Toward Emotion Recognition Embodied in Social Robots: Implementation of Laban Movement Analysis into NAO Robot

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Abstract:
This research note focuses on human recognition of emotions embodied in a moving humanoid NAO robot. Emotional movements emulated on NAO intended to induce joy or sadness were presented to participants whose facial expressions were recorded and analysed with a Noldus FaceReader. Our preliminary results indicate reliable emotion recognition using the Laban choreographic approach in modelling robot's affective gestures.

Keywords: *social robot, Laban movement analysis, artificial emotions, FaceReader*

1. Introduction

Recently, a number of robotics applications has become more and more widely used in real-life interactions. In the past, robots were mainly employed in manufacturing, but nowadays robots are used in education, health care, entertainment, communication or collaborative team-work [3]. At present, also a paradigm of embodied cognition is widely explored in robotics to design and implement effective HRI (Human-Robot Interaction). According to this theoretical framework, cognitive and affective processes are mediated by perceptual and motoric states of the body [3].

Some authors [8] also emphasise that non-verbal affective behaviours implemented in a humanoid robot such as NAO [9] are treated as important cues for human observers to recognise affective internal states of the robot and judge its personality. For instance, a novel robotics software designed to NAO [8] already implements dispositional or affective features of this robot tailoring its traits, moods, emotions or even attitudes toward human subject. A similar approach is considered in terms of developing child-robot interaction [2]. These authors focus on providing the humanoid NAO robot with the capacity to express emotions by its body postures and head position in order to convey emotions effectively [2]. Another approach to enhance the HRI interaction capacity of NAO combines its communicative behaviour with non-verbal gestures through the movements of hand and head as well as gaze orienting [6]. Some studies identified also a fixed set of non-verbal gestures of NAO that were used for enhancing their presentations and turn-management capability of NAO in the conversational interactions. In fact, the emotional expressions set for NAO has become a standard [2] successively employed in several applications, for instance, in designing a more complicated model of emotion expression in humanoid robots [10]. This model of robot's emotion involves components of arousal and valence, which are affected by ongoing emotional states of the partner in social interaction game with the NAO robot who expresses emotion states through its voice, posture, whole body poses, eye colours and gestures.

There are also several studies that aim at endowing the robot with ability to recognise and interpret human affective gestures, see for instance [1,5]. Some research shows that quantitative movement parameters can be matched to emotional states embodied in the agent (human or robot) with a Laban Movement Analysis (LMA) [1]. The work based on LMA [5] uses a parallel real time framework in the robotic system for recognition of emotions based on video clips of human movements. In particular, the authors argue that LMA analysis can serve as a tool for implementing common emotional language in terms of expressing and interpreting movements of the HRI and resemble in that way coding principles between action and perception of human. In fact, several works on recognition of expressive gestures in robots [1,5] rely on LMA to a large degree.

There is little known on using LMA in terms of recognition human affective states triggered by expressive gestures of the robot [2, 6, 8, 10]. Some authors [10] suggest to use professional software (e.g. Noldus FaceReader [7]) to monitor basic emotions of a human triggered by robot's movements, but none of mentioned works have employed this measurement technique. To the best of our knowledge, there is no ready implementation of complete and comprehensive analysis of emotional expression emulated on the NAO robot or a similar humanoid robot in real-life interactions. Thus, the idea of our research was to examine effectiveness of the Noldus FaceReader [7] as the recognition system of human emotions triggered by the NAO robot's affective gestures designed with Laban movement analysis.

