Artificial Emotions to Assist Social Coordination in HRI

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Abstract. Human-Robot Interaction requires coordination strategies that allow human and artificial agencies to interpret and interleave their actions. In this paper we consider the potential of artificial emotions to serve as coordination devices in human-robot teams. We propose an approach for modelling action selection based on artificial emotions and signalling a robot’s internal state to human team member. We describe an architecture that drives the display of artificial emotional gestures with a model latched internal emotional states. We also present preliminary data on human recognition rates for a candidate set of artificial emotional expressions in a Lego robot.

Keywords: artificial emotions, action selection, human-robot collaboration

1 Introduction

Robots could act as members of a human team by assisting people who share a given physical workspace, by performing action relevant to their joint goals. Research on human-robot interaction (HRI) must address a number of challenges to make coordinated action possible. For example, robots in shared environments must be designed to be safe in case of collision with their human co-workers and must operate at a pace that is compatible with human action. Robots must also act in a way that is understandable to the people with whom they are working, through the way they move and interact with objects in the shared space.

Visual cues such as facial expressions are important in human-human coordination because they assist people to make inferences about one another’s task-relevant state. For example, a grimace might indicate difficulty or a smile may suggest some success. Knowledge of this kind can help co-workers to bring their actions together at particular points, or to reschedule or reallocate work in case of difficulty. Research on emotion recognition, expression, and emotionally enriched communication is of great potential importance to HRI and has been the subject of significant research effort since the mid-1990s [1],[2],[3],[4],[7]. The importance of emotional expression as part of human communication has been explored scientifically since the 19th century, with the publication of ‘The Expression of the Emotions in Man and Animals’ by Charles Darwin. Research in Psychology, Ethnology and Neuroscience has shown
that affect can profoundly influence human and animal cognition, especially in social settings. Most of the existing work in social and humanoid robotics focuses on the recognition of human emotions or mimicking their expression [1],[4]. However, from an interaction perspective, understanding of social cues and a social context should not be considered as a one-sided process. In addition to understanding human emotions, more work should be done on the role of artificial emotions in influencing human behaviour in human-robot teams and their impact on interaction.

Artificial emotions could play several important roles in social human-robot interaction, depending on how well they model socio-emotional process in communication between people. Scheutz [8] highlighted the following 12 potential roles of emotions in artificial agents analogous to those in natural social systems:

- action selection
- adaptation
- social regulation
- sensory integration
- alarm mechanisms
- motivation
- goal management
- learning
- attentional focus
- memory control
- strategic processing
- self model

Achieving reliable artificial emotional displays and reliable emotion recognition are important goals in the context of designing virtual and robotic agents for human-robot interaction. In this paper, we present an approach to artificial emotions in robots that provides them a role of memory control, action selection and social regulation. These three roles are accomplished by coupling a subsystem that models robot affective state with a social signalling subsystem. We argue that this approach can assist in communicating the intent of a robot to a human during interaction by creating expectations of actions associated with approach or avoidance.

2 Method

Artificial emotions in this study are represented as a factor for dynamic action selection. A mechanism for generating an internal emotional state is used in conjunction with a selection mechanism for visual cues that are intended to communicating the current emotional state to a human. The artificial emotion system is designed to run concurrently with other robot subsystems, such as planning, learning and signal processing. Emotional states are thus continuously computed and can drive the production of emotional signals before and during the execution of actions [5].

2.1 Modelling Artificial Emotions

The framework for modelling artificial robotic emotions is presented in Figure 1. The first phase of the emotional action selection includes detecting specific internal and/or external conditions (C1, C2 and C3 in the Figure 1), following Breazeal [1]: presence of an undesired stimulus, presence of a desired stimulus, a sudden stimulus, delay in achieving goal. For determining an appropriate emotional state we use a simple valence-arousal representation for modelling basic emotional states, in a manner
analogous to Russell’s approach [7]. Here, arousal (EA in Figure 1) represents the strength of a stimulus, and the valence (EV in Figure 1) shows a positive/negative value of a stimulus.

Fig. 1. The framework for modelling artificial emotions in robot.

All the detected conditions influence both valence and arousal values and thereby a robot’s emotive response (E1, E2 and E3 in Figure 1). We also use intensity (EI1, EI2 and EI3 in Figure 1) as an additional property of an emotion. Emotional intensity in this model is an internal state of an agent, which is changed dynamically while robot is experiencing an emotion. Intensity depends on time, number of detected stimuli, and an impact factor of an executed behaviour. Each emotion calls a specific behaviour of a dynamic plan. We use an impact factor (Behavioural impact in Figure 1) as a property of a behaviour that depresses the intensity of the emotion this behaviour was triggered by. While the selected behaviour is being executed it inhibits the intensity of the emotion it was triggered by, i.e. intensity of an emotion is a function of a behavioural impact over time. ‘Feeling’ an emotion is modelled as a latched process [6], during which an intensity of the emotion is increasing over time from zero value until the maximum threshold of 100, and is reducing back to zero after the executing behaviour inhibits it.

