

Towards Simulating the Multi-Level Process Theory of Human Emotions in Brahms Multi-Agent Modeling System

Christine Lisetti
Multimedia Communications
Department
Institut EURECOM
Sophia-Antipolis, FRANCE
lisetti@eurecom.fr

Aurel Cami
Department of Computer Science
University of Central Florida
Orlando, FL 32816
acami@cs.ucf.edu

Maarten Sierhuis
USRA/RIACS
Computation Sciences Division,
M/S 269-1
NASA Ames Research Center
MST35B1, Moffett Field, CA 94035
msierhuis@mail.arc.nasa.gov

William J. Clancey
Computational Sciences Division,
M/S 269-3
NASA Ames Research Center
Moffett Field, CA 94035
william.j.clancey@nasa.gov

Abstract

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*.

Keywords: Emotion theories, multi-agent systems.

1. INTRODUCTION

Two main developments have inspired our ongoing research. The first one is the revived interest in the study of emotions in organization settings which has produced significant evidence on the pervasive influence that emotions have on judgements, decision making and behavior in organizations (e.g., Forgas & George, 2001; Kelly & Barsade, 2001). The second development is the effort to develop the Brahms multi-agent system (Clancey et. al., 1998, 2002; Sierhuis, 2001) as a system for modeling and simulating *naturally occurring* human behavior in work settings (as opposed to task-specific activities). We started this research with the intention to understand how Brahms architecture could be used to model the role of emotions in organizations, and how some of the assumed functionality attributed to emotions could be integrated into Brahms. In line with several other researchers we draw on *psychological* theories of emotion and assume that emotion is an evolved mechanism that serves both *attention-regulatory* and *motivational* functions (e.g., Smith&Kirby, 2000). There are two main emotion related processes we are modeling and simulating: (1) emotion *elicitation*, i.e., how various emotions arise, and (2) *adaptation* (or *coping*), i.e., the impact of emotional states in cognition and behavior. In this paper we describe how Brahms can be used as a testbed for a multi-level model of emotions and how the integration of this

emotion model into Brahms could give Brahms agents adaptive capabilities.

2. RELATED RESEARCH

Without claiming to provide a comprehensive review of the existing work, in this section, we discuss a number of systems that are most closely related to our current research.

2.1 Work of Gratch and Marsella

Building on Elliot's (1992) Affective Reasoner (AR), Gratch (1999, 2000) has proposed a model of emotion generation that generalizes Elliot's *construal theory*¹. The main feature of Gratch's approach is that it offers a *domain-independent* mechanism to model emotion generation (inspired by the similarity between planning algorithms and the way emotion appraisal process is assumed to work by many theorists). The more recent research of Gratch and Marsella (2001, 2002) introduces a plan-based method to model *coping*, which is viewed as the reverse process of appraisal. We are currently evaluating the feasibility of adopting the plan-based method in our architecture to account for the cognitive level of emotion generation. The difference between our research and the work done by Gratch and Marsella is that the plan-based methods focus essentially on the cognitive level of emotion,

¹ Construal theory proposes a realization of emotion elicitation as a match between a *domain-dependent* frame hierarchy (called construal frames) and the features of a situation.

while we aim at integrating the various processing modes of emotion generation (which are discussed in Section 3).

2.2 Hudlicka's MAMID architecture

MAMID (Hudlicka 2002, 2003) implements a general methodology intended to incorporate the effect of *individual differences* (or behavior moderators) such as *personality traits* and *emotional states* into a cognitive architecture. The central feature of this methodology is that it proposes a *parameterization* of each module of the architecture and of the connections between various modules. Furthermore, MAMID implements a mapping of the individual differences to this parameter space. This method allows for a rapid evaluation of various theories of emotion and offers a way to approach the problem of determining accurate parameters for a particular theory (through experimentation and fine-tuning). The distinction between MAMID and our research lies mainly in the differences between MAMID cognitive architecture (a sequence of modules from perception to action selection) and Brahms architecture (which is based on the subsumption architecture - as discussed in Section 4). We believe that, such complementary approaches will give us more insight into deciding which architectures offer more flexibility for various emotion computational models.