2. Laban Movement Analysis

2.1. Laban Effort and Shape Components of Movements

To establish affective gestures, the LMA model provides five major components describing movements, so called: Body, Effort, Shape, Space and Relationship parameters [13]. In terms of designing affective states based on the robot's gestures, the most relevant parameters of LMA analysis are Effort and Shape parameters [13]. The Laban Effort parameter reveals dynamics and expressiveness of the movement. The Shape parameter refers to changes of the body shape during the movement [13]. In our study, we focused on the Effort component and its relevant movement attributes: (i) space which reveals approach to the surroundings, (ii) weight which is an attitude to the movement impact, (iii) time that expresses a need or lack of urgency; and (iv) flow which refers to amount of control and bodily tension [13]. Each quality can be expressed in two extreme polarities: space quality can be direct or indirect (straight or flexible movements), weight can be strong or light (powerful or weightless movements), time can be quick or sustained (quick or lingering movements), while flow parameter may be bound or free (controlled or uncontrolled movements) [13]. For example, the difference between movements of reaching for something or punching someone is based on not only an arm organisation, but on weight, flow and time qualities as well [1]. These parameters can be translated into dynamic characteristics including curvature, acceleration and velocity [1].

2.2. The Laban Effort Graph for Generating Robots Affective Gestures

To design expressive movements, one can use a Laban effort graph [5] (see Figure 1). Depending on affective state to be generated in the robot, there is a need to focus on setting up specific movement parameters of Effort. For instance, if NAO robots' movement is intended to express state of joy, according to Laban Effort graph for joy, robot's gesture should engage specific Effort qualities denoted on red in the graph: space – indirect, weight – light, flow – free, time – sudden. It means that the robot should perform gesture not directed into any particular point in the space (space – indirect), and movements that are delicate (weight – light), uncontrolled and vivid (flow – free) in a quick way (time – sudden). In case of sadness, the robot's gesture should involve the following combinations of movements qualities: space – direct, weight – light, flow - bound, time – sudden [5]. Therefore, the robot should perform the gesture which indicates a specific point in the space (space – direct), and also movements that are delicate (weight – light), limited (flow – bound) and quick (time – sudden). As shown in Figure 2, we generated affective states (joy and sadness) of the NAO robot according to such LMA requirements.

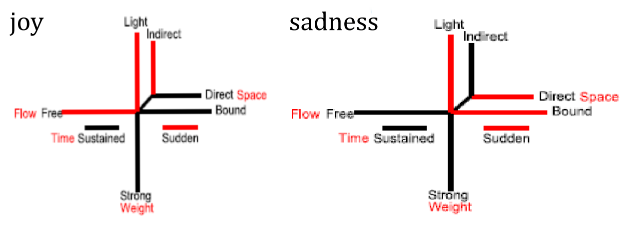

Figure 1. States of joy and sadness presented on Laban Effort graphs [5]

3. Methodology

3.1. Participants

Eleven undergraduate students took part in the study (1 female and 10 males) with an average age of 23.5 ($SD = 1.2$) from the Faculty of Electronics, Wrocław University of Technology. All completed informed consent forms before the experiment. This study was approved by the local Ethics Committee at the Institute of Psychology, University of Zielona Góra.

3.2. Face Reader

Noldus FaceReader [7] is a software for facial analysis than can detect six basic emotions of human: joy (happiness), sadness, anger, surprise, fear, disgust, and a neutral state. FaceReader can also determine components of facial expression such as contempt, gaze orientation and eyes or mouth openness or closeness as well as a position of eyebrows. In addition, FaceReader can detect the valence of emotion (whether it is positive or negative), the gender, age, ethnicity, the presence of glasses and facial hair (beard and moustache).

Facial expression analysis (FEA) is a highly demanding task because of a multidimensional problem of mathematical space [11]. Image and video data of human face is quite difficult to analyse in a form of bitmaps, therefore it is necessary to transform such data into a set of features beforehand. In addition, the FEA analysis is obscured be several factors as [11]: a location of the face in the image, size and orientation of the face, lighting of the face, and individual differences in facial expression. FEA analysis with FaceReader proceeds in the three steps [7]: (i) face finding, which determines the face position using a Viola Jones method [12]; (2) face modelling, which is based on Active Appearance Model (AAM) [4] to synthesise the artificial face model with 500 key points and the surrounded facial texture, AAM uses then a database of the annotated images to calculate image modifications; (iii) face classification, which is performed by the neutral network trained with over 10,000 manually annotated samples. The accuracy of the neural network in recognising six basic emotions can be up to the level of 90% or higher.

