Emotion based Agent Architectures for Tutoring Systems The INES Architecture

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Abstract

In this paper we discuss our approach to integrate emotions in the agent based tutoring system INES (Intelligent Nursing Education System). First we discuss the INES system where we emphasize the emotional component of the system. Afterwards we show how a more advanced emotion generation architecture, SHAME, can be integrated in INES. Then we show how INES can be extended with an action selection architecture for emotional agents. Finally we discuss some future research on how to integrate emotions, action selection and adaptivity in INES.

Keywords: agent architectures, emotions, tutoring systems.

1 Introduction

Learning and tutoring is a process full of emotions. Some of these emotions sit in the way of the learning process. They are frustrating it's goal: to master a practice or to learn a theory. Other emotions are stimulating. Building a virtual tutor system we should avoid that negative emotions arise in the learning process and we should implement ways to generate positive emotions. An intelligent tutoring agent should be capable of responding to the learners activities in an emotionally appropriate way, that is in such a way that it stimulates the learning process and avoids that the student becomes uninterested or frustrated. Easy said, but not so easy done, because how can we make our tutoring agent able to sense the emotional and motivational state of the learner? And how should the tutor response to the students actions and emotional state?

The Intelligent Nursing Education Environment (INES), Figure 1, is an application that has been built using our multi-agent platform [Hospers *et al.*, 2004].

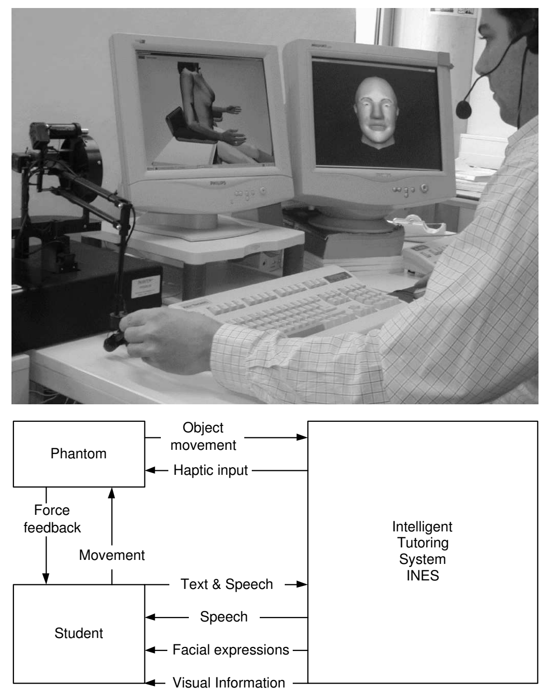

Figure 1: *A global overview of INES system. On top a picture including the phantom (haptic device), the tutor embodied through the face on the right screen and the embodied patient on the left screen. In the figure on the bottom the global components of the INES system are depicted including the interaction modalities.*

Agents are used to provide instruction to students that use INES. In the system we distinguish between several types of agents. Sensor agents (proactive) and processing agents (reactive). For example, in the chosen domain of subcutaneous injection a proactive 'sterile agent' looks every second if there are objects that are not sterile while they should be. On the other hand, there is, e.g., a reactive 'feedback agent' that acts if it receives a message from another agent; this feedback agent then will determine whether or not feedback should be given. Other agents include a task observer agent and an explanation agent. Students interact through an interface that shows the patient profile and the task and subtasks. The student can ask for demonstration and explanation. Text-to-speech synthesis is used to give feedback for a student. Part of the screen contains a view on the task in progress. In the current version it shows videos for the different subtasks. However, the system has been designed in such way that in future versions we can have a 3D virtual reality environment where a virtual human plays the role of patient, the tutor is represented as a virtual human and the nursing student can use speech input and a haptic device to perform an injection.

