Agent-Based Emotional Architecture for Directing the Adaptive Robot Behavior

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Abstract

The paper describes a work in progress for modeling an emotion-based autonomous robot controller designed to coordinate the interaction with the environment. The robot courses of actions are conceptualized as consequences of collaborative multi-agent fuzzy decision making processes.

Background

The approach to the study of emotions as control mechanisms for robot adaptive behavior has been inspired by the recent findings in neuroscience, which reveal that emotions are essential for making intelligent decisions (Damasio 1994).

The idea for evaluating the situations in terms of robot well being and the goal system based on motivations and emotions stems from neurophysiological research. Several works use emotions and motivations in synthetic agents and autonomous robots for monitoring the accomplishment of the goals (Murphy et al. 2002; Michaud et al. 2001), for responding emotionally to a situation and to manage social interaction with humans (Velásquez 1998; Breazeal 1998).

One of the first works that describes control architecture based on feelings and state evaluations is proposed by Bozinovski (Bizinovski, 1982).

Lisetti and Gmytrasiewicz incorporate emotions in the decision-theoretic paradigm of rationality to enhance the functionality of interactive systems (Lisetti and Gmytrasiewicz 2002). According to their view emotional states influence the action space, the utility functions and the probabilities of the states.

In this model motivations and emotions transform the robot decision-making abilities and guide the decision-making process by modifying the preferences assigned to the decision alternatives. I suggest that behaviors elicited by affective phenomena are consequences of collaborative multi-agent fuzzy decision-making processes.

Adaptive Role of Emotions

According to the research on emotions in evolutionary psychology (Cosmides and Tooby 2000), natural selection shapes modular subsystems for solving adaptive problems, such as foraging, predator avoidance and mating, which are coordinated by emotions. In organisms, evolution determined systems for making decisions according to the needs of the species they belong, and of what their potential preys and predators might be. Emotions are biological mechanisms whose function is to provide information related to the most important adaptive goals, and to activate the necessary mechanisms and engage the relevant resources for reaction.

This paper focuses on the adaptive functions of emotions that serve for solving the basic problems facing organisms. Survival in the unpredictable and dynamic environments depends on effective systems for situation assessment and decision making.

Multi-Agent Fuzzy Decision-Making Process

Multi criteria fuzzy decision-making paradigm (Yager 1978; Dubois et al.1996; Fuller and Carlsson 1996) is adopted as a theoretical framework for the computational model of behavior selection.

The emotional agents are represented as decision-makers that have their assessments for the decision criteria and the decision alternatives. Decision criteria have different importances for different emotional agents.

The decision-making situation is represented as a 3-tuple (S,A,C) where
$S=\{S_1, ..., S_n\}$are decision alternatives or courses of action,
$A=\{A_1, ..., A_m\}$are emotional agents or decision-makers,
and $C=\{C_1, ..., C_k\}$ are decision criteria.

Let p_j be the importance of the criterion C_j and s_{ij} be the fuzzy rating for the degree of appropriateness of the decision alternative S_i versus criterion C_j. The unit score U_i of appropriateness of the alternative S_i versus all the criteria is defined as an aggregation of p_j and s_{ij} by the following formula

$$U_i=((1-p_1)\oplus s_{i1}) \otimes ((1-p_2)\oplus s_{i2}) \otimes ... \otimes ((1-p_k)\oplus s_{ik}) \quad (1)$$

where the operators $\otimes$ and $\oplus$ are fuzzy multiplication and addition, respectively, and i=1, ..., n.

For each alternative a collection of unit scores is obtained $\{U_{i1}, ..., U_{im}\}$, where U_{ij} is the unit score of the i-th alternative evaluated by the j-th agent, j=1,..,m and i=1,..,n.

The next step of the procedure is to combine the agent's evaluations of the alternatives in order to select an optimal action. The basic idea of the mechanism for selecting the optimal alternative is that each agent tries to maximize its own interest, but its proposal is evaluated by other agents and has to be accepted by all of them.

