Socially Emotional: Using Emotions to Ground Social Interaction

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Abstract

In this paper we address the problem of how emotions ground perception and social interaction. We propose a virtual society in which each agent has its subjective perception of the others, and in which this perception is aimed at focusing a large potential of interaction into the most productive direction. Rather than to focus attention based on a cognitive evaluation of compatibility between different agent's interests, we argue for using features of appearance, presentation and material exchange as elements in a "social filter" that directs attention in an emotional as opposed to a cognitive (knowledge-based) way. We show how such external clues are tight into a hormonal model of emotions for behavior control. At the social level we develop ideas on how emotions play a role in agent interactions (emotional rhetoric) and long-term agent coordination (representation).

Introduction

The problem we address is the following: how do agents that are embedded in large societies—hundreds to millions of agents—focus the enormous potential for interaction with others towards the most productive encounters?

The relevance of this problem needs little argument. From a social studies viewpoint, it is tied to the understanding of a society's structure and how it—implicitly and explicitly, directly and through internalization mechanisms—regulates daily interaction. From a multi-agent (MA) studies perspective, the issue is fundamental to understanding artificial societies. In particular, it enlarges the scope of behavior control in agents, which is not only aimed at task achievement (e.g., finding food to survive), but at doing so in an evolving social context that, by the interdependencies it entails, makes every strict assumption of self-sufficiency a naive one. More technically, one cannot expect exhaustive exploration of potential encounters to be an efficient means of implementing large-scale agent societies. This is especially true for open MA systems—those in which the agents are being designed independently and without a predefined and globally known relationship towards the others. Finally, and here lies an important motivation for our work, such large-scale open agent societies will soon be of practical relevance—we assume that networks like WWW will evolve into large collections of software agents, each independently pursuing goals on behalf of their users, or trying to offer services to users and other agents.

This paper is concerned with the development of concepts and techniques that can enhance a variety of social processes in large, informally structured groups of agents inhabiting different types of realities. The kind of applications this research is aimed at involve information-intensive events in which the possibilities for interaction among participants are many, but not every encounter leads to a productive social process. For example, at a major fair there may be many potential buyers and sellers, but only some will come to a productive interaction—a business deal. Our practical goal is to focus this large potential for interaction so that the effectiveness of participation to such events is enhanced. To foster this goal, our work brings together two lines of research—one focusing on social dynamics in mixed-reality agent societies, the other addressing the problem of achieving flexible and adapted behavior in (societies of) self-sufficient, autonomous agents.

Co-Habited Mixed Realities

The particular context of our work is set by the concept of *co-habited mixed reality* (Van de Velde 1997), developed within the COMRIS research project[1]. A co-habited mixed reality consists of a pair of a real and a virtual space that are loosely coupled—there is a minimal awareness of one space within the other. The real world is inhabited by humans, whereas the virtual

one is inhabited by software agents. The originality of this concept relies on the type of relationship between both realities, which also gives it its strength. Contrary to augmented-reality models, we are relieved from the task of establishing a mapping between both realities, as well as from having to try any kind of perceptual integration. Instead, the processes in the two spaces must only serve each other, without the real participants having a feeling of virtual presence or the other way around. We only provide a personal link between both spaces, that ensures some form of "synchronization" so that the activities in one space further the ones in the other. This link is an electronic badge and earphone device integrating a vision system, wirelessly hooked into an Intranet, which each real participant wears as her personal assistant—the COMRIS *parrot*. It establishes a bidirectional link between both realities. It perceives what is going on around its host (context perception) and points her to relevant information so that participation in the ongoing event is enhanced (information push). At the same time, a similar event is going on in the virtual space, where software agents are the participants. The purpose of each agent is to represent, defend, and further a particular interest or objective of the real participant, including those she is not explicitly attending to.

To achieve this, the agents must be autonomous and self-motivated. Techniques of *interest-based navigation* bring together those virtual agents whose interests are likely to merge into a productive social process. To deal with the complexity of finding out about useful partners we propose the notions of *appearance*—the external "bodily features" that partly reflect the agent's internal state—and of *presentation*—the set of features that the agent shows to the agents it interacts with, depending on its interests in the communication process, its expectations about the others, etc. The different representatives of a user may have to compete to get their owner's attention at a given point. At all times, *competition for attention* mechanisms (Van de Velde et al.1997) that take into account several factors contributing to define the internal state of the agent, such as its competence, its performance, or the relevance of its action in a particular information context, drive the communication with the real participant through the COMRIS parrot.

