Communicative Behavior of Socially Situated Agents

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ABSTRACT

This paper introduces a model of user-agent and inter-agent interaction that supports basic features of affective communication. As essential requirements for animated agents' capability to engage in social interaction, we motivate reasoning about emotion and emotion expression, personality, and social role awareness. A (rather standard) appraisal program is employed to derive the agent's emotional state. The novel aspect of our approach is the introduction of a filter program that qualifies the agent's expression of its emotional state by its personality and more importantly, by the social setting in which the conversation takes place. This allows an agent to suppress an emotion, if the expression of the emotion would defeat a higher-order goal. We also discuss rudimentary mechanisms of social feedback.

1. INTRODUCTION

Our concept of affective communication is motivated by the influential paradigm of *affective computing*, "computing that relates to, arises from, or deliberately influences emotions" (Picard [14]). In line with this work, we assume that emotions are indispensable for effective communication, and thus promote the view that emotions should be integrated to models of human-computer interaction. Specifically, we envision that humans interact with animated agents, e.g., cartoon-style characters that may behave in believable and socially appropriate ways.

Recent years have seen a growing body of literature that aims to integrate emotions to architectures of autonomous agents. In order to position our own work, we will broadly categorize emotion research for autonomous agents into *cognitive* emotion approaches and *non-cognitive* (or innate) emotion approaches. Research in the first category mainly derives from Ortony, Clore, and Collins' [13] seminal work in cognitive psychology, where emotions are seen as valenced (i.e., positive or negative) reactions to events such as other agents' actions or objects, relative to the agent's goals, standards, and attitudes [6, 16, 8]. On the other hand, non-cognitive emotion approaches are mostly inspired by theories in neuroscience and ethology, which emphasize 'low-level' influences to emotion generation besides cognitive reasoning. For instance, Velásquez [18] considers four elicitors in his emotion model: neural, sensimotor processes, motivations, and cognition (see also [2, 20]).

Given this (rather ad hoc) classification, our approach clearly falls into the first category that approaches emotion from the cognitive point of view. Our main interest is the affective dimension in communication, which can be best modelled by explicitly representing mental concepts. In particular, our goal is to develop a general framework for affective and social communication that covers various forms of human-agent and inter-agent interactions. Consequently, we will propose 'higher-level' components of agents' mental models that enable them to process emotions and show affective behavior. A salient feature of our model is the following distinction:

- *Emotional states* are the result of reasoning about events, an agent's goals, standards, and attitudes.
- *Emotion expression* is the result of reasoning about the agent's emotional state, qualified by the agent's personality (or mood) and the social context.

A consequence of this distinction is a level of indirection between emotional state and emotion expression, which is mandatory when agents act in social settings where conventional practices apply [11]. So, for instance, an angry agent might not show its anger, if the agent interacts with another agent that has more social power or to which the social distance is large. Corresponding to the before mentioned distinction, two mechanisms are employed. An *appraisal program* evaluates an event as to its emotional significance for the agent, whereas a *filter program* qualifies the agent's emotion by its personality and the agent's awareness of the social threat from the other agent. Fig. 1 gives an example for the operation of appraisal and filter programs. Consider that someone crashes your computer. Depending on your attitude towards computers, you might be in a happy or angry emotional state. However, whether you will show your emotion will largely depend on your agreeableness and the social position of the aggressor. We claim that mechanisms of expression and suppression of emotional states are of key importance for socially intelligent behavior. Given a high-order maintenance goal, e.g., "keep your job", an agent

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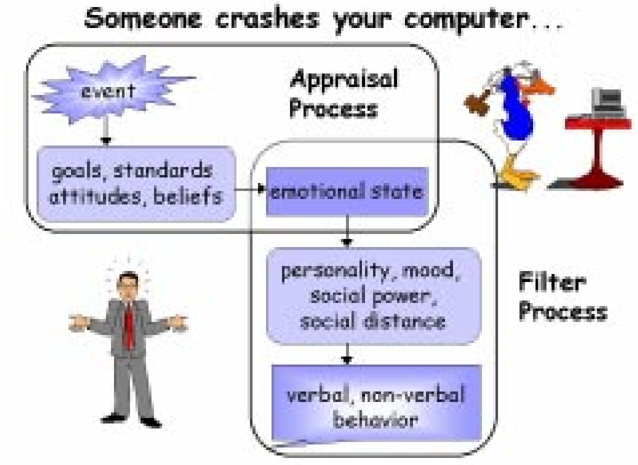

Figure 1: From events to emotion expression.

might suppress its 'angry' state, if it happens to be his or her boss who crashes his or her computer.

