A Reactive Competitive Emotion Selection System

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Abstract. We present a reactive emotion selection system designed to be used in a robot that needs to respond autonomously to relevant events. A variety of emotion selection models based on "cognitive appraisal" theories exist, but the complexity of the concepts used by most of these models limits their use in robotics. Robots have physical constrains that condition their understanding of the world and limit their capacity to built the complex concepts needed for such models. The system presented in this paper was conceived to respond to "disturbances" detected in the environment through a stream of images, and use this low-level information to update emotion intensities. They are increased when specific patterns, based on Tomkins' affect theory, are detected or reduced when it is not. This system could also be used as part of (or as first step in the incremental design of) a more cognitively complex emotional system for autonomous robots.

Keywords: Social Robotics, Human Robot Interaction, Emotional Models, Emotion production

1 Introduction

Social environments involve subtle interaction among people and the physical environment. These interactions, the context in which they take place, and people's mental perception of the world affect the emotions that arise. Different theories and models of how emotions arise have been proposed in psychology, such as [16, 18, 11]. Although these models seem acceptable and cogent to most of us, the hidden assumptions that authors make in their models [6, 15] emerge when trying to implement them in artificial agents and robots. Computational frameworks based on these "high-level" models have been implemented [10, 7], but they use abstract concepts that have to be defined in the system.
However, social robots need to be able to operate in real circumstances, where the information that the system needs to operate is not well defined or given beforehand and changes over time. Therefore, the robot needs to be able to

interpret relevant information necessary to be used as input (including by the above-mentioned frameworks) from its current sensory data and representation of its environment. Due to sensor limitations (e.g., accuracy, noise) the world model cannot be a complete nor precise representation of the current situation. Moreover, the representation used to model the environment could lack details that are necessary to correctly interpret the situation. The use of "high-level" computational frameworks for autonomous social robots is thus problematic.

Emotion-based robot architectures have been proposed that ground emotion elicitation on the robot's sensory data. For example, the robot presented in [5] uses data from simple (contact) sensors, interpreted following the model of general stimulation patterns proposed by Tomkins [20]. Other robots such as [4, 14] use complex sensory input (vision, voice) and a complex architecture to determine the robot's emotional state using some form of appraisal of the current situation.

This paper presents a reactive emotional system that combines elements of these two approaches. Also based on Tomkins' theory [20, 12], but using visual input and a complex architecture, the pre-selected emotions compete among them to be triggered. The system has been designed in a modular way, so to make it easy to combine it with other, more complex models such as the one suggested by Izard [11]. Our architecture is designed for use by a robot that needs to respond autonomously to relevant events (e.g., sudden changes in light conditions, presence of different agents or objects).

The rest of paper is organized as follows. Section 2 provides a brief overview of particularly relevant work closely related to our architecture. Section 3 outlines different emotional theories, paying particular attention to the model proposed by Tomkins. Section 4 describes our emotional system: the design and formulas that control the system. Finally, Section 5 covers the implementation and results.

2 Related Work

The robotic head Kismet created by Breazeal [4] uses cameras to perceive the world and head movements to interact with people. Kismet's emotions are the six basic emotions of Ekman [8]: happiness, sadness, surprise, fear, disgust, and anger. The emotion selection process can be summarized as a cyclic sequence of perceiving an event and appraising it [3]. The appraisal phase is where the change of emotion can be done.