In dealing with large-scale interaction potentials in the COMRIS context, two different types of scenarios are of particular relevance. A "synchronous" scenario involves the interaction between the software agents and a user by means of the parrot. Our main contribution here lies in linking a bodily-grounded emotion-based behavior control framework with the relevance-and competence-based attention mechanism.

The other scenario has to do more with the interaction patterns that are going on within the virtual world, regardless of the link with the real world. In addition to the above-mentioned mechanism of competition for attention, we are specifically focusing on the longer term, "asynchronous" coordination of agents' behaviors. If, as we argue, social interactions are based on constellations of agents' interests that can be furthered by those interactions, then long-term social structures must rely on some explicit or implicit encoding of these interest relationships. Instead of a purely "cognitive" encoding in which the agent accumulates a memory of other agents' (perceived or communicated) interests, we propose to explore alternatives that are no doubt being used in real societies. For example, values and emotional states play a major role as "filters" in learning and remembering social interactions. Appearance acts as another filter by expressing power relationships, clan or sub-culture membership, status, and so on. Similarly, the ritual of presentation[2] allows one to express one's intentions and expectations with respect to a particular party in a particular situation. Finally, material goods that are being exchanged represent such intentions and expectations over longer periods of time, thus regulating and coordinating behaviors of two or more agents.

The concrete direction that we explore here is to use *bodily-grounded emotions* and their various expressions as an essential part of appearance, presentation, and the emergence of long-term co-behaviors. Our software agents are also endowed with other affective phenomena, equally rooted in their physiological state, such as "survival-related" motivations driving them to act autonomously, moods, and temperaments that contribute to define their individual personalities.

Why Emotions?

The nature and role of emotions in biological systems are still not completely agreed upon nowadays. Several components are usually distinguished in the development and expression of emotions (Kandel et al.1995): the recognition of an important event; an emotional experience in the cortex that mediates outgoing signals to peripheral structures; and reflexive autonomic and visceral responses that prepare the body for action, some of which are also externally observable. Different aspects and the causality direction of the links among them have been stressed by diverse research

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[2]The behavior that precedes a purposeful act together, and that can be as simple as exchanging a business card or as complex as marriage negotiations in certain societies (Keane 1997).

paradigms (see (Cornelius 1996) for an overview). The multi-facetedness of these phenomena, which encompass neuro-endocrine, physiological, cognitive, and social aspects of animal behavior, make them a very rich tool to ground adaptation, autonomy, and social interaction in our society. Some of the roles that emotional states seem to play in biological systems are of particular significance for our work.

Emotional states are *adaptive mechanisms* that allow to deal with events, both internal and external, which are important for the survival of the agent (and the species) in a particular environment (LeDoux 1996). In this sense, they are considered as remnants of the creature's evolutionary past. The perception of a potentially life-threatening event, such as the presence of a predator, immediately puts the animal in a "fear state"; this state acts as a defense mechanism by eliciting a "fight-or-flight" reaction that prepares the organism to respond rapidly to the external environment (for example, a transient, rapid increase in blood pressure permits the animal to run faster).

Emotions play a major role in *motivating and guiding action*. At the simplest level, the categorization of events as pleasant/unpleasant, beneficial/noxious, turns "neutral" stimuli into something to be pursued or avoided. This idea lies at the heart of operant conditioning theories of learning. Due to their generality of object and time, emotional states amplify the effects of motivations, which are stimulus-specific and need an urgent satisfaction. As (Tomkins 1984) points out, "the affect system is the primary motivational system because without its amplification, nothing else matters, and with its amplification, anything else *can* matter." The role that emotional systems play in decision making (activity selection) and social relations has been evidenced by Damasio's studies of patients with damage in the prefrontal cortex and the amygdala (Damasio 1994).

