A Computational Model of Emotion through the Perspective of Benevolent Agents for a Cooperative Task

Sajal Chandra Banik, Keigo Watanabe and Kiyotaka Izumi
Department of Advanced Systems Control Engineering
Graduate School of Science and Engineering
Saga University, 1-Honjomachi, Saga 840-8502, Japan
baniksajal@yahoo.com, {watanabe, izumi}@me.saga-u.ac.jp

Abstract

This paper deals with a computational model of emotions and its application for cooperative benevolent agents. A stochastic emotion model based on Markov theory is adapted to perform their well organized tasks to achieve goal. The emotional model consists of four basic emotions: joy, anger, fear and sad. Different emotional behavior is obtained by updating the state transition matrix of stochastic model. Perception of stimuli has an impact on emotion inducing factors and thus, affects on emotion dynamics. With the developed model, a Matlab based simulation is performed to analyze the behavior of the agents with the emotional capability.

Keywords: Emotion, Benevolent agent, Markovian emotion model, Emotion inducing factor, Individuality factor.

1 Introduction

The concept of artificial emotion is expanding and increasingly used to design autonomous robot systems with the augmented capability, such as emotion based experience of environment, emotional interaction, etc. In [1], Ortony et al. stated that it is important for artificial intelligence to be able to reason about emotions—especially for natural language understanding, cooperative task solving and planning. There are many psychological evidences supporting the emotional concept to be needed for getting automation in agents. Now it is a matter of thinking whether emotions could have the same functional roles as ones that prevail in natural system. M. Scheutz [2] has found such 12 roles of emotions that can be used for artificial agents (may be for single agent or multiagents system) to develop emotional control mechanism such as: adaptation, action selection, sensory integration, motivation, alarming mechanism, goal management, representing, memory control, social interaction, strategic processing and self model. We have also notified the roles of emotional intelligence that may be required for creating benevolent agents for cooperating tasks (as shown in Fig. 1).

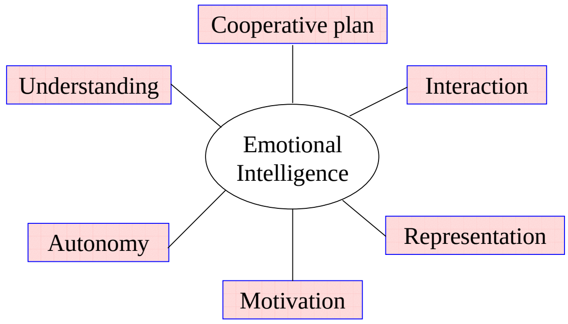

Figure 1: Basic roles of emotional intelligence

We consider agents as benevolent because they have desire to assist each other and user's interest is their best interest. Agents also try to maintain a certain level of group performance expected by the owner. The task to be performed is assigned by the user of the system and time to time evaluates the performance. The choice of behavior of an agent depends on: work load, the current emotional state of each robot, response of colleague robot and performance evaluation. In this paper, we have applied the rationality (the reasoning) of emotions and their internal mechanism to a benevolent agents system. Section 2 describes the related works where some researchers have developed emotional model to be used in multiagent system. Section 3 clearly describes the purpose of the research work, emotional modelling strategy with our developed model. Description of simulation software and its application to simulate emotional model to create some affective based behavior is given in Section 4. Finally, Section 5 concludes with the utility of the emotional model for future life-like robots.

2 Related Work

The idea of artificial emotion is increasingly used in designing autonomous robotics agents, by making robots be emotionally experienced with the changed environment or to make interaction with other agents [3]. For creating artificial emotion among the agents, there are different types of emotion models available such as: architecture level model, task-level model, mechanism level model, etc. (for more details see [4]). There are also some special models of human emotions like: circumplex model [5], Markovian emotion model [6], [7], etc. which can be adopted for creating artificial emotion among agents.

Schneider-Fontan and Mataric included an emotional model for using in communication for the minimization of interference [8]. In [9], Murphy et al. developed a multiagent control approach for interdependent tasks which imbues the agents with emotions and allows a satisfactory behavior to emerge. Adamatzky [10] has demonstrated a space-time dynamics of emotions with cellular automation (CA) models of affective solutions, where chemical species in the solution represent happiness, anger, fear, confusion and sadness. In our case, the emotion is also discrete state modulated with intensity level, but the carriers (benevolent agents) of emotion is performing task with some behavioral actions having a specific goal. Each of the emotions (in our case: joy, anger, fear and sad) can act as dominating affective state depending on its intensity level obtained from a belief strategy. The modelling approach is based on stochastic model following Markovian emotion model.

3 Emotional Model

This section describes the modeling approach which is applied for creating an emotional model to be used for generating behavior among benevolent agents. In our model, we have introduced a new factor: *emotion inducing factors*, which is very important for the model. This section also describes the updating process of the *emotion inducing factors* depending on the input stimuli.

