Integrating Adaptive Emotional Agents in ITS

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Abstract

Our project concerns the improvement of computer-based learning by the means of a lifelike presence in the learning environment. The approach combines Intelligent Tutoring System works with research on human emotion in Cognitive Science, Psychology and Communication. According for the relations between emotion, cognition and action in contextual learning, we propose an ITS model based on a multiagent architecture in which two adaptive emotional agents have been integrated. One is designed to elicit and analyse the learner's emotional experiences by mean of his interactions with the system, whereas the second manifests the tutor's emotional non-verbal expressions using a 3D embodied agent. We present here the current system's internal architecture, a first implementation focusing on the tutor's agents and future research perspectives.

Keywords Emotions, Learning, Adaptation, Intelligent Tutoring Systems

1 Introduction

According to several authors ([1], [2]), emotions play an important role in verbal and non-verbal communications and their perception appears to be polymodal. The ability to recognize emotions in a variety of behaviours like face, voice expressions, and gestures constitutes an essential basis for initiating action. In fact, emotion, cognition and action are integrally connected, and judgement is enhanced by feeling and passion rather than by taking an entirely dispassionate stance [3]. Cognitive reflection can help us to guide and moderate our emotions, and sometimes even to wilfully move us into another emotional state. There exists a wealth of emotional models, with starkly differing views concerning the relation between cognition and emotion, however they generally show emotions like a mechanism facilitating human adaptation and social integration. Moreover, it seems necessary for subjects to perceive an event as enabling or causing their mood, so they associate a specific event with their current mood.

In cognitive activities like learning process, our approach looks at the role of the context, not only constituted from the characteristics of the situation but also depending on the emotional and cognitive state of the system when stimulations occur. If we consider that human knowledge is specific and functionally organized, then the context is linked to the knowledge, because it determines these conditions of activation, these links with other knowledge and sets the boundaries of validity. The context's effects in many cognitive activities (from perception to problem solving and memory), was demonstrated in experimental studies. When people are in a positive mood, they experience more creative, expansive, and divergent thinking, whereas in negative mood, they tend to be more conservative, linear, and sequential in their thinking process and they experience having less options [4].

In an educational context, because cognitive processes can be affected by non-cognitive factors, particularly affects, effective learning involves both intellectual and socio-emotional aspects. To teach implies to check the student's behaviour, appearance of engagement and responsiveness, in order to detect his affective responses that can be feelings of interest, excitement, confusion, frustration, and so on. The observation and the recognition of the learner's emotional state enable expert teacher's actions that positively influence the learning process and the performance (remarks employed judiciously can reduce learner's emotional frustration or avoid him abandoning his work when he feels overflowed). Therefore, teaching can be considered as an emotional practice [5].

In the same way, in order to promote learning in Intelligent Tutoring Systems, emotion's management implies the introduction of emotional agents to improve interaction in training systems and therefore advance the affective mechanisms who modify the way in which learning takes place ([6], [7]). Nevertheless, methodological problems arise with new pedagogical strategies of computer-based tutoring: how detect and assess emotional states and their influences without interfering with the natural learning process? The learner's mental processes are not directly observable and, to date, the most objective approach for assessing changes in a person's affective state, to recognize in an unobtrusive manner relevant affective states in the interplay between emotions and learning, is via assessing sentic modulation using mechanisms to sense posture, eye-gaze and facial expressions [8]. However, it is very difficult to exactly know which attributes are relevant when differentiating between many emotional states, because in natural interaction, prototypic expressions of basic emotions occur relatively infrequently.

In our attempt to help students to play a proactive role in their learning, to engage them in a variety of reflective activities and to avoid the recourse on external sensors, we propose two adaptive emotional agents, integrated in an ITS model based on a multiagent system, that deal, for a first one, with the learner's emotions and, for the second, with those of the tutor.

2 Model for adaptive emotional agents in the context of an ITS

The architecture of the proposed system is shown in figure 1. The next overview briefly describes the six components designed that act together according to their respective roles.

2.1 The Student's Model (SM)

Research on the relationship between affect and cognition show that few differences in affective states may have a pronounced impact on cognitive processes [9]. The main question is "how different affective states are linked to different styles of information processing?". In general, the empirical evidence suggests that information processing in positive affective states is strongly influenced by heuristics, stereotypes, or scripts. In contrast, individuals in negative affective states seem to be more easily affected by the implications of specific information provided in the situation [10]. Thus, the Student Model includes two systems respectively named Cognitive State (Cstate) and the Emotional State (Estate). The first one is charged with managing the integrity and the coherence of the student's knowledge structure (Knowledge Management System). The second consists of two layers for temporal indexation of emotion: different emotions detected during the session are stocked in a Short Term Mood Memory (STMM) and updated by the Student's Adaptive Emotional Agent, and a Long Term Mood Memory (LTMM) layer registers the learner's mood average profile on several learning session. The existence of these two layers highlights the dynamic aspect of current emotions comparatively to that more constant of general mood (or emotional style). The learner can consult the SM's content which may help him understand himself.