Finally, the external manifestations of emotions can play a major role as "signaling" mechanisms[3], at several levels. First, they play a role of *social reference* (Dantzer 1994). The emotional expression of an individual can be used by another to "assess" the type of situation it is confronted with and adapt its behavior accordingly. Pheromones[4] can help to illustrate this point. For example, the smell of the urine of a rat exposed to electric shocks induces in another rat an increase of the pain sensitivity threshold. In some cases,

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[3]This does not imply that emotions evolved primarily as a communication tool.

[4]Chemicals released in the environment by the organism that influence the physiology and behavior of conspecifics and sometimes individuals of other species.

emotional expression seems to have a *communicative role*, as in the case of the diverse alarm calls emitted by monkeys in different fear-related situations and that elicit different behaviors in conspecifics (Kalin 1997); alarm calls (and emotional expression in general) can also vary depending on the "receptor", as reported in (Dantzer 1994). Emotional states also contribute to the *construction of intersubjectivity*. The recognition of the emotional state of a conspecific allows an animal to have certain expectations with respect to the other's behavior, but also to adapt its behavior and emotional state accordingly. For example, an animal will rarely attack another that shows signs of submission/sadness. In this sense, emotions contribute to the elaboration of the image an individual has of itself *with respect to the partner* it is interacting with. This self-image is a reflection of the image we have of the other, and elicits the mirror process in it, which in turn can elicit an emotional/behavioral reaction on my side that shows my agreement of the image the other has constructed about me, giving thus rise to the construction of a negotiated intersubjectivity.

Bodily-Grounded Emotions

Our model of motivations and emotions is based on (Cañamero 1997a), which draws on ideas from neurobiology, ethology, behavior-oriented AI, and artificial life to explore the effects of affective phenomena in behavior. This work stresses the role of affects as mechanisms for adaptation, both from an evolutionary perspective and in the sense that this term has in (Ashby 1952)—contributing to maintain the organism (a dynamic system) viable in its environment, i.e., internally "stable". Therefore, emotional states are not directly modeled at a "psychological level", but grounded in a physiology that ensures appropriate feedback between behavior and affective states in the interactions of the agent with the world. The original model, described in the next section, considered emotional states at the individual level. Here we propose an extension to deal with "social emotions" within the same framework.

Emotions in Viability and Adaptation

The experimental setting to explore these ideas in (Cañamero 1997a) is a dynamic two–dimensional world inhabited by two species—the "smart" agents (As) and the "enemies" (Es)—and which also contains food and water sources and blocks—geometrical figures—of varying shapes and sizes. The creatures are implemented as a collection of "modules" of different types. Es have a simple, rather stereotyped behavior, their main role being to introduce more dynamicity in the world—they wander around avoiding obsta-

cles, try to ingest every form of organic matter they run into, and they withdraw whenever they feel pain, caused by another creature's attack. As are more complex creatures used as a testbed for affects. Among other elements, their architecture includes: internal and external sensors, maps, behaviors, both appetitive (go-toward, look-for, find) and consumatory behaviors (eat, drink, play, rest, withdraw, etc.), motivations (e.g. fatigue, thirst, boredom) and basic emotions (fear, anger, happiness, etc.). In addition, they have a *synthetic physiology*—a set of parameters that define their internal bodily state and needs. This physiology includes both, controlled variables necessary for survival (e.g. heart-rate, energy, blood sugar level) and hormones released under different emotional states that modify the amount of the controlled variables. Controlled variables are monitored by motivations, implemented following a homeostatic model. Each motivation receiving an error signal (whenever the value of the corresponding controlled variable moves away from its ideal value) gets an activation level proportional to the magnitude of the error, and an intensity calculated on the basis of its activation level. Several motivations can be active at the same time, but that with the highest activation level gets the creature's attention and tries to organize its behavior so as to satisfy its main drive. The strongest motivation[5] selects the (consumatory or appetitive) behavior(s) that can best contribute to the satisfaction of the most urgent need. The execution of the selected behavior modifies the values of different controlled variables with an intensity proportional to that of the motivation, bringing the variable that triggered the drive to its ideal value, and therefore satisfying the need that originated the behavior. Motivations thus drive behavior selection and organization based on the notions of arousal and satiation, and also determine the agent's focus of attention. They can be thought of as implementing an implicit value system that ensures decision making, activity selection, and autonomy. Emotions are "second-order" modifiers or amplifiers of motives and therefore of behavior. Unlike motivations, the homeostatic model do not seems completely adequate in this case, in particular the notions of arousal and of activation as its indicator. Contrary to activation theories, we follow (Pribram 1984) to view emotional activation as an indicator of a change in configuration of neural and endocrine activity with respect to the habitual stable baseline of the organism. Emotional states are thus signs of internal "instability", but they also seem to play a role in homeostasis as mechanisms of re-equilibration, which derived from

