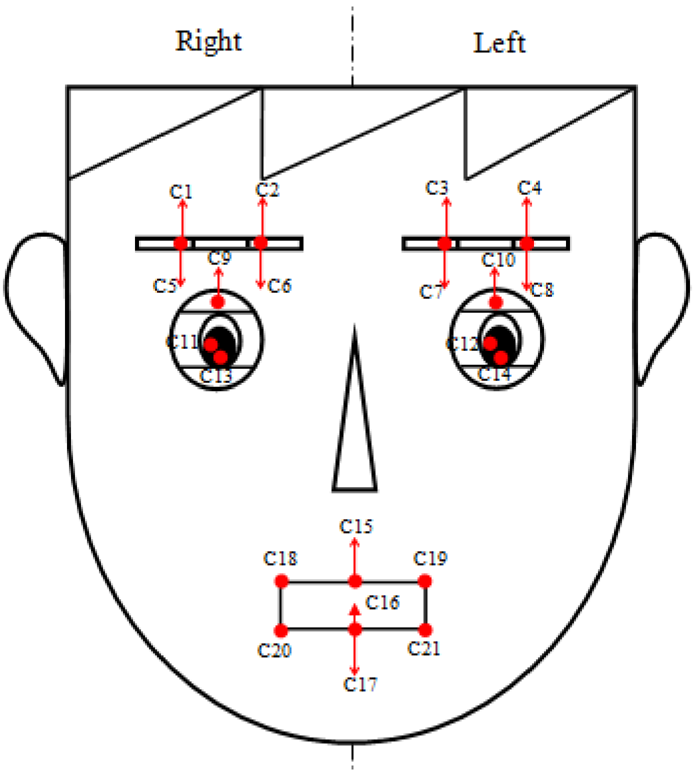
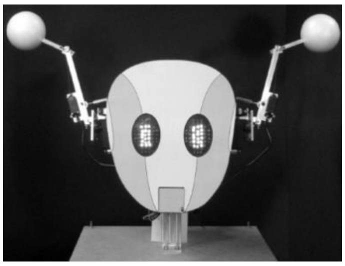


Figure 2.1: The position of control points and its moving direction

2.2 Research and Study

Table 2.3: Review for seven research papers

Element	**Paper 1**[9]	**Paper 2**[10]
Name of Robot	KOBIAN-R	Exaggerating Emotion Expresser
Type of Head	Human-like	Technical (insect character)
Proposed Method	-Include facial color on robot head and facial expression design based on computer graphic (CG) images	-No restriction on robot head design. Include arm-type antennae, emoticon eyes and exaggerating jaw and cheeks to express emotion
Type of Expression	Ekman's 6 basic expression (fear, disgust, joy, anger, surprise, sadness)	Ekman's 6 basic expression (fear, disgust, joy, anger, surprise, sadness)
Degree of Freedom	24-DoFs (8-DoFs for eyebrows, 5-DoFs for eyelids, 3-DoFs for eyes, 7-DoFs for lip, and 1-DoF for jaw)	13-DoFs (6-DoFs for antennae, 3-DoFs for jaw and cheeks, 3-DoFs for neck)
Type of Motor	DC motor & servo motor	DC motor
Type of Mechanism	Eyes-gimbals structure and metal ring turns around low friction PTFE sleeve Eyelids-wire driven mechanism with an ultrasonic motor Eyebrows-metal plate structure and CP driven by magnet through the cover Mouth-jaw joint	Arm-type antennae-lower link operate with two direct driven motor and upper link operate by a wire mechanism from a motor Emoticon eyes-made up of LED array (50 LEDs) and controlled by two FPGA microprocessors
Type of Controller	Computer	Bluetooth communication through computer
Dimension (mm)	150 x 214 x 181	N/A
Weight (kg)	1.7	N/A
Recognition Rate	Happiness – 71.5% Sadness – 73.1% Anger – 92.3% Surprise – 96.2% Fear – 19.2% Disgust – 57.7%	*Survey for the facial expression recognition rates was not conducted*
Design Overview		

