Affective Motivational Collaboration Theory

Abstract

We investigate the mutual influence of affective and collaboration processes in a cognitive theory to support the interaction between humans and robots or virtual agents. We will develop new algorithms for these processes, as well as a new overall computational model for implementing collaborative robots and agents. We build primarily on the *cognitive appraisal* theory of emotions (Gratch and C.Marsella 2004) and the *SharedPlans* theory (Grosz and Sidner 1990) of collaboration to investigate the structure, fundamental processes and functions of emotions in a collaboration context. As part of this work, we also address a deficiency in existing cognitive models by accounting for the influence of motivation on collaborative behaviors, such as overcoming an impasse. This motivation mechanism uses the results of cognitive appraisal to dynamically form new intentions related to the collaboration structure.

Ronald De Sousa in The Rationality of Emotion (Sousa 1990) makes a good case for the claim that humans are capable of rationality largely because they are creatures with emotions. The idea of having robots or other intelligent agents living in a human environment has been a persistent dream from science fiction books to artificial intelligence and robotics laboratories. However, there are many challenges in achieving collaboration between robots and humans in the same environment. Some of these challenges involve physical requirements, some involve cognitive requirements, and some involve social requirements. Thus far, there has been an emphasis on the design of robots to deal with the physical requirements. Many researchers are also working on the cognitive requirements, inspired by a diverse set of disciplines. As time passes, there is an increasing recognition of the importance of the social requirements.

Motivation

An important aspect of the sociability of robots and agents is their ability to collaborate with humans in the same environment. Therefore, it is important to understand what makes a collaboration effective. One's cognitive processes and the ability to understand the collaborative environment impact the effectiveness of a collaboration. Examples of cognitive capabilities that support the effectiveness of collaboration include: a) perceiving one's own internal states and b) communicating them, c) coordinating personal and group behaviors, d) identifying self and mutual interests, e) recognizing the accountability of private and shared goals, f) selecting appropriate actions with respect to events, and g) engaging others in collaboration.

We are investigating the cognitive processes involved in a collaboration in the context of a cognitive architecture. There are several well-developed cognitive architectures, e.g., Soar (Laird 2012) and ACT-R (John Robert Anderson 1998), each with different approaches to defining the basic cognitive and perceptual operations. There have also been efforts to integrate affect into these architectures (Dancy 2013; Marinier III, Laird, and Lewis 2009). In general, however, these cognitive architectures do not focus on processes to specifically produce emotion-regulated goal-driven collaborative behaviors. At the same time, existing collaboration theories, e.g., SharedPlans theory (Grosz and Sidner 1990), focus on describing the structure of a collaboration in terms of fundamental mental states, e.g., mutual beliefs or intentions. However, they do not describe the associated processes, their relationships, and their influences on each other. In contrast, *Affective Motivational Collaboration Theory* deals with the major processes, including affective and motivational processes, having an impact on the collaboration structure. This theory is informed by research in psychology and artificial intelligence. Our contribution, generally speaking, will be to synthesize prior work on motivation, appraisal and collaboration, and thus to provide a new theory which describes the prominent emotion-regulated goal-driven phenomena in a dyadic collaboration.

Collaboration and Emotion

Collaboration is a coordinated activity in which the participants work jointly to satisfy a shared goal (Grosz and Sidner 1990). There are many important unanswered questions about the involvement of an individual's cognitive abilities during collaboration. Some of these questions are related to the dynamics of collaboration, as well as the underlying mechanisms and processes. For instance, a general mechanism has yet to be developed that allows an agent to initiate proactive collaborative behaviors when it faces a blocked task. There is also a lack of a general mechanism that, in the event of a task failure, allows an agent to consider the collaborator's anticipated mental states and emotions, while managing its own internal goals and the collaboration's shared goal. There are also other questions about the components involved in these processes at the cognitive level, such as the processes that are involved for evaluative, regulatory or motivative purposes. There has also not been enough attention on the processes that are involved to maintain the social aspects of a collaboration.