Cañamero and Fredslund developed the LEGO humanoid robot Feelix that expresses emotions on its face based on physical (tactile) stimulation [5]. A tactile sensor is used to determine the stimulation which could fall in one of the following cases: short (less than 0.4 sec), long (up to 5 sec), and very long (over 5 sec). The events generated from the stimulation are used to determine the emotion activation based on the state of a finite state machine that implements general emotion activation patterns (cf. Fig 1) drawn from Tomkin's theory of emotions [20], that we have also used in this paper. Feelix could detect stimulation patterns for and display the following emotions: anger, sadness, fear, happiness

and surprise.
MEXI is a robotic face that is capable to interact with people through emotions [9]. MEXI is capable to understand people emotions through image analysis of data coming from two cameras, and its speech recognition system. MEXI's architecture lacks of any deliberative component, but it uses emotions and drives to control its behaviours. Its emotion system obtains information from the behaviour system and external perceptions to come up with the new values for each emotion. Each emotion is represented by a value between 0 and 1, updated according to the current perception. The considered emotions are: anger, happiness, sadness and fear.
The architecture described in [13] uses a mixture of hard-coded emotions and emotions learned by association. Their emotion system uses inputs from the deliberative and reactive architectural layers to select one of the emotions: fear, anger, surprise, happiness, and sadness. Each one of these emotions is triggered according to perceived events, internal state, and goals of the robot in the current movement. The emotion selected by the emotion system affects the way each behaviour is performed.
The emotional model proposed by Malfaz and Salichs [14] uses appraisals to select an emotion. Happiness is related to the fact that something "good" happens to the agent (e.g., interpreted as the reduction of a need), and sadness to something "bad" (e.g., interpreted as the increment of a need). Fear is related to the possibility that something bad happens to the agent and it is activated when something dangerous could be expected by the agent.

3 Tomkins' Emotion Theory

There are many theories of emotion, differing in assumptions and the components involved in the process. They can be classified in different ways. For example [19, 15] use the following categories:

- *Adaptational:* based on the idea that emotions are an evolving system used to detect stimuli that are of vital importance.
- *Dimensional:* organize emotions according to different characteristics, usually valence (pleasantness-unpleasantness) and arousal. One of the most widely used is the Russel's circumplex model of affect [17].
- *Appraisal:* argues that emotions arise from the individual's judgement, based on its believes, desires, and intentions with respect to the current situation. EMA [10] and Fatima [7] frameworks fall in this category.
- *Motivational:* studies how motivational drives could generate emotions.
- *Circuit:* supports the fact that emotions correspond to a specific neuron path in the brain.
- *Discrete:* are theories based on Darwin's work, the expression of emotion in man and animals. These theories use as a pillar the idea of the existence of a basic emotions.
- *Other approaches* are lexical, social constructivist, anatomic, rational, and communicative.

In practice, these theoretical categories overlap. The difference among these theories is mainly in how the process and inputs are considered in each one.
Tomkins' theory [20, 12], on which we base our model, integrates various perspectives. For Tomkins, the affect system evolved to solve the problem of overwhelming information present in the environment to which people are exposed. His theory states that people cannot manage to be conscious of all the information available from the environment, therefore the affect system comes to select what information could be relevant to be aware of in a given moment. For example, someone could focus on reading a book, ignoring the rest of events that are happening, but suddenly there might be a loud sound that gets his/her attention. This kind of behaviour could be obtained through the activation of different systems. He recognizes four systems closely related to affect:

- *Pain* is a motivator for very specific events that take place on our bodies.
- *Drive* deals with the basic needs that human body could need (e.g. urination, breathing).
- *Cognitive* interprets the world and make inference from it.
- *Affect* is focus on get person attentions to specific stimuli.

More importantly, Tomkins suggested that affect in certain situations could make that pain and drive systems are omitted, while the affect and cognitive could work together. Because affection has a main role in human subsistence, he describes nine affects that could be triggered depending on brain activity. Figure 1 shows activation patterns for relief, sadness, happiness, anger, interest and fear. For instance, sustained low stimulation leads to sadness, while a very highly increasing stimulation leads to fear, and a less steep increase in stimulation leads to interest. Moreover, the time windows for these emotions are different; for instance fear arises faster than happiness.

