Towards the Simulation of a Multi-Level Model of Human Emotions

Recent psychological theories of emotion have explicitly focused on modeling the multiplicity of levels of the human emotion system. This increased interest in creating multi-level theories of emotion matches similar efforts in the area of cognitive architectures. In this paper we report our initial work toward integrating a psychological multi-level model of emotions with Brahms, a multi-agent system that is used to model and simulate work practice.

The Multi-Level Appraisal Theories
The main postulate of the multi-level appraisal theory is that emotions arise from an evaluation, or appraisal, of a situation from the perspective of an agent’s goals, needs, and motivations. Almost all appraisal theorists conceive of appraisal as a process that is not just rational and conscious but one that involves other processing modes (associative/schematic and sensory-motor) in addition to deliberative conscious processing. However, only a few of the theories focus explicitly on the multiplicity of levels of the appraisal process. Currently, several different multi-level appraisal theories exist (e.g. Leventhal & Scherer, 1987; Power & Dalgleish 1997; Scherer, 2001). We follow the multi-level, process model offered by Smith & Kirby (2000, 2001), because it gives a more computational account of emotion generation. Figure 1, illustrates the multi-level model of emotion generation by Smith & Kirby (2001). As seen in the figure, the model makes an explicit distinction between the cognitive mode (represented by the Focal Awareness box) and associative mode of appraisal. The appraisal information generated from different modes of processing is captured by appraisal detectors, which combine this information into an integrated appraisal that initiates processes to generate the various elements of the emotional response: the subjective feeling, the action tendency, and the physiological arousal.

Overview of Brahms
Brahms is a system that is used to model human behavior in work settings whose central feature is to combine several different levels of analysis of human behavior: physical, cognitive and social (Clancey, 2002; Sierhuis, 2001). The system is influenced most by: activity theory (Leont’ev, 1979), situated cognition (Clancey, 1997), script theory (Schank & Abelson, 1977). The central concept in Brahms is activity which is conceptualized as an abstraction of naturally occurring behaviors. Activities are considered to be
triggered by motives and they are to be distinguished from tasks, which are formalizations of functions to be performed (thus, are not naturally occurring). A Brahms model does not represent goals explicitly, but represents behaviors that have desired impacts (so, the goals can be seen as embedded in Brahms activities). First a static model of the work practice is specified in the Brahms language, and then this model is simulated using the Brahms simulator - Brahms Virtual Machine (BVM) - which implements the subsumption architecture (Brooks, 1991).

**Integrating the Multi-Level Process Model of Emotions with Brahms**

Figure 3 gives a high level view of the Brahms agent architecture expanded with the emotion module. The box labeled “Brahms AGENT” contains the main constructs of a Brahms agent. Focal awareness is represented as a set of beliefs (first-order predicate calculus sentences). State of the world is represented through facts (which, like beliefs, are first-order predicate calculus sentences). Each agent has its own belief set, whereas the fact set is common for all agents in a model. The behavior is specified using activities, which may be simple or composite. A Brahms activity may have a predefined semantic (e.g. move activity changes the location of an agent; communicate activity allows the exchange of beliefs between agents), or it may be just a time occupier. Activities are executed by situation-action rules called workframes. The perception is modeled via detectables which are conditions attached to workframes (thus, perception is activity-specific). Using detectables an agent can turn facts into beliefs. Reasoning is modeled with forward-chaining production rules called thoughtframes. The activation of workframes or thoughtframes is dependent on certain preconditions (specified in their body) matching the beliefs of the agent. In turn, both workframes and thoughtframes may transform the belief set when executed. Furthermore, workframes can also modify the world state.

The arrows from the “Brahms AGENT” to “EMOTION” represent the three levels of the process of emotion generation: sensory-motor, schematic/associative, and cognitive/conceptual. The reverse arrows represent the impact of emotions in behavior and cognition (processes such as priming and priority selection).. In this paper we only focus on two of the processes depicted in Figure 3: the emotion generation at the sensory-motor level and associative/schematic level. These processes are explained next through a simulation example.

![Figure 3: Integrating a computational model of emotion with the Brahms architecture.](image-url)
Emotion elicitation: A Simulation

We illustrate the ideas with the following scenario taken from Smith & Kirby (2000, p.96):

“You are attending a conference in an unfamiliar city. It is late in the afternoon and you and a colleague are walking around the town intensely discussing the implications of an intriguing presentation you both have just heard. The two of you are so engrossed in conversation that you are not paying close attention to where you are going. This continues for a while until, suddenly, you realize that you are feeling rather anxious. Looking around, you quickly realize why: you have wandered off the beaten path, it is starting to get dark, the buildings around you look run down, and seedy-looking characters are wandering about. You stop the conversation to point out the situation to your companion and the two of you turn around and head back to the touristic part of town without incident”.

We now give details of how this scenario was modeled and simulated in Brahms. Any Brahms construct not previously defined will be explained briefly as we proceed.

Agent Model: Brahms agents usually belong to groups (which represent functional roles or any other characteristic that joins agents). For this scenario we created two groups: Professor and Character. The Professor group has two member agents: ProfessorA and ProfessorB (representing the two colleagues of the scenario). The Character group has several member agents, which represent the people observed as the colleagues walk and discuss the presentation.

