An Emotional Architecture for Virtual Characters

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Abstract. This paper presents the mechanisms proposed by a generic cognitive architecture for virtual characters with emotional influenced behaviors, called COGNITIVA, to maintain behavior control at will without giving up the richness provided by emotions. This architecture, together with a progressive specification process for its application, have been used successfully to model 3D intelligent virtual actors for virtual storytelling.

1 The Role of Emotions in Virtual Storytelling

Traditionally it was considered that intelligent behaviors could only be produced from pure rational reasoning processes. However, everyday experience shows that pure rationality fails when trying to explain many human behaviors, in which the emotional component has a decisive weight. Although quite a lot of efforts have been made to consider emotions in computational models of cognitive processes, emotion is still perceived by many as a non-desirable quality for a computational system [1]. Emotion, mood, personality or attitudes have been considered synonyms of loss of control and entropy growth, and, as such, non-desirable qualities and even something "non scientific" [2].

On the opposite side, recent theories [3] [4] suggest that emotions are an essential part of human intelligence, and are of paramount importance in processes such as perception, learning, attention, memory, rational decision-making and other skills associated to intelligent behaviors. Even more, it has been stated that an excessive deficit of emotion may be harmful to decision-making [5]. Emotion is essential to understand human cognition.

Many of the behaviors produced from pure rational models are far away from those observable in human beings, specially when these models are applied to contexts such as storytelling. Taking emotions away from most stories would make them boring and unbelievable. It is known by everyone that the characters in most stories sometimes do not make the most reasonable decisions, and many times their behavior is strongly influenced by their emotional state. If we want to be able to build believable virtual storytelling, reason and emotion should not be considered as antagonistic and irreconcilable concepts, but as complementary strengths that act upon the mental processes of our virtual actors.

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2 A Cognitive Architecture to Manage Emotions

Our proposal is to model actors using a truly emotionally-oriented architecture, not a conventional architecture with an emotion component. In our opinion, explainable and elaborated emotion-based behaviors can only emerge when the whole architecture has an emotional vocation.

The architecture that we propose, called COGNITIVA, is an agent-based one. Agents are a common choice to model autonomous virtual actors (not necessarily human-shaped actors but also animals or fantastic creatures), since they present a structure and operation suitable to their needs. Considering an agent as a continuous *perception-cognition-action* cycle, we have restricted the scope of our proposal to the "cognitive" activity, although no constraint on the other two modules (perceptual and actuation) is imposed. This is the reason why this architecture will be sometimes qualified as "cognitive".

In COGNITIVA, emotions are not considered just as a component that provides the system with some "emotional" attributes, but all the components and processes of the architecture have been designed to deal naturally with emotions.

Along this paper, we will analyze how COGNITIVA deals with emotions. Every component and function will be exemplified through the application of the architecture to the modeling of some characters in a well-known fairy tale, Little Red Riding-Hood.

COGNITIVA is a multilayered architecture: it offers three possible layers to the actor designer, each one corresponding to a different kind of behavior, viz reactive, deliberative and social (see Fig. 1). The interaction of these three layers with the other two modules of the actor, the sensors (perceptual module) and the effectors (actuation module), is made through two specific components, the interpreter and the scheduler, respectively.

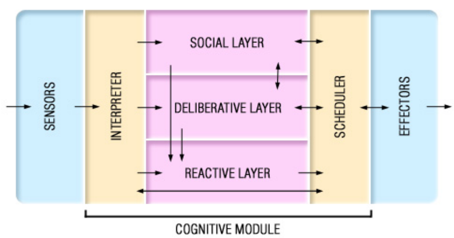

Fig. 1. General structure of COGNITIVA

The cognitive module described by COGNITIVA receives from the perceptual module (the actor's sensors) *perceptions* of the environment. This input may not be directly manipulable by most of the processes of the cognitive module and must be interpreted (for instance, sensors might provide measures about light wavelengths, but the cognitive module could only be able to manage directly colors). In other situations, many inputs may be irrelevant for the actor, and should be filtered (for example, when the woodsman is grabbing the wolf who just ate Little Red Riding-Hood, he would not mind anything about Grandma's house decoration).