2.3 Staller's and Petta's TABASCO architecture

TABASCO (Staller & Petta, 1998, 2001) is a system that aims to "integrate the emotion process within an architecture of a situated software agent". TABASCO is built on top of the JAM architecture by adding to it several modules, which implement emotion processes. The overall goals of our research and the research resulting in TABASCO are similar. For example, both systems take advantage of reactive-deliberative situated agent architectures in order to incorporate a multi-level emotion model. However, there are several architectural differences between Brahms and JAM, the most noticeable one being the explicit representation of goals in JAM while this is not the case in Brahms. These architectural differences will lead to changes in the design and implementation of the respective emotion modules.

3. MULTI-LEVEL EMOTION APPRAISAL THEORIES

Many computational models of emotion elicitation are based on some variant of emotion appraisal theory². The main postulate of this theory is that emotions arise from an evaluation, or appraisal, of a situation from the perspective of an agent's goals, needs, and motivations (Lazarus, 1991; Smith & Kirby, 2001; Scherer, 2001).

² Current state-of-the-art in appraisal theory is discussed, for example, in (Scherer et.al., 2001)

Several authors make the distinction between *structural* and *process* appraisal theories (Scherer, 2001; Smith & Kirby, 2000). Briefly, structural theories specify the different constructs involved in the process of emotion generation and the links that exists between them. Process theories, however, go beyond that and attempt to explicitly spell out the process of emotion generation, that is, how and when the different constructs interact with each other³. *Almost all appraisal theorists conceive of appraisal as a process that involves several distinct processing modes: deliberative, associative/schematic and sensory-motor.* 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 the *associative* mode of appraisal. A central construct of this model is the existence of what are called "appraisal detectors". These detectors continuously monitor and detect appraisal information generated from different modes of processing. This information is combined 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.*

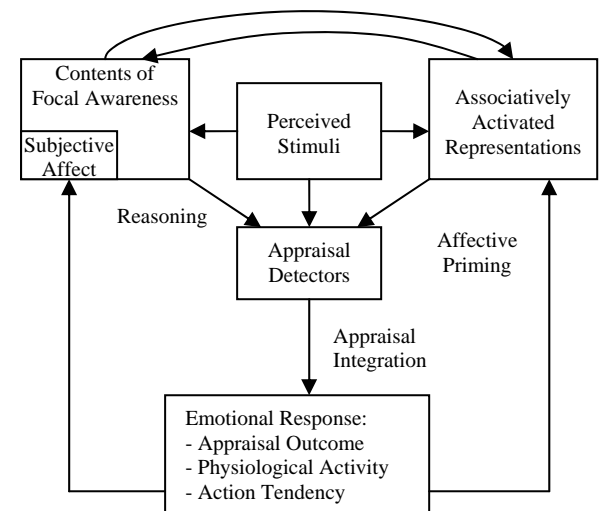


Figure 1: A multi-level model of the appraisal process (from Smith & Kirby, 2001)

This model makes explicit the interactions between the different processing modes. One important assumption

³ Because of the level of detail they provide, process theories are more suitable for computer implementations

of the model is that “the activation threshold at which appraisal information becomes available to the appraisal detectors is somewhat less than the threshold at which appraisal information becomes available to focal awareness” (Smith & Kirby, 2000, p94). This point will be revisited in Section 6. Next, we continue with an overview of the Brahms system.

