Facial Expression Simulator Control System using OpenGL Graphical Simulator

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Abstract

Verbal communication is communication that uses the language or voice interaction, whereas nonverbal communication is communication that interacts with one of these gestures is to show facial expressions. We propose of the implementation of controls based on the facial expressions of human face. Based on obtained the information expression then translated into a device simulator using the OpenGL graphics software as an indication tool and easy for analyzing the emotional character of a person through a computer device. In the implementation of the face was found that the mechanism of the humanoid robot head in nonverbal interaction has 8 DOF (Degree of Freedom) from the various combinations between the drive motor servo eyebrows, eyes, eyelids, and mouth in order to show the anger, disgust, happiness, surprise, sadness, and fear facial expression.
Keywords: Humanoid Robot, OpenGL, Facial Expression.

1. Introduction

Computer vision system is one of the newest approaches for human computer interaction. One of the application is it can be used to recognize face of a human with its features, hence, it also can be developed to recognize a human facial expression. Robot is a mechanical device that can perform physical tasks, under the supervision and control of human, or use a program that has been defined previously. Communication is owned by the human there are two kinds of communication are verbal and nonverbal.

The robot is a mechanical device that can perform physical tasks, whether using supervision and under human control, or use a program that has been defined first (artificial intelligence). Robots are typically used for heavy duty, hazardous and repetitive jobs. Usually most of the industrial robots used in manufacturing [1].

Humanoid is a term formed from the Latin meaning *Humanus* is human and Greece-*oeides* which means similarity of expression. This term is mentioned in 1918 to refer to the fossils that are considered close to the human species but it is not human, including species that are classified as *Homo* such as *Neanderthals* [2].

Asimo has the ability to recognize faces, even when Asimo or the human is moving. Individually Asimo can recognize about 10 different faces and recognize facial owner's name if already registered previously [3].

To support the development of facial recognition technology to the Asimo (humanoid robot), then one of them is using facial expressions as communication which is owned by humans. As we all know there are two ways of human communication is done by verbal and nonverbal communication. Verbal communication is communication using language or words and sounds in their interaction. Nonverbal communication is the communication process in which the message conveyed is not to use words. Examples of nonverbal communication is to use gestures, body language, facial expressions and eye contact, use of objects such as clothing, haircuts, and so on, of symbols, as well as how to talk like intonation, emphasis, voice quality, emotional style, and style of speaking.

The experts in the field of nonverbal communication usually uses the definition of "not using the word" strictly, and do not equate non-verbal communication with non-verbal communication. For example, sign language and writing are not considered as non-verbal communication because it uses the word, while intonation and speaking style classified as nonverbal communication. Nonverbal communication is also different from the unconscious communication, which can be either verbal or nonverbal communication. Verbal communication is above 60% of nonverbal communication by humans [4]. Facial expression is a very important emotional communication in human interaction with robots, as well as expression between human and human.

2. Previous Works

Humanoid robot is a robot created by mimicking the appearance of human form or mimic parts of human body. This allows a more human interaction with humans. In general humanoid robots have a body, two arms, two legs, and head. Androids are humanoid robots built to resemble humans, as well as the robot "Doldori" made in Korea is able to express human-like facial expression. Facial expression is a method of emotional expressions made by humans to recognize the emotional robot [5]. Facial expression on a humanoid robot has 6 different expressions of anger, disgust, surprise, happiness, sadness, and fear [6].

2.1. OpenGL Graphics Modeling

To adopt the form of modeling the head of a cartoon head. System of mechanisms such as eyes, eyebrows, and mouth in the form of animation limited because the mechanism of facial expression system possessed by humans is very complex. Thus, in this study provide constraints in terms of facial expression mechanism.

Shape model of the head in a simulator using the model as shown in figure 1. In this model there are two coordinate axes. To coordinate the green is situated in the middle of a global coordinate, while the coordinates of which are orange on the two eyebrows as local coordinates. For local coordinates on the eyebrows are used to process images from the coordinate transformation into the rotation. While the global coordinates are used to determine the coordinates of the image as a whole.