COGNITIVA provides a component, called **interpreter**, which acts as an interface between sensors and the rest of the cognitive module, receiving the perceptions coming from the perceptual module, filtering and discarding those non-interesting to the actor, and translating them into *percepts*[1], intelligible by the rest of the components and processes of the cognitive module.

On the other hand, each time some internal reasoning process, in any of the three layers of the architecture, proposes an action to be executed, it must be properly sequenced with other previous and simultaneous action proposals. This should not be a responsibility of the actuation module (effectors), since this module should not need to have any information about the origin and final goal of the actions it receives. COGNITIVA proposes a component, the **scheduler**, to act as interface between the cognitive module and the effectors, managing an internal agenda in which action proposals are conveniently sequenced and ordered. The scheduler organizes the actions according to their priority, established by the reasoning process that generated them, and their concurrence restrictions. Once it has decided which is/are the most adequate action/s to be executed, it sends it/them to the effectors.

The dynamics of the architecture follow a continuous cycle, represented in the Fig. 2, that leaves no room for chaotic behaviors.

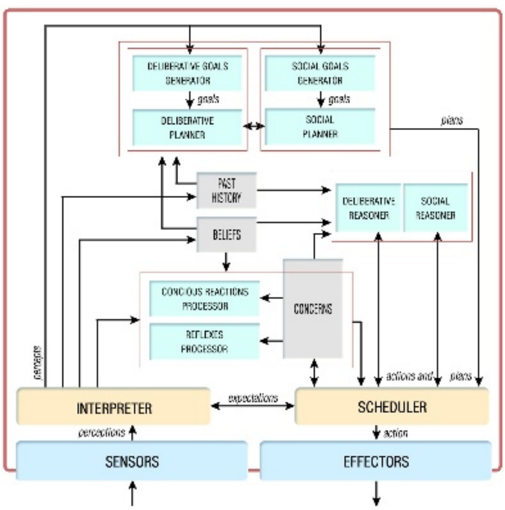

Fig. 2. Internal components and processes of COGNITIVA

[1] Name proposed by Pierce [6], in the context of visual perception, to design the initial interpretative hypothesis of what is being perceived.

3 What Does an Emotional Virtual Character Know?

3.1 Beliefs About the Current State of the World

Beliefs represent the information managed by the actor about the most probable state of the environment, considering all the places, objects and individuals in it. Among all the beliefs managed by the actor, there is a small group specially related to the emotional behavior. This set, that has been called the actor's *personal model*, is composed by the beliefs that the actor has about itself. More precisely, this personal model consists on personality traits, moods, physical states, attitudes and concerns.

COGNITIVA defines a taxonomy of beliefs, depending on their object and their nature. On one hand, a belief may refer to a *place* in the environment, to *objects* located in the environment, and to other *individuals*. Besides, the agent maintains beliefs concerning the *current situation*, for instance, a belief of Little Red Riding-Hood about the current situation may be the fact that she is engaged in a conversation with the wolf. That is not information about the wolf, nor about Little Red Riding-Hood, but about the situation that is taking place.

Beliefs about places, objects and individuals may include:

- **Defining characteristics (DCs)**, traits that mark out the fundamental features of places, objects or individuals. DCs will hardly change in time, and if they do, it will happen very slowly. For instance, the distance from Little Red Riding-Hood's home to the grandmother's house and their location may be DCs about the virtual stage (place); the capacity of her basket is a DC for an object; and a DC about her grandmother (individual) is its name.

  Among all the DCs that an actor can manage, COGNITIVA prescribes the existence of a set of *personality traits* (P) for individuals. Personality traits will mark out the general lines for the actor's behavior. For instance, the wolf can be provided with two personality traits, *ferocity* and *dishonesty*.
- **Transitory states (TSs)**, characteristics whose values represent the current state of the environment's places, objects or individuals. Unlike the DCs, whose values are, practically, static in time, the TSs values have a much more dynamic nature. Some examples of TSs could be the *number of characters on stage* (TS of a place), the *content* of the basket (TS of an object), or the *position* in the scenario of the wolf (TSs of an individual).

