Communicating Simulated Emotional States of Robots by Expressive Movements

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Abstract. This research focuses on the non-verbal communication of non-android robots by comparing the results produced by three different emotional models: Russell's circumplex model of affect, Tellegen-Watson-Clark model and PAD scale. The relationship between the motion of the robot and the perceived emotion is developed. The motion parameters such as velocity and acceleration are changed systematically to observe the change in the perception of affect. The embodiment is programmed to adopt the smooth human motion profile of the robot in contrast to the traditional trapezoidal velocity profile. From the results produced it can be concluded that the emotions perceived by the user is the same on all three scales, validating the reliability of all the three emotional scale models and also of the emotions perceived by the user. Moreover the selected motion parameters of velocity and acceleration are linked with the change of perceived emotions.

Keywords: Nonverbal communication, Human-robot interaction, Perceived emotion, Smooth spline motion, Affective robots, Social robotics

1 Introduction

Increasingly, research is focusing on techniques whereby robots can work together with humans in order to carry out tasks [1]. The safety and effectiveness of cooperation may be enhanced by the human understanding the robot's behavior and being able to anticipate what the robot will do next. It is natural for people to perceive motion in terms of emotional behavior [2]. Nonverbal communication through motion itself contains a lot of information about the physical state and the intentions of robots [3]. The central focus of this research is to develop low level programming of movement trajectories to represent a simulated emotional state of the robot. Three gestures were programmed and were compared using three different emotional models that are discussed in this paper. The key aspect of the experiment is that the robotic embodiment used does not have significant anthropomorphic or zoomorphic features. The embodiment is programmed to adopt a smooth motion profile based on human movement characteristics, unlike the traditional trapezoidal motion used in industry which looks "unnatural" [4].

adfa, p. 1, 2011.

2 Modeling Machine Emotions

The perception of emotions is very subjective. There are many different models that are available for categorizing the emotions of the machine by the user. The detailed study for these models can be found in [5] and [6]. Three different models of affective emotional experiences used for visualizing the emotions are: Russell's circumplex model of affect, the Tellegen-Watson-Clark model and the PAD scale. The first two models represent emotions in 2D space. The last scale used added the third dimension for measuring the perceived emotion [7]. The perceived emotion for the same robotic motion is measured by all the three scales to approve the validity of the user's perception of emotions as well as testing the reliability of all the scales used.

3 Robot Platform and Software

The robotic embodiment used for this research is a 5 degree of freedom arm made by IGUS©, as shown in Fig. 1. This platform was chosen because it allowed low-level control of the motor trajectory which was implemented using National Instruments LabVIEW running on a PC and a real-time hardware platform, cRIO 9074 with 5 stepper drive modules (9501).

4 Selection of Gestures and Features that Affect Emotions

Three different gestures were used for observing the emotional states of the robot: basic point-to-point motion, waving of the robotic arm and "bowing down to welcome". The motion parameters used to show the change in emotional state were velocity and acceleration. Changing these parameters, the robot changed its speed, trajectory, time taken to reach same point and curvature [3]. Thus these two features appeared to be relevant for the perception of the emotional state. The choice for the values of velocity and acceleration were a subjective decision bearing in mind the limitations of the robot hardware. The set of values for acceleration and velocity in arbitrary units corresponding to three different gestures are shown below in Fig. 2.

Fig. 1. IGUS© Robotic arm used for expressing emotions

Gesture: 1 Point-point motion	
Velocity	Acceleration
250	10
800	50
2000	300

Gesture:2 Waving of robotic arm	
Velocity	Acceleration
100	15
100	5
100	1.5

Gesture:3 Bowing of robotic arm	
Velocity	Acceleration
30	30
50	50
100	100

Fig. 2. Set of values used for all three gestures (arbitrary units)

5 Recognition of Emotions

Russell's and Tellegen-Watson-Clark model for measuring emotions are divided into four quadrants based upon the range of emotions. The third scale PAD is divided into three ranges to measures the overall perceived effect of emotion. Moreover pleasure, arousal and dominance are also measured individually at three different levels of low, medium and high.

6 Methodology

The 18 participants who took part in the study were shown the three variations of each of the three motions and were asked to mark on each of the model graphs the characteristic they perceived. Examples are show in Figure 3.