3.3. NAO robot

NAO is an autonomous, programmable humanoid robot developed by Aldebaran Robotics [9]. It is 57 cm tall, its weight is 5.4 kg. Rich capabilities of NAO in terms of HRI interactions motivate researchers to apply this robot as a research platform in various applications. Examples of emotional movements (gestures) used in our study modelled with the Laban movement analysis are shown in Figure 2. We developed two emotional gestures presenting joy and sadness. Note that specific stages of the relevant body motions of NAO are distributed along the time axis to express the values of Effort (space, weight, time and low) and Shape parameters (horizontal, vertical and sagittal). The development of joy gesture was inspired by work [8].

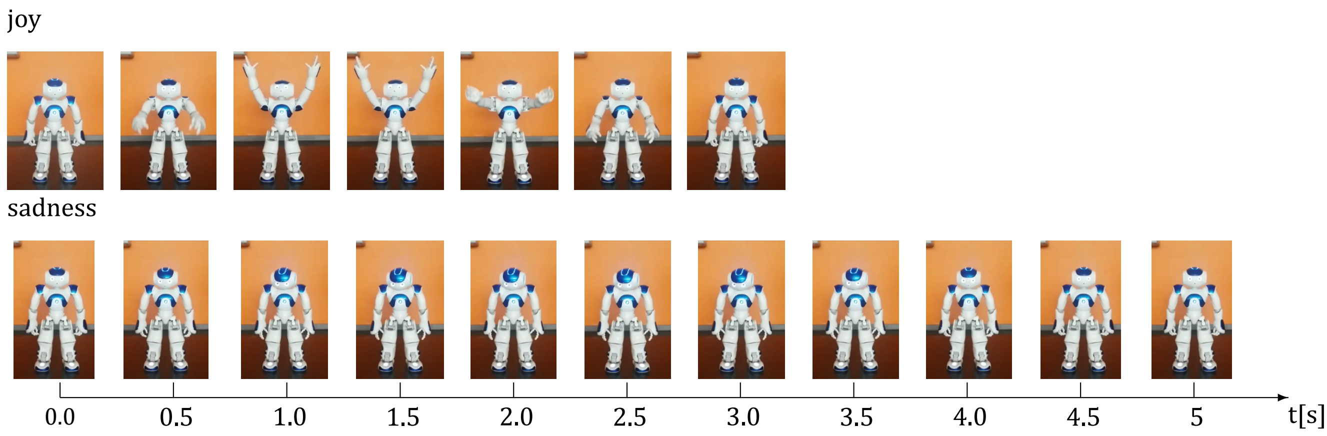

Figure 2. Emotional expressions in time: joy and sadness inspired by LMA

3.4. Experimental Scenario

Each participant was seated in the chair at the front of the NAO robot (at a distance about 1 meter). Participant's facial expression reactions were recorded with a camera located on the table. The participant was observing the NAO robot who was either in a neutral position or performed gestures intended to be emotions of joy (3 sec) and sadness (5 sec), separated by a neutral position of NAO (4 sec). When the robot was in a neutral state (no movements), it spoke aloud numbers to alert participant about emotion changes emulated by NAO movements. Facial emotional reactions for each individual were analysed with the Noldus FaceReader [7] in an off-line mode on the basis of the recorded video material.

4. Results

To examine accuracy of emotion recognition of emotions emulated by the NAO movements, we used the individual FEA data from the FaceReader. For each participant, we evaluated accuracy of facial emotion recognition as a function of time. First, we started our analysis by visually inspecting recognition of joy embodied within the robot's gestures. For eight individuals, we found that facial expression changes were indicative of joy. The results from two representative individuals (participants 4 and 5) are presented in Figure 3(a).

