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# Emotion modeling for intelligent agents – Towards a unifying framework

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## Abstract

*Existing computational models of emotions, although based on different psychological theories, share common properties and may be seen as the different facets of a common emotional process. We thus present our model GRACE - aiming at unifying existing models into a single architecture while preserving the peculiarities of each of them. We also demonstrate the generality of GRACE in emulating the behavior of these existing models.*

## 1 Introduction

Research in the field of computer-human interaction has long been focusing on incorporating anthropomorphic characteristics to make applications more familiar and acceptable by humans. Together with vocal and facial abilities, emotions in particular seem to have been playing a great role in reducing the distance between humans and machines [1][2].

Since the very first model of emotions in computer science, known to be the work of Simon in 1967, several applications in computer science have been developed (see [7] for a more detailed list). All of these computational models of emotions, although based on various psychological theories, share common properties and may be seen as the different facets of a common emotional process. GRACE is thus our attempt to propose a unifying framework, encapsulating and generalizing existing computational models, while preserving the peculiarities of each of them.

Section 2 of the paper presents the three main traditions in psychology along with computational models of emotions for virtual agents. In section 3, we present GRACE, which we consider as a generic framework for modeling emotional processes. To support our claim of GRACE's generality, we develop in section 4 a projection of the four models mentioned in section 2 into our model GRACE. We end the paper with some discussion about current results.

## 2 Three main approaches in the computational modeling of emotions

In this section, we review the different psychological traditions about human emotions and the main computational models that were developed on the basis of these traditions.

### 2.1 Basic emotions theories

Psychologists Ekman [4], Izard [5], and Johnson-Laird and Oatley [16] consider human emotions as being grouped into families. In these so-called *basic emotions theories*, human emotions are characterized by a set of basic emotions. Each basic emotion is a family of antecedent event, appraisal, physiological symptoms, behavioral response, etc. According to Izard [5], there are four groups of events that can trigger emotional processes. These are *Neural Elicitors* for those concerning brain activities, neurotransmitters; *Sensorimotor Elicitors* concerning sensorimotor processes (like facial expression, body gesture), *Motivational Elicitors* concerning all motivations that lead to emotions, like thirst, hunger; *Cognitive Elicitors* which can be understood as beliefs, desires, intentions, social standards, etc. This theory is also quite popular in computer science as it favors task-oriented or task-specific modeling.

*Cathexis* [9][10] is an attempt at modeling emotions in terms of proto-specialists introduced by Marvin Minsky [8] and implementing the four types of emotion elicitors proposed by Izard. This is one of the first realizations of basic emotions theories as a process. Beside *Cathexis*, other works also used basic emotions theories, such as the robot *Kismet* of Breazeal [17], the agent *Max* of Becker, Kopp, and Wachsmuth [18], and many others.

### 2.2 Appraisal process - OCC's model of emotions

Psychologist Ortony and colleagues proposed in 1988 a model of emotions aiming at being implemented in computational models, well known under the name OCC (for the names of the three inventors Ortony, Clore, and Collins) [11]. To

calculate an emotional response, this model considers three aspects of the perceived event, which are the *consequences of the event*, the *action of the agent*, and the *aspects of objects*. Thanks to its simplicity and its clarity, OCC's theory became a really popular reference for the design of agents.

One of the first applications of OCC is *Affective Reasoner* [12] – a computational model of emotions for virtual agents. The emotional process functions on the basis of a set of predefined rules (called *Emotion Eliciting Condition Relations* - EECRs) to do the emotion mapping. These EECRs were constructed based on the model OCC. Beside EECRs, the emotion mapping process also depends on the personality type of the agent, which means its goals, standards, and preferences.

There is also *Agent Greta* [13] - an emotional BDI agent, developed on the BDI model [19], which considers the influence of emotions on its actions. The affective state of *Greta* corresponds to the evaluation of the event using the OCC's theory. Other works also used OCC's theory as a reference model of emotions for agents, such as *FLAME* of El-Nars et al [21], the *Oz* project of the MIT [20].