Element	**Paper 3**[11]	**Paper 4**[7]	**Paper 5**[12]
Name of Robot	F & H robot	Flobi	SAYA
Type of Head	Human-like	Human-like	Human-like
Proposed Method	-Design and manufacture flexible face film with anti-cracking, anti-aging and anti-fading material -Implement the rope drive mechanism -Include the action of head to emphasize the emotion expression	-Design robot head with "baby face" appearance. -Display secondary emotion with four LEDs -Design hole-free lip with large motion range -Few parts of the robot head (hair, lips and eyebrows) is changeable	-Using McKibben type pneumatic actuators to control displacement of control point in facial skin -Using coil spring as head motion mechanism and implement new neck mechanism
Type of Expression	Ekman's 6 basic expression (fear, disgust, joy, anger, surprise, sadness), neutral and solemnity	5 basic expression (fear, joy, anger, surprise, sadness) and neutral	6 basic expression (fear, joy, anger, surprise, sadness, disgust) and calm
Degree of Freedom	14-DoFs (2-DoFs for eyeballs, 1-DoFs for eyebrow, 2-DoFs for lower jaw, 3-DoFs for neck, 6-DoFs for head)	18-DoFs (3-DoFs for eyes, 2-DoFs for eyebrows, 4-DoFs for eyelids, 3-DoFs for neck, 6-DoFs for mouth)	6-DoFs (2-DoFs for eyeballs, 1-DoFs for chin, 2-DoFs for mechanical frame, 1-DoF for eyelids)
Type of Motor	DC servo motor	DC motor	DC motor
Type of Mechanism	Face-non-metal rope drive mechanism	Individual part combined and attached to the core by using magnet	Facial skin-McKibben type pneumatic actuators Mechanical frame-oculomotor mechanism Neck-coil spring mechanism
Type of Controller	Computer and Intelligent Drive & Control Unit (IDCU)	AtmelXMega64 microprocessor and computer	Computer
Dimension (mm)	N/A	N/A	115 x 200 x 155
Weight (kg)	N/A	2.4	1.5
Recognition Rate	*Survey for the facial expression recognition rates was not conducted*	Happiness -83.3% Sadness -99.2% Anger –81.2% Surprise -54.5% Fear –33.4%	Happiness – 100% Sadness – 93% Anger – 86% Surprise – 100% Fear – 93% Disgust – 86%
Design Overview			

Element	**Paper 6**[13]	**Paper 7**[14]
Name of Robot	UKL Head	i-RoK
Type of Head	Human-like	Human-like
Proposed Method	-Simulate the silicon skin of the head and implement Ekman's action unit facial expression -Reduced the number of actuators and obtained trajectories in the emotion space -Implement face detection function on robot head	-Consider the general dimension of human head to design an anthropomorphic robotic head -Reduction of robot head weight for power consumption -Using rapid prototyping as manufacturing technique for robot head
Type of Expression	Ekman's 6 basic expression (fear, disgust, joy, anger, surprise, sadness) and neutral	N/A
Degree of Freedom	N/A	8-DoFs (4-DoFs for neck, 3-DoFs or eye, 1-DoFs for lower jaw)
Type of Motor	DC motor & servo motor	RC servo motor and DC servo motor
Type of Mechanism	Face-wire mechanism driven by servo motor	-
Type of Controller	Computer	N/A
Dimension (mm)	N/A	151 x 187 x 187
Weight (kg)	N/A	4
Recognition Rate	N/A	N/A
Design Overview		

2.3 Summary of Review

Table 2.4: Advantages and disadvantages on seven research papers

	Advantages	Disadvantages
Paper 1 [9]	Recognition rates for each emotion (except fear emotion) were improved by 25% in average compare to Kobian robot. Small and light for mounted on bipedal walking robot.	The recognition rate of fear emotion is too low (19.2%).
Paper 2 [10]	Exaggerative motion improved the effectiveness of facial expression. More efficiently invoke a human emotional response. Useful in entertainment industry.	Unrealistic facial expressions decrease the performance of the system support human-robot interaction. No facial emotion recognition test was conducted.
Paper 3 [11]	High similarity of human face skin structure improves the accuracy of facial expression.	Facial expression performance of the robot head is low as the mechanism drive control with only 14-DoFs. No facial emotion recognition test was conducted.
Paper 4 [7]	Appearance of robot is friendly and widely accepted. It able to expresssecondary emotion more efficiently (e.g.: shame with red cheek).More natural expression is available through construction of hole-free lips. Appearance of the robot head is changeable to satisfied different condition.	Disgust expression is not available.
Paper 5 [12]	High similarities of the movement of human-like head motion are achieved.	Limited movable range of the head motion. The amount of respondents for the recognition rate test is less and the accuracy of the data is low.
Paper 6 [13]	The real time method for image based face detection provide basic ability for human-robot interaction	Unfamiliar robot head design
Paper 7 [14]	The major dimension and weight of human head is take into account for the design had made the appearance of robot head more human-like	Only neck and eye region construction. No emotional expression available.