Integrating Emotions in the Triple ECA Model

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Abstract

This paper presents the introduction of emotion based mechanisms in the Triple ECA model. Triple is a hybrid cognitive model consisting of three interacting modules – the reasoning, the connectionist, and the emotion engines – running in parallel. The interplay between these three modules is discussed in the paper with a focus on the role and implementation of the emotion engine which is based on the FAtiMA agent architecture. The influence of emotions in Triple is related to the volume of the working memory, the speed of the inference mechanisms, the interaction between the reasoning and the connectionist engine, and the connectionist engine itself. Emotions will increase the most important cognitive aspects of the model like context sensitivity, rich experiential episodic knowledge and anticipatory mechanisms. Apart from higher flexibility and richness of the representations a considerable improvement in believability is expected from Triple augmented with emotion mechanisms.

Keywords: ECA, cognitive modeling, emotions.

Introduction

Virtual environments like Internet become more and more complex and rich and comparable with real environment with respect to the amount of information and its complexity. As is the case in robotics, human level of performance is difficult to achieve especially at the level of communication, user perception, etc. The latter stresses the importance of the use of cognitive models as 'minds' of the Embodied Conversational Agents (ECA) living in virtual environments. The problems related to perception and action on one hand and the interaction with human users on the other requires context sensitivity, flexibility, believability, and personalization of the ECA behavior. From the theoretical point of view, analogously to robotics, accomplishing tasks in complex environments seems to require novel approaches. Even the huge inferential power of modern computers leads to abundance of data difficult to deal with.

The model Triple, introduced for the first time in (Grinberg & Kostadinov, 2008), is aimed at being a cognitive model for cognitive systems and particularly for ECA platforms. It includes, on one hand, several of the necessary mechanisms mentioned above and on the other it tries to achieve maximal computational efficiency in order to allow real time functioning of the ECA. These two constraints lie at the basis of this model: adding all the useful cognitive modeling techniques which allow flexibility, context sensitivity and selectivity of the agent and in the same time – maximal computational optimization of the code and use of very efficient inference methods (e.g. see (Kiryakov et. al., 2005)).

In this paper the emotional module of Triple is presented and its relations to the other modules. The main motive to model emotions in the ECA is that it improves the interaction with human and make the agent more believable (Bates, 1994). The second reason is the widely accepted importance of emotions for adaptability and effective reasoning (Damasio, 1994).

There are different other models of the interplay between emotions and the rest of cognitive abilities within integrated cognitive architectures. For example, Cochran, Lee & Chown (2006) explored the impact of arousal on memory using ACT-R and suggested that any general cognitive architecture should integrate emotions to some extent in order to be able to account for a number of psychological findings.

FAtiMA (FearNot! Affective Mind Architecture) is agent architecture with major accent in modeling emotions and personality (Dias & Pavia, 2005; Dias, 2005). FAtiMA generates emotions from a subjective appraisal of events and is based on the OCC cognitive theory of emotions (Ortony et al, 1988.). The OCC is commonly used in a various agent architectures allowing endowing artificial agents with emotional behavior (Bartneck, 2002). FAtiMA has been successfully applied to modeling artificial intelligent agents in different domains (Brisson & Paiva, 2007; Zoll et. al., 2006). Thats are some of the reasons for using FAtiMA in the modeling process of the emotional part of Triple.

This paper continues the work with emotion modeling for artificial agents described in (Vankov et al., 2008). In (Vankov et al., 2008) the effects of emotion on analogical reasoning have been investigated based on two examples implemented with the DUAL/AMBR cognitive architecture (Kokinov, 1994).

The rest of the paper has the following structure. First there is a brief overview of the Triple model. Second follows a detailed description of the emotion engine and its interaction with the other parts of Triple. Some simulations are given to show the emotional dynamics based on different types of events.

The Triple Model

The Triple model is inspired from the DUAL/AMBR model for analogy making (Kokinov, 1994). Triple has some important mechanisms which are similar to

DUAL/AMBR but the underlying mechanisms are considerably different. Triple is based on three pillars which run in parallel and communicate on an event-driven basis (Figure 1). The Reasoning Engine (RE) part operates serially on a small amount of knowledge selected by the connectionist mechanisms of Similarity Asessment Engine (SAE) and influenced by the Emotional Engine (EE).