### 2.3 Coping mechanism for emotional agents in stressful situation

R. S. Lazarus suggested that the emotional response of humans is produced through two stages of evaluation – cognitive appraisal and coping [15]. The cognitive appraisal is in charge of evaluating the person-environment relationship, giving the former an adapted view about the current situation. At the stage of coping, there will be *problem-focused coping* or *emotion-focused coping*. In *problem-focused coping*, one tries to establish a plan to solve the problem that makes the situation stressful. In *emotion-focused coping*, one aims at reappraising the situation by changing personal goals and intentions so as to make the situation less stressful and more acceptable.

This theory of coping has inspired the model *EMA* by Gratch and Marsella [14], which aims at modeling human reactions in a simulation of stressful situations. The interesting issue of this model, in our opinion, is the implementation of the coping process into a model of emotions. Emotions in *EMA* can be not only a factor in the planning of the agent but also a factor that urges the agent to review/change its own beliefs and desires.

### 2.4 Incompleteness of existing models

Physiological reactions, which are surviving mechanisms that help living organisms get out of danger, appear to be an important aspect of emotional process. However, these reactions are taken into

account in *Cathexis* (via proto-specialists of *Fear* and *Anger*) but not present in *Greta Affective Reasoner*, and *EMA*.

We also agree with the authors of *EMA* that the coping mechanism plays an important role in the emotional process. Emotions are not only involved in the planning process but are also an important factor that modifies our way of thinking about reality. But again, only *EMA* implements this coping ability.

These lacks lead us to propose a generic model of emotions named 'GRACE' that incorporates all necessary elements in order to better reflect the emotional process in humans and other species.

## 3 GRACE – Generic Architecture to Create Emotions in software agent

According to Scherer, emotional processes of human-beings have in general five important features [3]. One interesting aspect of the work of Scherer is that these five general features can account for the different processes and strategies proposed by the other theories, reflecting his care to take into account existing theories into his proposal. Another aspect that draws our attention to the work of Scherer is his willingness to propose a computational model of emotions. Scherer's approach is thus consistent with our objective to have a general model of emotions that can be a blueprint for further implementations of complete emotional processes in computerized applications.

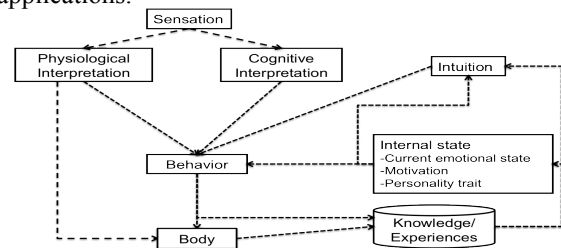


Figure 1 Architecture of GRACE

In the aim of incorporating the five features proposed by Scherer, we proposed *GRACE* [22][23][24] as a general framework of emotions for computerized applications (figure 1).

In this model, we can simulate reflex emotional reactions, like surprise or fear by transferring the event from *Sensation* to *Body* directly through *Physiological Interpretation*. The cognitive analysis is achieved by transferring the event through *Cognitive Interpretation*. Information from the two interpretation modules then goes through the module *Behavior*. This is the place where the model considers the current effect of the event (interpreted by *Cognitive Interpretation* and

*Physiological Interpretation*), re-evaluates that perception with the current internal state and motivation to produce a more informed emotional output. This emotional output is then expressed by the *Body* and triggers an update in the module *Knowledge* (corresponding to Experience), which further entails possible modifications of the internal state.

#### 4 GRACE vs. other models of emotions

This section explains how *GRACE* can emulate some computational models listed in the section 2.