  COGNITIVA considers essential two kinds of TSs for individuals: their *moods* (M), which reflect the emotional internal state of the actors; and their *physical states* (F), which represent the external state of the actors (the state of their *bodies* or representations in the virtual environment). In our fairy tale, Little Red Riding-Hood could have as moods *happiness*, *fear* and *surprise*, and the wolf could have as physical states, *hunger* and *fatigue*.
- **Attitudes (As)**, which determine the predisposition of the actor towards the environment's components (places, objects and individuals). Attitudes are less variable in time than TSs, but more than DCs. Examples of attitudes selected for our scenario are the *confidence* of Little Red Riding-Hood towards the wolf, as well as her *appreciation* towards Grandma. Attitudes are

important to guide the actor's decision making, action selection and, above all, to keep coherence and consistency in the actor's interactions.

The elements of the personal model in our architecture have been modeled with a fuzzy logic representation. Fuzzy logic linguistic labels are nearer to the way in which humans qualify these kind of concepts (it is usual to hear "I am *very* happy", instead of "My happiness is *0.8*"). Besides, fuzzy logic is a good approach to manage imprecision.

Relationships among personal model elements are a key point in COGNITIVA. Many of these beliefs are conceptually closely related, and have a direct influence on each other:

– Personality traits exert an important influence determining emotions. For instance, in a similar situation, the value of the mood *fear* will be different for a *courageous* woodsman than for a *pusillanimous* one.
– The set of attitudes of an actor has some influence on the emotions that it experiences. For instance, the sight of the wolf in Grandma's bed will produce an increment on the woodsman's *fear*, because of its attitude of *apprehension* towards wolves.
– Personality traits, in turn, have influence on attitudes. The *apprehension* towards the wolf will be different depending on the value for the personality trait *courage*: a cowardly woodsman will feel absolute rejection towards wolves, whereas a courageous one just will not like them.
– Physical states have also influence on emotions. For instance, when the wolf is *hungry*, its *happiness* will decrease.
– Finally, personality traits exert some influence on concerns. This influence will be explained later on.

All these relationships have been designed and implemented through special fuzzy rules and fuzzy operators. The result is a set of fuzzy relationships, which might include the following:

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courage DECREASES ⟨much⟩ fear

courage DECREASES ⟨few⟩ apprehension

apprehension DECREASES ⟨some⟩ happiness

apprehension INCREASES ⟨much⟩ fear
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3.2 Knowledge of Past Events

Behaviors that do not take into account past events are disappointing to human observers, specially in storytelling. COGNITIVA considers two mechanisms to maintain the actor's past history information:

– **Accumulative effect of the past:** this is an implicit mechanism, related to the way in which beliefs are managed. External changes in the environment or internal modifications in the actor's internal state may produce an update of the actor's beliefs. In the case of transitory states, this update is performed as a variation —on higher or lower intensity— on the previous value of the belief, avoiding abrupt alterations in the individual's state.

– **Explicit management of the past state:** an accumulative effect of the past events may not be enough to manage efficiently the past state, because it does not consider information related to the events themselves or to the temporal instant in which they took place. COGNITIVA maintains explicit propositions related to any significant event —to the actor— that happened. In the wolf's past history we could find events such as *talked to Little Red Riding-Hood*, *ran to Grandma's house*, *ate Grandma*... Past history allows the actor to reason considering facts occurred in past moments. As a possible way to implement it, an inverse delta based mechanism has been developed to manage past events.

4 How does an Emotional Virtual Character Behave?

Emotions, in particular moods, may be a strong force to drive the actor's behavior. As it was seen before, emotions are part of the state of the agent. If their values are properly updated and their effects are reasonable, the outcomes of the emotionally based behavior will not be unpredictable, but coherent responses.

4.1 The Effect of Perceptions on Emotions

COGNITIVA provides some mechanisms to update and control the internal state of the actor and, in particular, to control the values of the components of the personal model.