2.2 The Student's Adaptive Emotional Agent (SAEA)

Some of our concerns are the cognitive and behavioural consequences of the kind of thoughts and memories that come to mind when people are in different emotional states. Emotion-recognition decisions can be modeled using collections of production rules that specify classes of external situations that turn on particular emotions ([11], [12]). For example, thwarting or blocking progress toward a desired goal often elicits anger; perceived threats to self-esteem often produce anxiety. The principal goal of the SAEA is to detect, analyse learner's current emotions and to adapt himself to become increasingly specific to the learner. It acts like a "behavioural planner" by adapting his own behavioural rules according to current learner's "emotional actions" transmitted by the Communication Layer and interpreted by the Analyser (student's action analysis), to information stocked in SM and to learner's performance delivered by the Tutor Agent. SAEA also addresses queries to the learner about his own estimation of his internal emotional state during the session (self-evaluation scale or questionnaires) concerning motivational and affective factors. Even if it could seem subjective, self-esteem can serve as an outcome variable (how various experiences affect the way the student feels about himself) and as a mediating variable (self-esteem needs are presumed to motivate a wide variety of psychological processes) [13]. Three layers constitute this agent.

The deep layer (L1) contains general rules of hypothetic behavioural actions accompanying emotional experiences (emotional actions) induced by any specific stimulation and directed towards emotional regulation/adaptation according to valid norms and rules expected by the pedagogical goals ([7], [14]). The second layer (L2) (empty at session's beginning) contains new rules corresponding to L1's old rules revised, adapted to the learner's current emotional state and stored as contextual rules. This organisation supposes the generation of new rules when the difference (?e) between what is "expected", predicted by the layer L1 and what is really "observed" and obtained from the learner is relevant (i.e., ?e ? 0). The layer of analysis (Analyser) is dedicated to the examination of student's emotional behaviours and computes the value of ?e; when ?e is significant, the Analyser transmits the information to correct the initial rules in order to reduce the value of ?e. If ?e = 0, L2 keeps one empty set. The SAEA's rules integrate qualitative functions that modulate intensity and valence of pre-existing emotions that might in part determine the intensity of subsequently elicited learner's emotions.

2.3 The Tutor Agent (TA)

This agent manages the learning session by making decisions on the contents and the appropriated resources to present, and on the tutorial strategy to adopt (coaching, critiquing, trouble-maker…). It has his own Emotional State (OCC layer) [4] and Cognitive State (strategies, plans, scenarios, pedagogical goals, knowledge) to analyse the student's actions and results comparatively to its own desires or beliefs. Events and information from other sources (cognitive and emotional information on the student) given by the SAEA and SM, are what triggers the TA's emotional variations (experience). For example, a successful action event creates a Happy-For feeling depending on how many mistakes the learner made trying before. The variations carried by this event are also influenced by how difficult was this action to accomplish compared to the ones previously encountered. The TA's plans give an overview of how difficult the coming action will be. With the same example, emotions of Satisfaction or Relief are raised if this action was considered more difficult to accomplish than any of the ones expected to follow. These relations are expressed in the form of "if-then" rules and implemented in an expert system. This simplifies the task of specifying how different factors should influence the agent's emotional state with a low level of formalism (compared to mathematical functions). The Tutor Agent interacts with the learner via the Communication Layer and expresses itself visually via the Tutor's Adaptive Emotional Agent. The TA's exchange with the SAEA and SM are useful to adjust itself to the difficulty level associated with an event so it reflects more accurately the difficulty really encountered by the learner. TA updates the Student Model's cognitive state that contains information about the concepts mastered by the learner.