In the INES system, cf. Figure 3 the tutor agent directs the learner in the process of learning the practical task of giving a patient a subcutaneous injection. This task consists of a number of subtasks like preparation of the necessary equipment, including interaction with the patient, asking him to pull up the sleeve of his shirt. The learner uses a haptic device (Phantom) to interact with the virtual world that represents the patients arm and some medical equipment. The learner can interact with the patient as well as with the tutor agent. The latter gives feedback and hints when needed. The tutor has knowledge of the way the tasks have to be performed. As the learner works through the problem a hierarchical task planner evaluates the appropriateness of each step, taking into account the preconditions, effects, and ordering constraints that exist on subtasks. For each of the subtasks special dedicated error agents have been defined that monitor the actions of the learner and send error reports to the tutor agent. The tutor agents decides whether he will respond or not and if so how he will respond. The action selection is influenced by the type of error, the history of the learning process, the emotional state of the tutor and the motivational state of the learner. He can give a hint, give some motivating feedback or propose to show the student how to proceed. In the prototype of this tutoring system we restricted ourselves to two emotions of the tutor joy and distress. In order to evaluate the influence of the emotional state of the tutor and the of giving motivational responses on the learning process and the concentration and motivation of the learner several strategies for action selection have been implemented. In the current system the tutor has no possibilities to sense the students emotions or status of motivation. The only information available to the tutor concerns the way the learner proceeds in learning the task to be performed. But the multi-modal input allows the tutor agent to predict possibly emerging emotions of the student that is performing a task.

Although obviously the concept of emotion is inspired by human cognition, it is important to stress that our perspective is that of computer scientists and not that of cognitive scientists. That is, we are not primarily concerned with how human emotions are generated or function, but rather with how a notion of what we may call "emotion" in analogy with human emotions, may be employed to construct intelligent agent-based tutor systems.

In Section 2 the architecture of INES is introduced. Then the emotion process in INES is discussed in Section 3. Afterwards a possible extension of the emotional state calculator is described in Section 4. Finally the conclusions are given in Section 5 where also some possibilities of future work are discussed.

2 Architecture of INES

In this section the architecture of the INES system is presented, where the focus is on the components related to the emotion process.

2.1 Global overview of the INES architecture

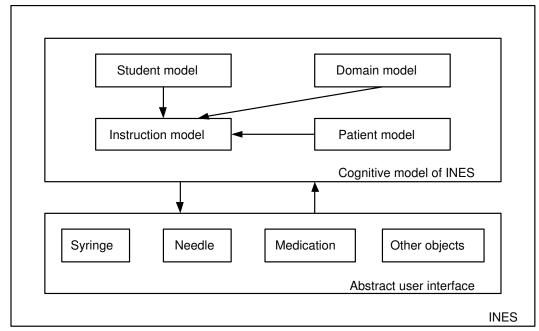

Figure 2: *Overview of the global architecture of INES.*

The INES system has different tutoring related components, a domain model containing the knowledge to be tutored, a student model containing the knowledge about those students which are to be tutored, a patient model containing knowledge about the (virtual) patient and an instruction model containing knowledge about tutoring itself [Heylen *et al.*, 2003].

2.2 The instruction component

Considering our focus on emotional tutor agents, the most important component of INES is the instruction component, cf. Figure 2. This component can be refined to the architecture depicted in Figure 3.

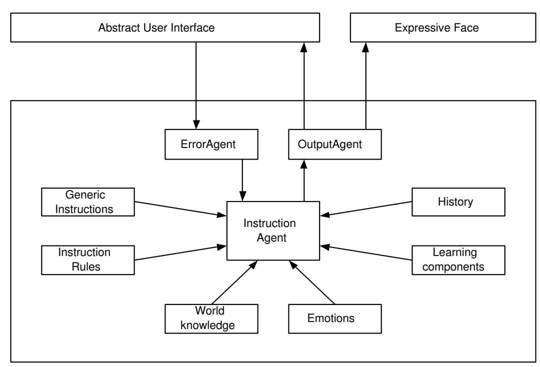

Figure 3: *Overview of the different agents and components in the tutor component.*

The type of action and the manner in which it is executed is determined by a number of factors. The tutor decides on a specific tutoring strategy or learning component (which might be changed in the course of the lesson). The choice of strategy influences the kinds of actions that are performed and the sequence in which they are performed. For instance, when the Socratic method is active, the tutor agent will choose to ask a lot of questions. We are interested in having our tutoring system teach the students certain practical skills with an insight into the reasons for doing tasks in a specific way. An important part of tutoring sessions is therefore to let the students practice some task. In this case the tutor simply observes what the students do and provides feedback. Ideally, the student should be active and self-motivated to practice the tasks. Because the typical exercises involve practicing a task, the error-agents form an important component of the system. They observe the student's actions, diagnose them and report to the instruction-agent.

Affect is modelled in INES from various angles and on different levels.