processes that try to stop ongoing behavior, complementing this way the role of motivations—appetitive processes that try to activate action as a response to deprivation. In our model, emotions are implemented following a hormonal model (Cañamero 1997b). They exert further control of the agents behavior by sending synthetic hormones that may affect not only the agent's controlled variables, but also its perceptual, attentional, and motivational mechanisms, this way modifying the intensity and execution of the selected behavior. The inclusion of emotions in autonomous agents fosters flexibility of behavior and adaptation.

The integration of the original model in the COM-RIS agents requires some modifications and extensions to accommodate the demands of complex social interactions, as well as those of an information context. Let us consider the main ones. First, the physiology of the agents must be augmented to include parameters which are relevant for an agent that has to survive in an information context: parameters to keep track of the amount and relevance of information, of the agent's performance, of its competence, etc. Motivations, implemented again according to a homeostatic model, monitor these variables by selecting behaviors whose execution modifies the parameter in the desired direction. In the same way, the particular modules integrating the agents (sensors, maps, behaviors, etc.) must be adapted to this particular world. As for emotions, we propose to complement the set of basic emotions used in the original model, each implementing an adaptive function fundamental for the survival of an agent in its particular environment, with a set of "social emotions" that come to play only in the context of social interactions, and that should contribute to the adaptation of the agents to their social environment. Therefore, the main extensions have then to do with the ability to show, perceive, and react to emotional expression, as we will see in the next section.

Negotiating Difference: Emotional Rhetoric

The model of "social emotions" that we propose here is inspired by that of Aristotle in his *Rhetoric*, which considers emotional states as tools to negotiate social interactions. This view starts by accepting the fact that individuals are different, and that they have to live together; in order to do so in harmony, they must take into account their differences and accept them or negotiate them. Emotions are signs of a difference between individuals, and at the same time the tools that allow them to negotiate this difference, fulfilling various roles—epistemic, rhetoric, ethical, and political. The model of affects that Aristotle proposes in its *Rhetoric*

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[5]A second motivation is also taken into account to allow for oportunistic behaviors.

is based on a couple of relationships between individuals: identity/distance (according to their interests, affinities) and symmetry/asymmetry (rank, status), as perceived by each partner. A social interaction between two individuals will produce an emotional state in each of them according to its own perception of the relation along these dimensions and of the image that the other shows about it. The effect of an emotional state, as far as social interaction is concerned, will be to try to maintain, increase or decrease the distance in each dimension, through external manifestation such as emotional expression and/or the execution of an appropriate behavior. For example, love between A and B implies the mutual perception of an "almost-identity" (empathy) and of symmetry that both individuals will try to maintain or increase. Emotions can also activate each other and form "rhetoric" chains to negotiate distance and symmetry. For example, an overconfident individual A engaged in an interaction with B will perceive itself as having a much higher rank than B, disregard the "distance" dimension, and disdain whatever B proposes or does towards A. If the perception that B has of this relation is that A overestimates its self-image and underestimates B (i.e., the relation is not as asymmetrical as A seems to believe), B will enter in an angry state that will lead it to do something that increases the distance and decreases the asymmetry as perceived by A ("Hey, who do you think you are talking to?!!"). Emotions form a sort of interactive network, with opposition (e.g., love versus hate) and inhibition relations (e.g., anger and fear cannot be active at the same time) as well.