2.4 The Tutor's Adaptive Emotional Agent (TAEA)

By defining, maintaining or avoiding a relationship, emotional expression is an important dimension of human communication in such way that observers can reliably infer current affective state, enduring mood, and some cognitive activity like concentration or boredom of a person from nonverbal behaviours (attitudes, body language and facial expressions). Without any verbal communication, this agent focuses on the tutor's emotional expression displayed on computer screen with body gestures, facial expression and eye gaze that will amplify the tutor's emotional feedback and increase the power of its representation. For instance, eye gaze can regulate the flow of conversation, signal a waited feedback during an interaction, express emotion like looking downward in case of sadness and thus influence learner's reaction. Three layers generate, represent and express emotions of the Tutor Agent embodied in a 3-D agent (to be presented in section 2.2). The Emotion Generator is a set of relations that define how events, plans and records of past events that induce variations in the TA's OCC Layer, should influence variation to the TAEA's appearance. To ensure a good bodily expression's concordance with the homologous internal data, there should be a specification of symbolic gesture associated to semantic representations. Thus, the Motor layer is a set of relations that defines how emotions expressed in the Emotion Generator are translated in a representation in the agent's interface. This choice allows the elaboration of emotional and behavioural knowledge that we structure to build a collection of propositions that characterize the different behaviours in a human being, where facial expressions and gestures are physiologically linked. The Tutor's behavioural expression is inferred directly from its emotional representation. For example, a direct relation is established between the emotion of Joy and smiling and inversely with Distress. The Interface Layer is a definition of the agent's appearance, free of geometrical considerations, used to produce a visual output of the agent.

2.5 The Virtual Laboratory (VL) and the Communication Layer (CL)

The Virtual Laboratory used as a test environment is a micro-world, which contains definite primitives that permit the manipulation of environmental objects in a learning context. For example, the Cyberscience's system [6], a learning interface for science and engineering courses, offers a collection of virtual laboratories (some of them in 3D) where the students must perform tasks (part of different scientific curriculum) and solve problems using interactive virtual simulations. In addition, the goal of the Communication Layer defined between the virtual laboratory and the internal agents is to get the learner's actions syntaxically validated and to communicate them to the agents. Examples of student's actions are "the student has turned the button X", "the student moved the object Y" [15].