In this paper, we will describe the influence of mental concepts to emotional state and emotion expression. Important issues include the integration of the intensities of the various mental states to the (overall) intensity of emotion expression, as well as the impact of the user's (or another agent's) communicative act on the response of the agent. Our approach is used to improve English conversation skills of native speakers of Japanese, where we adhere to the "conversation training as role-playing in interactive games" metaphor as an enjoyable learning environment. The programmable interface of the Microsoft Agent package is used to run our interactive role-playing scenarios. The package comes ready with a speech recognizer and text-to-speech engine that allow client-side execution in a web browser. We currently use off-the-shelf 2D cartoon-style characters, but have 3D agents under development to overcome restrictions on the embodied behavior of the 2D agents. Our system are discussed in a related paper [15].

The rest of the paper is organized as follows. In the next section, we sketch our communication model and interaction protocol. After that, we describe an affective reasoner for reasoning about emotion, and report on an influential theory of emotion expression. The following section introduces a so-called 'filter program' that functions as a 'filter' between the agent's affective state and emotion expression. First, we briefly describe a simple model of personality and social role awareness, and then give some examples of filter rules. Next, we outline two simple social feedback mechanisms. The final section concludes the paper.

2. MODELLING AND SIMULATING CONVERSATIONS

Conversations can be characterized by the presence of multiple (locutor-)agents that communicate through various channels, such as verbal utterances, gestures, body movement, and facial display. Following [11], we can distinguish three levels of communication.

- At the *communication level* agents perform activities related to communication maintenance and turn-taking.
- At the *conceptual* level, agents transfer concepts (mental states).
- At the *social* level, agents manage and respect social relationships that hold between agents.

In this paper, we will focus on the conceptual and the social level. At the conceptual level, information is exchanged between agents as simplified symbolic representations of the utterance together with stylistic and affective markers. Consider an agent called 'Al' ordering beer from an agent called 'James', by saying "Bring me a beer, right away". As a basic interaction protocol between agents, we propose communicative acts of the form

com_act(al,james,order_beer,rude,anger,s0)

where 'al' is the speaker, 'james' is the hearer, 'order_beer' is the conveyed information, 'rude' is a qualitative evaluation of the linguistic style of the utterance, 'anger' refers to Al's emotion expression, and *s0* denotes the situation in which the utterance takes place. In animated agents, the expressed emotion can be generated, e.g., by acoustic signals [12] or facial display [5]. Concerning users' emotion expression, 'neutral' is set as the default value, as an emotion (expression) recognition module is not part of our system (but see [14]).

Each agent involved in a conversation is assumed to have its own mental model. A mental model contains different kinds of entities (components), including world knowledge (beliefs), and representations of 'higher-order' mental concepts (emotions, personality traits, standards, attitudes, goals). Similarly, Allen [1] considers a broad range of higher-level mental concepts—personality, attitudes, standards, moods, emotions, desires, intentions, and plans—which he calls (motivational) *control states*. A mental concept is considered as a control state if it might function as a predictor of behavior. If we can say "she does this because she is in a bad mood", without referring to other of the observed agent's mental concepts (e.g., attitude), it is a good indicator that mood is a control state. Our current model considers the following mental concepts (or control states): emotion, personality, mood, attitudes, standards, goals, and a control state that we call 'social role awareness' [15]. The integration and interaction of those concepts allows for a broad variety of believable agent behaviors that might be conceived as intelligent.

3. APPRAISAL PROGRAM

Affective reasoning is concerned with an agent's *appraisal process*, where events are evaluated as to their emotional significance for the agent (Ortony *et al.* [13], Elliott [6]). The significance is determined by so-called 'emotion-eliciting conditions', which comprise an event and three types of mental concepts.

- *Goals.* States of affairs that are (un)desirable, that the agent wants (does not want) to obtain.
- *Standards.* Beliefs about what ought (not) to be the case, events the agent considers as praiseworthy.
- *Attitudes.* Dispositions to like or dislike other agents or objects, what the agent considers appealing.