4. OVERVIEW OF BRAHMS MULTI-AGENT SIMULATION SYSTEM

4.1 Theoretical Perspective

Brahms is a system that is used to model human behavior in work settings. The central feature of the system is that it combines several different levels of analysis of human behavior: physical, cognitive and social (Clancey et.al, 1998; Clancey, 2002; Sierhuis, 2001). The system is influenced most by: *activity theory* (Leont’ev, 1979), *situated cognition* (Clancey, 1997), *script theory* (Schank & Abelson, 1977)⁴. 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). For example, Clancey (2002, p30) argues that task analysis (description of behavior in terms of goals, conditional operators and problem states) “omits ‘off task’ behaviors related to emotional motives (e.g. resting, listening to music), as well as the circumstantial detail of how goals are accomplished as located, mediated, inherently social interactions”. Thus, the modeling of behavior in terms of activities intends, among other things, to make explicit the role of motives and emotions. Our efforts aim to develop these initial ideas of the Brahms’ authors into a fully functional model of emotions.

4.2 Modeling and Simulation in Brahms

Figure 2 illustrates the steps followed to model and simulate work practice with Brahms. First, a static model of the work practice is specified in the Brahms language.

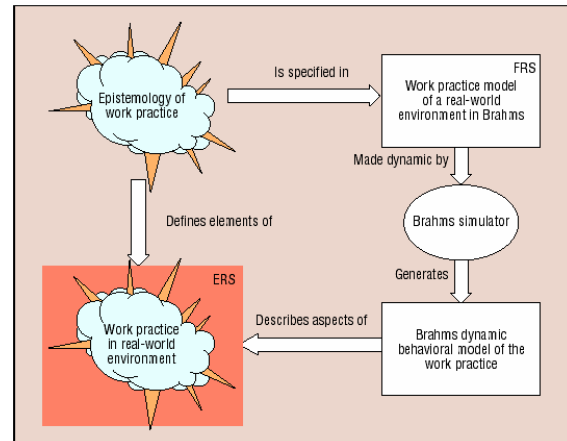


Figure 2: Describing real-world work practice (Empirical Relational System (ERS)) with computational modeling (Formal Relational System (FRS)) (from Sierhuis & Clancey, 2002)

Next, this model is simulated using the Brahms simulator - a.k.a Brahms Virtual Machine (BVM) which implements the *subsumption* architecture (Brooks, 1991)⁵. The results of the simulation can be viewed using a graphical display tool called AgentViewer.

5. INTEGRATING THE MULTI-LEVEL PROCESS MODEL OF EMOTIONS IN 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.

Characteristics of agents are represented through *attributes*. Attributes can get values only through beliefs or facts. The behavior is specified using *activities*, which may be simple or composite. A Brahms activity may have a predefined semantic (e.g. the *move* activity changes the location of an agent; the *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*. Perception is modeled via *detectables* which are conditions attached to workframes and

⁴ See Clancey (2002) for a detailed discussion of how Brahms was influenced by these theories.

⁵ In this architecture behaviors are organized hierarchically and the higher-level behaviors can be active at the same time as lower-level ones; thus the higher-level behaviors are said to *subsume* the lower-level ones.

therefore perception in Brahms is activity-specific. Through detectables an agent can turn facts into beliefs. Reasoning is modeled with forward-chaining production rules called *thoughtframes*. The activation of workframes or thoughtframes depends 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.

We have labeled the Brahms agent extended with the emotion module: “Emotive Brahms AGENT”. 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 (as in the model by Smith & Kirby). The reverse arrows represent the impact of emotions in behavior and cognition. In this paper we focus on three of the processes depicted in Figure 3: the *emotion elicitation at the sensory-motor level and associative/schematic level*, as well as the impact of emotion on the activity selection (denoted by the “Action Tendency and Priming” arrow). The first two processes are explained next through a simulation example. Impact on activity selection is discussed in Section 7.