In the first place, the interpreter will direct the interpreted percepts to the convenient processes in every layer of the architecture. The interpreter also feeds information for updating past history and beliefs. Most of that updating may be more or less automatic, and needs no further processing. For instance, when Little Red Riding-Hood perceives her Grandma in bed, the interpreter will update automatically the beliefs about her appearance (size of her ears, eyes and teeth, for instance).

However, that is not the case for moods, and moods are the core of emotional behavior. The new value of moods depends on their old value and on the perceptions, but also on what was expected to happen and to which degree that occurrence was desired. Moods need a new factor to be conveniently generated. With this aim, COGNITIVA includes the mechanism of the **expectations**, inspired on the proposal of Seif El-Nasr [7], which has been adapted, in turn, from the OCC Model [8].

Expectations capture the predisposition of the actor toward the events — confirmed or potential. In COGNITIVA, expectations are valuated on:

– Their *expectancy:* Expressing how probably the occurrence of the event is expected.

– Their *desire:* Indicating the degree of desirability of the event.

Through expectations, the interpreter has a mechanism to update moods from perception:

– When the event **occurrence has not yet been confirmed**. Moods will be updated depending on the degrees of expectancy and desire for the event. For example, if the Grandma knows that Little Red Riding-Hood was going to visit her, but it is getting late, she may elaborate the expectation "something happened to Little Red Riding-Hood in the forest". That is an undesirable event, whose occurrence has not been confirmed yet, that produces a sensation of *distress*, increasing the value of Grandma's "fear" and decreasing the value of her "happiness".
– When the event **occurrence has already been confirmed**. Again, depending on the degrees of expectancy and desire for the event, moods will be updated. For instance, if someone informed Grandma that Little Red Riding-Hood effectively was attacked by the wolf in the forest, her fears would be confirmed, and her *distress* would transform into *sadness*, decreasing considerably the value of her "happiness".
– When the event **non-occurrence has already been confirmed**. The degree of expectancy and desire of the event will determine the updating of moods. For instance, when Grandma hears someone knocking on her door, she believes that Little Red Riding-Hood has arrived safe, so her expectation about Little Red Riding-Hood being attacked vanishes, and *distress* would give way to *relief* by increasing "happiness" and "surprise".

This is how expectations are used to update moods, but, what is the origin of those expectations? Actions will have a set of associated expectations. When the scheduler selects an action to be executed, it informs the interpreter about what is expected to occur in the future, according to that action.

4.2 The Effect of Emotions on Actuation

It is reasonable that actions proposed by the reactive layer have a higher priority in the queue of actions to be executed than those coming from the deliberative o social layers. Even more, it makes sense that deliberative or social action executions are interrupted when a reactive action emerges. Then, does not that mean that reactive, instinctive, passional actions will always take the control of the actuation, leaving out higher level behaviors? Is not that, in fact, losing control? In fact, humans have, to some extent, the ability to control the reactions that logically follow from their emotional state.

The mechanism proposed in COGNITIVA to allow higher level control the actor's actuation is the use of *concerns*. Beliefs represent information about what the actor thinks is the most probable state of the environment, including itself and the rest of the actors. For instance, when the woodsman enters Grandma's house and sees that the wolf has just eaten Little Red Riding-Hood, he will know that he his feeling fear for the wolf, but as this is not at all a desired state for him, he should try to do something to change that state (run away).

Concerns express the desirable/acceptable values for the TSs of an actor anytime, in particular, for **emotions** and **physical states**. Concerns restrict the range of values of the TSs of the actor, expressing the acceptable limits in a certain moment. With this aim, concerns provide two *thresholds*, *lower* and *upper*, for every TS. All the values among them will be considered as desired by the actor; those values out of this range will be unpleasant, and the actor will be inclined to act to avoid them and let them move to the desired range.

Then, a reaction, besides some triggering conditions, the operator to be executed, the consequences of its execution, and some other parameters, such as its priority or its expiry time, will be provided with *justifiers*, i.e., emotional restrictions that must be satisfied to execute the action. Justifiers are expressed in terms of restrictions related to the value of the actor's concerns, that is, restrictions on the desirable state of the actor. For instance, a justifier to trigger a reaction to run away because of the fear produced by the wolf will be:

$$fear > upper\_threshold\_concern(fear) \tag{1}$$

Whenever some actor wants to be able to stand a bit more fear, it first must raise the value of the upper threshold of this concern. If fear does not surpass the value of the upper threshold, the reaction will not be justified and it will not be triggered.