- The emotional state of the student is modelled and taken into consideration as one of the factors in determining which tutoring strategy to use and which instructional act to perform (feedback, motivation, explanation, steering, etcetera).
- The emotional state of the tutor is modelled as well, including values for emotions and parameters such as satisfaction, disappointment, and surprise.
- The dialogue acts come in different forms, with variation in affective values.

3 Emotions in INES

Tutoring situations can be characterized as a social event, the goal of which is for a student to learn some task or acquire knowledge with the tutor acting in all kinds of ways to assist the student with this goal. As with about all actions we carry out, our emotional state plays an important part in the selection of action and the evaluation of the result and in turn the actions we carry out and their results have an impact on how we feel. Bales ([Bales, 1950]) systematically observed groups in laboratories and found that a substantial proportion of group interaction is devoted to the socio-emotional issues of expressing affect and dealing with tension. The actions of the tutor are also not just restricted to pure instructions but they should also create the right emotional conditions for a student to act. The fact that the tutoring situation is a social encounter means that influencing the emotional state proceeds through social acts with emotion changing potential. For instance, the tutor has the status to judge and criticize (or praise) the student for his actions. Other interpersonal actions that give rise to affect appraisals are defining a task (consider the difference between the psychological effect of formulating this as an order or as a suggestion). The tutor has to steer and motivate the student, know when the student welcomes a hint, etcetera. The emotional state related to this form of social interaction typically involves elements and variables such as: social rewards, dependence, status, power, face. In general one of the goals that people want to come out of of social interaction is to enhance the self of each actor. The ideal outcome is that the student is proud of his achievements and feels highly estimated by the tutor.

Motivation is one of the key terms used in education. The emotional state of the student contributes a lot to whether a student is motivated or challenged, which are key conditions for certain actions. Curiosity and puzzlement may lead to investigate problems. But also frustration may lead to action, although it is a more negative affect. The tutor can choose to consider taking certain actions to bring about a change in the emotional state. Lepper [Lepper, 1993] identified four main goals in motivating learners: challenge, confidence, curiosity and control. Some ways to implement these tactics are the following.

- The student can be challenged by selecting appropriately difficult tasks, or by having the difficulty emphasized or by having some kind of competition set up.
- Confidence can be boosted by maximizing success directly (praising) or indirectly ('it was a difficult task, you managed to do').
- Curiosity is typically raised in Socratic methods.
- The tutor can leave the initiative to the student or offer options that suggest the student can make choices and thereby influence the student's feeling of being in control.

3.1 The Emotion Process

As explained above emotions play an important role in the interaction between the student and the tutor. Hence it is of utmost important to equip the tutor agent with emotions. But which emotions should the tutor have? The emotions should give the tutor agent the possibility to experience *content* related with the emotions satisfaction, relief and joy, *discontent*, related with the emotions disappointment, fears-confirmed and distress, or *sympathy* related with the emotions happy-for and sorry-for. Furthermore hope and fear give the tutor agent to have an expectation to a certain goal to be reached.

A way to model the emotional state of the tutor is by a numerical vector where each component is a scalar value between -1 and 1, and indicates the intensity of an *emotion couple* (a positive emotion and corresponding negative emotion such as joy and distress). A positive (negative) value corresponds to the positive (negative) emotion and the emotion intensity given by the absolute value. The emotion couples for INES are derived form the above mentioned emotions and the work of Frasson [Frasson, 1998]: *happy-for/sorry-for*, *satisfaction/disappointment*, *relief/fears-confirmed*, *positive surprise/negative surprise* and *joy/distress*.

Event appraisal

In the current implementation of the INES system the most important events that are appraised by the tutor and that affects his emotional state are directly related to the actions performed by the student while he is practicing the tasks to be learned. The actions of the learner are observed by several specialized error agents who send error reports to the tutor agent.

The emotion types generated and their intensities depend on the harmfulness of the error, the expectation the tutor has with respect to the performance of the student and the current emotional state of the tutor.

For each emotion under consideration an emotion potential is calculated. These emotion potentials are calculated by simple rules, similar to the rules proposed by Ortony et all. in [Ortony *et al.*, 1988]. For example the rule for *happy-for* is of the form

$$\begin{aligned}&\textit{IF } D(e,t) > 0\\ &\textit{THEN } P_{hf} := F_{hp}(D(e,t), I(p,e,t))\end{aligned}$$

where $D(e,t)$ is the desirability of the event e at time t, P_{hf} is potential for the emotion *happy-for* and $I(e,t)$ the effect of global variables which affect the potential of the emotion *happy for*. In the INES system F_{hp} just returns a constat greater then the threshold defined in the next subsection.