Geography: Brahms agents are situated in locations, which are specified as part of the geography of a model. In our scenario everything happens in CityX represented as a Brahms area. We assumed that the initial location of ProfessorA and ProfessorB is the center of the city represented as an area contained in CityX. We also modeled three other areas called Place1, Place2, and Place3. The various characters are distributed among these three areas. The city center and places are connected through Brahms paths.

Object Model: Brahms objects are used to represent the artifacts, and tools that are part of the scenario. They are organized in classes. We created a Buildings class and several instances of this class. The various buildings are distributed among Place1, Place2, and Place3.

Activity and Timing Models: Most activities are coded for the group Professor and they are inherited by ProfessorA and ProfessorB thorough the Brahms’ inheritance mechanism. The main activity we modeled is the DiscussAPresentation activity. The two professors will be engaged in this activity as soon as the simulation starts. This activity will be stopped when the professors’ perceived danger level becomes greater than a threshold. This stopping condition is modeled using a Brahms detectable. The activity DiscussAPresentation has two sub-activities: MoveToLocation and LookAround. Illustrating the subsumption architecture the discussion of the paper will be active at the same time that professors are moving around or observing the environment. The MoveToLocation activity simply will move the professor to another (desired) location. LookAround activity models the observation of the environment (more on this later). As explained in Section 4, each Brahms activity is executed by a workframe, so we have created a workframe for each of the preceeding activities.

Reasoning Model: We created several Brahms thoughtframes (inference rules) for professors to model the process of deciding where to go next. The rules that we created specify that the professors will move from hotel to Place1, Place2 etc. if there is no danger present. If the perceived danger is greater than a threshold professors will go back to the city center.

Communication Model: The communication of danger by ProfessorA to ProfessorB is modeled using a Brahms communicate activity which basically will transmit a belief (of being in danger) from ProfessorA to ProfessorB.

Emotion Elicitation Model: We modeled the emotion elicitation only for ProfessorA to remain true to the scenario. Both the intensity of anxiety feeling and the appraisal detector (see Figure 1) for anxiety are represented as attributes of ProfessorA (attributes are a Brahms construct representing characteristics of agents). The perception of seedy-looking characters and run down buildings is modeled as detectables attached to the LookAround activity. The important thing here is that by using variables we are able to create a detectable that will detect any character or building. The characteristics of characters and buildings that are perceived (seedy-looking and run down) are represented as attributes. Whenever a seedy-looking character or run down building is perceived the associative activation of their appraisal meanings will happen (we have assumed that ProfessorA has some stored appraisal meanings about seedy-looking characters or run down buildings). This associative activation is modeled using Brahms workframes. The theoretical basis of this choice is the fact that Brahms workframes are similar to scripts (Schank & Abelson, 1977). Whenever a seedy-looking character is perceived, the Brahms java activity UpdateAppraisalDetector is called. This activity updates the value of the appraisal detector by modifying a fact about the value of AppraisalDetector. According to Smith & Kirby model (Section 2) it is crucial that this update happens outside of awareness until a certain threshold is passed. Although there is no way in the Brahms language itself for an agent to detect something without it becoming a belief of the agent, by making use of Brahms’ java activity capability we were able to realize the update of the appraisal detector outside of ProfessorA’s awareness. All the incoming cues (different instances of
characters and buildings) will contribute to the increase of the value stored in the appraisal detector. In addition to that, the change in the darkness attribute of TimeOfDay object (passing of time is realized through a Clock object that broadcasts the time in regular intervals) will automatically contribute to the increase of the value of appraisal detector for anxiety. This represents the sensory-motor mode of appraisal generation.

When the value stored in the appraisal detector reaches a threshold (which is detected by a detectable attached to the LookAround activity) the fact about the value of appraisal detector will turn into a belief that represents the ProfessorA’s felt anxiety. This means that ProfessorA will become aware for the first time that he/she is feeling anxious. Although some more processes can still be modeled, (for example, the ProfessorA would be looking for cues of danger, which could be modeled as detectables) at this point we made the ProfessorA simply communicate to ProfessorB that this is a dangerous situation (by transmitting a belief through a communicate activity). After that, both professors will be aware of the danger and the goBack activity will be triggered which will move the professors back to the city center.

**Discussion**

Many approaches Elliot’s (1992) Affective Reasoner (AR), Gratch (1999, 2000), MAMID (Hudlicka 2003) and TABASCO (Staller & Petta, 2001) are related to ours in ways that we cannot describe due to space limitations. Our simulation illustrates two points: (1) it gives an idea about how the integration of the physical (e.g. geography and surroundings objects), cognitive (reasoning) and social (communication) aspects of human behavior in Brahms allows for a detailed representation of the context of the behavior which is considered to be important for modeling emotion processes; (2) it illustrates how the combination of Brahms’ perception mechanism (detectables) and workframes can be used to model the sensory-motor and associative modes of processing in emotion generation. The scenario, however, is very simple and the representation leaves out several important issues related to emotion generation, which will be addressed in future work.

**References**