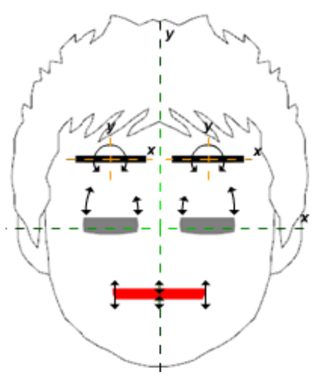

Figure 1: Head Shape Model

2.2. Coordinate System

Image coordinate system used is the 2D coordinate system (2 dimensions), namely x and y axis. The basic elements of computer graphics in 2D has a value (x, y). Another basic element is a 2D vector which has 3 elements:

$$v[1] = x \quad (1)$$

$$v[2] = y \quad (2)$$

$$v[3] = 1 \quad (3)$$

To build a complex object can be done using a mathematical equation $y = f(x)$ can be described as a curve with a variation of sine, cosine, exponential, and logarithmic or joint function. Forms of mathematical equations that are made are mathematical equation using polar coordinate system as follows:

$$r = f(\theta) \quad (4)$$

$$x = r\cos(\theta) \quad (5)$$

$$y = r\sin(\theta) \quad (6)$$

Symbols θ is the angle that runs from 0 to 360 degrees which is expressed in radians (0 hingga 2π). Various kinds of $r = f(\theta)$ can produce a varied picture.

2.3. Two Dimension Transformation

In 2D there are some structural transformations that must be made in advance of 2D point data structure. The changes in the structure of 2D point data used for drawing objects to the computer screen. While the basic structure of the vector used to transform the object. Things to do is change the structure of the data point to a vector data structure, calculating a transformation, changing the structure of vector data to point data structure, and the last is a drawing object. This transformation process will provide an animated effect on the simulations that will be created.

2.3.1.Translation

Translation is the process of moving an object from point P to point P 'is linear. In the translation parameters required to transfer to the axis, or can be written with matrix models:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} dx \\ dy \end{bmatrix} \quad (7)$$

Translation process by using the definition of 2D vector can be written:

$$\begin{bmatrix} \widehat{v_1} \\ \widehat{v_2} \\ \widehat{v_3} \end{bmatrix} = \begin{bmatrix} 1 & 0 & d_x \\ 0 & 1 & d_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} \quad (8)$$

Matrix transformations of translation, namely:

$$\begin{bmatrix} 1 & 0 & d_x \\ 0 & 1 & d_y \\ 0 & 0 & 1 \end{bmatrix} \quad (9)$$

2.3.2. Scaling

Scaling is a moving object from point P to point P ', where the distance point P' is m times the point P that can be formulated:

$$x' = m_x x \quad (10)$$

$$y' = m_y y \quad (11)$$

The process of scale by using the definition of 2D vector can be written by:

$$\begin{bmatrix} \widehat{v_1} \\ \widehat{v_2} \\ \widehat{v_3} \end{bmatrix} = \begin{bmatrix} m_x & 0 & 0 \\ 0 & m_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} \quad (12)$$

Matrix Transformation of the scale is:

$$\begin{bmatrix} m_x & 0 & 0 \\ 0 & m_y & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (13)$$

2.3.3. Rotation

Rotation is the movement of an object from point P (x, y) to point P '(x', y ') in the form of displacement axis rotating at the desired angle. For more details on the calculation of the rotation process can be formulated as follows:

$$x' = x\cos(\theta) - y\sin(\theta) \quad (14)$$

$$y' = x\sin(\theta) + y\cos(\theta) \quad (15)$$

The process of rotation by using the definition of 2D vector can write follows as:

$$\begin{bmatrix} \widehat{v_1} \\ \widehat{v_2} \\ \widehat{v_3} \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} \quad (16)$$

Transformation matrix of rotation, namely:

$$\begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (17)$$

2.4. Matrix Multiplication

In the transformation of the position, in addition to providing the functions for the transformation matrix is also needed some treatment, such as the sum of matrices and matrix multiplication. Matrix multiplication is an important time of the operational transformation. Matrix multiplication is used for operations resulting transformation matrix.

2.4.1. Matrix Multiplication with the Matrix

Matrix multiplication is used for operations resulting transformation matrix.

$$c_{ij} = \sum_{k=0}^{2} a_{ik}\, b_{kj} \quad (18)$$

There i and j values from 0 to 2.

2.4.2. Matrix Multiplication with the Vector

Matrix multiplication is used for operational transformation so as to produce a new vector of the transformed object point.

$$c_i = \sum_{k=0}^{2} a_{ik}\, b_k \quad (19)$$

There the value of i is from 0 to 2.

