A FRAMEWORK FOR SIMULATION OF AGENTS WITH EMOTIONS

Diana F. Adamatti, Ana Lucia C. Bazzan
Instituto de Informática
Universidade Federal do Rio Grande do Sul
Av. Bento Gonçalves, 9500 – Porto Alegre – RS
{adamatti, bazzan}@inf.ufrgs.br

ABSTRACT

The use of emotions by human beings play an important role, leading to more flexible and rational decision-making. It allows the design of agents, which interact with others in a way to be defined by the user. The use of agents for simulation environments is not new. In the Multiagent simulation a phenomenon is decomposed in a set of elements and interactions, where the construction of the model is less complex. In multiagent simulation a new paradigm with high potential can be modelled: agents can be taken as equipped with more sophisticated behaviour and enabled with methods of adaptation, in comparison with process-oriented models or celullar automata. This paper describes the development of a framework for simulation of agents with emotions. The behavior is structured over the model proposed by Ortony et al. This pragmatic theory is based on groups of emotions according to their eliciting conditions.

1. INTRODUCTION

There are several arguments suggesting that emotion affects decision-making (see for instance (Damasio, 1994) for a discussion on this issue). In the least, it is universally recognized that the benefits of humans having emotions encompass more flexible decision-making, as well as reativity. In (O'Neil, 2000) it is argued that the more serious the decision, the more it will involve emotion. These ideas have been employed in the field of Multi-Agent Systems in order to explain the achievement of cooperation and coordination. However, little work has focused on the investigation of interactions among social agents whose actions are somehow influenced by their current emotional setting.

The research on human emotions has a long tradition, both on a cognitive as well as on a physiological basis. See for instance the work in (James, 1884; James, 1890) for the latter. However, we focus our work on the former, especially on the synergy between research in this field and decision-making, which, in turn, is relevant to many areas of artificial intelligence. In fact, a trend in the direction of agents displaying heterogeneous behaviors is reported in the literature (in quite distinct scenarios).

We do not attempt here to define what emotions are. As Picard (Picard, 1997) puts it, researchers of the area do not even agree on a definition. However, they recognize the various facets of the available definitions. For example, emotions involve feelings, experience, behavior, physiology, and cognition. In this work, we do not focus on such aspects as the physiological one.

Rather, we concentrate on the cognitive and behavioral aspects of emotions as a computationally tractable model. Cognitive influences to emotions involve appraisal, comparison, categorization, inference, attribution, and judgment. This brings us to the need of stating the eliciting conditions for a particular emotion to arise, as well as the actions carried out as a consequence of it.

Many authors have tried to categorize emotions. Picard, as well as Ortony *et al.* (Ortony, Clore and Collins, 1988), provide good surveys on the matter, so we refer to their work for details. For our purposes, it is enough to cite the main points of such taxonomies. James (James, 1884) differentiates between standard emotions (which involve little or no cognition), and more complex emotion-inducing perceptions (with high degree of cognition), such as events related to a violation of social conventions. Damasio (Damasio, 1994) distinguishes between primary (innate) and secondary emotions (those arising later in the development of an individual as systematic connections are identified between primary emotions and categories of objects and situations). Sloman (Sloman, 2001) defines one another level of emotions, the third, that they are related with the absorption of cultures in diverse areas, as mathematical, philosophy and science. Then, many authors argue in favor of the appraisal/arousal theory. Finally, there is a discussion on whether or not emotions can be simply divided into basic and non-basic ones.

Our overall goal is to create a framework to allow users to define the characteristics of a given interaction, the emotions agents can display, and how these affect their actions (and hence those interactions). The idea to use agents for simulation framework is not new. In a multiagent simulation, a phenomenon is decomposed in a set of elements and interactions, rendering the construction of the model of less complex. Some multiagent-based simulations frameworks are available, as SeSAm (Klüegl, Oechlein and Puppe, 2001), SIEME (Magnin, 2001), SIMULA (Frozza, 1997) or SWARM (Daniels, 2001). These frameworks present positive aspects, such highly portable programming language or graphical interface of easy use, as well as negative ones – only tackle reactive agents or no support to parallelism. Therefore this has motivated the development of a new framework, in order to tackle those negative aspects of other frameworks.

