Accounting for Emotions in Multi-Agent Modeling and Simulation Systems

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Abstract

In this paper we describe our work in progress for exploring the role of emotions in the behaviour and decision-making of artificial agents in modeling and simulation systems. The computational model of emotions we are using is based on a multi-level theory of emotions that accounts for the three layers identified in the human emotional system: the *sensory-motor* level, the *schematic* level and the *conceptual* level. Our current interest lies in modeling and simulating the impact of emotions in the *workplace*, both at the individual and at the group level. We are working to incorporate our model of emotions into Brahms, a multi-level modeling and simulation system being developed at NASA Ames Research Center.

1. Introduction

The workshop topics most relevant to our current research are (1) methods for constructing models of user affect, and (2) evaluation and validation of computational models of emotion. In fact, the goal of this research is twofold. On one hand, we are using a multi-agent modeling and simulation system, Brahms, as a workbench for *testing* and *evaluating* theories and computational models of emotion. On the other hand, we expect to improve the modeling capabilities of this system by enriching it with mechanisms for representing affect and emotion. We start with a brief overview of Brahms system and than discuss the advantages of using Brahms for evaluating models of emotion and our approach for including the known role of emotions in *work practice* simulations.

1.1 Brahms system overview

Brahms is a multi-agent modeling and simulation tool developed by scientists at NASA Ames Research Center. This system is used to model and simulate the human activity during work practice. The main hypothesis behind Brahms is that multiple, complementary views – cognitive, social, physical – should be integrated in order to better understand work practice (Clancey et.al, 1998). Brahms has a multi-agent language for describing agent and object activities. For a more detailed description of the language see (Sierhuis, 2001). A Brahms model of work practice has seven integrated components.

1. *Agent Model* represents the group-agent membership hierarchy of the people in the work system. Groups may be normal roles and functions or based on location, interpersonal relations, interests, etc.
2. *Object Model* represents the class-hierarchy of all the domain objects and artifacts, e.g., tools, desks, documents, vehicles.
3. *Geography Model* depicts the geographical areas in which agents and objects are located, consisting of area-definitions (user-defined types of areas, such as buildings, rooms, and habitats) and areas (instances of area-definitions).
4. *Activity Model* represents the behavior of agents and objects in terms of the activities they perform over time. Agent or object activities are mostly represented at the group-level or class-level respectively, but are also often specific to agents and objects. Activities are inherited and blended through a priority scheme.
5. *Timing Model* describes the constraints on when the activities in the activity model can be performed, represented as preconditions of situation-action rules (called *workframes*). Activities take time, as determined by the predefined duration of primitive actions. Workframes can be interrupted and resumed, making the actual length of an activity situation dependent.
6. *Knowledge Model* represents an agent's reasoning as forward-chaining production rules (called *thoughtframes*). Thoughtframes can be represented at group/class levels and inherited. Thoughtframes take no time. *Inquiry* is modeled as a combination of activities (e.g., detecting information, communicating, and reading/writing documents) and thoughtframes. *Perception* is modeled as conditions

attached to workframes (called *detectables*); thus observation is dependent on what the agent is doing.

7. *Communication Model* represents the actions by which agents and objects exchange beliefs, including telling someone something or asking a question. A *conversation* is modeled as an activity with communication actions, either face-to-face or through some device, such as a telephone or email. The choice of device and how it is used are part of the work practice.