3.1 Modeling Approach

Until now there is no concrete and universally accepted definition of emotion that can be considered as the ideal one. Emotion is a complex biological process within the brain and body that can be also created artificially and then can be applied for multirobot/multiagent system. In our case, the emotional model is developed based on stochastic approach following Markov model and the model consists of four basic emotions [11]: joy, anger, fear and sad. These emotions are defined as follows for our emotional model:

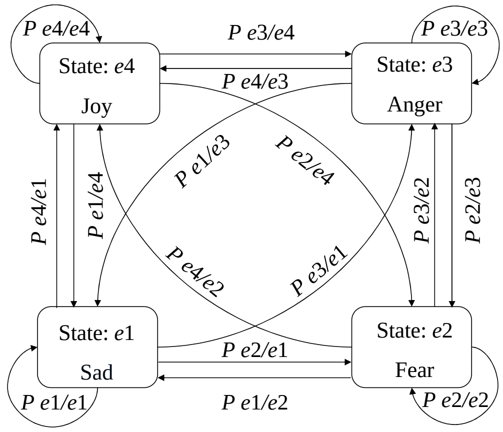

Figure 2: Topology of Markovian emotion model

- *Joy*: An agent is in joy state when it has high energy level to perform task, workload is normal and colleague/user's evaluation is good.
- *Anger*: Anger state increases with facing obstacles or any barrier to achieve the goal and getting low evaluation.
- *Fear*: Fear is activated when getting high workload and having low energy level.
- *Sad*: This is an emotional state of becoming sorry for ignoring help messages.

In our model, we have not included calm (normal) state because we assume that if overall working state is normal to an agent, then the agent is in happy state to be motivated and to continue its task. An application of Markov modeling theory for our purposes is described by Markovian emotion model as shown in Fig. 2. We have applied it for pure agents emotion due to its memoryless property as behaviors and commands are highly dependent on emotional present state than the history of arriving the state. The Markovian emotion model with four states can be expressed as follows:

$$X_{k+1} = AX_k \tag{1}$$

with emotional state points

$$\Omega = \{Joy, Anger, Fear, Sad\} \tag{2}$$

where X_k represents the current emotional state and A is the emotional state transition matrix (so called stochastic matrix). To get emotional impulses from respective emotion state, we have considered an iterative belief model considering some meta-state of emotions like: $e4$, $e3$, $e2$, $e1$ for joy, anger, fear and sad respectively as shown in Fig. 2.

Considering the meta-state, stochastic matrix A becomes as follows:

$$A = \begin{bmatrix} P_{e4/e4} & P_{e4/e3} & P_{e4/e2} & P_{e4/e1} \\ P_{e3/e4} & P_{e3/e3} & P_{e3/e2} & P_{e3/e1} \\ P_{e2/e4} & P_{e2/e3} & P_{e2/e2} & P_{e2/e1} \\ P_{e1/e4} & P_{e1/e3} & P_{e1/e2} & P_{e1/e1} \end{bmatrix} \quad (3)$$

In the Markovian emotion model, the nodes represent the emotional states and the arcs/arrows indicate the probability of getting out of states to the directed state. The arc/arrow values are set to initial values (e.g. q_1, q_2,..., q_{16}) which give the initial state transition matrix of Markov model. These values can be modified later on with the influence of *emotion inducing factors*: α, β, γ and δ for joy, anger, fear and sad respectively. In this model, there are four types of transition probabilities from each of the present state. For example, the probability of state transition (arc/arrow values) from joy to other states can be expressed by following equations:

$$\left.\begin{aligned} P_{e3/e4} &= q_2 + (\beta - \alpha)q_2 \\ P_{e2/e4} &= q_3 + (\gamma - \alpha)q_3 \\ P_{e1/e4} &= q_4 + (\delta - \alpha)q_4 \\ P_{e4/e4} &= 1 - (P_{e3/e4} + P_{e2/e4} + P_{e1/e4}) \end{aligned}\right\} \quad (4)$$

where q_2, q_3 and q_4 are the initial arrow values for $P_{anger/joy}$, $P_{fear/joy}$ and $P_{sad/joy}$ respectively. For each of the states, there are similar equations combining to total of 16 equations which render new values to the state transition matrix to be updated. More details of the model and computational procedures are given in [6], [7].

3.2 Updating Process

In a sense, the emotion factors reflect the total environmental conditions surrounding the agents. The emotion inducing factors are updated through the information from inputs, e.g. from sensors, user, response of colleague or internal events (see Fig. 3). Here, we can see that the input variables affect on the emotion inducing factors (α, β, γ and δ) and thus affect on the emotional state generated by the Markovian emotion model. All the environmental variables are grouped into three variables: workload (w), comfort (c) and evaluation (e). Each of them is scaled as 0 to 10 indicating low to high. For each of the emotion factors, we have used a second order polynomial in the three dimensional space of (w, c, e) for approximate mapping of emotion factors from input variables. The coefficients of the polynomial are *individuality factors* that vary from agent to agent. The user of the agent can design the benevolent characters through the manipulation of the *individuality factors* by approximating emotion factors with response surface method (RSM).