Previous works described particular scenario above agents display emotions, Prisoner's Dilemma (Bazzan and Bordini, 2001) and an extension of the scenario propost by Castelfranchi, Conte and Paolucci (Castelfranchi, Conte and Paolucci, 1998) regarding the "study of social norms" (Bazzan, Adamatti, Bordini and Ghilardi, 2002).

The present paper describes the taxonomy to study of emotions proposes by Ortony *et al.* (Ortony, Clore and Collins, 1988), and the analysis and the implementation of the multiagent-based simulation framework with emotions based in OCC model.

The use of emotions in computing to OCC model is given in Section 2. The proposed framework and its analysis using agents with emotions are presented in Section 3. In Section 4 simple example of use of the framework is explained. Section 5 concludes the paper.

2. OCC MODEL

For the purpose of implementing an environment for simulations of agents with emotions, we find the so-called OCC theory by Ortony, Clore, and Collins (Ortony, Clore and Collins, 1988), the most appropriate one. First, the authors are very concerned with issues dear to the Artificial Intelligence community (for instance, they believe that cooperative problem-solving systems must be able to reason about emotions). This is clearly an important research issue in Multi-Agent Systems as well. Second, it is a very pragmatic theory, based on grouping emotions by their eliciting conditions: events and their consequences, agents[1] and their actions, or objects. This renders a computational implementation more easy. Note that the classification goes beyond the established idea of just basic and non-basic emotions, an idea which Ortony *et al.* reject.

Ortony *et al.* recognize that this model is a highly oversimplified one, since in reality a person is likely to experience a mixture of emotions, especially when considering a situation from different perspectives at different moments. However, this co-occurrence would probably render the model unfeasible. According to Sloman (Sloman, 2001) *"the taxonomy of Ortony et al. focuses on a particular set of cognitive and motivational states"*.

One motivation behind the OCC theory that it should be made into a suitable computer model, consistent with an understanding of which emotions people are likely to experience under certain conditions. That is, they are not concerned with machines with emotions, but with the prediction and explanation of human emotions by means of manipulating various parameters and examining their consequences. The popularity of this model arose precisely because performing such experiments in an experimental laboratory setting is a very hard task.

In this model, another central idea is that emotions are valenced reactions; the intensity of the affective reactions determines whether or not they will be experienced as emotions. This points to the importance of framing the variables which determine the intensity of any reaction.

The overall structure of the OCC model is based on emotion types or groups, which in their turn are based on how people can perceive the world. They assume that there are three major perception aspects in the world: *events*, *agents*, and *objects*. Events are simply people's construal about things that happened; objects are also a very straightforward level of perception; and agents are both human and nonhuman beings, as well as inanimate objects (as explained next) or abstractions. In our work, we use an extension of the work of Ortony *et al.*, carried out for Elliott (Elliott, 1994), adding four emotions in proposed initial set.

The structure of the OCC model based on types of emotions has three main branches, corresponding to the three ways people react to the world. The first branch relates to emotions which are arising from aspects of **objects** such as *liking, disliking*, etc. This constitutes the single class in this branch, namely the one called *attraction* which includes the emotions *liking* and *disliking*.

The second branch relates to emotions which are consequences of **events**. As a reaction to them, one can be pleased, displeased, etc. Four classes constitute in this branch. The first class is *fortunes-of-others*, that includes the following emotions: *happy-for, resentment, gloating* or *Schadenfreude, jealousy, envy, sorry-for*. The second class is *prospect-based*, with *hope, fear*. The third class is *well-being*, with *joy, distress*. The last class is *confirmation*, with *satisfaction, disappointment, relief, fears-confirmed*.

The third branch is related to **agents**. It also has only one class, namely the *attribution* class, comprising the following emotions: *pride, shame, reproach, admiration*.

