Improvement of Group Performance of Job Distributed Mobile Robots by Emotionally Biased Control System

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Abstract

This paper deals with the implementation of emotions in mobile robots performing a specified task in a group to develop intelligent behavior and easier form of communication. The overall group performance depends on the individual performance, group communication and synchronization of cooperation. With the emotional capability, each robot can distinguish the changed environment, can understand colleague robot's state, enables adaptation and reacts with changed world. The adaptive behavior of a robot is derived from the dominating emotion in an intelligent manner. In our control architecture, emotion plays a role to select the control precedence among the alternatives like behavior modes, cooperation plans and goals. Emotional interaction is happened among the robots and a robot is biased by the emotional state of the colleague robot in performing task. Here emotional control is used for better understanding to read the colleague's internal state, for faster communication and better performance eliminating dead time.

Keywords: Emotion, Multi-agent system, Markov modeling theory, Colleague robot, Distributed job, Emotional embodied intelligence.

1 Introduction

Emotions have important role in intelligence, decision making process, learning, social interaction, perception, memory, creativity and more [1]. At present emotional robotics is not an oxymoron, moreover researchers are working to incorporate emotional embodied intelligence in robotics. Damasio [2] suggested that emotions can provide a selection mechanism for eliminating bad alternatives and then decision making process is simplified. For a human team, a lot of emphasis is given on the emotional state of the members of a team and on the understanding each others' emotions and thus keeping all motivated to the general goals [3], [4]. Emotions act like a value system, allowing each individual to take a decision rapidly through the perception of situation and then act quickly. By understanding the colleague's emotional state, others can understand the situation that they are in and also can be motivated to do the task. For example, if one is in happy state, others can find out the reason of happiness, then he is motivated to follow the happy colleague in doing job. On the other hand, if one is in fear state, then others can get alert and understand the situation and thus plan to escape the situation by collaborating with the feared colleague or by compensating for his action. In [5], Nair et al. showed that in mixed agent teams (agent-human teams) as well as in pure agent teams, the introduction of emotions could help in bringing the same advantages that emotions bring to human teams.

In this paper, we describe a method to increase the group performance of a team of robots with the implementation of emotionally biased control system by taking the advantages from emotional understanding, communication and synchronization. Here, the choice of behavior depends on the current emotional state of each robot as well as emotional state of colleague robot. The emotions can be considered mainly as a particular type of information that is exchanged among the robots. Section 2 describes the related works where some researchers have applied emotions to control robots and multiagent system. Section 3 clearly describes the purpose of the research work, the system where emotion is applying to control the robot team and the control strategy. Description of simulation software and its application to simulate emotional based behavior is given in Section 4. Finally, Section 5 concludes with advantages of the emotionally biased control method as well as discusses the limitations with some open issues.

2 Related work

The idea of artificial emotion is increasingly used in designing autonomous robotics agents, by making robots to experience emotionally with the changed environment or to make interaction with other agents [6], [7]. In our research work, the topics are related to cooperation between job distributed robot teams, computational architecture for modeling emotions, use of emotion for control and avoiding stagnation.

Mataric et al. [8] and Parker's [9] research works have relation with distributed coordination of robots, but have significant differences in backgrounds and approaches, and also have different architecture with different implementation. In [8], control architecture is based on subsumption architecture and cooperation emerged from the structure of behavior. Later, Schneider-Fontan and Mataric included an emotional model for using in communication for the minimization of interference [10]. In [11], Murphy et al. developed a multiagent control approach for interdependent tasks which imbues the agents with emotions and allows a satisfactory behavior to emerge. In this approach, a formal multilevel hierarchy of emotions is used where emotions modify active behaviors at the sensory-motor level and also change the set of active behaviors at the schematic level. It mainly focuses on interdependent tasks, not purely cooperative and one robot cannot perform the other one's task. Our work in this article is different in task mode (job is distributed to each robot, but each one is capable to do other one's job if necessary) and emotion is generated based on Markov modeling theory [12].

3 Approach

This section describes distributed job among the agents, control architecture and emotional model that has been applied for dominating emotion generator.

3.1 Distributed job

For the simplicity, we have considered two robots working in a group. One robot cleans the center part of a floor by pushing laid objects to the wall side and another (colleague robot) picks up the objects from the wall side simultaneously. But in case of any inability of the robot (due to over work-load with respect to time limit or if battery operated and power shortage occurred or any other causes), colleague can also help in cleaning floor and thus continuing the work process targeting to finish the assigned task in time maintaining a constant level of performance.

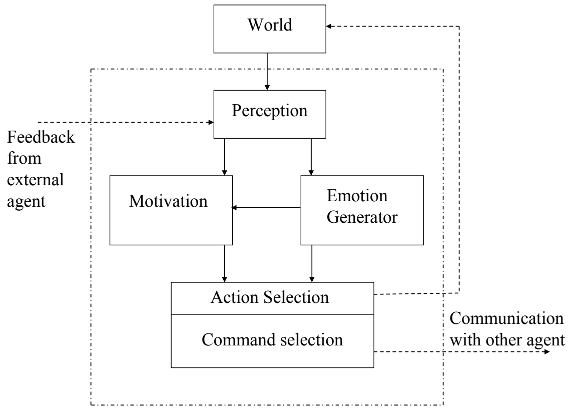

Figure 1: Architectural view of the control mechanism and communication

3.2 Control and communication strategy

The architecture is based on four basic subsystems: perception, motivation, emotion generator and action-command selection subsystems as shown in Fig. 1. The world (or environment) is perceived by the perception subsystem through some parameters. The motivation subsystem selects the present need (or goal) to be satisfied through the subsequent analysis of the perceived parameters and emotion. The behavior of the motivation subsystem can be expressed by the following equation:

$$f(p_1, p_2, \ldots, p_n, e) = Modification\_input$$

where p_1, p_2,..., p_n are the perceived parameters rendered by the perception subsystem and e is the generated emotional state of the agent. The selection subsystem selects two things at a time: one is the action to be performed by itself which is best suited with the present need and the other is a communication command to express its emotional state and situation to the external agent (colleague). In response to the command, colleague robot sends a feedback to its perception subsystem. Behaviors of each robot are adapted according to two emotional signals: global one, generating for all robots and local one, generating specifically for itself [18].

3.3 Emotional model

With the emotionally biased control system, we want to exploit the roles that emotion plays in biological systems which enhance adaptation in dynamic, uncertain and cooperative environment. The emotional model consists of four basic emotions [13]: joy, anger, fear and sad. The eliciting conditions and functional responses of each emotion are summarized in Table 1. An application of Markov modeling theory for our purposes is described by Markovian emotion model as shown in Fig. 2. Although this model is justified by previous work in psychology of modeling human emotion [12], [14], [15], 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.

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. For example, the probability of state transition (arc/arrow values) from joy to other states can be expressed by following equations:

$$P_{anger/joy} = q_2 + (\beta - \alpha)q_2$$

$$P_{fear/joy} = q_3 + (\gamma - \alpha)q_3$$

$$P_{sad/joy} = q_4 + (\delta - \alpha)q_4$$

$$P_{joy/joy} = 1 - (P_{anger/joy} + P_{fear/joy} + P_{sad/joy})$$

where q_2, q_3, p_4 are the initial arrow values for $P_{anger/joy}$, $P_{fear/joy}$ and $P_{sad/joy}$ respectively. These new values are used to get the updated state transition matrix. In [12], [16], more details of the model and computational procedures are given.

4 Simulation Results

The simulation is performed using *KiKS* which is a Matlab based Khepera simulator and can simulate in a very realistic way [17]. For simulation purpose two robots are considered: the *Cleaner* and the *Collector*. The *Cleaner* robot is able to push the balls (as laid objects on the floor) to wall side and the *Collector* has the wall following character to collect the balls from wall side shown in Fig. 3. But it is also able to help in cleaning floor and vice versa, if necessary. The emotional state of each robot is a function of its present working condition, work load and *colleague*'s emotional state. The emotion eliciting conditions and effects on colleague are created according to Table 1.

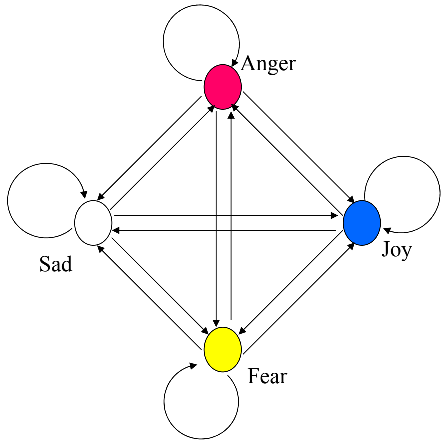

Figure 2: Markovian emotion model

Table 1: Emotion eliciting status and effects on colleague

Emotion	Eliciting status	Effects on colleague
Joy	Success in achieving goal.	Motivated to work.
Anger	Goal either fails or is about to fail due to colleague.	Commanded to increase performance.
Fear	Believes a goal is likely to fail.	To be care about other.
Sad	Unable to do usual job or goal fails.	Evoked to help or alternative.

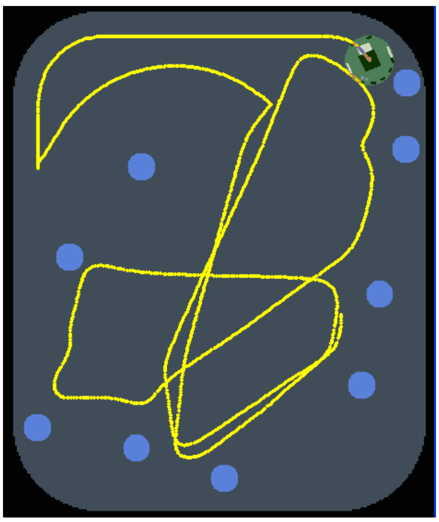

Figure 3: Floor cleaning and collecting behavior of a robot

5 Conclusion

The aim of this work has been to explore emotions as one of the possible methods to control multi-robot systems. This illustrated the way to achieve desired cooperation among the job distributed robots using emotions. Although emotion generation is very complex, here a Markovian emotion model is applied emphasizing the present state, which seems to work well. With the emotional causes, the collector robot can dynamically adjust its speed which leads to better collecting process in a synchronized way. On the other hand, the cleaner robot is also able to modify its behavior as well as environment by its internal emotions which lead it to actions.

To bring the same advantages for pure agent team that emotions bring in human teams, it needs more exploration of emotion generation and implementation. The behavior is also a function of emotional intensity, which is ignored for simplicity of the emotional model. Also a burning question arises about the co-occurrence of emotions and their filtration process. These drawbacks are the pending issues for future work.

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