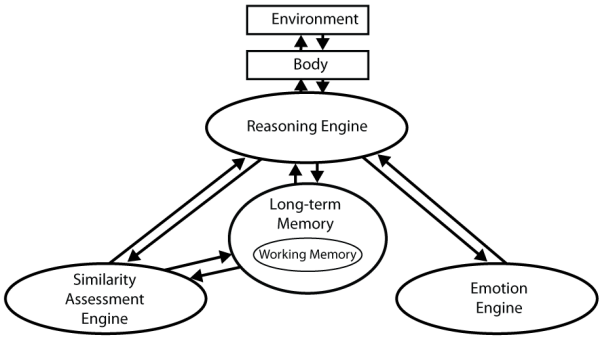

Figure 1 The basic modules in Triple

The RE is coordinating and synchronizing the activities of the model and relates the agent with the environment (e.g. user, other agents, etc.) and with the tools the agent can use (e.g. tools to communicate with the user, make actions like access ontologies and data bases, search the Internet, extract LSA information from documents, etc.) (see (Grinberg & Kostadinov, 2008). RE is also responsible for instance learning – storing of useful episodes in LTM after evaluation.

The SAE is designed to be a connectionist engine, based on fast matrix operations and is supposed to run all the time as an independent parallel process. The main mechanism is activation spreading in combination with similarity or correspondence assessment mechanisms which allow retrieving knowledge relevant to the task at hand.

The third part is the Emotion Engine (EE) which is based on FAtiMA. Some mechanisms are directly transferred from FAtiMA in EE. The others are just based on ideas of FAtiMA because of the BDI structure of FAtiMA, which is not presented in Triple. EE, similarly to SAE, is supposed to run in parallel and influence various parameters of the model like the volume of WM, the speed of processing, etc EE is supposed also to react to external events without much cognitive processing. This paper is devoted to the description and discussion of EE and its role in Triple.

The Emotion Engine

The Emotion Engine (EE) of Triple is a separate module which communicates with the 'body' of the agent, i.e. receives symbolically represented information about the environment. On the other hand EE communicates with the Reasoning Engine (RE) and through it influence several cognitive mechanisms as discussed below (Figure 1).

The structure of EE is given in Figure 2. It can be formally divided into two parts: 'reactive' and 'deliberative' (see Figure 2). The reactive part communicates mainly with the environment and provides fast emotional response to some external events. Reactive and deliberative appraisals generate the emotion base potential (when internal or external event is perceived) which is used to generate new emotional state. The Emotional State (ES) of the model processes all emotions related to the mood of the system and some rules representing the emotional internal dynamics. Considerable changes in the ES reflect in actions in the avatar to express the strongest emotion. At the same time emotions and mood at each moment influence the reasoning process in a psychologically plausible way.

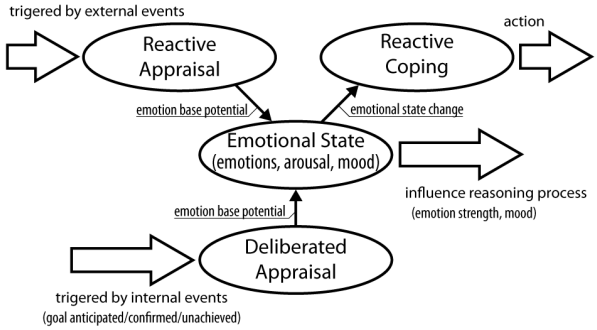

Figure 2 Structure of the emotion engine and relation to the other modules of the model

Reactive Emotional Processing

Following FAtiMA model (Dias & Pavia, 2005), the reactive process in EE consists of:

- Reactive appraisal: handles specific external events and emotionally appraise them to produce emotions;
- Reactive coping: produces actions based on the strongest emotion in the moment.

Reactive appraisal

The reactive appraisal process is based on a set of predefined emotional reaction rules. They provide a fast appraisal mechanism to generate most types of OCC emotions. When an external event is perceived (as utterance written from the user for example) it is sent to the emotional module as a specific emotional event. It generates suitable values of the appraisal variables (AV). There are some different AV in FAtiMA but the current stage of implementation of EE uses only the Desirability AV. Desirability AV indicates generally how good or bad is the event for the agent. The set of emotions which could be generated via the reactive appraisal using the Desirability AV in the current implementation is joy and distress.

External events that are appraised from the reactive module are related to interaction with the agent's user. For example direct feed back from the user or interpretation of some of her utterances can lead to events like "the user is sad" and "the user is happy". Another external event is when the system is started and the agent is awakened. This event is appraised as very desirable and thus RASCALLO begins its life with joy.