Other two additional classes of emotions can be referred to as *compound classes*. The first is called *well-being/attribution compound* and it involves the emotions of *gratification, remorse, gratitude, and anger*. The second class is called *attraction/attribution compound* and it involves the emotions of *love and hate*.

Previous works have used OCC model, Elliott (Elliott, 1994) describes the construction the Affective Reasoner, that maps situation and agent state variables onto a set of specific emotions, producing behaviors corresponding the specific emotion. The Affective Reasoner has an embedded symbolic AI model which is an extended version of the OCC model. The Affective Reasoner functions in the context of an agent world, where each agent has set of symbolic appraisal frames that contain the agent's goals, preferences, principles guiding behavior, etc. Bates (Bates, 1994) constructed micro-worlds to emotional agent, the Oz Project. Bazzan *et al.* (Bazzan and Bordini, 2001) presented a prototype of such a framework using the Iterated Prisoner's Dilemma (IPD) scenario as a metaphor for interactions among agents.

3. THE PROPOSED FRAMEWORK

Our overall goal is to create a framework that allows the user to define the characteristics of a given interaction, the emotions agents can display and how these affect their actions, and hence those interactions. Such a framework is intended to be very open; that is, the user specifies the purpose of the simulation, the scenario for the interactions (which rules or norms agents follow when they meet), the environment (e.g. interactions happenning among agents which belong to particular groups, interactions with respect to a spatial/geographical configuration, etc.), the general parameters of the simulation (time frame, size of environment, etc.), the classification of emotions that does not belong to the original OCC model, and parameters related to each agent in the simulation (e.g. thresholds, types, etc.).

We base our framework on the OCC model due to the reasons already explained. Additionally, this model can be translated into a rule-based system which synthesizes and generates cognitive-related emotions in an agent. These rules all look like " if <condition> then <action>". We now explain how rules look like in such a system. The condition part tests either the desirability (of a consequence of an event), or the praiseworthiness (of an action of an agent), or the appealingness (of an object). The action part sets the potential for generating an emotional state (e.g., a joyful state). We exemplify here explaining a rule related to the emotion *liking*.

Let *A(p,o,t)* be the appealingness of an object that a person p assigns to the object *o* at time *t*, *P_ l(p,o,t)* the potential to generate the state of liking, *G(vg_1,..,vg_n)* a combination of global intensity variables, *I_l(p,o,t)* the intensity of liking, *T_l(p,t)* a threshold value, and *f_l(.)* a

[1] Note that this particular instance of the word *agent* in this paper does not refer to computational agents within a multi-agent system; the concept as used here is, however, also related to an important aspect of computational agency in so far as it deals with action.

function specific to liking. Then, a rule to generate a state of liking looks like:

IF P_l(p,o,t) > T_l(p,t)
THEN set I_l(p,o,t) = P_l(p,o,t) - T_l(p,t)
ELSE set I_l(p,o,t) = 0

This rule is triggered by another one:

IF A(p,o,t) > 0 THEN set P_l(p,o,t) = f_l(A(p,o,t),G)

Ortony *et al.* omit many of the details of implementation; a difficult issue might be to find appropriate functions *f(.)* specific to each emotion.

As for the architecture of the framework proposed, the explanation carried out next follows the sequence presented in Figure 1. However the user does not need to follow that order necessarily. The main modules and their functionalities are described below.

- ✓ Agents Definition: module where the agent is created, defining its characteristics (such as name, class, etc). An agent can be of the type object, where its functions are related to the environment or of the type no object, where its functions are related the actions to that the agent must carry out.
- ✓ Rules Definition: module where the rules of behavior to the agents are created. The framework provides some basic rules for the agents, such as TO MOVE(to a position in the grid), and the others rules are supplied by the users, based on the primitives provided by our framework.
- ✓ Emotions Templates: module where each class of model OCC has a specific template (therefore each class has different tests of validation).
- ✓ Environment Definitions: module where the dimensions of the environment, the number of cycles and the disposal of the agents are defined as well as what is to be store in files for later analysis.