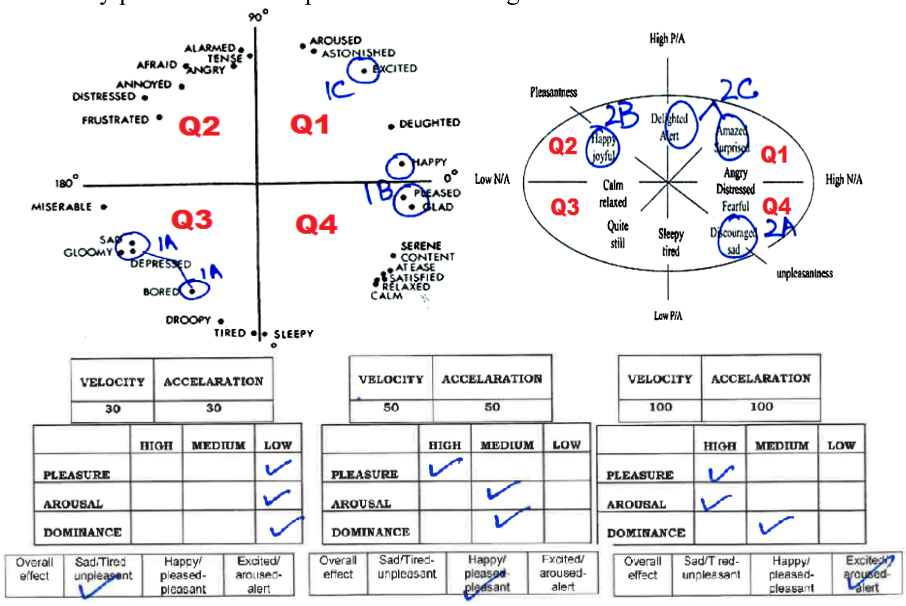

Fig. 3. Sample of marked questionnaires by the participants for all three scales

7 Results

7.1 Low velocity and low acceleration

For point-to-point motion at low values of acceleration and velocity, 95%, 83% and 100% of people perceived the emotion as sad, unhappy or tired according to Russell's, Tellegen-Watson-Clark and PAD model respectively. Similarly for waving of robot 83%, 83% and 95% of participants marked the motion as same for the three scales respectively. The same holds true for bowing gesture i.e. 83%, 72% and 100% of people marked same emotions for all three scales respectively.

7.2 Medium velocity and medium acceleration

At medium values of acceleration and velocity, the majority of subjects observing the point-to-point motion i.e. 39%, 61% and 61% of people according to Russell's, Tellegen-Watson-Clark and PAD model respectively, marked the emotions as happy, pleased or calm. Similarly for the waving gesture, 39%, 61% and 78% of participants marked the same perceived emotion for all the three scales respectively. The results were similar for the bowing gesture i.e. 83%, 72% and 100% of people marked same emotions for all three scales respectively.

7.3 High velocity and high acceleration

When the values of acceleration and velocity were raised, it was found that for point-to-point motion 67%, 50% and 67% of participants according to Russell's, Tellegen-Watson-Clark and PAD model respectively marked the emotions as excited, alert, aroused or surprised. Similarly for waving of robot 72%, 67% and 78% of participants marked the motion as same for the three scales respectively. The results are similar for the bowing gesture i.e. 61% of people according to all three scales marked the same perceived emotion.

8 Discussion of results

From the results, it can be seen that the selected motion parameters of velocity and acceleration are linked with the change in the perceived emotions. According to each model for all the three gestures i.e. point-to-point motion, waving of the robotic arm and bowing down to welcome, the majority of the participants perceived the motion to be sad, unhappy or tired if the velocity and acceleration were low. As the acceleration and velocity increased, the perceived emotion changed to happy and then excited.

9 Conclusion

A link was developed between the change in user perception of emotions and the variation of the motion parameters of velocity and acceleration [8]. Moreover, a robotic embodiment without any android features was capable of conveying emotions to the user. The robot's velocity profile at five different joints closely resembled the human arm trajectory profile as shown by curves obtained by LabVIEW in Fig.4, Fig.5 and Fig.6. For sad/unpleasant emotions the spline is distributed on the graph, for pleasant/happy emotion it is contracted with an increase in amplitude and for excited/alert emotion, amplitude is high and the splines have shown contraction on the graph**.** This profile can be compared with the velocity profile trajectories produced by human arm [10].

It was observed that the audible noise produced by the robot changed with change of emotional behavior. Research (e.g. [9]) has shown that sound is connected to emotional expression. When the robot was perceived to be sad or unhappy the noise associated with it was very low. However as the perceived emotion changed from sad to happy and then to excited as the noise associated with robotic embodiment increased.

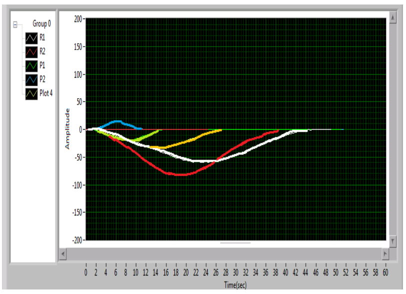

Fig.4. Splines at V=25

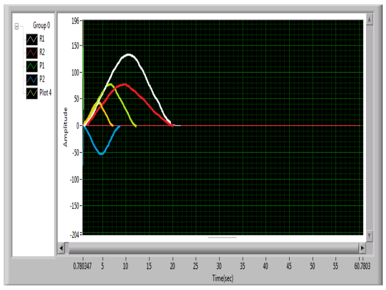

Fig.5. Splines at V=800

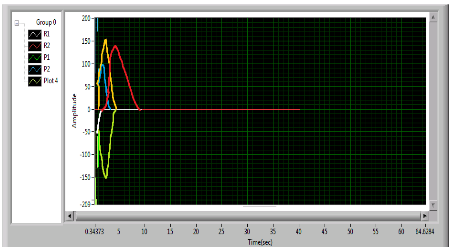

Fig.6. Splines at V=2000

10 Limitations and Future Work

It is important to highlight that the gestures were deliberately selected to be expressive. However it was important from the aspect of developing a movement that should be expressive and communicative to the user [11]. This might have had an effect on the results found in this research.

Another potential bias associated with this robotic embodiment is the noise that it makes during its motion (the sound from the stepper motors). This might help the user to identify the perceived emotions.

The experiments performed for this research were preliminary. Clearly, more detailed and varied experiments should be carried out. For instance, comparing the spline motion with the traditional trapezoidal trajectory generation or by repeating the experiments with more gestures and emotions. Moreover, this research could be performed on an anthropomorphic robot to see if the perception of emotions differs according to the type of robot.

This research into the emotional behavior of the robot gives rise to several questions that remain to be answered e.g. in the field of care and medication, is slow motion perceived as a sad gesture or a careful gesture by the patient? For industrial purposes can these emotional robots have the same efficiency and productivity rate as the ones used now?

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