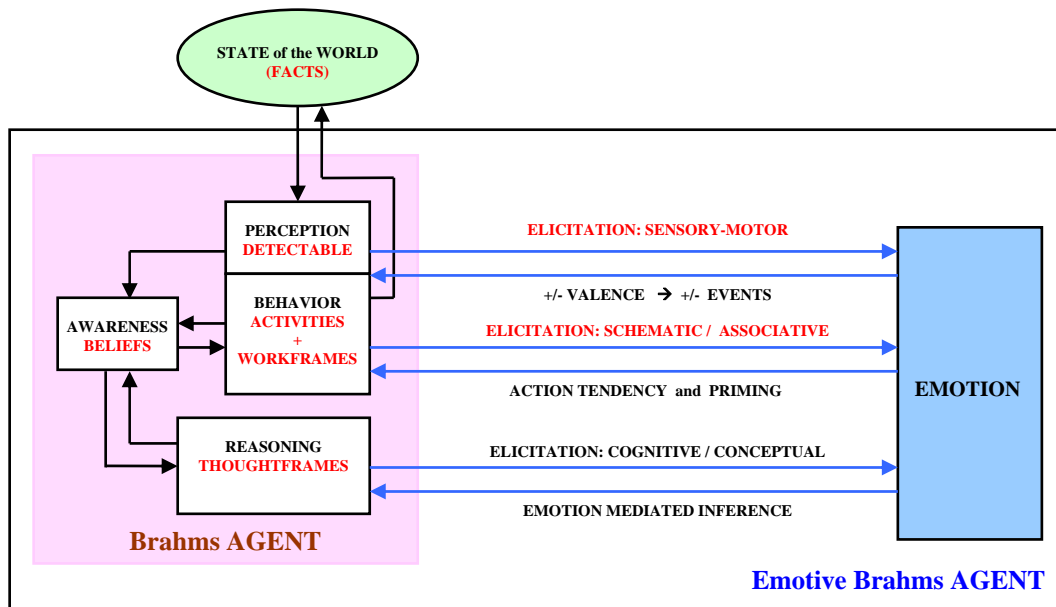


Figure 3: Integrating a computational model of emotion with the Brahms architecture.

6. EMOTION ELICITATION IN BRAHMS – A SIMULATION EXAMPLE

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”.

Now, we 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 CityA 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 CityA. 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 through 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' become aware of the danger. 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 5, each Brahms activity is executed by a workframe, so we have created a workframe for each of the preceding 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. When danger is detected, 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 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 value of the *appraisal detector* (see Figure 1) for anxiety are represented as *attributes* of ProfessorA. The perception of seedy-looking characters and run down buildings is modeled through *detectables* attached to the *LookAround* activity.

It is important to note that by using *variables* we are able to create a detectable that will detect *any* character or building having certain characteristics (seedy-looking and rundown, respectively). We have assumed that ProfessorA has some stored appraisal meanings about seedy-looking characters or run down buildings.

Thus, whenever a seedy-looking character or run down building is detected *the associative activation* of their appraisal meanings will occur.

This associative activation is modeled through Brahms *workframes*. The theoretical basis of this choice is the fact that Brahms workframes are similar to scripts (Schank & Abelson, 1977)⁶. The workframe that models the activation of stored appraisal meanings has in its body the Brahms *java activity*⁷ *UpdateAppraisalDetector*.

This activity increments the value of the *appraisal detector* in a fact (recall that appraisal detector is an attribute and it can get a value only through a belief or a fact) by an amount proportional to the degree of seediness of a character or rundown characteristic of a building. 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* construct we were able to model the update of the appraisal detector outside of ProfessorA's awareness (in agreement with the model by Smith & Kirby – Section 2).

All the incoming cues (different instances of characters and buildings) will contribute to the increase of the value stored in the appraisal detector. The mechanism just described for updating the appraisal detector corresponds to the *associative (or, schematic)* path of appraisal information generation in the model of Smith & Kirby and the multi-level process theory of Leventhal & Scherer (1987). In addition, the change in the *darkness* attribute of TimeOfDay object will automatically contribute to the increase of the value of the appraisal detector.