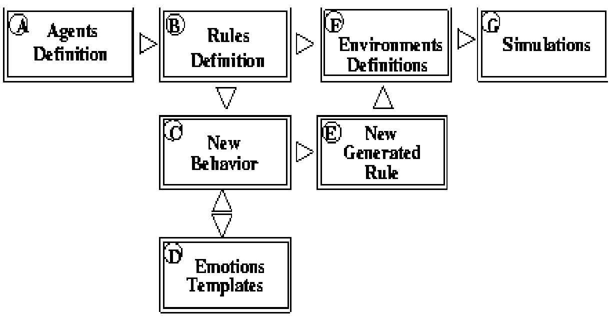

Figure 1. Architecture of the Framework

The data generated in a simulation (environment, agent, and rules) is stored in a database and can be used in further simulations. In Figure 2, we see that the data created in a simulation are used in other simulations, provided the agents use similar rules, and the rules have similar characteristics and the definitions of the environment have similar values.

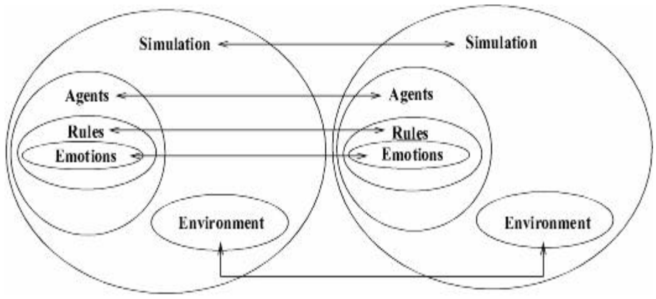

Figure 2. Reuse of Agents, Rules, and Environment Definitions

4. EXAMPLE OF USE

For a better understanding of the developed framework, this section presents a simple example of use. The chosen example was the simulation cat/mouse. The world is a two-dimensional 10x10 square grid where cats, mice and foods are randomly placed. Mice have to look for food and run away of the attack of the cats. The cats look for mice, kill them and eat them. The initial number of mice, cats and food are 20, 5 and 15, respectively. Cats and mice have initial strength of 20 points. Mice as well as cats can move for four directions(above, below, right and left), and at each movement they lose one point. Mice do not reproduce and they earn a score for each food that they eat (5 points). Cats earn a score for each mouse that they kill and eat (10 points). Mice perceive cats in two grid positions regarding to each available direction. The simulation finishes when all mice are killed.

Only mice display emotions in example and these can be: fear and hope (branch *events*, class *prospect-based*). Mice have fear when they perceive that cats are near them. And they have hope when they do not perceive cats. When the mice have fear, they run away from cats only. When they have hope, them they look for food (the order of action depends on emotion). The mice and cats have the following characteristics:

Mouse	Cat
Strength : integer Perceive_cats : boolean Emotion : string	Strength : integer

The Figures 3, 4 and 5 present how the example described above was modelled in the proposed framework. The use of a graphic interface helps the implementation of the application. The Figure 3 presents how agents are created in the framework. The characteristics that each agent are informed by clicking over the button *characteristics*. The user has to define the mouse: the strength, the flag to perceive cats and the type of emotion.

Figure 3. Agent Definition

The Figure 4 explains how rules are created. The user must define a name for the rule, its conditions and its actions. In the button *Emotions Templates* emotions according with OCC model are included. To the rule *perceive-cats* the mice use the "base rule" *pos(row, column)*, where a comparison is done with the element in specific position (in example, the comparison is done to the four directions).