Reactive coping

The reactive coping process is a simplified version of the one impelemented in FAtiMA. EE checks continuously for significant changes in the emotional state of the agent. If such a change is intercepted, a corresponding event is triggered and the emotional expression of the agent updated. The current implementation of Triple is using the Rascalli multiagent platform (Krenn, 2008) and Radon's character (http://www.radonlabs.de/technologynebula2.html). Tripple control the avatar by chaging the parameters of mouth, eyebrows, body posture, etc. The avatar could also pronounce some utterance to emphasize the emotion..

Reactive coping stands for the character's impulsive actions performed by the agent without reasoning (action tendencies). Said otherwise action tendencies are similar to the innate biological impulses of the human. The matching process is triggered only when a considerable change in the emotional state occurs.

Screenshots of the male and female agent expressing emotions are given in Figure 3.

Figure 3 RASCALLO expressing disappointment and RASCALLA expressing joy

Deliberative emotional processing

The deliberative emotional processing is inspired by the deliberative part of FAtiMA model. In Triple, the same prospect based emotions like in FAtiMA are used and a similar appraisal process. But there are some major differences. The main reason is that the deliberative appraisal in Fatima is dealing with plans of actions as FAtiMA is a BDI type model. Triple does not implement such BDI type planning mechanisms but retrieves action plans and respective outcomes from memory based on analogy like mechanisms. This retrieved information is used in the deliberative appraisal process. As in FAtiMA, the deliberative appraisal consists of emotional appraisal of expected future evens related to the agent's goals and has basically two parts:

- Appraisal of goal achievement anticipation;
- Appraisal of goal achievement success/failure.

Appraisal of goal achievement anticipation

Triple EE uses an internal heuristics to generate the emotions hope and fear related to a desired future event. Once generated these emotions are added to the emotional state and start participating in the emotional dynamics. These heuristics allows specifying:

- the importance of the agent's goal (value in the interval [0,1], '0' meaning completely unimportant event and '1' a very important one);
- the success probability to achieve the goal (value in the interval [0,1]).

The success probability is continuously recalculated in the relevant moments of the reasoning process and hope and fear for the excepted event are changing over time. The goal achievement success probability is calculated as follows. When an expectation of a future desired event is triggered it receives a basic probability of success based on the formula:

$$P_{basic}(success) = \frac{\sum_i success\_rating_i}{N} \quad (1)$$

where, N is the number of past episodes in which this goal was anticipated, success_rating_i is the rating for successful achievement of the goal in episode i. It is a value in the interval [0,1] and shows how much the result satisfied the agents expectation ('0' means a complete failure; '1' means that the result was completely congruent with the agent expectation).The above equation is based on the assumption that the assignment of the probability of a future event is based on past experience with same or similar events. Events that have occurred in the past are more likely to be expected in the future and vice versa.

That basic probability is continuously updated during the run of the system until Triple receives information about the goal achievement success or failure. That update is based on the formula:

$$P(success) = \alpha P_{basic}(success) + (1-\alpha) P_{current}(success) \quad (2)$$

α parameter here represents how much the agent rest on its past experience comparing the current one. The current probability of success is some estimation how the current events relate to the expectation for the anticipated event. This parameter could depend on the personal differences of the agent as well as on the current emotional state.

Using the probability of success and the importance of the event fear and hope emotions are generated with the formulas:

$$BaseHopePotential = P(success)\ ImportanceOfSucess \quad (3)$$

$$BaseFearPotential = P(failure)\ mImportanceOfFailure \quad (4)$$

In the present implementation of Triple, the only goal which is emotionally relevant is 'user is satisfied'. The importance of that goal is a fixed value in any session. The base probability of success is calculated when the agent receives a new task from the user. That probability is changed over time during the reasoning process when events such as transfer of correspondence hypotheses or the result of a search in the database are triggered. For example if the DB search tool returns no answer to a query, the

corresponding event will decrease the base probability of success and the agent may start feeling fear.

Appraisal of goal achievement success/failure

The success rating of the event is calculated based on the user evaluation of the information provided by the agent. In the current ECA implementation this can be done by pressing two buttons – the 'praise' and the 'scolding' buttons. If the user presses the 'praise' button this means full success to the agent. Pressing the 'scolding' button means the opposite – zero success rating. In the no feedback condition, a value of 0.7 is assumed, which means that it is more likely that the user is satisfied.

After Triple receives information about an expected event and based on the dominant emotion at this moment, the following prospect based emotions are generated: satisfaction, relief, disappointment, and fear confirmed (see Table 1). For example if the agent was very hopeful that the user will be satisfied but it is scolded instead disappointment is generated.

