Intelligent Expressions of Emotions

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Abstract. We propose an architecture of an embodied conversational agent that takes into account two aspects of emotions: the emotions triggered by an event (the felt emotions) and the expressed emotions (the displayed ones), which may differ in real life. In this paper, we present a formalization of emotion eliciting-events based on a model of the agent's mental state composed of beliefs, choices, and uncertainties, which enable one to identify the emotional state of an agent at any time. We also introduce a computational model based on fuzzy logic that computes facial expressions of emotions blending. Finally, examples of facial expressions resulting from the implementation of our model are shown.

1 Introduction and Motivation

A growing interest in using animated characters as interface of computational system has been observed in the recent years. This is motivated by an attempt to enhance human-machine interaction. Animated characters are generally used to embody some roles typically performed by humans, as for example a tutor [9] or an actor [11]. When facing these virtual interlocutors, the user has the propensity to interact in a similar way as when communicating with a human [15]. One of the crucial issues in the creation of animated characters is to enhance them with social intelligence and communicative abilities to give them the capacity to interact with the user in natural way and to display complex and subtle expressions.

Recent researches have highlighted a specific aspect of social intelligence based on emotional abilities, called *emotional intelligence*. It represents the capacity to express, understand and manage one's own emotions, and to perceive and interpret those of others [20]. In interpersonal relationships, the emotional intelligence determines an individual's chances to achieve her aims [6].

Introducing emotional intelligence into an animated character means, first, to give her the ability to express emotions. That requires two types of emotional skills: the knowledge of the circumstances under which emotions are triggered, and how to express them. However, an expressed emotion does not always reveal a felt emotion. A person may decide to express an emotion different from the one she actually felt because she has to follow some socio-cultural norms or she is pursuing some others of her goals. Ekman [4] refers to the former as display rules. We distinguish two kinds of emotions: the felt emotion named *elicited-emotion* and the expressed one called *expressed-emotion*. The elicited-emotion is triggered by a person's evaluation of a significant event [21]. One can suppress, intensify, de-intensify, mask or replace her own elicited-emotion in order to display an expressed-emotion consistent with some display rules [4]. Most of researches so far have focused on elicited-emotions of animated characters while less attention has been paid to the second type of emotion.

In this paper we propose a model that enables an agent to *intelligently* express emotions. That is, the type and intensity of the elicited- and/or expressed-emotions must be consistent not only with an event that has triggered it, but also with the socio-cultural context of the interaction. To achieve this goal, it is necessary, on the one hand, to distinguish between elicited- and expressed- emotions, and one the other hand, to go beyond the facial expression of basic emotions and to take into account blending of emotions.

2. System Overview

Figure 1 illustrates the agent architecture capable of displaying elicited and expressed emotions. It is composed of a natural dialog engine called *Artimis* [19] which can interact with users in natural language. It is based on a BDI approach. After the occurrence of an event, it computes the mental state of the agent and sends it to the Emotional Module. Depending on the current mental state and the socio-cultural context, the *Emotional Module* identifies the elicited and expressed emotions and their intensities. Finally, the *Facial Expressions of Emotions Blending Module* computes the resulting facial expression. The emotions are then displayed through the facial expressions of embodied conversational agent *Greta* [12].

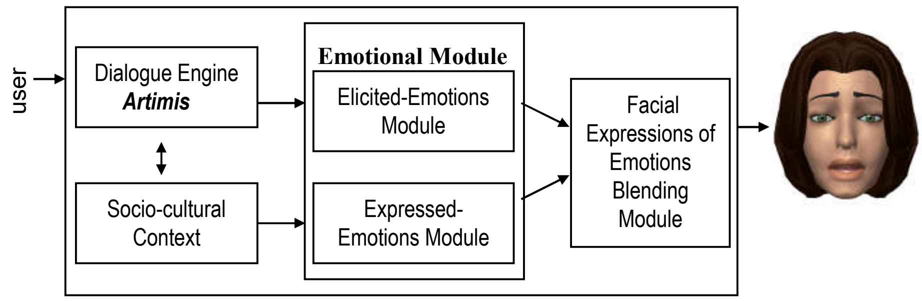

Fig. 1. Architecture for the intelligent expressions of emotions.