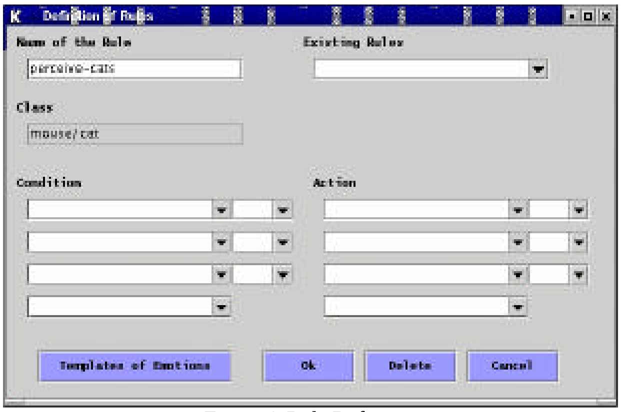

Figure 4. Rule Definition

Again, the users must select the emotion and define the pre-conditions and actions to this emotion to be execute. Figure 5 present how emotions are included in the rules. The rules for the emotions related to this example are described below.

- ✓ Rule for fear:

IF $D(p,e,t) > 0$
THEN set $P_j(p,e,t) = f_j(D(p,e,t),G,L)$

function f_j: returns the value $T_j(p,t) + \varepsilon$ (Perceive_cats = true)

IF $P_j(p,e,t) > T_j(p,t)$
THEN set $I_j(p,e,t) = P_j(p,e,t) - T_j(p,t)$
ELSE set $I_j(p,e,t) = 0$

- ✓ Rule for hope:

IF $D(p,e,t) < 0$
THEN set $P_r(p,e,t) = f_r(D(p,e,t),G,L)$

function f_r: returns the value $T_r(p,t) + \varepsilon$ (Perceive_cats = false)

IF $P_r(p,e,t) > T_r(p,t)$
THEN set $I_r(p,e,t) = P_r(p,e,t) - T_r(p,t)$
ELSE set $I_r(p,e,t) = 0$

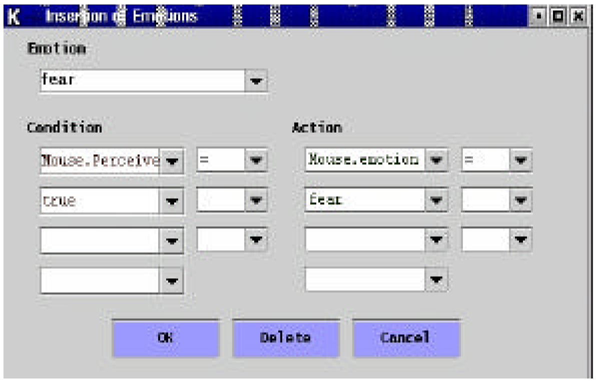

Figure 5. Emotions Templates

In this example, we could show how agents, rules and emotions are created in the framework. A full comparison for our framework with others regarding a given scenario and the use of others models or strategies (as BDI architecture) will be done soon. However, to this date, we can affirm that the taste of creating a scenario is much more easy in our framework than it was the related woks which tackle emotion in agent systems.

There are others multiagent-based simulations frameworks as (Klüegl, Oechlein and Puppe, 2001; Magnin, 2001; Frozza, 1997; Daniels, 2001), but they do not implement emotions in their rules directly. Our framework is based on these frameworks, in order to get a more complete environment. We decided to develop a new framework, based in OCC model, because the implementation of scenarios of diverse areas will be carried out in a more complete and faster way. Until now, there was not a framework which uses all classes from the model OCC and which could solve any kind of problem.

5. CONCLUSIONS AND FURTHER WORK

The importance of emotions for human beings is that they yield more flexible and rational decision-making. The emotional state cause great impact in the decision-making, action, memory and attention. We find the OCC model the most appropriate one, especially due to to its pragmatical aspects. The central idea, in this model, is that emotions are valenced reactions (the intensity of the affective reactions determine or not the emotions).

According Klüegl *et al.* (Klüegl, Oechlein and Puppe, 2001), the best method to examine such emergent phenomena is multiagent simulation. A multiagent model is a simulated multiagent system that exists in a simulated environment. It is a natural form of modelling, especially for societies, as active entities in the original are also interpreted as active in the model. That means that systems, which can be observed as multiagent systems in the original, are conceived as multiagent systems in the model as well.