##### 4.1 Basic emotions theory - *Cathexis*

As we already underlined, the emotional process in *Cathexis* is triggered by four kinds of Emotion Elicitors (Neural Elicitors, Sensorimotor Elicitors, Motivational Elicitors, and Cognitive Elicitors). Regarding the functionality of each kind of Elicitors, we propose to implement them into *GRACE* as following (see figure 2):

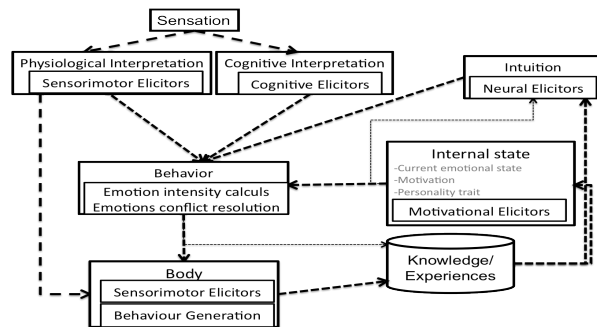


Figure 2 *GRACE* emulating *Cathexis*

As compared to *Cathexis*, *GRACE* more clearly relates the different elicitors to one another. Moreover, with *GRACE*, it is possible to simulate different personalities by simply changing the way each elicitor affects the emotion intensity computation in Behavior. This would significantly facilitate the design of empathetic agents with different personalities.

##### 4.2 Appraisal process - *Affective Reasoner*

*Affective Reasoner*, as a model of mapping rules, can be easily transferred to *GRACE* (see figure 3). While the rule set EECRs of *Affective Reasoner* embraces the agent's personality, *GRACE* allows separating the two elements, which makes it more flexible and scalable. *GRACE*, in addition, can be more flexible as it allows taking into account, among other things, the current internal state or immediate reactions, which influence the final emotional output.

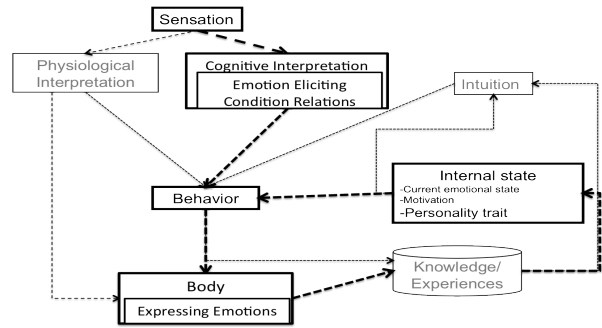


Figure 3 *GRACE* emulating *Affective Reasoner*

##### 4.3 Appraisal process - *Greta*

In *GRACE*, the mechanism of *Greta*'s Mind can be implemented in Cognitive Interpretation. The output of Cognitive Interpretation is the same as the output of Mind, i.e. the appropriate emotion in OCC. That output is then transferred to Behavior, where the intensity of the emotion is determined upon agent's personality. The output of Behavior is finally expressed using Body expressive features. Emotion decay occurs in Internal State component. In addition, *GRACE* can enrich *Greta* with other properties of emotions, such as physiological symptoms, imaginary events (through Intuition), etc.

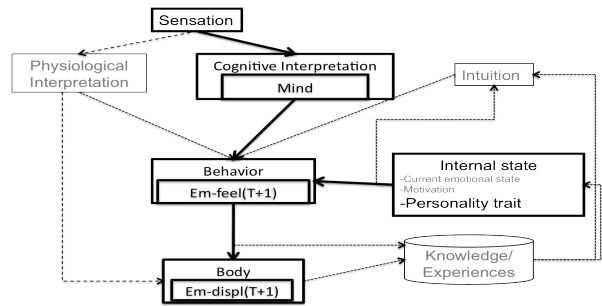


Figure 4 - *GRACE* emulating *Greta*

##### 4.4 Coping strategy - *EMA*

To emulate *EMA* in *GRACE*, we propose to implement its cognitive analysis into Cognitive Interpretation. Its appraisal values represent the understanding of the agent about the perceived event, which helps the agent in establishing a plan (either emotion-focused or problem-focused plan) in response to the event. Coping process is implemented in Behavior. In *GRACE*, coping can account for personality defined in the module Internal State. *GRACE* also provides to the design of *EMA* the possibility, in stressful situations, to have emotional reflexes without going through the coping process. Also, re-appraisal can be seen as a kind of neural