As can be seen, there was a distinct emotional response in case of the *joy* movements emulated by the robot's scenario. To quantify the correspondence between the accuracy of joy recognition and the NAO's affective gesture, we calculated the Pearson correlation coefficients. The correlation coefficients were calculated for the 7-sec time window. The start and the finish time lags of this window were established with respect to the negative time lag for the pre-stimulus (1 sec) and the positive lag for the post-stimulus (3 sec) (see Figure 3(b)).

The correlation analysis showed that there was a strong positive correlation for one participant, $r = 0.73$, $p < 0.0001$. The moderate correlations between the facial expression changes and affective gesture produced by NAO were observed for three subjects who yielded the correlation values: $r = 0.49$, $p = 0.0001$, $r = 0.38$, $p < 0.0001$ and $r = 0.43$, $p < 0.0001$. In case of four participants the correlation values were low but significant, $r = 0.25$, $r = 0.17$, $r = 0.20$, $r = 0.27$ (for all cases $p < 0.05$). The remaining participants showed no association between the affective gestures and the facial response, or presented some artefacts. The same methodology was repeated for sadness recognition. In case of sadness, the correspondence between emotion recognition accuracy and affective robotic gesture was rather low. The visual inspection of the stimulus-response

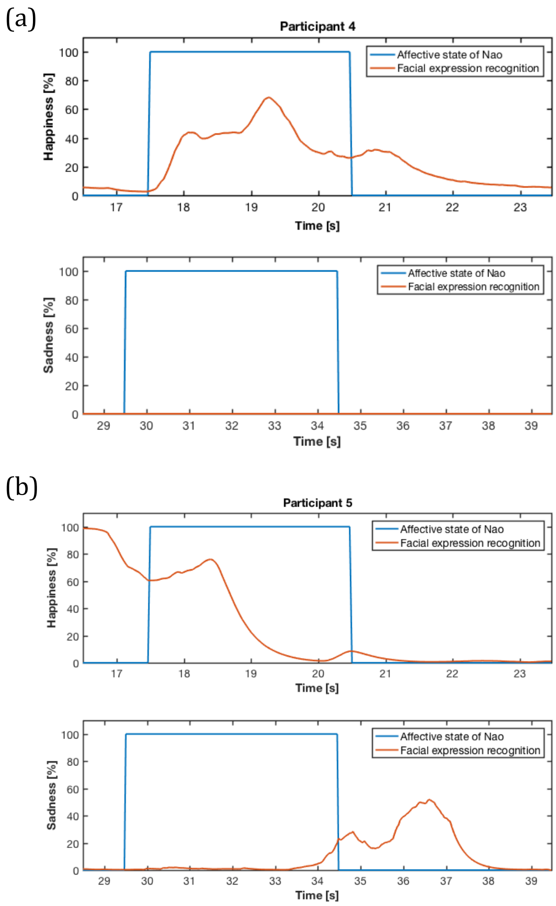

Figure 3. Facial expression recognition of joy and sadness; results for participants 4 (a) and 5 (b)

plots indicated that only two participants responded in a distinctive manner to sadness expressed by NAO movements. This finding was confirmed by a positive correlation coefficient value that was $0.32, p < 0.0001$, for the participant 1. We also observed a significant negative, moderate correlation for participant 5 (see Figure 3(b)), $r = -0.48$, $p < 0.0001$ suggesting that there is a time lag between the stimulus and facial expression response for this emotion. Note that the time window for analysing sadness was expanded to 11 sec.

5. General Discussion

Our study provides compelling evidence that affective states embodied in the humanoid NAO robot on the basis of the Laban movement analysis can be effectively recognised by human. We presented participants with two emotional gestures embodied in NAO such as happiness and sadness. As indicated by FaceReader analysis happiness expressed through the NAO's body was a readable emotion. Although a similar conclusion in terms of sadness cannot be made as this emotional gesture was less pronounced.

Our research indicates that future social robot construction should be equipped with facial expression recognition system, similar to FaceReader. This enables a new social robot's design that can effectively carry out objective measurements of basic emotions of human in a real-time processing mode from a videostream of a camera (built-in a robot or external with respect to a robot) [10].

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