Those mental states are considered to be independent in the sense that an agent may be said to have a certain attitude

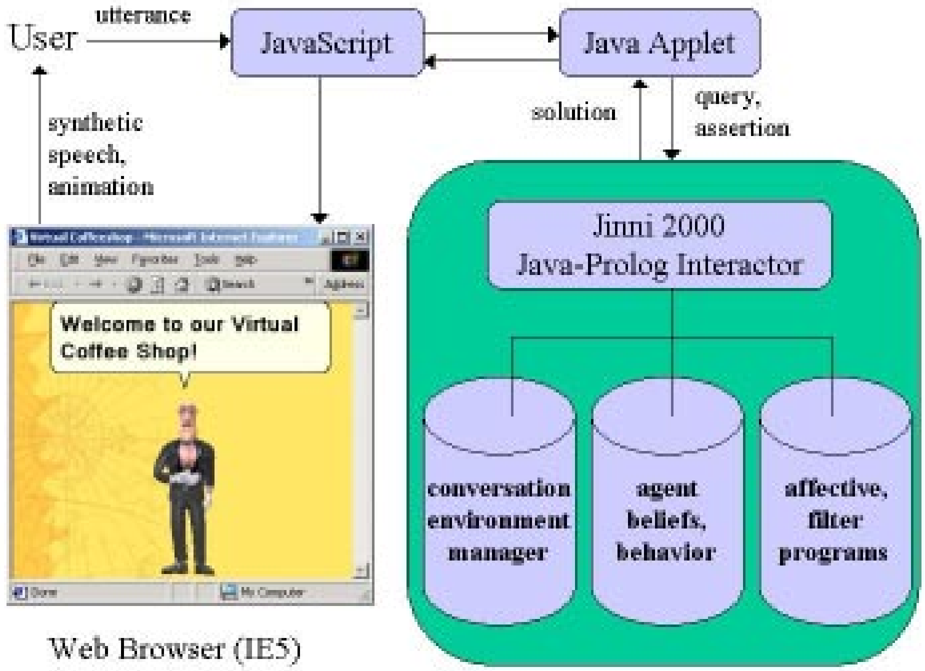

Figure 2: System Architecture.

without referring to its standards or goals. According to the emotion model of Ortony, Clore, and Collins [13], also known as the OCC model, emotion types are just classes of eliciting conditions, each of which is labeled with an emotion word of phrase.[1] In total, twenty-two classes of eliciting conditions are identified. The OCC model can be represented by a set of rules and might thus be seen as a model of (emotion) *causation* that allows to reason about emotion.

One of the simplest emotions is the well-being emotion *joy* which has the following specification.

$$joy(L,F,\delta,S) \leftarrow wants(L,F,\delta_{Des(F)},S) \wedge holds(F,S)$$

In words, a (locutor-)agent L is in the emotional state of *joy* about fluent (i.e., state of affairs) F with intensity degree δ in situation S, if F is desirable for L in S with desirability degree $\delta_{Des(F)}$, and F holds in S. For all intensities of mental concepts related to reasoning about emotion, such as emotion intensities or goal desirability, we assume intensities $\delta \in \{1, ..., 5\}$. In the case of *joy*, we set $\delta = \delta_{Des(F)}$. In general, however, assigning appropriate intensities to emotions is a nontrivial task [13, 16, 8]. Consider the fortunes-of-others emotion *happy-for*, which is formalized as

$$\begin{aligned} &happy\text{-}for(L1,L2,F,\delta,S) \leftarrow \\ &\quad likes(L1,L2,\delta_{App(L1,L2)}) \wedge \\ &\quad joy(L2,F,\delta',S0) \wedge S0 < S \end{aligned}$$

where δ' is the presumed intensity of the *joy* emotion of the observed agent. For instance, if the observed agent $L2$ expresses happiness, which is communicated to the observing agent $L1$ in the form of a *com_act/6* representation, $L1$ has good reasons to believe that $L2$ is in the emotional state of *joy*. On the other hand, if the observing agent has beliefs about the observed agent's goals and their desirability, the agent can infer the emotional state of the other agent by using the very same emotion rules (see also Elliott and Ortony's [7] *Concerns-of-Other* representations).

Following Reilly [16], we employ logarithmic combination to compute the intensity of an emotion, i.e., for intensities δ_i, the combined intensity δ is

$$\delta = \log_2 \left(\sum_i 2^{\delta_i} \right).$$

So, if an agent has evidence that another agent is very joyful ($\delta = 4$) and has a very positive attitude towards the other agent ($\delta_{App} = 5$), then the intensity of the agent's *happy-for* emotion would be 5 (computed values δ are rounded and set to 5 if $\delta > 5$). There are other ways to combine intensities (winner-takes-all, additive), but we found this choice the most natural. The specification of *happy-for* also assumes that the other agent was happy some time before the agent holds that belief. If needed, situation calculus frame axioms are used to project facts to future states.