1.2 Advantages of Brahms for evaluating computational models of emotion

Our choice of Brahms as a system into which to incorporate emotions was based on the important advantages it offers for modeling work practice. As argued by one of his main developers (Sierhuis, 2001), Brahms departs from previous cognitive modeling systems (Soar, Act-R), distributed artificial intelligent systems (TacAir-Soar, Phoenix), and computational organization theory (Plural-Soar, Team-Soar) by representing several aspects of practice that are not comprehensively covered in any of the previous systems: e.g. *collaboration, off-task behaviors*, *multi-tasking*, *interrupt* and *resume*, *informal interaction*, *cognitive behavior* and *geography*. The attractiveness of this *holistic* method for modeling human behavior lies in two aspects. First, contrary to previous cognitive systems that account for emotions in multi-agent settings (e.g. Affective Reasoner (Elliot, 1992), Èmile (Gratch, 2000)), which focus mainly on the cognitive aspects of emotion (based on the OCC model (Ortony et.al, 1988)) it allows us to also consider non-cognitive aspects that accompany emotion processes (e.g. effect of the physical environment such as temperature, and subconscious reflex-like or schematic memory phenomena). Second, Brahms allows us to model and evaluate the impact of affect in *several* different processes such as perception, decision-making and communication (see Section 2). In contrast, the aforementioned systems have a limited representation for the effects of emotion on *behavior*, dictated by the features of the multi-agent system that was used in each case. In summary, the *holistic* approach that Brahms takes to model human behavior offers a *rich* environment for modeling both cognitive and non-cognitive aspects of the role of emotions, moods, and personality on human activities.

1.3 Need for representing affect in Brahms

As it currently stands the affective states of Brahms agents cannot be represented in a model. However, it has already been shown that emotional phenomena play a substantial role on the cognition and behavior of humans. As a result, such phenomena cannot be excluded from the models of human behavior and research must be performed to find mechanisms for representing them. As an example, consider the modeling of a student's day described in detail in the Brahms Tutorial (Acquisti et.al., 2001). One of the activities modeled in this example is the activity of *getting money from the ATM*. A precondition for this activity is that the student, correctly recalls the PIN number of his/her account. Assume, however, that the student is in the middle of a very stressful situation (e.g., final exams period). In accordance with research findings that intense stress can obstruct *memory* accuracy (Sven-Ake Christianson, 1992), there is a high probability that the student will forget his PIN number. This in turn might have significant implications for the rest of his day. Using the current Brahms language it is not possible to represent this situation in a meaningful way.

Emotions can also influence other processes such as *attention* (Forgas and Bower, 1987), *motivation* (Forgas, 1998), *decision-making* (Isen, 1993) and *social behavior* (Berkowitz, 1993). We propose to develop a psychologically grounded paradigm to specifically enable the modeling of such influences.

2. The technical approach to incorporate emotions into Brahms models

In this section we discuss the specific theories of affect we draw upon, and mention the computational models of emotion that are appropriate for our purposes, when such models exist. We also link the proposed affect-related mechanisms to the current Brahms architecture. Our approach for including the impact of affect and emotion in simulations is based in part on the MAMID methodology (Hudlicka and Billingsley, 1999). We consider two levels of inclusion of affect in Brahms models. The first level deals with modeling the affective characteristics of *individual* agents, whereas the second level deals with the combination of these individual characteristics to form a *group's* affective composition.

2.1 Individual Affective Characteristics of Agents

There are, broadly, three main problems that have to be solved with respect to including affect into the individual agents of a Brahms model: (1) the *representation* of affect in a Brahms model, (2) the *elicitation* of affect, and (3) the circular *impact* of affect on the thinking and behavior of agents, and back.

2.1.1 Affect Representation

The representation formalism that we propose is based on the Affective Knowledge Representation (AKR), (Lisetti, 2002). This representation, in agreement with the contemporary emotion research, does not split 'affect' from 'cognition', but rather merges them into a structure that encapsulates each of the three phenomena accompanying emotions: (1) Autonomic Nervous System arousal (2) expression of affect, and (3) subjective experience of affect. Probably the main advantage of using this representation for affect is that it integrates the representation of several affective phenomena (affect, moods, emotions). While the main focus of our efforts are emotions we are also interested in less focused phenomena such as *moods* because they seem to have a substantial role in work groups (Ashkanasy, Hartel and Zerbe, 2000; Lord, Klimoski and Kanfer, 2002). In the AKR each affective episode is considered to be composed of several physiological components such as *valence*, *intensity*, *duration* as well as *stimulus checks* such as *novelty*, *modifiability* (of the eliciting situation), *certainty* (about a stimulus). These can in turn be computationally represented by a *probabilistic frame* (Koller and Pfeffer, 1998), a representation scheme that combines the classical frame representation systems (limited in their ability to deal with uncertainty) and Bayesian Networks (limited in their ability to handle complex domains), with the advantage of allowing for all the components of emotion to be represented and associated with probabilistic values given the uncertain nature of some of these. In Brahms, this representation could be implemented by creating a new construct, *affective-frame*, which would encapsulate the existing Brahms concept, *beliefs*.