Fig. 2. Latched process of ‘feeling’ an emotion.

The expression of emotion starts after an increasing intensity of the emotion reaches the specified level threshold1 and stops when the specified level threshold2 is reached while the intensity is decreasing, as shown in Figure 2. The red line shows the
time period while the emotion is being expressed. The execution of the selected behaviour starts when the intensity of an emotion reaches threshold 3. The execution of behaviour, if not interrupted, stops when intensity of the emotion is zero. The green line indicates the period of time while the selected behaviour is being executed.

Such a model of latching is a modified version of Rohlfshagen and Bryson [6] flexible latching. The similarity between these two models is a latching behaviour of an emotional intensity which triggers action selection in certain time points and manages the mechanism of actions’ interruption. The difference is in interpreting the function of a latched behaviour. In our model, the intensity of an internal emotional state increases continuously if no actions are executing. The role and the purpose of a selected action is to suppress the growing emotional intensity.

The execution of the selected behaviour starts when the intensity of an emotion reaches a specific level which is above the level of the start of expressing the emotion and below the maximal intensity level. The execution of behaviour, if not interrupted, stops when intensity of the emotion is zero. For managing interruptions, the following model is used: if interruption happens when emotion intensity is below the threshold 1 level the behaviour stops, otherwise the behaviour is resumed. There is a delay between the expression of an artificial emotion and the initiation of a behaviour it selects. This presents a co-worker with the opportunity to infer its state and potential next action in relation to their own actions, and to adjust their work accordingly.

2.2 Expressing Artificial Emotions

We are planning a series of studies to better understand whether a non-humanoid robot can express artificial emotions in the way understandable for a human. As a first step, we have been experimenting with a Lego robot using two basic movements of its body: moving the ‘neck’ forward/backward, and raising/lowering ‘eyebrows’. The inspiration for this simple scheme is drawn from our basic arousal-valence underlying model, with approach and avoidance of the neck as a metaphor for valence and eyebrows reflecting the arousal concept. We programmed six combinations of these two movements and then photographed them from two angles – front and ¾ views, as shown in Figure 3:

Fig. 3. Lego robot, expressing artificial emotions using a combination of two basic movements of its body: moving the ‘neck’ forward/backward, and raising/lowering ‘eyebrows’.
The six pairs of pictures were used to construct a questionnaire. 27 people (14 females and 13 males) agreed to participate in a study to determine whether our simple set of valence-arousal robotic gestures could be interpreted as emotional signals. 18 had no previous experience with any kind of robots, 4 considered themselves as roboticists, and the rest had some previous interaction experience with robots. 18 were over 40 years old, 3 were between 30 and 39 years old, and six were between 20 and 29 years old.

For each pair of images, participants were asked to select the most appropriate emotional term from a set of possible responses: sadness, happiness, anger, surprise, excitement, fear, other, no specific emotion and don’t know. They were also asked to use a five-point Likert scale (very easy, easy, neutral, difficult and very difficult) to rate their degree of confidence making that judgement.

3 Preliminary Results

Our preliminary data suggest that our simple two-dimensional robot movements can be interpreted by people as expression of several basic emotions – sadness, happiness, anger, surprise and excitement. However, judgements of sadness and surprise were made most consistently participants, with a few alternative interpretations. For example, the robot captured in the picture No3 was interpreted as being surprised by 14 participants, while none of alternative interpretations collected more than 6 votes (Figure 4). Most participants rated their confidence in judging the emotional meaning of the robot images as Easy (Figure 5), with no clear indication that some were harder to interpret than others.

4 Discussion and Future Research Direction

The robot signals, treated as artificial emotional expressions, were recognized quite easily by most participants. However, although the questions where users were asked to evaluate the certainty of detected emotions were mixed with other questions in the questionnaire, some of their answers were influenced by a central tendency bias, i.e.
users avoided extreme ratings. The questionnaire is going to be improved for the future studies in order to avoid this problem.

The preliminary data shows that people find it easy to ascribe emotional states to the robot they see in the picture. Several pictures of the robot were interpreted with less noise and these were the pictures where users associated the robot with the emotions of surprise, sadness and fear. We can suggest that high level of arousal (as in surprise and fear) or high level of valence (as in sadness) helps people to interpret artificial emotions expressed by robot more easily. However, more studies are required to check this suggestion, especially in a dynamic context.

The architecture proposed earlier has been implemented and is currently being validated by tests. We plan to further investigate our model of emotional action selection for a human-robot collaborative task where the robot must solicit assistance to achieve its goal. We intend to investigate joint action as a function of three conditions: emotional action selection with and without expression and emotion free action selection. Our observations will help us to understand whether emotional communication will empower the robot to influence a human’s behaviour, and how social coordination in HRI may be helped or hindered as a consequence.

5 References