For the moment, the socio-cultural context is not implemented in our system. In this paper, we focus on two components of the process of emotion displaying: the generation of elicited-emotions (the elicited-emotions module) and the computation of facial expressions for blends of emotions (facial expressions of emotions blending module).

3. The Elicited-emotions Module

An agent who expresses emotions should be able to identify the emotional meaning of a situation in order to trigger appropriate emotions. According to cognitive appraisal theories [10, 21], emotions are elicited by the evaluation of an event based on specific set of criteria (called *appraisal variables*). The values of these variables depend both on situational and cultural factors and on particular individual's features (such as goals, preferences, personality traits,…) [21]. In the next section, we present some models that integrate aspects of appraisal theories. Then, we propose a representation and formalization of elicited-emotions based on mental states of a rational agent.

3.1 Computational Models of Elicited-Emotion Generation

In architecture Tok, the module Em provides the emotions triggered by a perceived event and their intensity according to a set of rules [13] based on the well-known OCC theory [10]. In deRosis et *al.*'s model [16], the elicited-emotions are represented by a Dynamic Belief Network and correspond to a particular modification of the agent's beliefs about the achievement or a threat of an agent's goal. Gratch and Marsella [8] have recently developed a complex model of emotions which takes into account coping behaviors.

Most of researches propose to consider specific modules or particular representations of the world to compute the values of appraisal variables in a situation to identify the elicited-emotions.

3.2 An Agent's Mental State

Rational agents with an explicit representation of the notion of mental state (as for example the BDI agents) allow for identifying directly the elicited-emotions through their mental states without adding a specific representation of the world or a module of appraisal variable evaluation. The mental states of BDI agents are composed of mental attitudes such as beliefs, desires and intentions. We use a model of rational agent based on a formal theory of interaction (called *Rational Interaction Theory* [18]), and on a BDI approach. The implementation of this theory has given rise to a rational dialog agent technology (named *Artimis*) that provides a generic framework to instantiate intelligent agents able to engage with both human interlocutors and artificial agents in a rich interaction [19].

In the Rational Interaction Theory, the model of an agent's mental state is based on three primitive attitudes: *belief*, *uncertainty*, and *choice,* formalized with the modal operators B, U, and C as follows (*p* being a closed formula denoted a proposition): $\mathbf{B}_i p$ means "agent *i* thinks that *p* is true", $\mathbf{U}_{i,pr} p$ means "agent *i* thinks that *p* has a probability *pr* to be true". If *pr* equals to 1 then uncertainty is equivalent to belief. $\mathbf{C}_i p$ means "agent *i* desires that *p* be currently true". Several others operators have been introduced to formalize the occurring action, the agent who has achieved it, and temporal relation (for more details see [18, 19]).

3.3 Emotional Mental States

A mental state corresponds to an agent's cognitive representation of the world at a given instant. It includes a representation of the event perceived in the environment. Accordingly, an occurred emotion eliciting-event is also represented through mental attitudes. We call *emotional mental state* the configuration of mental attitudes corresponding to an emotion elicited-event. According to the appraisal theories, an emotion eliciting-event corresponds to a particular combination of appraisal variable values [21]. Then, an emotional mental state is a representation of these specific values by mental attitudes.

We base our researches on the OCC model of emotions [10] which is particularly adapted to a BDI approach. In the work presented here, we focus on the emotions that differ, according to the OCC model, in their appraisal variable "Desirability of an event": joy, sadness, fear and anger. We consider also the emotion of surprise. The positive (resp. negative) emotions are elicited by a desirable (resp. undesirable) expected or occurred event. An event is desirable (resp. undesirable) if it allows for the increasing (resp. decreasing) of the *achievement degree* of one (or several) agent's goal(s). In terms of primitive mental attitudes, a goal corresponds to the choice (*p*) of an agent (*i*). The achievement degree is expressed by the probability (*pr*) associated with uncertainty ($U_{i,pr}p$). An agent's choice is totally achieved if the achievement degree is equal to 1 (*i.e.*, when it corresponds to an agent's belief), and is partially achieved if it inferior to 1. We distinguish four literal values for the desirability appraisal variable:

(1) ***Present desirability of an event e for a choice p***: It corresponds to an agent's mental state that involves the belief that an occurred event *e* has enabled to increase the likelihood (*i.e.*, achievement degree) of one of her choice *p*. Let us give an example to illustrate *present desirability*. Suppose that an agent *i* wishes to have received a mail from a friend (choice *p* of *i*: $C_i p$) who has promised to send it. As long as agent *i* has not checked her mailbox, she is uncertain about having received it (*p* is an uncertainty with a probability *pr_past*: $U_{i,\ pr\_past}p$). After having checked her mailbox (event *e*), she realizes that she has received it (i.e. $U_{i,\ pr\_present}p$ with pr_present > pr_past). In this case, the combination of these primitive mental attitudes corresponds to a *present desirability* of event *e* for choice *p*.

(2) ***Future desirability of an event e for a choice p***: It corresponds to an agent's mental state that involves the belief that an event *e* expected with a certain probability *pr_feasibility* can increase the likelihood of one of agent's choice *p*. In the example above, if agent *i* believes that by checking her mailbox (that it can do with a probability *pr_feasibility)* she will realize that her friend has send her the mail, then her mental state corresponds to *future desirability* of event *e* for choice *p*.

(3) ***Present*** and (4) ***Future undesirability of an event e for a choice p*** corresponds to cases where the likelihood of a choice *p* of an agent decreases because of an (expected/occurred) event *e*.

Each of these literal desirability values is associated with a numerical value called *desirability degree*. It is function of the variation of the achievement degree and the feasibility likelihood (*pr_feasibility*) of an expected event. Accordingly, the more the achievement degree of an agent's choice is increased by an event and the more the event is likely to occur, the more this event is desirable.

From these formalisations of the desirability variable and based on the OCC model [10], we can represent the emotional mental states associated with the emotions with mental attitudes. Joy is elicited by the occurrence of a desirable event. Accordingly, the emotional mental state of joy corresponds to the configuration of mental attitudes of *present desirability* described above. A rational agent generates an elicited-emotion of joy if her mental state contains this emotional mental state. In the example described above, the agent who receives the mail experiences joy. In the same way, given the fact that sadness emotion corresponds to an undesirable occurred event, the associated emotional mental state is equivalent to the configuration of mental attitudes of *present undesirability.* The emotion of anger corresponds to mental state which is composed of the configuration of mental attitudes of *present undesirability* and the agent's belief that another one is responsible of the event occurred. Fear emotions are triggered by an undesirable expected event. Then, the emotional mental states associated correspond to the *future undesirability* configurations of mental attitudes. The intensity of these emotions is function of the desirability degree.

The emotion of surprise corresponds to the mental state which contains the belief of the occurrence of unexpected event. The intensity of this emotion is function of the probability of the feasibility of the event (*pr_feasibility*) before its occurrence.

A rational agent can experience different emotions at the same time. For instance, given the formalisation described, the emotions of anger and sadness can be triggered because of a same event. These elicited-emotions and their intensities are then provided to the Facial Expressions of Emotions Blending Module.

4 The Facial Expressions of Emotions Blending Module

The term *emotion blending* refers to several different phenomena in the literature. In [14], "affect blends" are defined as "multiple simultaneous facial expressions". Indeed, a person may show two or more emotions at any time [4]. Blending appears if two emotions overlap in time [5]. Emotions are usually expressed on different facial areas. One facial area may rarely display expressions which are characteristic for two different emotions. Emotions may also occur in rapid sequences one after the other. Blends may be due by rapid sequences, superposition of two or more emotions or by masking one from another one. Finally, different blending of facial expressions can be distinguished depending both on the type of emotions (elicited or expressed-emotions) and on their apparition in time (sequence, superposition…) [4, 5]. In this section, we propose a model to compute facial expressions of emotions blending based on fuzzy logic.

