Building Affective Robots

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The Problem: Affect is inherently intertwined with several attributes that we associate with intelligent behavior, such as multimodal sensory-motor integration, attention, natural social interactions, and learning and development [1, 2]. The primary focus of this research is to investigate affect from a computational perspective by implementing models of affective processing on a variety of robotic platforms [3].

Motivation: Recently, efforts have shifted from behavior-based approaches to robotics that deal with insect-level competence, to those that try to build humanoid robots with an increasingly complex behavioral repertoire that includes, among other competences, the ability to interact socially [4, 5].

If we are to build robots that exhibit robust and adaptive behavior, and which are responsive to social interactions, then we must deal with issues such as motivation and emotion, which have not been considered essential in previous behavior-based robotics, but which are crucial in humanoid robotics.

Previous Work: Research in the area of computational approaches to emotion, and affect in general, has received increased attention over the last couple of years. Several models and architectures have been proposed for a variety of domains and environments, including, but not limited to, synthetic characters [6], human-computer interaction [7], and robotics [3, 5].

Approach: We have developed a novel methodology for building robots that follows an affect-based decomposition. This methodology, which extends previous work on behavior-based robotics and humanoid robots [4], stresses the use of computational models of affective processing to build and control intelligent systems that are capable of performing a variety of complex behaviors in the real world.

- **Integration:** This methodology accentuates the notion of building complete systems that not only integrate models of affect, but that also take into account systems that mediate perception, attention, motivation, behavior, learning, and motor control. We propose the idea of an affect program as a useful abstraction that offers a natural decomposition for this task. Affect programs integrate a variety of sensory information and synchronize a number of functions in response to biologically significant events. Thus, they are well suited to act effectively as an integration mechanism by which activity in many different systems is bound together in a coherent manner.

- **Natural interaction:** We also argue that the expressive components of affect play an essential role in communicating internal states and promoting natural interactions. By endowing our robotic systems with such expressive skills, we can capitalize on people's natural abilities to support social interaction. This provides a more natural way for human-machine interaction as well as novel approaches for learning [8].

- **Development:** Development is an extensive and gradual process by which organisms acquire increasingly elaborate behaviors and new abilities. Recent work in robotics has begun to deal with issues of cognitive development. Affective development, on the other hand, is a new challenge that lies at the core of this work.

  Our approach focuses on the use of affective learning schemes such as incentive learning and reward-based learning, which can focus the robot's attention and reduce the learning space by providing information concerning when to learn and what to learn.

Difficulty: The main challenge of this endeavor into computational models of affect is integrating ideas, evidence, and techniques from a variety of fields, such as neuroscience, psychology, and ethology, in such a way that it is feasible to design and implement appropriate abstractions for affective processing that can be used as the basic blocks for bulding and testing our models.

Impact: Building affective robots offers a unique opportunity to address scientific questions regarding the nature of affective processing in humans and animals. Given that we have a direct window into the robot's control systems, it is possible for us to selectively manipulate our models and perform testing in a controlled and repeatable environment. This facilitates the comparison of our implementations with respect to cognitive, ethological, or neurobiological models, thus giving us some insight into the validity of those models and into affective processing in general.

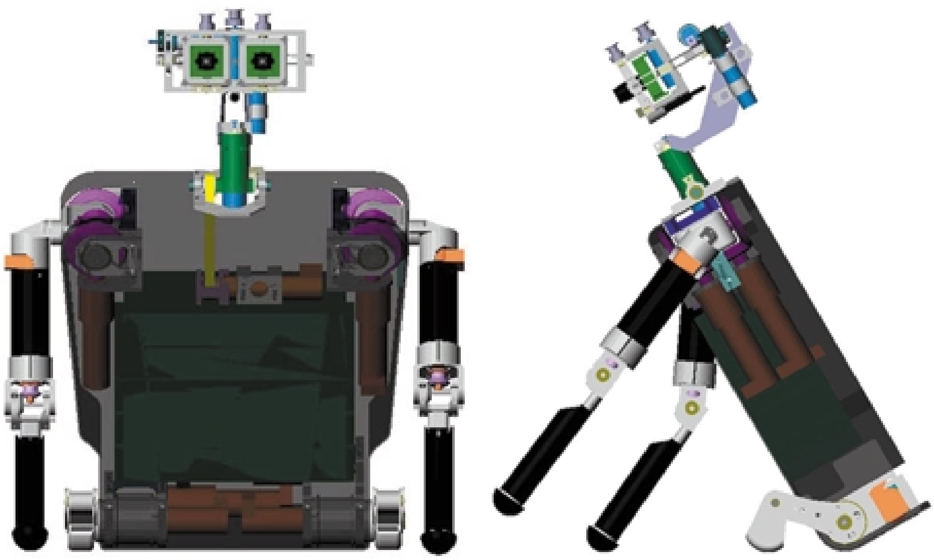

Figure 1: Schematics of the Coco robot, a 15 DOF quadruped with gorilla-like proportions currently under development at the MIT AI Laboratory.

Future Work: Most of our previous and current work has focused on the design and implementation of appropriate abstractions for affective processing. We have created several affect-based control systems for a variety of autonomous robots, including an ape-like robot named Coco (see Fig 1). These systems range from simple emotion-modulated reflexes, to facilitation of attention, and affective learning.

Our future work will concentrate on the design and implementation of effective learning mechanisms that extend these abstractions and encapsulate new ones that capture the notion of habit learning and action repertoires.

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