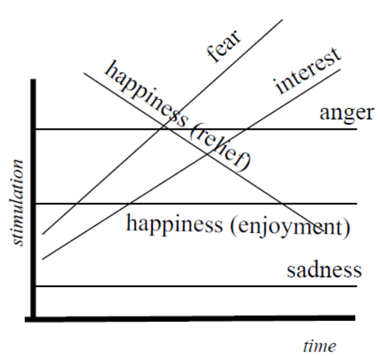

Fig. 1. Patterns for relief, sadness, happiness, anger, interest and fear, after Tomkins.

4 Emotional System

As suggested by Izard [11], among others, emotion elicitation can be performed at different levels, and at some of these levels we are not aware of the process. Our system focuses on the “reactive”, “pre-aware” part of emotion elicitation (and selection, in our case) using as an input gray scale images from a web cam. Our system does not take in consideration any cognitive information from the environment; instead, we compare two consecutive images to determine changes in pixels in order to detect disturbances in the environment that could be of interest for the robot. This difference (the quantity of pixels that have changed over a threshold) is given as input to the stimulation calculator to determine the “stimulation” that is later used by the emotion generator to update the intensity of each emotion. This update is done searching for the patterns suggested by Tomkins (Fig. 1). The previous process is always modulated by the time delay between the two images considered. This delay is of vital importance in the system because it could not be determined with certainty beforehand. Using this delay in the equation makes the system behave in the same way regardless of whether the delay is short or long. Consequently, the system gives different values of “stimulation” depending on the delay between the images.
Figure 2 depicts the general process with all the subsystems. These subsystems were selected to permit upgrades in the system without the need to make considerable changes in the code. For example, the change detector subsystem could be improved to detect additional features from the images; if the output remains as percentage (value between zero and one), the rest of the system could still use it to update the emotion intensity.

4.1 Stimulation Calculator

This subsystem obtains the percentage of change provided by the change detector and updates the new stimulation ($stimulus(t)$) based on the current change ($s\_increment$), the last stimulation ($stimulus(t-1)$), and a reduction value ($s\_decrement$), as shown in Equation 1. In addition to $stimulus(t-1)$, functions $s\_increment$ and $s\_decrement$ use the time delay ($delay$) as a parameter.

$$\begin{aligned} stimulus(t) = {} & stimulus(t-1) \\ & + s\_increment(percentage, delay) \\ & + s\_decrement(stimulus(t-1), s\_increment(percentage, delay), \\ & delay, bias) \end{aligned} \tag{1}$$

The $s\_increment$ function ranges on the percentage of change and the delay time, and it is calculated as it is shown in the equation 2. The $s\_increment$ uses an exponential function with a desire base ($base\_increase$) and displacement coefficient (d). This displacement coefficient is used to obtain values greater than one, but it also introduces a small bias that is corrected by the second part

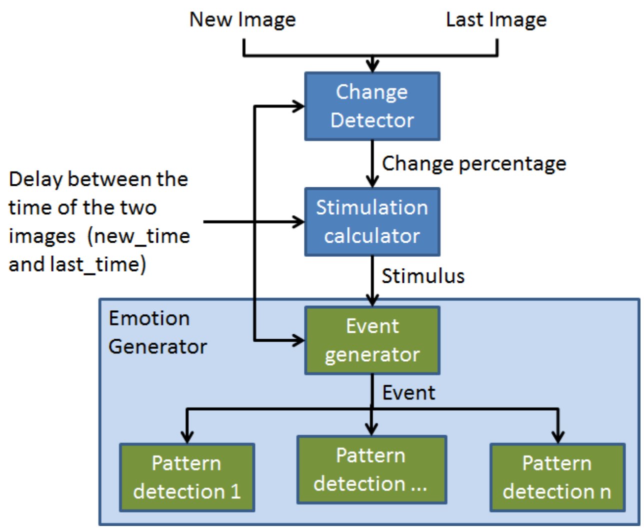

Fig. 2. General architecture of the system. The arrows show the information flow. The time difference between the two images is used to modulate each module.