In the "original" COMRIS model the agent features of appearance, presentation, competence and relevance are used to regulate interest based navigation and competition for attention. Having adapted the agent's emotional apparatus, we can take the crucial step of involving *emotional expression* in each of these factors. Emotional expression can be kept simple, and however rich enough to meet the requirements of both appearance and presentation. Each emotional state automatically carries some external features over which the agent has no control (for example, a color associated with each emotion) and that affect its appearance—a pattern that reflects the agent's self-perceived "rank" or competence regardless of other individuals. This "rank" or competence level can be a function, for instance, of the history of successful interactions (e.g., those that increased the "pleasure" variable above a certain threshold), and the amount and relevance of accumulated information or wealth. Ranks can belong to a culturally determined typology, and establish hierarchical relations in the society. The "rank" of an agent

then tells at least as much about its social "type" (to which a social role can be associated) as it does about its history (how successful it has been in its interactions); it is thus a "social identifier". In addition, the agents should be able to control some of the components of emotional expression so that they can choose how to present themselves to the others depending on their state, interests, and the image the have of the other, i.e., of their view of the distance and symmetry dimensions of the relation. Presentation can be expressed by modifying the pattern used to show appearance as a function of the "social" emotional state. In this way, presentation reflects the agent's self-image in the context of a social relation, reflecting also the image it has of its partner. This image of self and the other has also a behavioral impact in the interaction; for example, in the "price" that an agent proposes to exchange goods or information with another. As for emotion recognition, we propose the use of expressive patterns characterizing the different emotions. In particular, the difference between the appearance and presentation patterns of an agent A can be used by another agent B to recognize the image that A has of the relation, and therefore of B. A comparison of this difference (A's point of view) with the difference between B's own appearance and recognition patterns (B's view of the relation) will trigger a particular emotional state in B that will have an impact on B's physiology, and produce an appropriate behavioral reaction towards A intended to negotiate the difference between their images. The recognition process does not need to be cognitive itself. For instance, a mechanism similar to the use of pheromones for rank and emotion recognition in some mammals can serve to implement the recognition of appearance and presentation, and the effects that their difference produces in the agents' physiology and behavior. In cases when it is important to maintain a history of individual interactions with other agents (or of interactions with types of agents), this difference in viewpoints can be kept as an emotional memory or "snapshot" that bootstraps the process in future interactions.

Conclusion and Prospect

The main roles that emotions play in social interactions in COMRIS can be summarized according to the scenarios that we distinguished previously.

At the individual agent level, emotions ground the notions of competence and relevance. Emotional states being in part a consequence of the agent's competence and relevance, as reflected in the level of the pertinent physiological parameters, these two notions are manifested in terms of emotional expression. This way, they

have a direct impact in social interaction. In turn, the level of success in this interaction feeds back into the agent's emotional state.

In the synchronous scenario, emotional states play a major role in the agents competition for the user's attention. Similarly, emotional expression is used by the parrot to solve the competition for attention game. Ideally (but admittedly not easy) this should imply the selection of agents that seem to best fit not only the current interests of the user (e.g., the agents that look more self-confident) but also her emotional state (e.g., the parrot may decide that a sad user might need a happy agent).

In the asynchronous scenario, we envisage two main roles for emotions. One is the negotiation of difference between individuals—of their "proximity" in terms of interests and of the "symmetry" of their relation as perceived by each partner. An interesting issue to explore here is whether, and under what circumstances, the local interactions between couples (or small groups) of agents can lead to the equilibrium of the society, as claimed by Aristotle for his City, i.e., the political role of emotions. The other role is in the creation of long-term interest relationships. For example, a very self-confident agent unable to achieve a goal on its own may have to call for another agent's help. This can make the first agent to feel "ashamed" because it was not self-sufficient, and create a debt towards the second agent that it might want to pay back only privately—without the presence of witnesses that would know about its weakness. Or a sad agent that received the gracious help of another one can develop a long-lasting grati-tude debt towards it, possibly implying more than one action at different times to show (and pay back) this gratitude. A concrete case that we have explored in more detail—and which is also well studied in anthro-pological literature—is the ritual act of present giving (Keane 1997). A present, whatever physical object it is, becomes a re-presentation of the present-giving act, which is embedded in a complex socially determined script of recognition and obligation. By its persistent nature and the emotional binding that both giver and receiver have with it, it creates co-behavior patterns that can extend over longer periods of time, especially when the exchange was witnessed by others (think of marriage rituals). We are proposing a scheme in which agents can exchange "material" tokens, that they as-sociate with an "emotional snapshot" of the exchange event. In later dealings with the other agents involved, the token-snapshot combination triggers a (culturally determined) emotional pattern. In this way, then, we hope to bridge the gap between bodily-grounded emo-tions and their social roles.

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