Depending on the personality traits of the individual, which have some influence on concerns as it was mentioned before, the real new value for that upper threshold will be higher or lower. Coming back to the scenario of the fairy tale, if two woodsmen, one courageous and another one easily frightened, enter Grandma's house when hearing Little Red Riding-Hood's cry, and they will perceive the wolf, their fear will raise and a reaction of escape would be triggered. Once they are far enough and their fear has descended under the value of the upper threshold of its corresponding concern, still they will feel worried about Little Red Riding-Hood. However, the new information included in their beliefs, the position of the wolf, prevents them from generating a plan to save Little Red Riding-Hood if they do not consider assuming some risk. As far as Little Red Riding-Hood's life is really in danger, they decide to increase their fear tolerance (the upper threshold of their concern about fear), each one according to their possibilities (their personality traits). They come back to the house, perceive the wolf and, again, their fear raises. But, this time, the level of the fear of the brave woodsman does not surpass its fear tolerance upper threshold, and he grabs the wolf to get Little Red Riding-Hood and Grandma out of its belly. The other woodsman, less courageous, cannot raise enough its fear tolerance upper threshold, and, again, he escapes frightened.

In this way, higher processes of the architecture (deliberative and social) can adjust the value of the thresholds of the actor's concerns to control the instinctive actuation whenever it is not desirable.

5 Related Work

The search for architectures combining rational and emotional behaviors has been a frequent challenge in the last two decades.

Most of the solutions proposed hitherto follow one of two main emotional computational models, generally, the appraisal model (cf. [9], [10]) or the motivational model (cf. [11], [12]). However, although all these models present many interesting virtues, they also suffer from some well-known drawbacks.

Sometimes, emotional elements and mechanisms are so interwoven with the restrictions and particularities of the application context and with the problem faced, that these proposals turn to be very hard to be reused in different contexts. (cf. [13], [14]). In other cases, emotional architectures are very generic, independent from any specific problem (cf. [11], [12]). However, these proposals tend to be less-efficient and computationally demanding. Moreover, they lack of mechanisms suitable to facilitate the adaptation of the architecture to the particular necessities of the problem. Frequently, this adaptation is only achieved through simplification of some of their inherent features and with a lot of effort.

Our solution provides a balance among these two extremes. One of the main characteristics of COGNITIVA—and one of its strengths— is that, having been conceived as a generic, domain-independent architecture, not restricted to any emotional theory or model, and applicable to a wide range of domains and problems, it is accompanied by a progressive specification process in two phases (Functional Specification and Contextual Specification) to be applied for the design and adaptation of the abstract structures and functions proposed, to the particular needs of the application context (the details of the process are out of the scope of this paper, but can be found in [15]).

6 Conclusions

Human and animal behaviors are rarely exclusively explainable through pure reasoning. There exist other emotional factors that influence decisively on them, that must also be considered. However, the efforts until today to build architectures including those emotional factors have not yet succeeded, and emotion is still frequently observed as an undesirable quality to be included in computational systems.

This paper presents some of the mechanisms proposed in COGNITIVA, an architecture with generic mechanisms and structures to build actors with emotionally influenced behaviors, and which is able to deal with the problem of the loss of control in the emotionally based behavior generation.

COGNITIVA does not intend to constitute yet another theory of emotion, but an abstract architecture able to leave room for multiple theories. With this philosophy, in the functional specification proposed we have developed a possible theory (with fuzzy relationships among personality traits and moods, for instance) with the aim of checking the applicability of the architecture, and not the empirical validity of the theory itself —which must not be considered, in fact, as anything else than an example of application.

COGNITIVA has already been applied to quite different contexts and scenarios [16], and it has proved (together with the specification process) to be a useful approach to the construction of virtual characters for storytelling.

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