of the equation. The $increase\_factor$ is a coefficient that modulates the gain of the function, which is used to obtain less or more stimulation. And $delay$ is a variable coming from the time delay between the two pictures used to generate the percentage.

$$
\begin{aligned}
s\_increment(.) = & ((base\_increase)^{(percentage-d)} \\
& - \underbrace{(base\_increase)^{d}}_{\text{correction factor}}) * increase\_factor * delay
\end{aligned}
\tag{2}
$$

Figure 3 illustrates the behaviour of $s\_increment(.)$, showing that this function produces greater values when the delay increases. The $s\_decrement(.)$ function (Equation 3) uses $s\_increment(.)$, time delay, and a bias to determine the decrease value. The parameter $bias$ is used to modify the lower output value of the system. Like $s\_increment(.)$, this equation depends on time to make the modulation. Figure 4 illustrates its behaviour with a $decrease\_factor = -0.5$ and with different time delays.

$$
\begin{aligned}
s\_decrement(.) = & (stimulus(t-1) + s\_increment(.) - bias) \\
& * decrease\_factor * delay
\end{aligned}
\tag{3}
$$

4.2 Emotion Generator

This subsystem was divided in two modules (event generator and pattern detection) to give the possibility of adding or deleting new emotion patterns, and of

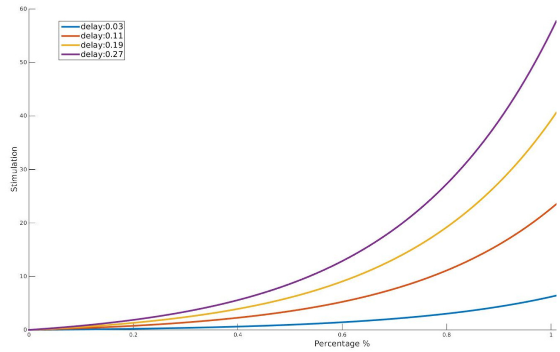

Fig. 3. Behaviour of the increase function for different delays in the image using parameters $base\_increase = 30$, $d = 0.1$, and $increase\_factor = 10$.

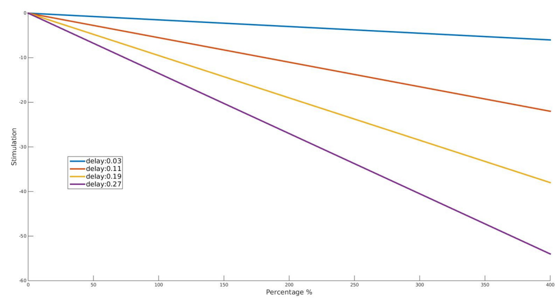

Fig. 4. Behaviour of the decrease function for $decrease\_factor = -0.5$ and different time delays.

modifying the event characteristics. Event generator centralizes the process of detection of relevant events from the stimulation slope. The events considered are: null, small, medium, large, and huge slope. Except null slopes, the other events could be either positive or negative. A pattern detection module is implemented for each emotion that should be detected. Each pattern detection module considers a different pattern as well as the number of events to search for in the pattern. The emotions, their patterns, and their update functions are:

– *Surprise* is recognized just when one of the following events are present in its time window: large or huge positive slope. Due of this strong constraint, every time that this pattern is detected, its intensity grows faster than for other emotions.
– *Fear* is increased when three or more consecutive recent events have either large or huge positive slopes.
– *Interest* occurs when three or more consecutive events have either medium or small positive slopes.
– In contrast to the rest of emotions, *Relief* works with negative slopes and its intensity increases when at least five negative slope events are detected.

We have considered only emotions affected by stimulus change since we focus on the reactive processes to activate emotions, while emotions related to constancy of stimuli in Tomkin's model are expected to be managed by the cognitive part of a larger system.