3. Control System Simulator of Facial Expression

Control system used in this simulator is an open loop control. The process initially starts from the collection of human facial expression information data through a camera image processing. Then the information of the image processing is processed using the OpenCV (Open Source Computer Vision Library) by Neural Network method. Results of processing image data sent to the simulator control system via RS-232 to display a virtual human facial expression. Furthermore, the data is received via the RS-232 by the robot mechanism of the electronic device microcontroller.

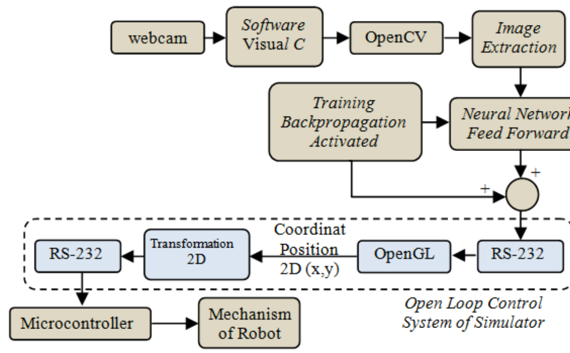

Figure 5: Control System Facial Expression Simulator

As for the simulator control system itself that is the first time reading the data obtained from image processing of facial expressions via webcam. The result of data processing was then sent to OpenGL for processing into the simulation graphical form by drawing a shape coordinates the movement through a process of transformation of 2D animation. When the data obtained shows the expected data in the form of expression, it would appear the expressions of someone in the form of cartoons and then the data is translated into the microcontroller to move the robot mechanism.

The result of this is contained in the simulated robot with a physical robot can be monitored and observed its expression by a human through the simulator. So the expression data shown in the robot can be analyzed properly.

4. Experimental Results

The analysis is based on testing the performance of simulators such as facial expression test by giving the value of the variable expression of a few people through a webcam. Some expressions are evaluated parameters include the value of facial expression anger, disgust, happiness, surprise, sadness, and fear of the percentage of one's emotional expression.

In the experiment this time to prove the performance of the simulator is able to work in real-time OpenGL and whether the data can be received well or not. The following table 1 is the result of data from multiple testing of the simulator.

Table 1: Data Retrieval Facial Expressions

Facial Expressions	Output Data Camera (100%)	Input Data Simulator (100%)	Error (100%)
Anger	26,8	26	0,8
	8,8	8	0,8
	12,6	12	0,6
	44,0	44	0,0

	62,9	62	0,9
	67,4	67	0,4
Disgust	33,8	33	0,8
	0,3	0	0,3
	6,8	6	0,8
	70,3	70	0,3
	1,0	1	0,0
	93,7	93	0,7
Surprise	3,1	3	0,1
	2,4	2	0,4
	8,6	8	0,6
	0,1	0	0,1
	1,7	7	0,7
	0,9	1	0,9
Happiness	0,5	0	0,5
	2,4	2	0,4
	2,4	2	0,4
	7,5	7	0,5
	0,8	0	0,8
	17,2	17	0,2
Sadness	62,9	62	0.9
	0.9	0	0.9
	95,0	0	0,5
	84,7	84	0,7
	44,8	44	0,8
	67,5	67	0,5
Fear	0.3	0	0,0
	1,2	1	0,2
	71,9	71	0,9
	2,3	2	0,3
	6,5	6	0,5
	1,8	1	0,8

The results of this data collection can be seen that the process data from the webcam to OpenGL simulator results can be well received. While the picture response simulation of facial expressions displayed on the screen simulator with the data received cannot be followed in real time, so that the animated images that appear approximately between 0.5 to 1 second.

A graphic result of the expressions of OpenGL that is displayed on the simulator consists of 6 facial expressions such as anger, disgust, happiness, surprise, sadness, and fear. This facial expression shows the percentage of one's emotional value in the form of a virtual 2D animation with 20 intervals from the smallest which is 20% up to a maximum percentage value emotional of 100%. Here are six forms of facial expression seen in the simulator is shown in Table 2.