This represents the *sensory-motor* mode of appraisal generation (Smith & Kirby, 2000; Leventhal & Scherer, 1987). When the value stored in the appraisal detector reaches a threshold (which is detected by a *detectable* attached to the *DiscussAPaper* activity) the fact about the value of the anxiety 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 in the model, ProfessorA simply communicates to ProfessorB the belief that this is a dangerous situation (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. Figure 4, shows a

⁶ See Clancey (2002, p23) for an analysis of this.

⁷ Brahms *java* activities are written in the Java language and can be executed by BVM. By using such activities and the Brahms Java API one can manipulate a simulation in various ways (for example by asserting/retracting facts or beliefs at runtime).

timeline of the simulation as shown by the Brahms Agent Viewer.

Discussion: This simulation example illustrates two main points. First, 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 (e.g. Lazarus, 1991; Smith & Kirby 2001; Leventhal & Scherer, 1987). Second, 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 important issues related to emotion generation. For example, the simulation does not consider the cognitive level of emotion generation. Furthermore, we have represented only the subjective feeling component of the emotional response, without considering, for example, the action tendency. Besides, we do not specifically model the decay of the intensity of emotional states (e.g. Gratch, 2000). All these are issues that are already treated in previous research and which we will handle in our architecture as our research matures.

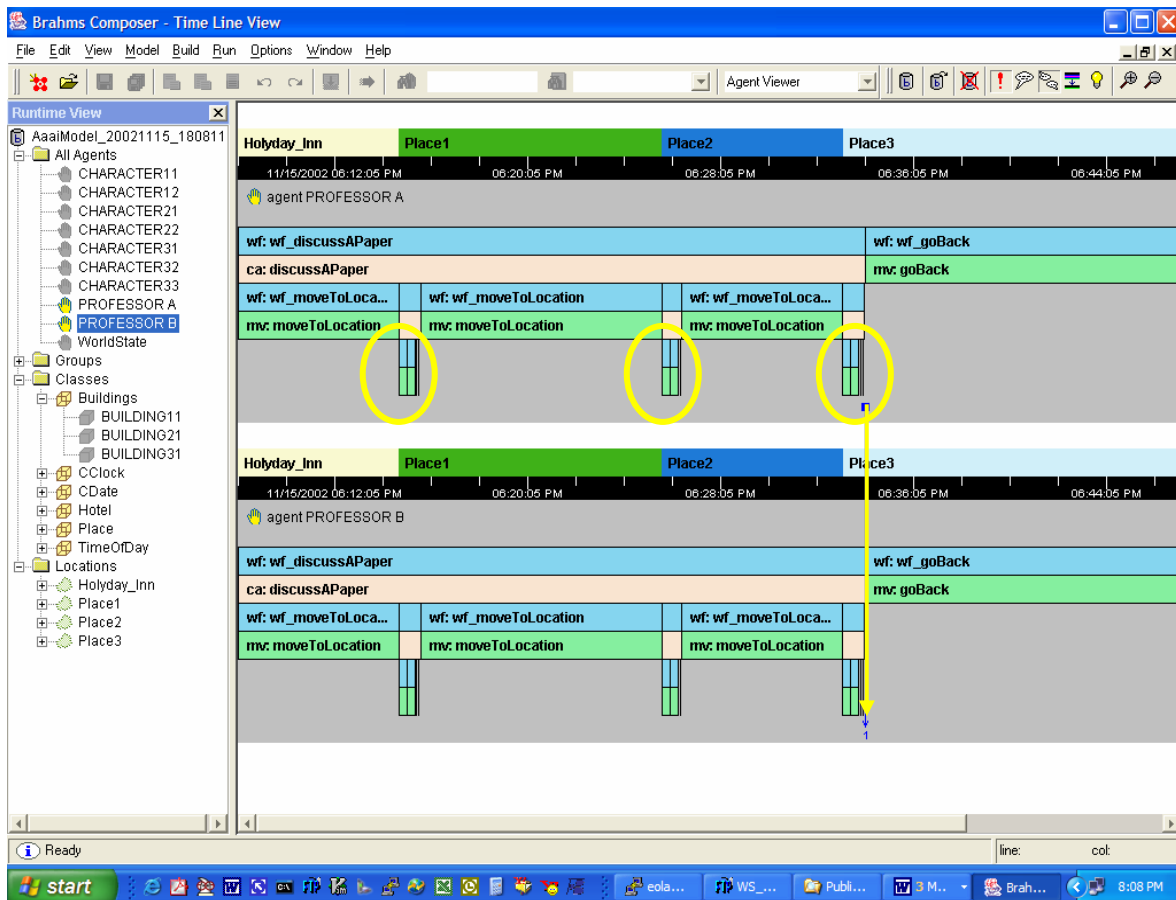