Prospect-based emotions such as *hope* or *disappointment* require calculating the probability of goal attainment, i.e., reasoning about plan states. Since our current model does not support this functionality, values have to be set in advance (but see [8]). As another example, we shortly introduce the combined emotion *angry-at* (*reproach* and *distress*), which depends on the agent's standards.

$$\begin{aligned} &angry\text{-}at(L1,L2,F,\delta,S) \leftarrow \\ &\quad holds(did(L2,A),S) \wedge causes(A,F,S0) \wedge \\ &\quad wants(L1, \neg F,\delta_{Des(\neg F)},S) \wedge opposite(F, \neg F) \wedge \\ &\quad blameworthy(L1,A,\delta_{Acc(A)}) \wedge prec(S0,S) \end{aligned}$$

[1] Ortony *et al.* [13] clearly distinguish between (emotion) types and (emotion) tokens, whereby the latter ones all share the specification of the corresponding type. E.g., the emotion type *joy* is associated with the tokens 'happy', 'cheerful', 'pleased', and so on. Having said this, we will subsequently often use 'emotion' rather than 'emotion types'.

Briefly, this means that an agent is angry with another agent if an undesirable fluent is caused by that agent's blameworthy action performed in the previous situation. δ_{Acc} refers to the degree to which the action is not acceptable for the agent.

Many models of emotion seem to suggest that once we have derived an agent's emotional state, all we have to do is to just let the agent express its emotion. However, it is far from clear how to express a *happy-for* emotion, and how to distinguish the expression of this emotion from the expression of a *joy* emotion or a *hope* emotion. Moreover, there might be no direct mapping, e.g., between the *angry-at* emotion and the expression of *anger*. At this point, the agent's personality comes into the play, as well as features of the social context. Personality and social setting will be the topic of the next section. Before that, we will briefly discuss the issue of emotion expression.

Emotions can be expressed through various channels, such as facial display, speech and body movement. The so-called 'basic emotions' approach (Ekman [5]) extracts those emotions that have distinctive (facial) expressions associated with them:[2] *fear*, *anger*, *sadness*, *happiness*, *disgust*, and *surprise*. Murray and Arnott ([12]) describe the vocal effects on the basic emotions found in [5], e.g., if a speaker expresses *happiness*, his or her speech is typically faster, higher-pitched, and slightly louder. When running our human-agent conversation system, however, we found that vocal cues are rather ambiguous and therefore often rely on linguistic style to clearly express an agent's emotion.

4. FILTER PROGRAM

Following the OCC model, we have argued that goals, standards, and attitudes are the core mental concepts involved in an agent's appraisal of events, leading to a particular emotional state. Besides 'internal' emotional states, we briefly discussed the agent's ('external') expression of its emotion. A *filter program* is at the interface of the affective reasoner and the emotion expression module. It decides whether an emotion is expressed or suppressed, as well as the way and intensity in which an emotion is expressed. In our model, two factors determine emotion expression: the agent's personality and the agent's awareness of conventional practices that are applicable to the (social) situation.

4.1 Personality

Moffat [9] suggests to characterize personality as "the name we give to those reaction tendencies that are consistent over situations and time" (p. 133). He argues that there is a close relationship between personality and emotions, although they seem very different at first sight. Emotions are short-lived and focused on particular events, whereas personality is stable and not focused. As a working hypothesis, Moffat assumes that the same cognitive structure underlies both emotion and personality. So, e.g., personality can be considered as a permanent and global emotion. In this paper, we prefer to keep mental concepts distinct, and use an agent's personality to bias an agent's emotion expression, given a certain emotional state. Thereby, we can guarantee that the agent's behavior is consistent (with its personality), which is of key importance to an agent's believability [17]. In our current system, however, which only allows for rather short user-agent interactions, personality essentially collapses with *mood*, which is global (like personality) and rather short-lived (like emotions). Moffat also considers *sentiment* which is focussed on a particular agent or object, and has long duration. Given these characteristics, sentiment is very similar to our notion of attitude discussed in the previous section.

Our personality model is very simple, and considers just two dimensions, which seem crucial for social interaction. *Extroversion* refers to an agent's tendency to take action: sociable, active, talkative, optimistic. *Agreeableness* refers to an agent's disposition to be sympathetic: friendly, good-natured, forgiving. In our model, we assume numerical quantification of dimensions, with a value from the set $\{-3, -2, -1, 1, 2, 3\}$. For instance, a value of 3 in the agreeableness dimension means that the agent is very friendly. Currently, the extroversion dimension is only considered in a conversational manager, where the initiative agenda (turn-taking) is handled.