From the observation on the simulator OpenGL on facial expression analysis can be taken a graph, where the appropriate expression between the expression of anger, disgust, happiness, surprise, sadness, and fear that figure 6 is as follows:

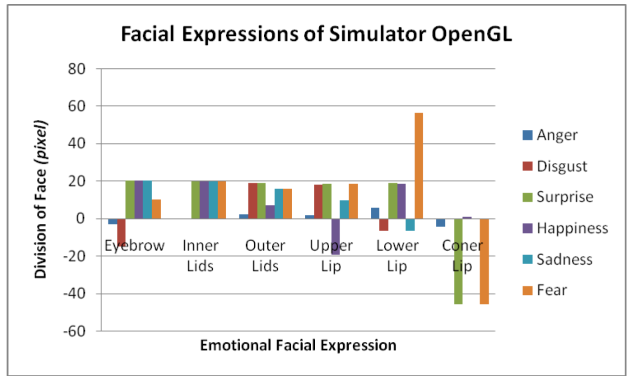

Figure 6: Facial Expressions Graph 6 on the Simulator

After the measurement of facial expression analysis based on the results of someone's face the computer graphic images obtained by the maximum value, we then conducted tests on several parameters of a person's character to get the reading of emotional facial expressions that appear in the simulator. The results of facial expressions on OpenGL simulator shown in table 3.

5. Conclusion

Based on the simulator program has been created and the results of the analysis has been done on measuring the performance of facial expression determination occurs in a variety of emotional person, so in this research can be drawn some conclusions. The results simulator for one's facial expressions and implemented into the robot otherwise have succeeded. Data acquisition emotional facial expressions from image processing to the simulator through a virtual communication serial delayed a few seconds. Value of the percentage reading of emotional facial expressions has a different value on each person's face.

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Table 2: The Experimental Result of Facial Expression Simulator

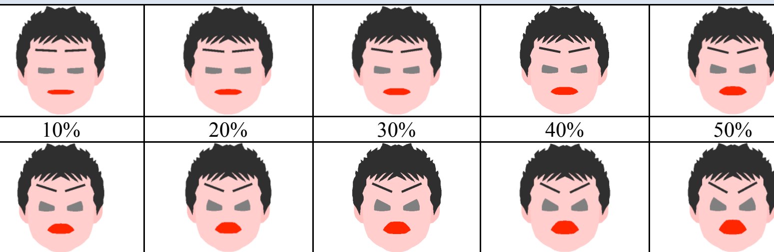
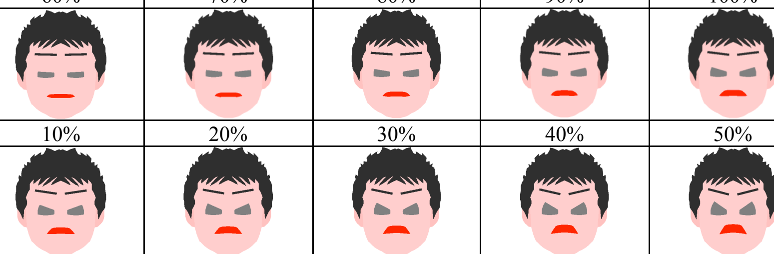
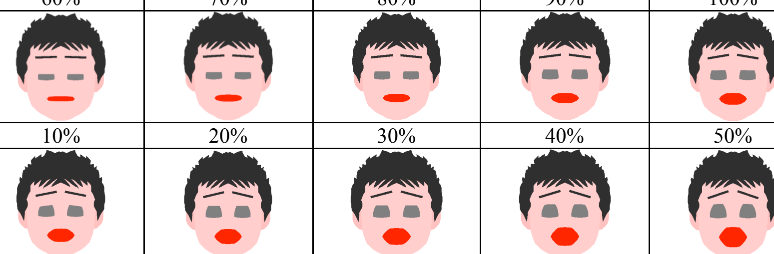
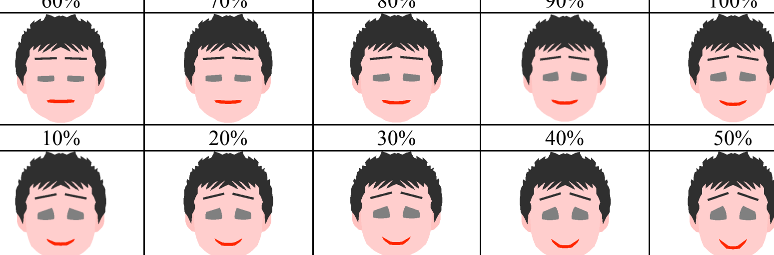
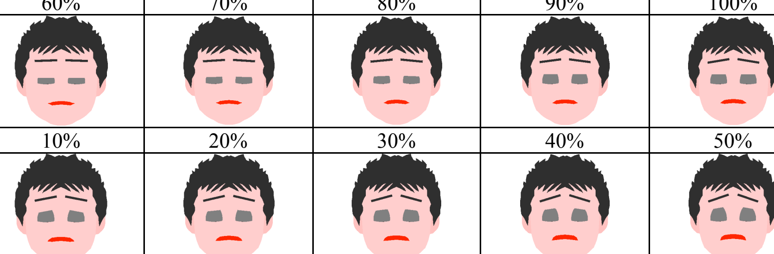
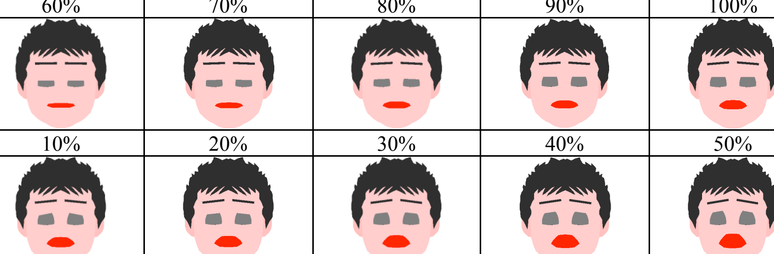
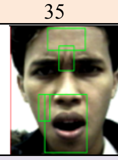
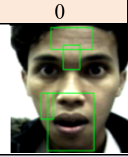
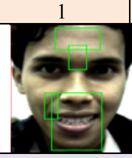
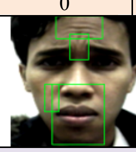
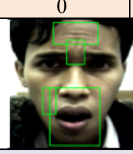
Facial Expression	Percentage				
Anger					
	10%	20%	30%	40%	50%
	60%	70%	80%	90%	100%
Disgust					
	10%	20%	30%	40%	50%
	60%	70%	80%	90%	100%
Surprise					
	10%	20%	30%	40%	50%
	60%	70%	80%	90%	100%
Happiness					
	10%	20%	30%	40%	50%
	60%	70%	80%	90%	100%
Sadness					
	10%	20%	30%	40%	50%
	60%	70%	80%	90%	100%
Fear					
	10%	20%	30%	40%	50%
	60%	70%	80%	90%	100%