Figure 4: A graphical display of the simulation results shown in the Brahms Agent Viewer. The encircled activities correspond to the update of Appraisal Detector as a result of the detection of characters and buildings. The arrow indicates the moment when the Appraisal Detector passes the threshold and ProfessorA communicates to ProfessorB the belief about the danger.

7. ADAPTATION

How could the Brahms system benefit from the inclusion of a functional emotion module? Many theorists have postulated that emotions are necessary for autonomous agents with *limited resources* to cope successfully with (1) multiple (possibly conflicting)

goals (2) need for coordination with other agents (3) uncertainty (Johnson-Laird & Oatley, 1992; Lisetti & Gmytrasiewicz, 2002).

We discuss here in more detail how an emotion-based mechanism can improve Brahms agents' ability to decide what course of action to take when faced with multiple alternatives.

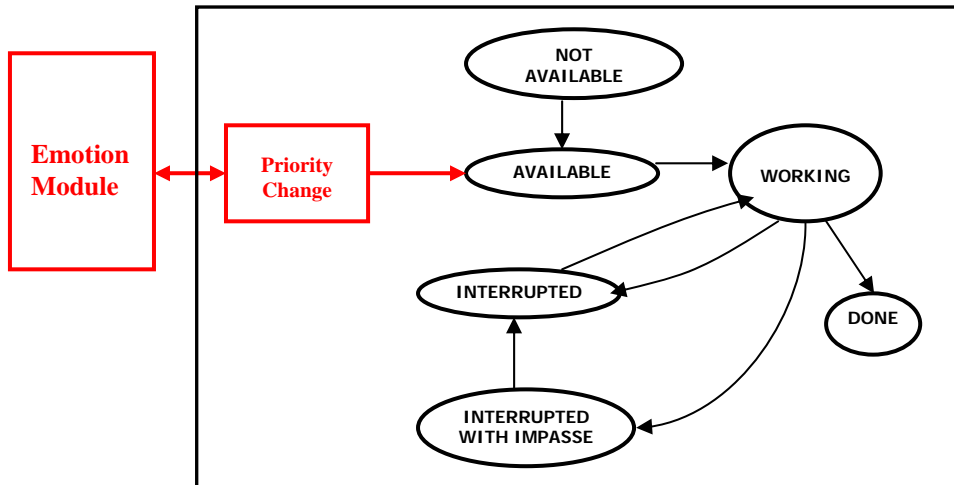


Figure 5: State transition diagram for Brahms workframes (modified from Sierhuis, 2001) and the proposed Priority Change module.

Figure 5 represents the state transition diagram for Brahms workframes. Of interest to our discussion is the transition from state AVAILABLE to the state WORKING. At a given time during simulation, each workframe whose preconditions do not match the beliefs of the agent for whom it is defined, is in the NOT AVAILABLE state. When the preconditions of the workframe match the beliefs of the agent, the workframe will be instantiated, that is, move to the AVAILABLE state. At a given moment several workframes may be in the AVAILABLE state. However, the Brahms Virtual Machine, can execute (work on) only one workframe at a time.

To select the workframe to be executed in a time step, Brahms uses a priority mechanism (each activity/workframe can be assigned a priority by the modeler). This priority-based mechanism is static and dependent on pre-assigned priorities.