5 Implementation and Results

The system was implemented in C++ and uses OpenCV to analyze images. The final implementation was then interfaced with ROS to enable easy use in other systems. To facilitate easy parameter change, two configuration files were added: one related to all the general parameters (e.g. threshold and $increase_{coefficient}$) and the other to establish the increment, decrement, and time window (number of events to consider) for each of the implemented patterns. The system was tested online with information coming from a Logitech CY270 Web-Cam. The intensity and events obtained are depicted in the Figure 5, where the relationship between the stimulation's slope and the events can be seen. Figure 6 depicts

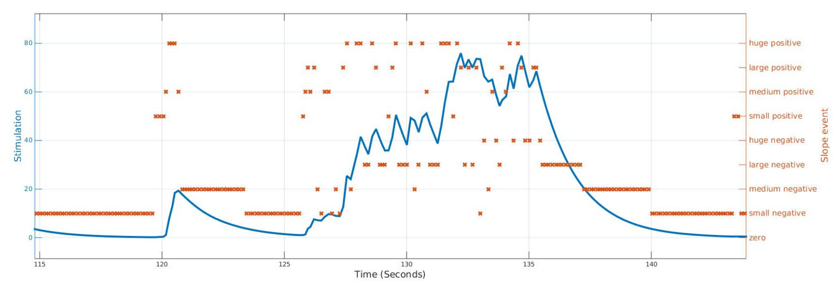

Fig. 5. Stimulation (continuous line) and events (dots in horizontal lines) obtained from the comparison of to consecutive images. The y-axis on the left represents the stimulation level, while the one on the right represents the events generated from the slope detected.

the intensity obtained for each pattern implemented (fear, interested, surprise and relief), also showing that each pattern module updates its emotion intensity independently. This is clearly seen at second 120 when fear, interest, and surprise unevenly increase their intensities and after some time they also reduce their intensity unevenly. This (increase and decrease) unevenness shows the pattern's configuration, which is not the same for each emotion. The presence of more than one emotion with a value different from zero suggests that a further mechanism should be used to determine which emotion should be elicited, for example taking the one with higher intensity or just modifying behaviour parameters proportional to each intensity. In other words, our initial aim to use this system as first step to select an emotion is achieved.

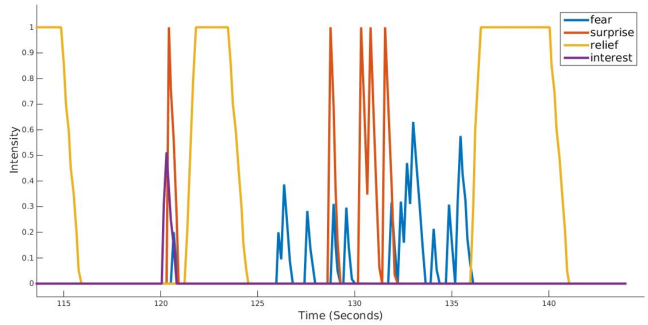

Fig. 6. Intensity obtained by our system for the four emotions implemented: fear (blue), interested (purple), surprise (red) and relief (yellow).

6 Conclusions and Further Work

We have presented a reactive emotional system based on Tomkins' theory. The system is modular to permit its integration with more complex systems and its configuration based on the output from the pattern detection modules. The system was implemented in C++ with interface to ROS to make it possible to used it in other models and in robotic platforms. Four patterns (fear, surprise, interest, and relief) were implemented and tested. The results show that the output compete with each other, and the emotion has to be selected in a further step with a logic that suits the specific purpose, which could be as simple as take the emotion pattern with higher intensity, or weight behaviours by the intensity of the corresponding patterns. Additionally, this reactive system could be used as complement for cognitive systems.
As a further work, the system is going to be integrated to our theatrical system [1, 2], to provide changes in the emotion that is going to affect the robot's movement parameters. Finally, a simple behaviour will be implemented, to be triggered by the selected emotion appropriate to the situation.

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