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A Cognitive and Affective Architecture for Social Human-Robot Interaction

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ABSTRACT

Robots show up frequently in new applications in our daily lives where they interact more and more closely with the human user. Despite a long history of research, existing cognitive architectures are still too generic and hence not tailored enough to meet the specific needs demanded by social HRI. In particular, interaction-oriented architectures require handling emotions, language, social norms, etc, which is quite a handful. In this paper, we present an overview of a Cognitive and Affective Interaction-Oriented Architecture for social human-robot interactions abbreviated CAIO. This architecture is parallel to the BDI (Belief, Desire, Intention) architecture that comes from philosophy of *actions* by Bratman. CAIO integrates complex emotions and planning techniques. It aims to contribute to cognitive architectures for HRI by enabling the robot to reason on mental states (including emotions) of the interlocutors, and to act physically, emotionally and verbally.

1. INTRODUCTION

Robots tend to be found in the developed world in domains such as search and rescue, space exploration, hospitals, daily life companionship etc., in close interactions with the users. By closeness, we point towards not only the sharing of a close physical space but towards the concepts of goals and beliefs, which are used to achieve a common task through interactions. The study of interactions between humans and robots is thus fundamental to ensure the development of robotics and to devise robots capable of socially interacting intuitively and easily through speech, gestures, and facial expressions. Many applications involving robots exist, but the underlying robot's cognitive architecture is not always explained. The development of cognitive architectures for robots while taking into account the complexity of social human-robot interaction is a real challenge. It requires various features to be present: emotions, reflexive and deliberative levels (fast emotional answers versus slower and more deliberate answers), explicit manipulation of mental states (to enable self-explanation).

Ever since the pioneer works on robot and cognitive architectures, e.g., [3], researchers have developed several architectures based on different underlying techniques, e.g., symbolic, connectionist or hybrid. For instance, some architectures are based on a set of generic and symbolic rules such as Soar [5] based on the unified theory of cognition, or ACT-R [2]. Many of these architectures are based on the-mind-is-like-a-computer analogy. In contrast, other techniques specify no such rules *a priori* and rely on emerging properties of processing units. Hybrid architectures combine both the types of processing (CLARION [9] for example). In spite of the numerous contributions in the field of cognitive architectures, credible social interactions have not yet reached a reality. Therefore, a research on different approaches to build cognitive architectures oriented for interaction able to deal emotion and social aspects of HRI is highly useful.

2. CAIO ARCHITECTURE

The CAIO architecture (see figure 1) aims to contribute to cognitive architectures for HRI by reasoning on five mental states called BIGRE (Beliefs, Ideals, Goals, Responsibilities, Emotions) of the interlocutors; and acting physically, emotionally and verbally.

The CAIO architecture consists of two loops: a *deliberative loop* which used to reason on BIGRE mental states and produce plans of action, and a shorter *reflexive loop* to immediately trigger emotional reactions. Each loop takes as inputs the result of the multi-modal perception of the environment (the interaction with the human). During the deliberative loop, the **deliberation module** deduces the robot's communicative intentions based on its BIGRE mental states and the mental states of the interlocutor. Then, it selects the most appropriate one. The **planning and scheduling module** produces a plan to achieve the selected intention (*i.e.* a set of ordered actions, communicative acts and/or physical actions), and schedules the robot's next action. Finally the **multi-modal action renderer** executes this scheduled action. Modules can provide feedback to each other; the planning module informs the deliberation module of the feasibility of the selected intention; the action renderer informs the planner of the success or failure of action performance. Simultaneously, during the reflexive loop, the **appraisal module** uses the mental states to trigger the

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robot's complex emotions (*regret*, *disappointment*, *guilt*, *reproach*, *moral satisfaction*, *admiration*, *rejoicing* and *gratitude*) that can be expressed by the multi-modal action renderer via the corresponding expressive communicative acts. Both emotion and action are finally merged by the multi-modal action renderer to produce the appropriate interaction with the robot's available actuators. For instance, in the case of a verbal action, the action renderer module produces the expression that fits the emotion and utters the propositional content of the communicative acts.

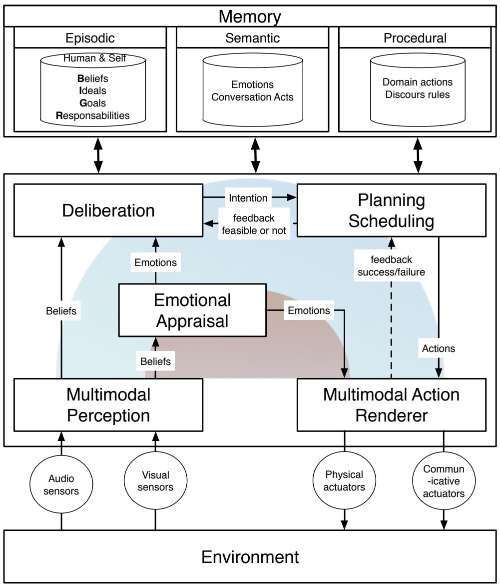

Figure 1: The CAIO architecture.

CAIO architecture is made up of 5 modules:

Multi-modal perception module. The aim of the multi-modal perception module is to merge multi-modal inputs such as *natural language* and *facial expressions* in order to generate beliefs on the user's mental states. This stimulus will then be evaluated by both emotional appraisal and deliberative modules.

Memory module. The robot's memory is divided into three parts in accordance with the state of the art. The *episodic* part contains the BIGRE [4] based knowledge representations of self and human in interaction. The *semantic* part is composed by definition of emotions concepts and conversational acts. The *procedural* part deals with the domain action (how-to) and the discourse rules (i.e. when asked a question, one should reply).

Appraisal module. The appraisal module takes as input the robot's perceptions and mental states and triggers the complex emotions from their logical definition in terms of the mental states. See [8] for more details.

Deliberation module. The deliberation is the process that allows to decide the robot's communicative intentions, i.e., the goal to achieve. The CAIO architecture uses three kinds of communicative intentions: the *emotional* and *obligation-based* intentions useful to local dialogue regulation, and the *global* intention which defines the dialogue direction. The robot's communicative intention is selected *via* practical reasoning from its mental states and a set of priority rules. See [1, 7] for more details.

Planning module. The planning module [6] is in charge of finding a way of achieving the selected communicative intention according to a plan-based approach of dialogue. The plans produced contain communicative acts and/or physical actions. The formalization of their preconditions and effects uses the classical planning formalism PDDL (Planning Domain Description Language).

Multi-modal Action Renderer. The last module takes as input an action to be executed and the complex emotion computed by the appraisal module. The role of this module is to control the robot's actuators to executed the input action and to dynamically generate the expression to accompany the communicative acts achieving the communicative intention selected by the deliberation module.

3. CONCLUSION

In this paper, we have given an overview of a new affective and cognitive architecture for HRI, called CAIO. CAIO provides new contributions regarding the state of the art in cognitive architecture for companion robot. The two main ones lie in (1) its two loops : a *deliberative loop* used to reason on BIGRE mental states and to produce plans of action, and a shorter *reflexive loop* to immediately trigger emotions and (2) in the integration of emotions in cognitive HRI. This architecture has not achieved its final state and several improvements are under way. For instance, we are working on a learning module that could enable the robot to learn ontologies that could be used as new rules (procedural memory) and new concepts (semantic memory) by its reasoning modules. We are also working on an experimental scenario to evaluate CAIO architecture involving children in interaction with a companion robot.

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