Emotions have a key role in influencing the cognitive processes involved in social interaction and collaboration. Emotion processing and decision-making are integral aspects of daily life and maintain their prominence during social interaction and collaboration. However, researchers' understanding of the interaction between emotions and collaborative behaviors is limited. We believe that the evaluative role of emotions, as a part of cognitive processes, helps an agent to perform appropriate behaviors during a collaboration. To work jointly in a coordinated activity, participants (collaborators) act based on their own understanding of the world and the anticipated mental states of the counterpart; this understanding is reflected in their collaborative behaviors. Emotions are pivotal in the collaboration context, since their regulatory and motivational roles enhance an individual's autonomy and adaptation as well as his/her coordination and communication competencies in a dynamic, uncertain and resource-limited environment.

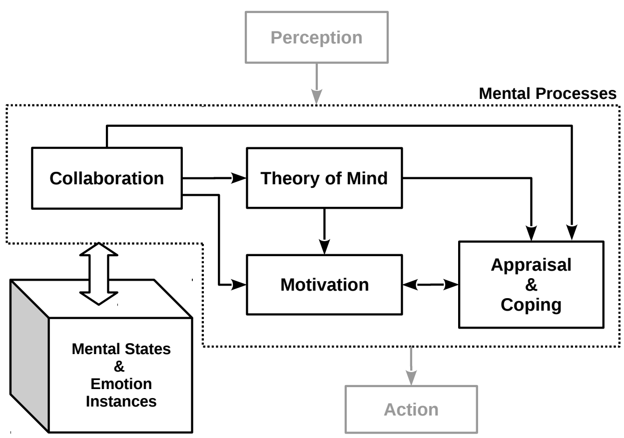

Figure 1: Computational framework based on Affective Motivational Collaboration Theory (arrows indicate primary influences between mechanisms).

Affective Motivational Collaboration Theory

We are building Affective Motivational Collaboration Theory on the foundations of the *SharedPlans* theory of collaboration (Grosz and Sidner 1990) and the *cognitive appraisal* theory of emotions (Gratch and C.Marsella 2004). Affective Motivational Collaboration Theory is about the interpretation and prediction of observable behaviors in a dyadic collaborative interaction. The theory focuses on the processes regulated by emotional states. The observable behaviors represent the outcome of reactive and deliberative processes related to the interpretation of the self's relationship to the collaborative environment. Affective Motivational Collaboration Theory aims to explain both rapid emotional reactions to events as well as slower, more deliberative responses. The reactive and deliberative processes are triggered by two types of events: *external* events, such as the other's *utterances* and *primitive actions*, and *internal* events, comprising changes in the self's mental states, such as belief formation and emotional changes. Affective Motivational Collaboration Theory explains how emotions regulate the underlying processes when these events occur during collaboration. This theory elucidates the role of motives as goal-driven emotion-regulated constructs with which an agent can form new intentions to cope with internal and external events.

Affective Motivational Collaboration Theory explains the functions of emotions in a dyadic collaboration and show how affective mechanisms can coordinate social interactions by enabling one to anticipate other's emotions, beliefs and intentions. Our focus is on the mechanisms depicted as mental processes in Figure 1 along with the mental states. The *Mental States* includes self's (robot's) beliefs, intentions, motives, goals and emotion instances as well as the anticipated Mental States of the other (human). The *Collaboration* mechanism maintains constraints on actions, including task states and the ordering of tasks. The *Collaboration* mechanism also provides processes to update and monitor the shared plan. The *Appraisal* mechanism is responsible for evaluating changes in the self's Mental States, the anticipated Mental States of the other, and the state of the collaboration environment. The *Coping* mechanism provides the self with different coping strategies associated with changes in the self's mental states with respect to the state of the collaboration. The *Motivation* mechanism operates whenever the self a) requires a new motive to overcome an internal impasse in an ongoing task, or b) wants to provide an external motive to the other when the other faces a problem in a task. The *Theory of Mind* mechanism is the mechanism that infers a model of the other's anticipated mental state. The self progressively updates this model during the collaboration.

Conclusion

Current computational theories for human-robot collaboration specify the structure of collaborative activities, but are weak on the underlying processes that generate and maintain these structures. Emotions due to their regulatory, evaluative, communicative, and motivative intra/interpersonal functions are crucial to be used by the underlying processes of collaboration. We are developing a new computational theory, called Affective Motivational Collaboration Theory, that combines emotion-based processes, such as appraisal and coping, with collaboration processes, such as planning, in a single unified framework. In the future, we are going to implement the processes involved in the underlying emotion-regulated mechanisms to develop collaborative behaviors in an interactive robot.

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