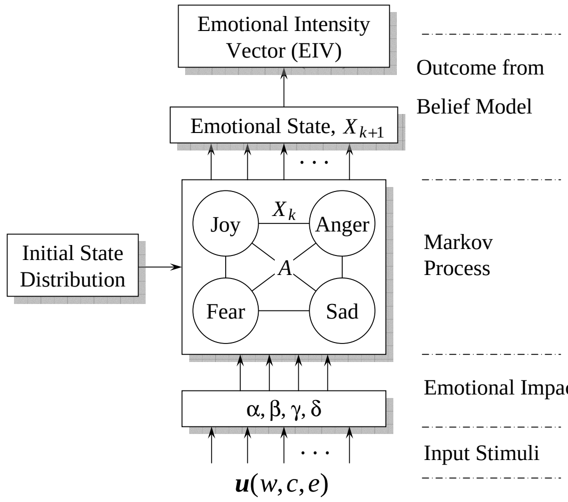

Figure 3: The emotional state generator

4 Simulation Results

We have simulated the model with two robots considering as benevolent agents in *KiKS* environment (see [12] for *KiKS*). Task (room cleaning) is assigned by the user of the system (see Fig. 4) with defining workload (which is a function of workspace to be cleaned, number of balls and prescribed time). Workload (w) can be expressed as following equation:

$$w = C\left(\frac{Work\ space}{Time}\right) \quad (5)$$

where C is an integer value increased with the number of balls to be cleaned. With the assigned workload, both robots start with the corresponding working speed and pushing the balls towards the wall and thus cleaning the center of the room. At first the working area is divided into equal space, but the individual working space is changeable if required. For example, if one robot is feared to complete the cleaning of its space (due to many balls in its area) and it needs help, then another one shares with the working space by extending its previous workspace.

The workload is assigned as: workspace 600 mm × 600 mm, no. of objects 15 and time limit 100 sec. In Fig. 5, we can see the emotional state of robot A, which is in Fear state as probability of failure to complete the task is high due to excess work load. So it sent several help messages to robot B. First few steps, robot B did not response to help messages of robot A due to its own task and thus increasing sad intensity (see Fig. 6), though its dominating emotional state is joy. Later on, it extended its work space sharing the work space of robot A and thus helping in room cleaning.

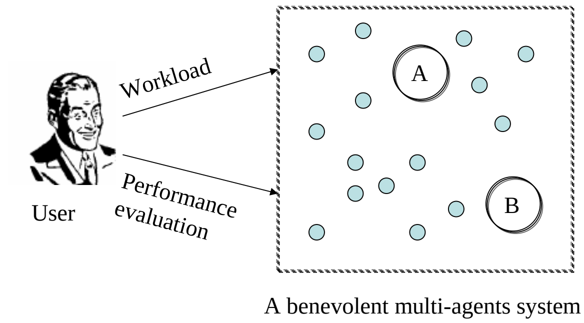

Figure 4: Task assignment and evaluation by user

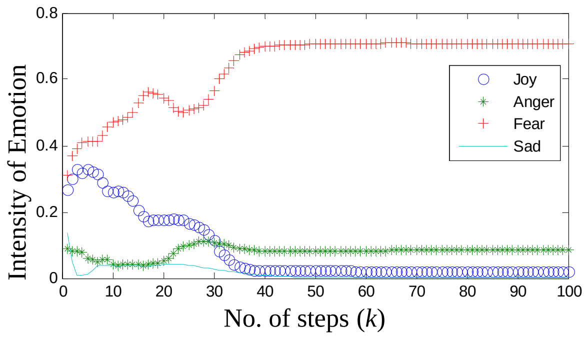

Figure 5: Emotional state of Robot A

5 Conclusion

The proposed computational model of emotion has been based on Markov modeling theory and for simulation; it was applied on a benevolent agents system to generate some behavior with some input stimuli from environment. A benevolent agent was able to be created in affective way by designing the *individuality factors* according to the user's consent. If the agent is taught the work and duties of user, then the user's position may be replaced by the agent (in case of leave or unable to work for any other reason) to work with the same environment with the same emotional behavior of the user.

This model can be also used to develop human-robot interaction architecture in an easier and simpler structure. With the augmented capacity from emotional intelligence robot/agent will be more life-like and thus increasing the robot acceptance to all.

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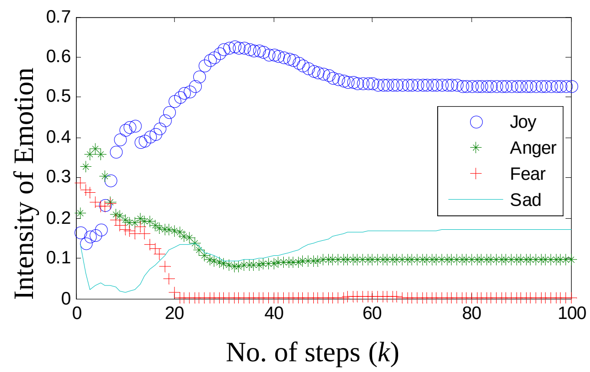

Figure 6: Emotional state of Robot B

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