Evaluation of the Decision Criteria

For illustrative purposes I present an example where internal drives hunger, pain and tiredness are used as decision criteria and four basic emotions act like decision-makers. Following term set of the linguistic variable importance is used for assessment of the decision criteria T(importance)={VeryHigh,High,Neutral,Low,VeryLow}.

agent	criterion		
	hunger	pain	tiredness
joy	VL	N	N
sadness	VH	N	N
fear	N	VH	H
anger	N	H	VH

Table 1. Evaluation of the decision criteria

The importances assigned to the decision criteria in Table 1 show that the energy level (hunger) is more indicative for the emotions joy and sadness than bumping into obstacles (pain) and progress in the accomplishment of the goal (tiredness). Obstacles or enemies on the way to the target will cause the delay in fulfillment of the goals, which is monitored by emotions fear and anger.

In this approach emotional agents act as supervisors of the robot goals, which is similar to the works of Murphy and Michaud (Murphy et al. 2002; Michaud et al. 2001). Internal drives and external stimuli are used as activation mechanisms for the emotions.

Conceptual Configuration of the Controller

The control architecture coordinates the behaviors according to the robot's goals, needs and estimated external conditions. The basic adaptive goals of the robot, in this approach, are related to the "universal problems of adaptation", as described by Plutchik (Plutchik 1980). The universal problems of adaptation are hierarchy (anger and fear), territoriality (exploration and surprise), identity (acceptance and rejection) and temporality (joy and sadness).

Emotional agents joy and sadness are responsible for the maintenance of the robot's appropriate energy level. Exploration and surprise monitor the process of exploring the environment in order to reach the targets. Anger and fear are related to the progress of accomplishment of the goals. They are used to coordinate behaviors for avoiding or removing obstacles and relations between preys and predators. Acceptance and rejection refer to the group membership. They can be used to include the signals from the external robots about the environment or potential threads in the process of evaluating the situations.

The module for perceiving the external environment provides the sensory information obtained through different modalities. It assigns fuzzy desirability measures to the alternative courses of actions.

Action-selection mechanism enables execution of the behavior that is consistent with the current set of environmental stimuli and with the internal states. When the robot executes the action that fulfils a certain need the intensity of the respective drive is modified and another behavior becomes more appropriate. The robot is considered to have a number of behavior systems each organized to address a specific biological function: investigative, eliminative, ingestive, destructive, etc.

This paper gives a theoretical framework for investigating the effects of affective components on the robot-environment interactions using the techniques of fuzzy decision-making theory.

References

Bozinovski, S. 1982. A Self-Learning System Using Secondary Reinforcement. In Trappl, R. ed. *Cybernetics and Systems Research*. North Holland. 397-402

Breazeal, C. 1998. Regulating Human-Robot Interaction Using Emotions, Drives and Facial Expressions. In *Proceedings of Autonomous Agents 98*. Minneapolis, MO.

Cosmides,L.; and Tooby,J. 2000. Evolutionary Psychology and the Emotions. In Lewis,M.;and Haviland-Jones, J. eds. *Handbook of Emotions*. New York: Guilford Press. 91-115

Damasio, A. 1994. *Descartes' Error: Emotion, Reason, and the Human Brain.* New York: Putnam.

Dubois, D.; Fargier, H.; and Prade, H. 1996. Possibility Theory in Constraint Satisfaction Problems: Handling Priority, Preference and Uncertainty. *Appl. Intelligent* 6 (4): 287-309.

Fuller, R.; and Carlsson, C. 1996. Fuzzy Multiple Criteria Decision Making: Recent Developments. *Fuzzy Sets and Systems* 78:139-153.

Lisetti, C.; and Gmytrasiewicz, P. 2002. Can a Rational Agent Afford to be Affectless? A Formal Approach. *Applied Artificial Intelligence* 16:1-33.

Michaud, F.; Lachiver, G.; and Le Dihn, C.T. 2001. Architectural Methodology Based on Intentional Configuration of Behaviors. *Computational Intelligence* 17 (1):132-156.

Murphy,R.;Lisetti, C.;Tardif,R.;Irish,L.;and Gage,A. 2002. Emotion-Based Control of Cooperating Heterogeneous Mobile Robots. *IEEE Transactions on Robotics and Automation* 18(5):744-757.

Plutchik,R.1980. *Emotion:A Psychoevolutionary Synthesis*. New York: Harper & Row.

Velásquez, J.D. 1998. A Computational Framework for Emotion-Based Control. In *Workshop on Grounding Emotions in Adaptive Systems, Conference on Simulation of Adaptive Behavior*.

Yager, R.1978. Fuzzy Decision Making Including Unequal Objectives. *Fuzzy Sets and Systems* 1:87-95.