4.2 Conventional Practices

A significant portion of human conversation takes place in a socio-organizational setting where participating agents have clearly defined *social roles*, such as sales person and customer, or instructor and student (Moulin [10]). *Conventional practices* are guidelines (or restrictions) about socially appropriate behavior in a particular social setting. We can distinguish two kinds of guiding restrictions:

- *Behavioral constraints* concern responsibilities, rights, duties, prohibitions, and possibilities associated with a social role.

- *Communicative conventions* function as a regulatory for the agent's choice of verbal expressions in a given social context.

Our interest is the choice of verbal and non-verbal behavior (emotion expression), depending on the agent's social role and personality.

Formally, in social or organizational groups, roles are ordered according to a *power scale*, which defines the social power of an agent's role over other roles (Moulin [10]). Power relations between agents L_i and L_j are represented as $P = p(L_i, L_j)$, where $P \in \{0, 1, 2, 3\}$. The value 0 means that agents have same rank. Otherwise, e.g., if the value of P is 1, then the rank of L_i is slightly higher than the rank of L_j. The *social network* is specified by the social roles and associated power relations. Following Walker *et al.* [19], we also consider the *social distance* D between two agents, represented as $D = d(L_i, L_j)$, where $D \in \{0, 1, 2, 3\}$. If agents know each other very well, the social distance can be set to 0. Observe that the social distance between two agents can be high even if they have the same rank.

When agents interact, they do not only exchange information but also establish and maintain social relationships. Hence it is important that agents avoid introducing disharmony into a conversation (Moulin [10]) or threaten other agents' public face (Walker *et al.* [19]). We assume that emotion expression (e.g., facial display or linguistic style) is determined by personal experience, background knowledge, and cultural norms [19], as well as the 'organizational

[2] As there is only a limited number of comprehensive 'emotion words', we use *slanted* when referring to basic emotions rather than *italics* for emotional states.

culture' [10]. Consequently, human agents determine the values of the social variables 'social power' and 'social distance'. Based on the values of social power $P = p(L_j, L_i)$ and social distance $D = d(L_i, L_j)$, the agent L_i computes the *threat* θ from L_j of expressing a certain emotion by using the following simple equation

$$\theta = p(L_j, L_i) + d(L_i, L_j).$$

High values for θ typically lead to the agent's suppression of the expression of its emotional state, whereas low values allow the agent to show its emotional state. If $\theta = 0$, the agent considers itself as of same rank and high familiarity with the other agent. A zero value can also mean that the agent ignores conventional practices. In Prendinger and Ishizuka [15], we suggest the term *social role awareness* as a mental concept (or control state) that determines socially situated behavior.

4.3 Filter Rules

Basically, a (social) filter program consists of a set of rules that encode qualifying conditions for emotion expression. The program acts as a 'filter' between the agent's emotional state and its rendering in a social context, such as a conversation. As mentioned above, we consider the agent's personality and the agent's awareness of its social role as the most important emotion expression qualifying conditions.

In the following, we will give some examples of such filter rules. If the conversational partner has more social power or the social distance is large (i.e., θ is high), the expression of 'negative' emotions is typically suppressed, resulting in 'neutralized' emotion expression (our distinction into 'positive' and 'negative' emotions is based on Reilly's [16] intuitive hierarchy).

anger(L1,L2,F,ϵ,S) $\leftarrow$
  social_threat(L2,L1,θ) $\wedge$
  personality(L1,α) $\wedge$
  angry-at(L1,L2,F,δ,S) $\wedge$
  $\epsilon = \delta - (1 + \alpha + \theta)$

The first condition of the rule concerns social parameters, the second condition refers to the agent's agreeableness, and the third condition accounts for the output of the affective reasoner, the emotional state. As a first approximation, the intensity ϵ of emotion expression is computed as $\epsilon = \delta - (1 + \alpha + \theta)$. As an example, consider the case where the agent is very angry (i.e., $\delta = 5$), rather unfriendly ($\alpha = -2$), and the social threat is maximal ($\theta = 6$). Here, $\epsilon = 0$, which means that the emotion is completely suppressed. On the other hand, if the agent does not respect social practices, i.e., $\theta = 0$, the agent's agreeableness dimension comes into effect, resulting in $\epsilon = 6$ $(= 5 - (1 - 2))$. Since five is the maximal intensity level, greater values are cut off. If the agent is definitely angry ($\delta = 4$) but very friendly ($\alpha = 3$) and $\theta = 0$, then the *anger* intensity is zero, i.e., the agent's agreeableness 'consumes' the negative emotion. The equations we currently use for computing the intensity of emotion expression are certainly not 'objective', although they seem to bear some plausibility.