What is needed is a dynamic control mechanism. This is recognized by the Brahms authors, and Clancey (2002) specifically proposes that “some kind of motive-based activation model, related to emotional and physiological factors, is required to explain why many human behaviors stop and others begin”. We propose that emotional state of an agent should influence (change, bias) the *priority* level of workframes.

A priority level would give Brahms agents adaptive capability and a change in priority level corresponds to a change in *action tendency* (Frijda, 1984) associated with an emotional state, i.e. the tendency toward a specific action (e.g. flee, fight, approach) that each emotion has evolutionarily been ‘programmed’ to point to. Our proposal is compatible with the postulate that action tendencies may or may not result into actions (e.g. Frijda, 2001). Whether or not an emotional state leads to action will depend on the

context (that is, whatever else the agent is doing at that time – the priorities of the other AVAILABLE workframes).

8. CONCLUSION

As stated at the beginning, this paper describes our *initial* efforts to integrate ideas of situated activity theory with a multi-level process model of emotions. We discussed emotion elicitation at the sensory-motor and schematic levels as well as use of emotion in changing the priorities of activities. The explicit modeling and simulation of the multiplicity of levels in emotion generation, will allow us to study important problems such as the *interaction* between the different levels of appraisal (Smith & Kirby, 2001; Leventhal & Scherer, 1987; van Reekum, 2000) which, so far, is not well understood. Furthermore, the level of detail that Brahms allows for modeling work practice, coupled with the extensive existing data in the organizational behavior, seems promising for the *evaluation* of the computational model of emotion under consideration. In fact, we have just started to model in Brahms real video data filmed during a recent expedition of a team of scientists in the Mars Research Desert Station and we plan to use this data as a tool for the validation of the computational emotion model.

ACKNOWLEDGEMENTS

Some of this work was initiated when C. Lisetti was at the University of Central Florida.