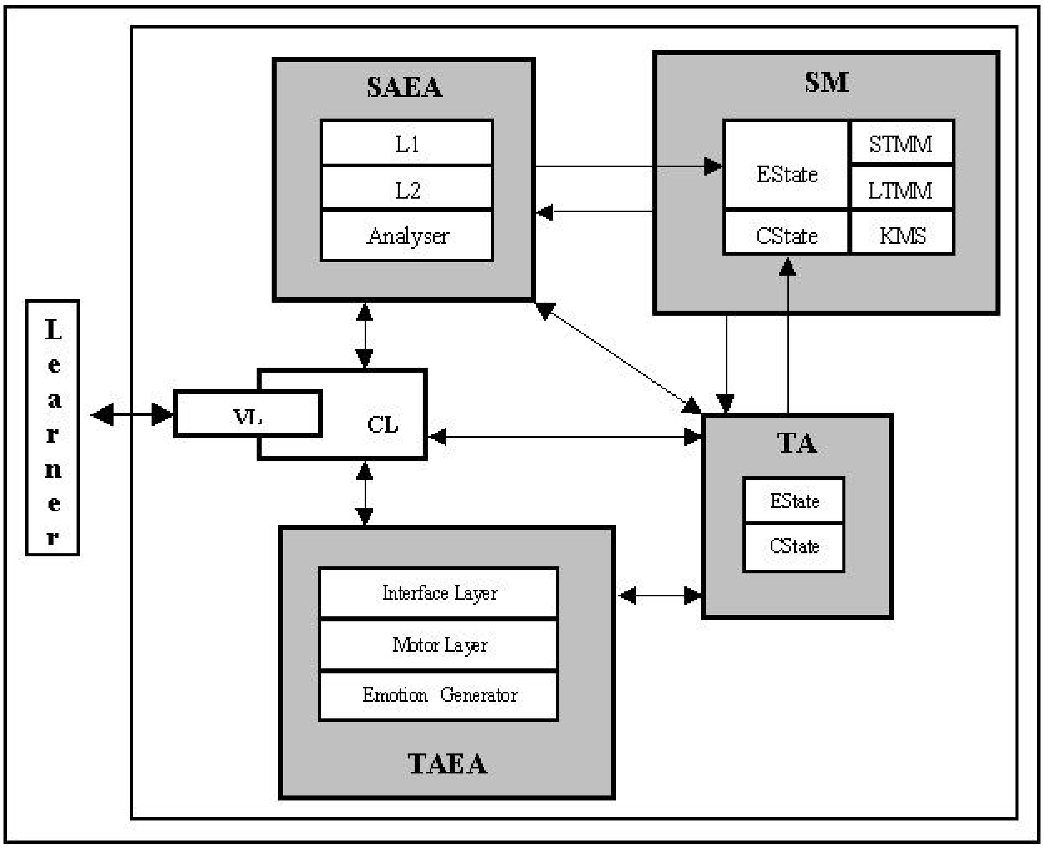

Fig. 1. Architecture of the system

3 Initial developments concerning the tutoring aspects

In designing EMILIE, our first generation of 3-D embodied tutor, we used a process similar to qualitative reasoning to simulate emotional responses to learner's manipulations in a virtual training laboratory. This permits us to formalize its modeling process relying on representation of continuous aspects of the world such as space, time and quantity, while enabling reasoning based on a small quantity of information [16]. Since we can hardly measure emotions in different settings in a real world situation, such a model is appropriate to assign relations between different emotions, values, and properties outside of the emotional model (for example, relation between a feeling of joy and the amount of smiling) and to express a relation between two factors without knowing exactly how much and following what function the first factor influences the second. The TA's emotional model we used is the OCC Model [12] that has had some success at simplifying an individual's emotional state representation, at providing a clear, non-overlapping set of emotional parameters. The emotional state is represented at any given moment via a combination of 24 different emotion types to which values are assigned; some emotions are identified as couples, such as Joy and Distress (i.e., one cannot feel distress and joy at the same time, and an event bringing joy to an individual equally reduces that individual's feeling of distress).

In order to split TA's emotional states into TAEA's behavioural units, we considered a set of meaningful finite situations, onto which we applied some rules for reasoning to build up a collection of propositions characterizing various system behaviours. TAEA's Emotion Generator received a list of the difficulty factors that should be encountered by the student before he completes an activity; it used intervals and sign algebra to represent the state of the agent (Hope, Fear, Satisfaction, Relief, Fears-confirmed and Disappointment) toward the emotion couples at a given time in an expert system. Emilie's environmental perception was carried forward to reading a feed of user's actions expressed by the degree of difficulty of the action accomplished (or aiming to be accomplished, in a case of failure) and the degree of student "wrongness" (how far the student's action is from the expected action, the right action having a value of zero). It also received the sequence of action leading to activity completion in order to have knowledge of what to expect. Another parameter carried in an event involving geometrical coordinates placing event occurrence on the screen is used by the Motor Layer to adjust the character's sight. Emilie could not influence, interact with the virtual environment and was unable to give any explanation to the user, it was only a pictorial representation of the agent as a humanoid character (figure 2)[6].

