Asynchronous Learning by Emotions and Cognition

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Abstract

The existence of emotion and cognition as two interacting systems, both with important roles in decision-making, has been advocated by neurophysiological research (LeDoux, 1998; Damasio, 1994). Following this idea, this paper proposes the ALEC agent architecture which has both emotion and cognition learning capabilities to adapt to real-world environments. These two learning mechanisms embody very different properties which can be related with those of natural emotion and cognitive systems.

Experimental results show that both systems contribute positively for the learning performance of the agent.

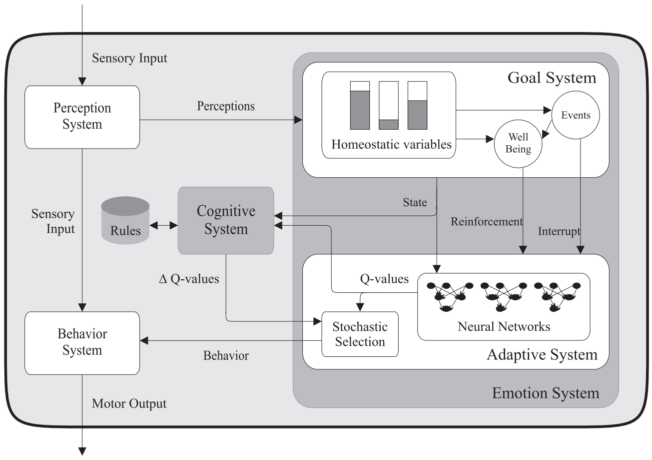

Figure 1: The ALEC architecture.

1 Introduction

Gadanho and Hallam (2001) and Gadanho and Custódio (2002) proposed an emotion-based architecture which uses emotions to guide the agent's adaptation to the environment. The agent has some innate emotions that define its goals and then learns emotion associations of environment state and action pairs which determine its decisions. The agent uses a Q-learning algorithm to learn its policy while it interacts with its world. The policy is stored in neural networks which allows limiting memory usage substantially and accelerates the learning process, but can also introduce inaccuracies and does not guarantee learning convergence.

The ALEC (Asynchronous Learning by Emotion and Cognition) architecture proposed here aims at a better learning performance by augmenting the previous emotion-based architecture with a cognitive system which complements its current emotion-based adaptation capabilities with explicit rule knowledge extracted from the agent-environment interaction.

2 The ALEC Architecture

The ALEC architecture is an extension of the emotion-based architecture presented in (Gadanho and Hallam, 2001; Gadanho and Custódio, 2002). Inspired by literature on emotions, Gadanho and Hallam (2001) have shown that reinforcement and deciding when to switch behavior[1] can be successfully addressed together by an emotion model. The justification for the use of emotions is that, in nature, emotions are usually associated with either pleasant or unpleasant feelings that can act as reinforcement (Tomkins, 1984) and frequently pointed to as a source of interruption of behavior (Sloman and Croucher, 1981). Later the emotion model was formalized into a goal system with the purpose of establishing a clear distinction between motivations (or goals) and emotions (Gadanho and Custódio, 2002). In this system, emotions take the form of simple evaluations or predictions of the internal state of the agent. This goal system is based on a set of homeostatic variables which it attempts to maintain within certain bounds. The emotion-based architecture is composed by two major systems: the goal system and the adaptive system. The goal system evaluates the performance of the adaptive system in terms of the state of its homeostatic variables and asynchronously determines when a behavior should be interrupted. On such interruptions, the adaptive sys-

*Post-doctorate sponsored by the Portuguese Foundation for Science and Technology.

[1] Behavior-switching may be motivated by several factors: the behavior has reached or failed to reach its goal, the behavior has become inappropriate due to changes in circumstances, the behavior needs to be rewarded or punished. The correct timing of behavior-switching can be vital (Gadanho and Hallam, 2001).

tem learns which behavior to select using reinforcement-learning techniques which rely on neural-networks to store the utility values.

The ALEC architecture adds a cognitive system to the emotion-based architecture described previously. The function of the cognitive system is to provide an alternative decision-making process to the emotion system. The cognitive system collects knowledge independently and can step in to correct the emotion system's decisions because it relies on a more exact memory representation based on a collection of important individual events which is not prone to inaccuracies due to over-generalization. The cognitive system is based on the rule-based level of the CLARION model (Sun and Peterson, 1998). One of the main reasons for selecting CLARION's rule system is that it does not derive rules from a pre-constructed set of rules given externally, but extracts them from the agent-environment interaction experience.

The cognitive system maintains a collection of rules which allow it to make decisions based on past positive experiences. Rule learning is limited to those few cases for which there is a particularly successful behavior selection and leaves the other cases to the emotion system which makes use of its generalization abilities to cover all the state space. If the rule is often successful the agent tries to generalize it by making it cover a nearby environmental state; otherwise if the rule's success rate is very poor it attempts to make it more specific (same as in Sun and Peterson, 1998). In ALEC a behaviour is considered successful if it leads to a positive transition of the agent's internal state, or more specifically, of its homeostatic variables.

If the cognitive system has a rule that applies to the current environmental state, then it makes the selection of the behaviors suggested by the rule more probable.

3 Experiments

The experiments tested ALEC within an autonomous robot which learns to perform a multi-goal and multi-step survival task when faced with real world situations such as continuous time and space, noisy sensors and unreliable actuators.

Results show that ALEC not only learns faster than the original emotion-based architecture (Gadanho and Custódio, 2002) but also achieves a better final performance level.

The cognitive and the emotion systems together perform better that either one on its own. On the one hand, the cognitive system of ALEC improves learning performance by helping the emotion system to make the correct decisions. On the other hand, the cognitive system cannot perform well without the help of the emotion system because it only has information on part of the state space.

4 Conclusion

The ALEC approach implies that while emotion associations may be more powerful in its range capabilities, they lack explanation power and may introduce errors of over-generalization. Cognitive knowledge, on the other hand, is restricted to learning about simple short-term relations of causality. Cognitive information is more accurate, but at a price — since it's not possible to store and consult all the single events the agent experiences, it selects only a few instances which seem most important.

The way the emotion system influences the cognitive system is akin to Damásio's somatic-marker hypothesis (Damasio, 1994). In his hypothesis, Damásio suggested that humans associate high-level cognitive decisions with special feelings which have good or bad connotations dependent on whether choices have been emotionally associated with positive or negative long-term outcomes. If these feelings are strong enough, a choice may be immediately followed or discarded. Interestingly, these markers do not have explanation power and the reason for the selection may not be clear. In fact, although the decision may be reached easily and immediately, the person may feel the need to subsequently use high-level reasoning capabilities to find a reason for the choice. Meanwhile, a fast emotion-based decision could be reached which depending of the urgency of the situation may be vital.

ALEC shows similar properties, when it uses emotion associations to guide the agent. Furthermore, the cognitive system can correct the emotion system when this reaches incorrect conclusions. Knowing the exceptions from previous experiences, it may choose to ignore the emotion reactions, which although powerful can be more unreliable.

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