Facial Mechatronics of a Humanoid Social Robot

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ABSTRACT – The emergence of studies on man-machine cognitive interaction has created humanoids that are indistinguishable from real humans. This study marks the initial step towards developing the first socially interactive robot with Malay features. The robot appears as a young adult Malay male and able to express three basic facial expressions i.e. neutral, happy, and surprised. The control points on the robot's facial skin will be attached to servomotors to create motions on the robot's face. Currently in development stage, this robot will use seven Action Units (AUs) to realize human-like emotional expressions. From the initial sketch analysis, 7 AUs are sufficient. Apart from AUs, its neck has 2DoF for nodding and turning. This robot is able to move around its neck to face the talking partner and engage in conversation.

1. INTRODUCTION

Humanoids remain as the most complex and sophisticated type of robot that consists of electrical and mechanical components and sensors to mimic several functions or responses based on human body architectures and thinking. Building a humanoid robot is the challenge par excellence for researchers in artificial intelligence and robotics. For effective interaction between a humanoid and human to take place, facial expression is an important feature to consider in designing an expressive robot.

This study develops the first version of Malaysia's very own locally developed facial humanoid robot based on three robot technologies: mobility, dexterity and social (MDS). MDS is a term representing a new class of robots being developed at MIT's Media Lab [1]. MDS supports research goals in human-robot interaction, teaming and social learning. Current research developments in Malaysia signals that now is the practical time for this nation to develop its own humanoid technology. Though advanced humanoids like Sophia [2], Nadine [3] and Erica [4] have been developed worldwide, related technologies for example facial robot mechatronics, skin technology, artificial intelligence for human-robot interaction and Malay language dialogue engine are still scarce in Malaysia. Thus, this study shall pioneer and groom its own engineering talents in developing a social robot with Malay features based on its facial outlook, expressions, speech and gestures.

A social robot, defined in [5]; is 'to behave in a manner a physical entity embodied in a complex, dynamic, and social environment sufficiently empowered conducive to its own goals and those of its community'. A robotic head that provides facial expression similar to human requires a mechanical skeleton supporting artificial facial musculature that is able to pull and exert their effects on an artificial skin. Thus, the skin for robotic head must be flexible and exhibit a deformation profile similar to the human skin. Also, the skin need to adopt Malay features and skin tones. To achieve a robot head that able to mimic the identified facial expression, the appearance of the robot head must be convincing and realistic.

2. METHODOLOGY

The main objective of this study is to design, fabricate and build a robot head and neck mechanism to express three main expressions: neutral, happy, and surprised. In the preliminary stage, Daz3D 4.0 software produces the 3D modelling of the robot's facial motion capture (mocap), F-clone Ver. 1.2 animates each facial expressions and CATIA V5 produces the detailed conceptual design. These simulations are vital to demonstrate the effectiveness of the robot head to deliver its emotion. Following Ekman's Facial Coding System (FACS) [6], appropriate control regions are selected to generate sufficient facial expressions. In FACS, 44 Action Units (AUs) represent the movement of the facial muscles. A combination of Control Points (CPs) forms each AU. Apart of the computer simulations, sketching is also used to determine sufficient number of AUs to be activated during the human emotion realizations.

The measurements for the robot head and its part should comply with the anthropometric measurements

of human face. It is also important to ensure that the anthropometry measurements used are of a Malay male age between 30-35 years old.

3. METHODOLOGY

Figure 1 shows the three facial expressions modelled using Daz Studio software. Figure 2 shows the conceptual CAD design of the robot head using CATIA V5. For this study, seven AUs are sufficient to realize the three human expressions. It was identified through initial sketch analysis. Figure 3 shows one of the sketching results. For neutral face, none of the AUs were triggered. Meanwhile, to express a happy face, four AUs were triggered i.e. Cheek Raiser, Lip Corner Puller, Lips Apart and Jaw Drop. Four different AUs were needed to express surprised, i.e. Inner and Outer Brow Raiser, Upper Eye Lid Raiser and Jaw Drop. During conversation, the robot needs to turn, nod and move its head to face its talking partner. It also uses its eyes to make 'eye contact' with its talking partner to create human-like interaction. A 2 DoF mechanism seems viable and sufficient for neck design.

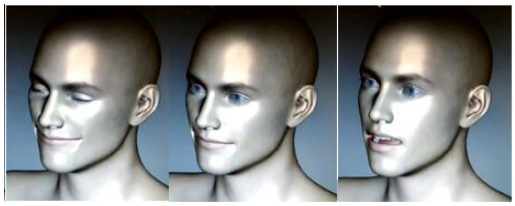

Figure 1: Expressions modelled using Daz Studio 4.10 software (from left: happy, neutral and surprised)

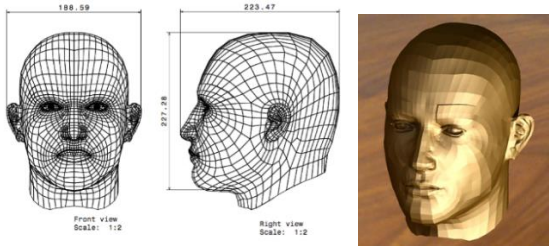

Figure 2: Conceptual CAD design using CATIA V5

IMAGE of A NEUTRAL FACE	NEUTRAL - Expression 1	HAPPY - Expression 2	SURPRISED – Expression 3
			
ACTION UNIT (AU)	**ACTUATION SIGNAL TO AU**		
Inner Brow Raiser	OFF	OFF	ON
Outer Brow Raiser	OFF	OFF	ON
Cheek Raiser	OFF	ON	OFF
Upper Eye Lid Raiser	OFF	OFF	ON
Lip Corner Puller	OFF	ON	OFF
Lips Apart	OFF	ON	OFF
Jaw Drop	OFF	ON	ON

Figure 3: Sketch results with seven AUs

4. CONCLUSION

For the initial development of this facial robot, seven AUs will be used accordingly to produce humanlike expressions. Three types of human expression i.e. neutral, happy and sad will be scope of this project. Motor energy consumption are vital in the neck design. For example, a 2DoF neck body actuated by a system of three motors pulling three tendons for roll and pitch rotations is proposed in [8]. The mechanism allows stiffness control, however it requires pulling the motor all the time to keep the neck in a stiff position. This might lead to higher energy consumption. The current technology using electromagnetic actuators are unable to meet the requirement of space limitation and at the same time provide high displacement and force [9]. Regardless of motor type, a 2 DoF mechanism is sufficient to turn, move and nod the robot's head.

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