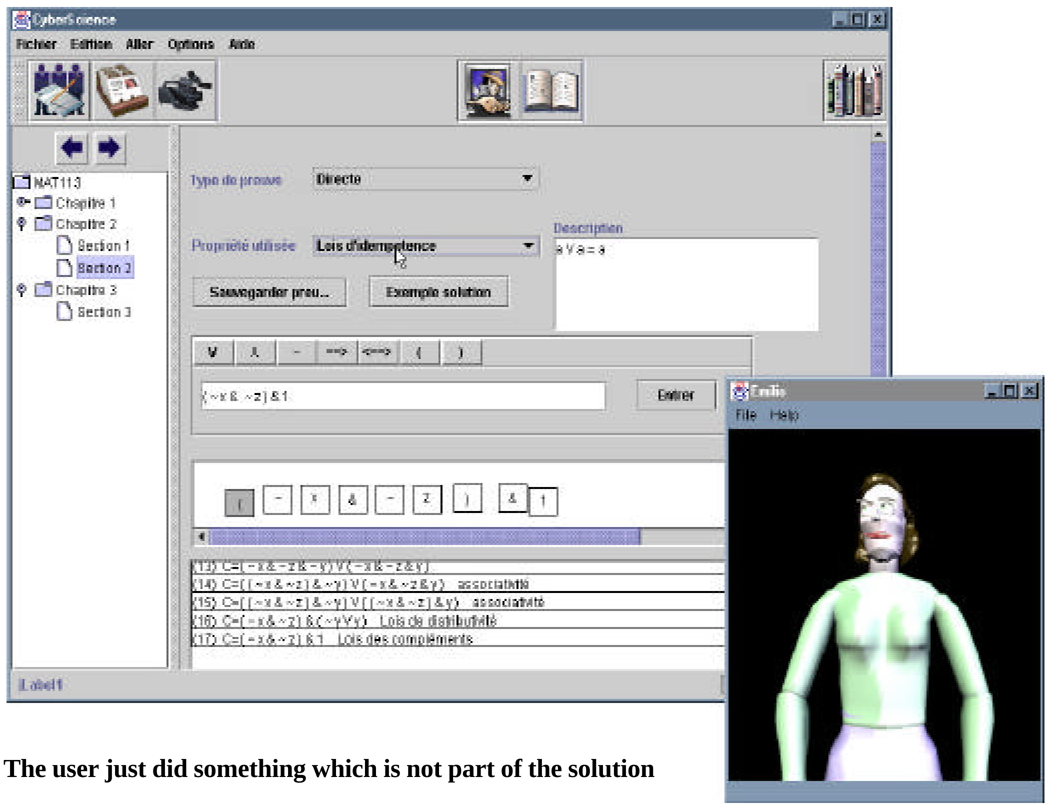

Fig. 2. The user just did something which is not part of the solution

When the TA's emotional state changes, the agent's visual representation can be affected in two ways. Firstly, its facial expression is inferred directly from its representation of emotions with relations specified between different emotions and facial characteristics. Secondly, changes in the Estate can influence the visual appearance is by initiating gestures when changes exceed a certain specified threshold (the fire small pre-recorded movements for example, a sudden raise in the Sorry-For emotion triggers a gesture of the agent shaking its head bent forward looking down). A lower variation would have initiated a gesture of the agent briefly smiling down, lowering the outer eyebrows and slightly closing the eyes. These gestures amplify the emotional feedback, increase the power of representation and make transitions between different emotional states more obvious. In figure 2, the user just performed a mistake by selecting an item in the drop down list while it should have chosen another one; to show this the agent looks at the source of the event while having an expression caused by the sudden rise of disappointment and distress.

Advantageously, the information necessary for Emilie to produce emotional responses in this current system is very limited. Nevertheless, some expressions being difficult to represent with the OCC Model, we are looking for a more suitable emotional model (it is still unclear how the system should represent confusion when the user accomplishes an unexpected action that is of unknown value). Numerous improvements could be made to the visual interface of the agent (a new 3D model more cartoon-like requiring fewer polygons to draw), placing it the same window where activities take place.

4 Conclusion

The impact of computer-based learning on learner and on pedagogical strategies is not yet sufficiently well distinguished; nevertheless, to supplant the richness of human communication and develop a greater incentive in the learning process, the Intelligent Tutoring System must be enriching human-machine interactions with more personalized communications (explicit and/or implicit) and interrogative methods. Providing consistent support (advice, confidence, encouragement) and expressions of interest by vocal expression of speech and body language, an animated actor could be able to induce, influence a particular mood state to the learner (emotional contagion) or at least a positive impression [17].

We think an adaptive learning context will contribute to raise the student's productivity by inciting him to discover new strategies, like the cooperative aspects that are usually encountered in classrooms. We hope our model will facilitate and enrich our knowledge about learner-system interaction and contribute to positive changes in the quality of student learning. In order to validate our hypothesis and to determine if TAEA really plays as an extrinsic motivator, experimental projects will be conceived. Following the fact that the learner can obtain information about himself consulting the SM and then becomes aware of its errors analysing them, we presume that this could increase his motivation and thus learning over time.

The project is just in its early stages and several points will be enriched. The first one concerns methodological problem of the SAEA's reliability and the Analyser's "integration, development" with the recognition of learner's emotions by coding and classifying them in real-time application with significant degree of psychological colourability. Secondly, consulting educational domain, we will determine what kind of emotions could be considered pedagogically adequate or inadequate in the scenarios considering pedagogical goals of the learning context in the attempt to actively engage the learner. Are these same emotions both relevant for the SAEA and the TAEA? While comparing the two layers of SM we will have an clearer idea on how the current emotional state can influence the learning strategy in particular, and the cognitive state in general. Thirdly, to improve the impression of communication reciprocity, we have to determine the interaction frequency necessary to maintain student's attention, depending on context, cognitive and emotional styles. Frequent messaging would produce significant positive effects on student impression and relationship development between student and the system.

In our present work, we just focus on the tutor's emotional expressions arising from plan generation and execution through body gestures and facial expressions. Some functionality will have to be integrated later on. The tutor must really act as a coach and should be able to converse with the user in some way giving him positive or negative self-relevant feedback (e.g., telling the learner he is high or low in some ability) with the adapted words. In a natural and fluent prosodic context, sentence formulations depend on linguistic, paralinguistic parameters, speakers and on situations in which they stand (context-dependence, effects of verbal cues, impact of tone of voice to engage student). Vocal expression's aspect is not yet integrated in our model, just envisaged in future work with models of verbal communication inspired by psycholinguistic and social literature [18].

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