Observe that the suppression of a negative emotional states such as *angry-at* can be called 'intelligent' if it allows the agent to uphold certain goals which would otherwise be threatened by the direct expression of the negative emotion.

In the following, we briefly discuss the effect of personality and social context on the expression of positive emotions, such as *joy*.

happiness(L1,L2,F,ϵ,S) $\leftarrow$
  social_threat(L2,L1,θ) $\wedge$
  personality(L1,α) $\wedge$
  joy(L1,F,δ,S) $\wedge$
  $\epsilon = \delta - (\theta - \alpha)$

The intensity of positive emotions is computed as $\epsilon = \delta - (\theta - \alpha)$. Consequently, the agent's unfriendly personality or a high threat will diminish the expression of a positive emotion. Consider an agent that is very happy ($\delta = 5$) but unfriendly (e.g., $\alpha = -2$), communicating with a slightly distant conversant (i.e., $\theta = 1$). This agent will express *happiness* with intensity degree $\epsilon = 2$.

5. SOCIAL DYNAMICS

Although filter programs endow agents with awareness of the social context they are situated in, they do not provide them with mechanisms to *change* social parameters as a result of social interaction. However, when (human) agents interact, they establish and maintain social relationships, hence, e.g., the value of social distance changes, an issue that attracted strong interest in the biology-inspired field of Socially Intelligent Agents (see Dautenhahn [4], Cañamero [3]). In the following, we will discuss an instance of short-term as well as long-term social feedback.

5.1 Reciprocal Feedback

An interesting phenomenon of human-human communication is the *reciprocal feedback loop* where, e.g., one agent's use of polite linguistic style results in another agent adapting its linguistic style. For instance, consider the following utterances with varying linguistic style (polite, neutral, rude):

- I would like to drink a glass of beer. (*polite*)
- I will have a glass of beer. (*neutral*)
- Bring me a beer, right away. (*rude*)

Our system supports a limited form of reciprocal feedback, whereby depending on the user's (or agent's) linguistic style, 'intensity units' are added or subtracted to (from) the agreeableness degree. Hence, if the agent would give a cheerful answer with intensity degree $\epsilon = 3$, it might respond with degree 5 if asked politely, and with degree 1 if asked in a rude way (given appropriate intensity values for the remaining control states). A neutral question does not change the emotion expression intensity.

5.2 Social Feedback

As opposed to the rather momentary influence of reciprocal feedback, *social feedback* refers to changes of agents' relationships over more extended periods of time. For instance, when agents interact frequently, the value of social distance will eventually decrease, and also, power relations can change. Similarly, the appealingness degree associated with the agent's attitude may undergo changes when the agent repeatedly faces positive (negative) feedback from another agent. A promising direction for future research might be to incorporate a reinforcement-based algorithm for enhanced agent-user adaption (Breazeal and Velásquez [2]).

In fact, the very basis of dramatic action is that values associated with mental concepts turn (change). We started to investigate the mechanisms behind social dynamics resulting from interactions, which will allow for a richer interaction experience than one solely based on agents' believable reactions. Currently, intensities of control states are manipulated in a rather ad-hoc fashion, by summing up positive (negative) feedback values and updating the overall intensity of mental concepts.

6. CONCLUSION

In this paper, we propose to include reasoning about personality and social context to mental models of animated agents, which complements the affective reasoning component. All of the mental concepts (control states) involved in the reasoning process have associated intensities. Our initial experience with a web-based system implementing those features indicate enhanced believability of animated characters, at least for language conversation training tasks [15]. However, our system can also be used as a general-purpose platform for experimenting with behavioral patterns of animated agents, which is important for evaluating users' reactions to different styles of an agent's affective responses.

The prime focus of the proposed filter program is to support high social accuracy (or appropriateness) of agents' responses, e.g., by considering parameters such as social power and distance. The socially qualified response is motivated, e.g., as the suppression of a typically negative emotion in order to uphold a higher-level goal. Agents that modify emotion expression can be called *socially intelligent* as the expression of negative emotions often threatens their desire for autonomy. By considering more sophisticated mechanisms of social interaction, we hope to gain a better understanding of the complexity of social interactions.

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