The main problem with applications based in agents is the that they are domain-dependent (Bazzan and Bordini, 2001; Bazzan, Adamatti, Bordini and Ghilardi, 2002). The development of general framework for simulation solves this problem, but the "implementation" for the application is responsibility of the users (definition of rules, for example). We extend some primitives that can be combined by the users in constructing their own environments, to render the use more easy. A rule always has the " if <condition> then <action>", which is similar to those given in Section 3.

The form that the framework was structured aimed at reusing existing definitions and the implementation of problems of different areas of knowledge. Thus, when the users define and modify the agents, the rules and the definitions of environment, they can verify variables that influence the decision-making.

Our future plans include the test more examples for the simulations, like Prisoner's Dilemma (Bazzan and Bordini, 2001) or Study of Social Norms (Castelfranchi, Conte and Paolucci, 1998), where agents have emotions. These examples have similar simulations in applications which are domain-dependent.

ACKNOWLEDGMETS

We would like to thank to the graduate student Thiago Ghilardi for your help during development this framework.

This work was partly supported by CNPq.

REFERENCES

BATES, J. *The role of emotion in believable agents*. In Communications of the ACM, Special Issue on Agents, July, 1994.

BAZZAN, A. L.C.; ADAMATTI, D. F.; BORDINI, R. H.; and GHILARDI, T.. *Extending the computational study of social norms with a systematic Model of emotions*. Acepted in SBIA (Simposio Brasileiro de Inteligencia Artifial), 2002.

BAZZAN, A.L.C. and BORDINI, R. H. *A framework for the simulation of agents with emotions: Report on experiments with the iterated prisoner's dilemma.* In Jorg P. Muller, Elisabeth Andre, Sandip Sen, and Claude Frasson, editors, Proceedings of The Fifth International Conference on Autonomous Agents (Agents 2001), 28 May 1 June, Montreal, Canada, pages 292299. ACM Press, 2001.

CASTELFRANCHI, C.; CONTE, R. and PAOLUCCI, M. *Normative reputation and the costs of compliance.* JASSS, 1(3), 1998. <http://www.soc.surrey.ac.uk/JASSS/1/3/3.html>.

DAMASIO, A.R. *Descartes's Error*. Avon, New York, 1994.

DANIELS, M.. *The swarm simulation system - a tool for studying complex systems*, 2001. <www.swarm.org>.

ELLIOTT, C. *Multi-media communication with emotion-driven believable agents.* In AAAI Spring Symposium on Believable Agents, Stanford University inPalo Alto, California, March 21-23, 1994.

FROZZA, R. *Simula - ambiente para desenvolvimento de sistemas multiagentes reativos.* Master's thesis, UFRGS - Universidade Federal do Rio Grande do Sul - Brasil, Rio Grande do Sul - Brasil, 1997.

JAMES, W. *What is an emotion*? Mind, 9:1, 88:205, 1884.

JAMES, W. *The Principles of Psychology*. Holt, New York, 1890.

KLÜEGL, F.; OECHLEIN, C., and PUPPE, F.. *Sesam. the multi-agent simulation environment*, 2001. <http://www.simsesam.de>.

MAGNIN, L. *Sieme: An interactions based simulation model*, 2001. Electrotecnical Laboratory, Umezono, Tsukuka, Ibaraki, Japan.

O'NEIL, B.. *Approaches to modelling emotions in game theory*. In Proceedings of the Conference on Cognition, Emotion and Rational Choice. UCLA, April 2000.

ORTONY, A.; CLORE, G. L. and COLLINS, A.. *The Cognitive Structure of Emotions.* Cambridge University Press, Cambridge, UK, 1988.

PICARD, R. W. *Affective Computing*. The MIT Press, Cambridge, MA, 1997.

SLOMAN, A.. *Beyond shallow models of emotion*. In Cognitive Processing, number 1 in 2, pages 177-198, 2001.