2.1.2 Affect Elicitation

We propose to design the emotion elicitation mechanism around a blending of *appraisal theory* (Scherer, et al, 2001) with the *multi-level process model* of emotions (Leventhal and Scherer, 1987). Building on the Leventhal's multilevel process theory of emotions, Leventhal and Scherer proposed that the *stimulus checks* involved in Scherer's appraisal formulations can develop from three levels of processing: (1) the *sensory-motor* level having to do with the automatic, even reflex-like activation of expressive-motor programs by external stimuli and internal changes of state (e.g., physical pain's activation of aggressive urges), (2) the still non-volitional *schematic* level within which sensory-motor processes are integrated with simplified, general prototypes of emotional situations, including the emotions typically aroused in these episodes (e.g., feeling relaxed immediately walking into a spa, or nervous entering an exam room), and (3) the highly cognitive and volitional *conceptual* level involving abstract propositions, planning, anticipating, and role-playing processes.

2.1.3 Impact of Affect on the Thinking and Behavior of Agents

We have already researched and formalized some of the impacts of affect on decision-making and behavior and we propose to integrate these with Brahms.

Affect Priming: Bower's (1991) *network model* suggested that affective states might be directly linked to cognitions within a single associative network of mental representations. Affect may *prime* thoughts and cognitive constructs as it selectively activates memory structures to which it is connected. There is a strong empirical support for this model (Forgas and Bower, 1987). Affect priming can have important consequences for cognition and behavior. For example, people who are in a negative affective state tend to perceive facts of the world that are negative (impact on *attention processes*). This can be reflected in Brahms by modifying the *detectable* construct so that the affective state of agents is taken into account.

Action Tendency: Emotions have an action tendency associated with them i.e., they cause an agent to narrow the set of possible actions that might be taken at a given moment (Frijda, 1986). For example, an angry agent may consider only a subset of its behavioral alternatives, say, ones of aggressive nature. In Brahms, this could be implemented by creating a mechanism that allows changing the consequence part of a *workframe* (by narrowing the set of activities to be performed) during a simulation. It might also require a mechanism for changing the *priority* of *activities* during the execution of activities, to reflect the changes in affective state.

2.2 Group-level affect

There is evidence that the individual-level affective experiences combine to form the affective composition of a group (Kelly and Barsade, 2001). Work groups may develop an identifiable *group affective tone* which in turn may impact group decision-making, prosocial behavior, and withdrawal behaviors. The development of an affective tone for a group comes from a sharing of affective states among group members. Kelly and Barsade (2001) propose several processes that enable affective sharing some of which are discussed below in the context of Brahms.

Affect contagion: Affect contagion refers to the processes whereby the moods and emotions of one individual are transferred to nearby individuals (Hatfield et al., 1994). This means that one agent's affective state can influence the affective state of another agent that is in proximity to the first agent or that is communicating with the first agent. The Simulation Engine of Brahms can be modified so that whenever there is a change in the affective state of an agent, the affective states of other agents in the same location might also change. It also requires mechanisms that allow for emotions to be induced from an agent to another during their communication i.e., it requires modifying the syntax of *communicate* and *broadcast* activities or the way they are simulated by the Simulation Engine.

Behavior entrainment and interaction synchrony: Both those terms refer to completely nonconscious processes by which one individual's behavior is adjusted to synchronize with another (Kelly, 1998). Synchrony can arise from both mirroring another's movements, and from a sequential coordination of speech and movement during an interaction. When behavioral entrainment or interaction synchrony occurs, the outcome is positive affect that can take the form of liking of the partner, and satisfaction with the interaction. In Brahms, we could have a mechanism whereby positive affect would emerge as a result of two or more agents involved in a sequence of communications during an activity, when such communication is harmonious (e.g., when an *uninterrupted* sequence of communications happens between two agents).

3. Future Work

The mechanisms proposed above represent only samples of our technical approach. We are continuously developing and refining those mechanisms to better integrate the numerous findings of research on affect with the Brahms architecture.

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