REFERENCES

- Brooks, R. (1991). Intelligence Without Representation. *Artificial Intelligence*, 47: 139-159, Elsevier Science Publishers
- Canamero, D. (1998). Issues in the Design of Emotional Agents. In *Proceedings of AAAI Fall Symposium 1998*, Orlando, FL
- Clancey, W.J., Sachs, P., Sierhuis, M., van Hoof, R. (1998). Brahms: Simulating Practice for Work Systems Design, *International Journal on Human-Computer Studies*, 49: 831-865
- Clancey, W.J. (2002). Simulating Activities: Relating Motives, Deliberation and Attentive Coordination, *Cognitive Systems Research*, 3(3): 471-499.
- Clancey, W.J. (1997). *Situated Cognition: On Human Knowledge and Computer Representations*, Cambridge: University Press
- Elliot, C.D. (1992). *The Affective Reasoner: A Process Model of Emotions in a Multi-Agent System*. PhD Thesis (TR#32), Northwestern University.
- Forgas, J.P., & George, J.M.(2001). Affective Influences on Judgments and Behavior in Organizations: An Information Processing Perspective, *Organizational Behavior and Human Decision Processes*, 86(1), 3-34.
- Gratch, J. (1999). Why You Should Buy an Emotional Planner. *Agents'99 Workshop on Emotion-Based Agent Architectures*.
- Gratch, J. (2000). Emile: marshalling passions in training and education. *Proceedings of the Fourth International Conference on Intelligent Agents*, Barcelona, Spain.
- Gratch, J. & Marsella, S. (2001). Tears and Fears: Modeling Emotions and Emotional Behaviors in Synthetic Agents. *Proceedings of the 5th International Conference on Autonomous Agents*, Montreal, Canada.
- Hudlicka, E. (2002). This Time With Feeling: Integrated Model of Trait and State Effects on Cognition and Behavior, *Applied Artificial Intelligence*, 16: 611-641.
- Hudlicka, E. (2003). Modeling Effects of Behavior Moderators on Performance: Evaluation of the MAMID Methodology and Architecture, In *Proceedings of the 12th Annual Conference on Behavior Representation in Modeling and Simulation (BRIMS'03)*, Scottsdale, AZ.
- Kelly, J.R., & Barsade, S. (2001). Mood and emotion in small groups and work teams. *Organizational Behavior and Human Decision Processes*, 86(1), 99-130.
- Lazarus, R.S. (1991). *Emotion and Adaptation*. Oxford Press
- Leont'ev A. N. 1979. The problem of activity in psychology. In Wertsch, J. V. (editor), *The concept of activity in soviet psychology*. Armonk, NY: M. E. Sharpe. pp. 37-71.
- Leventhal, H. (1984). A Perceptual-Motor Theory of Emotion. In L.Berkovitz (Ed.), *Advances in Experimental Social Psychology*, 17: 117-182, New York: Academic Press.
- Leventhal, H. & Scherer, K. (1987). The Relationship of Emotion to Cognition: A Functional Approach to a Semantic Controversy, *Cognition and Emotion*, 1(1): 3-28.
- Marsella, S., & Gratch, J. (2001). Modeling the Interplay of Emotions and Plans in Multi-Agent Simulations. In *Proceedings of the 23rd Annual Conference of Cognitive Science Society*.
- Marsella, S., & Gratch, J. (2002). A Step Towards Irrationality: Using Emotion to Change Belief. In *Proceedings of the 1st International Conference on Autonomous Agents and Multi-Agent Systems*, Bologna, Italy.
- Power, M.J., & Dalgleish, T. (1997). *Cognition and Emotion: From Order to Disorder*. Hove: Erlbaum.
- Schank, R. C., & Abelson, R.P. (1977). *Scripts, plans, goals, and understanding: An inquiry into human knowledge structures*. Hillsdale, NJ: Lawrence Erlbaum Associates.
- Scherer, K. R., Schorr, A., & Johnstone, T. (2001). *Appraisal processes in emotion: Theory, Methods, Research*. New York: Oxford University Press.
- Scheutz, M., Sloman, A., Logan, B. (2000). Emotional States and Realistic Agent Behavior. *Proceedings of GAME-ON 2000*, Imperial College, London, 2000.
- Sierhuis, M. (2001). *Modeling and Simulating Work Practice. Brahms: A Multi-Agent Modeling and Simulation Language for Work System Analysis and Design*, PhD Dissertation, SIKS Dissertation Series No. 2001-10, University of Amsterdam.
- Sierhuis, M., & Clancey, W.J. (2002). Modeling and Simulating Work Practice: A Method for Work

Systems Design, *IEEE Intelligent Systems*, 17(5): 32-41.

Smith, C.A., & Kirby, L.D. (2000). Consequences Require Antecedents: Towards a Process Model of Emotion Elicitation, In J.P.Forgas (Ed.) *Feeling and Thinking, The Role of Affect in Social Cognition*, Cambridge: University Press.

Smith, C.A., & Kirby, L.D. (2001). Toward Delivering on the Promise of Appraisal Theory, In K.Scherer, A.Schorr, T.Johnstone, (Eds.) *Appraisal Processes in Emotion: Theory, Methods, Research*, Oxford: University Press.

Staller, A., & Petta.P. (1998). Towards a Tractable Appraisal-based Architecture for Situated Cognizers, In D. Canamero, C. Numaoka, & P. Petta, (Eds.), *Grounding Emotions in Adaptive Systems, Workshop Notes, 5th International Conference of the Society for Adaptive Behavior (SAB'98)*, Zurich, Switzerland.

Staller, A., & Petta, P. (2001). Introducing Emotions in the Computational Study of Social Norms: A First Evaluation. In B. Edmonds & K.Dautenhahn (Eds.), *Journal of Artificial Societies and Social Simulation, Special Issue on Starting from Society - the Application of Social Analogies to Computational System*.

Van Reekum, C. (2000). *Levels of Processing in Appraisal*, PhD Thesis, Geneva University