4.1 Different approaches for Expressions of Blending

While most of the existing animated characters use facial expressions to show emotions, less attention has been paid to expressions of blending. From a dimensional model of emotions, Tsapatsoulis et *al.* [22] and Albrecht et *al.* [1] applied an interpolation between expression parameters of two emotions to compute the blending expressions. The Emotional Disc model [17] uses a bi-linear interpolation directly between two expressions. Based on Ekman's results, Duy Bui [3] proposes fuzzy logic rules for each possible emotions pair to determine the blending expressions according to emotions intensity.

Instead of basing our model at the level of facial muscle contractions as previous models did, we propose a face partition based-model to compute not only the facial expressions resulting from the superposition of two elicited-emotions but also from the masking of an elicited one by another one. This allows our models to differentiate the facial expressions resulting from the blending of elicited and expressed-emotions.

4.2 Computational model for Emotion Blending

Emotion blending leads to a particular facial expression that may either result from combining the facial components of both emotions or may differ from them. The visual effects of blending depend on both the type and intensity of emotions as well as if they are felt (elicited-emotion) or fake (expressed-emotion). Indeed, the expression of two elicited-emotions can be different from the blending of the same pair of emotions when one is felt and the other one is expressed. Usually, humans are not able to control all their facial muscles efficiently [5]. For example, masking sadness with anger is different from feeling both sadness and anger at the same time [4]. For the moment, we have considered only these two cases of emotion blending: the superposition of two elicited-emotions and the masking of an elicited-emotion by an expressed one (a felt emotion being masked by a fake emotion due to some display rules). The case of the sequence of emotions will be dealt in the future. We have implemented different computational models for each blend type, superposition and masking.

Superposition. Ekman [4, 5] proposed a model of blended expressions by combining the upper part of one expression with the lower part of the other one. We use these findings and we consider two areas in the face: the upper face (noted *U*) and the lower face (noted *L*). Bassili [2] and Gouta [7] found that negative emotions are mainly perceived from the upper part of the face while positive emotions on the lower part. We use the results of this perceptual test to generate facial expression of two emotions to ensure that the resulting expression conveys both emotions. To combine emotions, we introduce the priority operator noted ">" and the equivalence operator "≡". "$E_i > E_j$" means that E_i is expressed through the upper area in the case of blending of E_i and E_j, while "$E_i \equiv E_j$" means there is no predominance for this particular face area. This latter case occurs for instance, when surprise and fear are blended [4].
The fuzzy inference is used to model the combination of the facial expressions of two elicited-emotions. More precisely, the fuzzy rules are based on both: the predominance between emotions introduced by the operators ">","≡" and intensities of emotions. Using fuzzy logic allows us not to consider separately all possible emotion pairs. It takes into account the different types of emotions and all the spectrum of their intensities to generate distinct facial expressions.

Masking. Ekman [4] claims that upper face expression is usually more difficult to control. So we can postulate that usually the upper face region shows felt emotion and the lower region is used to mask it. Moreover, Ekman distinguishes some reliable features of felt emotion like: fear or sadness brows, or glary eyes in case of anger. Such reliable features lack in fake expressions. The masking can be seen as asymmetric emotion-communicative function, whereas superposition is rather symmetric. Indeed, given two emotions *Ei* and *Ej*, the masking of *Ei* by *Ej* leads to a different facial expression than the masking of *Ej* by *Ei* [4], while this is not the case for superposition. Following Ekman's research [4], we have defined the face area that contains the reliable features for each felt emotion. In our model this area displays the elicited-emotion, while the other area shows the masking (i.e. expressed-) emotion (See: Fig. 2c). Doing so enables us to model the asymmetry property of masking.

a) anger | b) superposition of sadness and anger | c) sadness masked by anger | d) sadness

Fig. 2. Facial expressions of the ECA Greta [12]

5 Conclusion

In this paper, we have presented a formalization of events triggering emotions as well as a model for the facial expression of blends of emotions. In the near future we aim at evaluating our model, in particular related to the perception of blends of emotions. The next steps consist in adding the abilities to the agent to determine the most appropriate emotion to express according to a socio-cultural context or to achieve specific goals. Future developments are also foreseen to work on a more fine-grained face partition to improve the agent's expressiveness and believability.

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