Table 1 Prospect based emotions

	Dominant emotion during the goal anticipation	
Goal result	Hope	Fear
Success	Disappointment	Fears confirmed
Failure	Satisfaction	Relief

The elicited emotions are added to the emotional state and expressed by the agent character. At the same time that result of the event is used to determine the success_rating, which will be used in future appraising of the same event.

Emotional State

OCC theory specifies for each emotion type an emotional threshold and decay rate. An emotional threshold specifies a character's resistance towards an emotion type, and the decay rate assess how fast does the emotion decays over time. When an event is appraised, the created emotions are not necessarily "felt" by the character. The appraisal process described so far determines the potential of emotions. However such emotions are added to the character's emotional state (ES) only if their potential surpasses the defined threshold (the threshold is specific for each emotion). And even if they do overcome the threshold, the final emotion intensity is given by the difference between the threshold and the initial potential.

Every emotion has an associated Intensity value to it which is related how strong that emotion is. Each emotional event can update that value. When nothing happens the emotion decays naturally. The model uses a decay function for emotions proposed by Picard (1997) which characterizes intensity as a function of time. At any time (t), the value for the intensity of an emotion (em) is given by the formula:

$$Intensity(em,t) = Intensity(em, t0).e^{-bt} \quad (5)$$

The value b determines how fast the intensity of this particular emotion will decrease over time. The value Intensity(em, t0), refers to the value of the intensity parameter of the emotion (em) when it was generated. When the value of Intensity(em,t) reaches a defined threshold near zero, the emotion (em) must be removed from the ES

The emotions created by the reactive and deliberative appraisals are sent to the ES to be processed. When the ES receives an emotion (even if later it is not added to the ES), his mood level will change according to the emotion potential multiplied by a constant:

$$Positive\ emotion,\ Potential = Potential + Mood*k \quad (5)$$

$$Negative\ emotion,\ Potential = Potential - Mood*k \quad (6)$$

where $0<k<1$.

A negative mood (bad mood) increases the potential of every negative emotion and decreases the potential of positive emotions. A positive mood acts in the opposite way. But on the other hand, emotions also influence mood. Good emotions raise the character's mood and bad emotions make him feel worst thus lowering his mood. Depending on the emotion potential, this change will be greater or smaller. Empirical tests determined this value as 10 % of the potential.

$$Mood = Mood+Potential(Emotion)*0.1, \quad (7)$$

for positive emotions and

$$Mood = Mood - Potential(Emotion)* 0.1, \quad (8)$$

for negative emotions

Mood slowly decays linearly to the neutral value 0. Characters tend to maintain mood for large periods of time.

Finally an emotion is added to the character emotional state only if the emotion potential surpasses the defined threshold for that emotion. Final intensity of the emotion is:

$$Intensity = Potential - EmotionThreshold \quad (9)$$

Impact of Emotions on the Reasoning Process

Some additional mechanisms have been implemented in Triple, which complement the ones taken from FAtiMA. They are based on the integration of emotions in the DUAL/ABMR model for robotic applications and the simulations reported in (Vankov et al., 2008). The new mechanisms could be formally divided two basic types:

1. Adding emotional nodes to long term memory
2. Modifying internal parameters in RE and SAE based on the current emotional state

Adding emotion nodes to LTM

Adding emotional nodes in the memory of the agent is related to the explicit representation of emotions in Triple's LTM. First of all, emotion concept nodes for each of the implemented emotions have been added to LTM (Figure 4). Instances of the emotion concepts are then used in the episodic part of LTM so that each episode has an emotion node attached to it related to the dominant emotion felt by the agent in that episode. This node is encoded during the learning process (storing of relevant episodes) by using the most active emotion in the emotional state. Composition of emotions is an option to be considered in the future, as the episode (or parts of it) may point to a number of emotions with different intensity. Interesting are the effects expected from the addition of emotion nodes to episodic memory for analogy making as suggested by the simulations in (Vankov et al., 2008). Past episodes experienced with congruent to

the current emotion will be more likely to be retrieved and used for the analogy-making which could lead to different action plans and outcomes. That is consistent with some psychological research that most of the time people tend to retrieve memories related to a mood similar to their own current mood (Teasdale & Fogarty, 1979).

