A Model for Embodied Cognition in Autonomous Agents

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Abstract. The traditional efforts to mimic basic human behavior in embodied agents use an approach that draws a clear line between the "mind" and the "body" of those agents. However, recent findings in neuroscience show that our bodies have an active role in what we call "intelligence". We studied several processes related with our body and propose a model to integrate them in generic embodied agents. The model was validated in a small case study with the NAO robot.

Keywords: Embodied Agents; Body Model; Physiological Approach

1 Motivation and Related Work

The concept of embodied agent has been widely explored in both robotics [7] and computer science [4]. The traditional computational approach for such agents uses a dualist perspective: a central "mind" receives sensory information and performs actions through the "body" (sensors and effectors) in a continuous sense-reason-act loop. However, using a centralized decision-making process has some implications. The mind has to cope with different levels of control and abstraction at the same time, which range from lower-level sensors and effectors to higher-level cognitive tasks.

Human beings, on the other hand, have intermediate layers of control at different levels. Our bodies have regulation mechanisms that perform subconscious tasks in parallel with the higher-level cognitive tasks. And although one may argue that most physiological processes are "hidden" and will have a limited impact on embodied agents, we think that they have an important role in the the generation of subconscious behavior which, to some extent, shapes the conscious mind [6].

Some previous work that explored physiological architectures includes an hormonal approach to model motivations and emotions in behavior selection [3], and an action-selection mechanism grounded in ethology [2]. More recently, Lim et al. [9] developed an approach to add physiological aspects to agents with high-level emotional planning and storytelling capabilities. We follow the latter work and propose a model of embodied cognition to be used in generic agents with different forms of embodiment.

2 Embodied Cognition

The main idea behind Embodied Cognition is to enrich the aforementioned sense-reason-act loop with an explicit model of the body. The model defines: a physiological space [1], which represents the current state and condition of the body; a set of *internal sensors*, which monitor the body's physiological condition (interoception [5]) and gather feedback from the effectors (proprioception [8]); a set of *internal effectors*, which can execute changes within the body; and an implicit memory [10], which stores procedural memories (sequences of actions which are executed in certain conditions). These mechanisms are part of a secondary control loop, a "subconscious mind", that runs in parallel with the "conscious mind" (Figure 1).

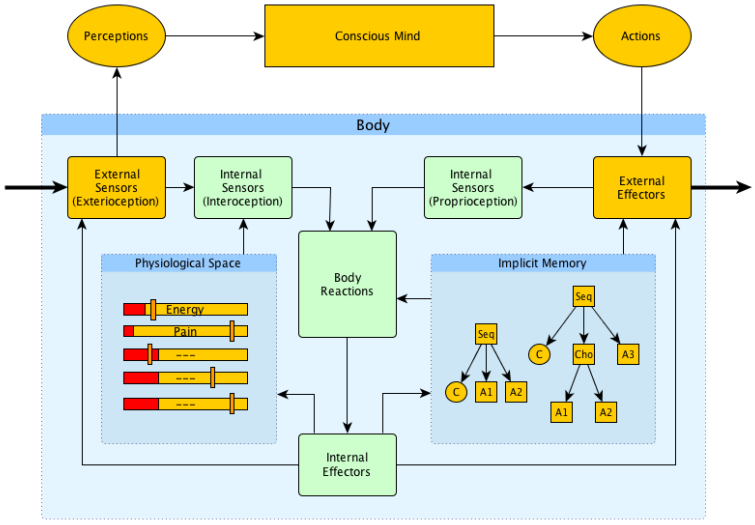

Fig. 1. Generic Architecture of an Agent with the Model of Embodied Cognition

The model was implemented in a small case study with the NAO robot. The "subconscious mind" creates a parallel execution layer that frees the "conscious mind" from body-related tasks, like background behaviors or instinctive reactions. The "conscious" layer is in control, but the "subconscious" can always step up to cope with unbalanced situations regarding the body. The "subconscious" also filters sensory data and adapts motor commands, thus creating an indirection that fosters the definition of generic bodily behaviors to be shared across different types of embodiment (both robotic and virtual). Therefore, the next step will be to explore the reusability of the model in different bodies using the same "conscious mind". We believe it will support a faster development of complex behavior in embodied agents as well as richer interaction possibilities.

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