Table 3: Facial Expressions Test Data Simulator

Examination	Data Emotional Facial Expressions					
	Anger	Digust	Surprise	Happiness	Sadness	Fear
1	Delivery of Data Output from the Process Image Processing					
	73.0	0.4	0.0	2.0	0.7	0.2
	Retrieving Data Through the Input Simulator OpenGL					
	73	0	0	2	0	0
						
	Image Processing			OpenGL Simulator		
2	Delivery of Data Output from the Process Image Processing					
	18.9	35.7	0.0	0.2	0.2	2.0
	Retrieving Data Through the Input Simulator OpenGL					
	18	35	0	0	0	2
						
	Image Processing			OpenGL Simulator		
3	Delivery of Data Output from the Process Image Processing					
	0.0	0,0	42.4	0.2	0.1	0.8
	Retrieving Data Through the Input Simulator OpenGL					
	0	0	42	0	0	0
						
	Image Processing			OpenGL Simulator		
4	Delivery of Data Output from the Process Image Processing					
	1.6	1.5	0.1	83.6	0.0	0.0
	Retrieving Data Through the Input Simulator OpenGL					
	1	1	0	83	0	0
						
	Image Processing			OpenGL Simulator		
5	Delivery of Data Output from the Process Image Processing					
	0.0	0.0	7.9	0.1	32.4	1.0
	Retrieving Data Through the Input Simulator OpenGL					
	0	0	7	0	32	1
						
	Image Processing			OpenGL Simulator		
6	Delivery of Data Output from the Process Image Processing					
	0.0	0.0	0.2	0.0	20.0	52.7
	Retrieving Data Through the Input Simulator OpenGL					
	0	0	0	0	20	52
						
	Image Processing			OpenGL Simulator		