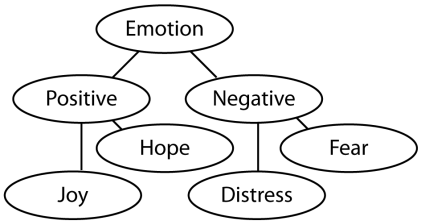

Figure 4 Part of the emotional conceptual structure

Emotion influence to the internal parameters of the model

It is well known that emotions influence reasoning in various ways. Most of the important mechanisms in Triple are influenced by the emotional state of the system. Some of the mechanism and parameters affected are the following:

- Parameters which influence what kind of similarity should be preferred in SAE in the analogy making process – structural or taxonomical
- Parameters of the constraint satisfaction mechanism which control how much different solutions will comes to mind for a particular task
- The time of waiting for the searching tools before producing – "I don't know" answer
- etc.

That influence of the parameters of Triple based on the current emotional state is based on psychological plausibility as well as pragmatic reasons. The latter could be the interaction between a human user and the agent or the effectiveness and efficiency of the model.

Communication of EE with the other Triple Modules

The connection of the emotion module and the rest of the architecture are presented in the next table. Table 2 shows how different events inside or outside of the system influence the emotional dynamics.

Table 2 External and internal events' effect on the EE

Event	Emotional processing	Example
Emotionally significant external event is processed	Reactive appraisal is called. It updates the ES based on the appraisal rules and the current value of the mood variable	The user uttered something assessed as positive. Triple appraises that event as desirable and reactive appraisal adds 'joy' in the emotional state
A goal is set or a new evaluation of the goal achievement success is calculated	Hope and fear are added to the ES based on heuristics for the importance of the event and its failure/success probability.	When Triple receives a new task from the user hope and fear for the goal – "the user is satisfied" –are generated. The potential of fear is stronger because of the previous failures of the system.
A goal is achieved or not	New prospect based emotion is generated based on the dominant emotion when the goal is anticipated	The user "praises" the agent which was fearful about the result. Then relief is achieved.
The emotional state changed 'considerably'	Reactive coping is triggered and the agent expresses the emotion	The emotion 'joy' is added in the emotional state with an intensity surpassing the threshold. The agent smiles and displays a happy face
	If the strongest emotion in the ES changed then a new node corresponding to that emotion is added to in the description of the target episode	
The mechanisms involved in the reasoning process are influenced by the emotional state	The emotional state is evaluated by the reasoning engine and the relevant parameters changed leading to different behavior	The agent is in positive mood. When SAE is called the mood parameter is such that the module will produce deeper analogies and probably come to more creative solutions .

Simulations

Some series of simulations were performed. The emotional dynamics based one typical series of events is shown below. Before each event the time when it has happed (in seconds after the start of the system) is shown. The dominant emotion each time is put in bold. After each prospect based event its importance for the agent and the estimated probability of success are shown.

■ 00s: RASCALLA is awaken
current mood = 1.80
Joy @ 6.0
RASCALLA starts its life with a smile
■ 05s: The user gives a task to RASCALLA
goal importance=1.0, success probability=0.9
current mood = 4.27
Hope @ 8.51
Joy @ 2.59
After some time the user gave her a task. She is hopeful based on the predominant success in the previous trials
■ 07s: The tool for searching in the DB returns some answer.
goal importance =1.0,success probability=0.95

current mood = 4.20
Hope @ 9.76
Joy @ 2.26
Database returned answer, which increase the estimated success probability of the goal to satisfy user, which is appraised from the EE as increasing hope potential
■ 15s : The user presses the SCOLD button
goal importance =1.0 goal result = failure
current mood = 3.52
Disappointment @ 1.19
Joy @ 0.73
After reading the RASCALLA's answer the user pressed the scold button expressing that she is not satisfied from the results. RASCALLA is disappointment
■ 190s: no emotions in the ES
Each emotion has decayed below the threshold already
■ 272s: neutral mood
The positive mood also decayed to the neutral value

Conclusion

In this paper the implementation of the emotion engine in the model Triple based on FAtiMA model was presented and discussed. The relation and influence of EE on the other modules were described. EE allows for the encoding of emotions in episodic memory and subsequent retrieval based on the emotion state or mood of the agent. Moreover the agent based on Triple can feel emotions and be in a specific mood which can be reflected by the expression of the virtual character and be changed by external and internal events. Conversely, the emotional state can influence the cognitive processing of the agent making it more adaptable and believable.

Future work will try to investigate what are the advantages and disadvantages of the emotion engine in the context of realistic tasks and what is its effect on the performance of Triple in a ECA platform.

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