Emotional state calculator

The intensity for each emotion under consideration is calculated by the following transfer function, cf. Figure 4. It is based on the work of Ortony, Clore and Collins [1988]. This transfer is very simplistic, for

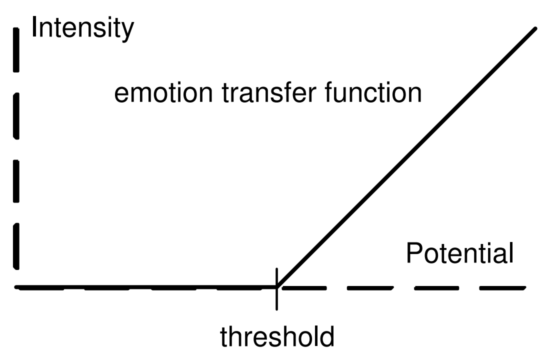

Figure 4: *The transfer function. This function transfers emotion potentials to intensities.*

each emotion it compares the emotion potential with a threshold, if the value is above the threshold then the intensity of the emotion is given by potential minus the threshold, else the intensity is zero. Moreover the intensity of an emotion is independent of the potentials of other emotions. A more advanced transfer function would be a "sigmoidal" one has proposed by Picard:

$$f(x) = \frac{g}{1 + \exp(-(p-t)/s)}$$

where g is amplitude of the intensity, p the potential of the emotion, t the threshold, s the steepness of the sigmoid. It is a bounded differential approximation of the transfer function proposed by Ortony et all. Still it lacks the property of taking into account the potential of other emotions. The decay of emotions is modelled by an exponential decay.

3.2 Action Selection and Emotions

The actions of the tutor are organized in a hierarchical way. The upper level is the teaching task that consists of a sequence of instructions. So is the *support task* a sequence of *feedback* followed by *motivation* and *support*. Each of the instructions can be realized by a number of dialogue functions. These functions are realized by dialogue acts; those are the concrete acts the tutor performs in a tutoring dialogue. A particular feed-back can either be realized by a *head nodding* act, by a *speech act* or by a combination of these two acts. The selection of these actions depends on the emotional state of the tutor (but this dependency can be switched off, so it can be tested how the emotions of the tutor influence the interaction and the learning process), the belief the tutor has about the character of the student, the type and harmfulness of the error made and the teaching strategy that is followed by the tutor. A teaching strategy is characterized by a prevalence for certain teaching tasks. The Socratic method assigns more weight to the task of asking questions and less weight to the task of giving lengthy explanations. The beliefs the tutor has about the student's emotions are currently not dynamically induced from the observed student's actions. The student model distinguishes two student characters: a *confident* type and an *insecure* type. The type of student can be set statically. The type of student influences the action selection and the wording the tutor uses in giving feedback, offering hints or motivating the student.

4 Extending the Emotions in INES

In the previous section 3.1 the current emotion model in INES is discussed. It is a simplistic rule based system. In this section we will discuss how a more complex emotion model, based on the SHAME architecture (Scalable, Hybrid Architecture for the Mimicry of Emotions) [Poel *et al.*, 2002] could be integrated in INES.

The SHAME architecture, Figure 5, is an architecture for the generation of an emotional state. It is an implementation of the event appraisal model described by Ortony, Clore and Collins [1988], the OCC model. Event appraisal means that changes in the emotional state are triggered by external and internal events.

The emotional state is described by a vector $\langle e_1, e_2, \ldots e_n \rangle$ of length n, depending on the number of emotion types which should be implemented. Each component e_i denotes the intensity of the emotion corresponding to index i. One could also made the design decision that a component e_i refers to a pair of emotions, for example those described in Section 3. If $e_i > 0$ ($e_i < 0$) then the positive (negative) emotion is experienced with intensity e_i ($-e_i$). Due to this design choice the model cannot generate positive and negative emotions of the same pair, for instance 'happy-for' and 'sorry-for', simultaneously. Furthermore we assume that the values of the e_i are bounded, and without loss of generality we may assume that $0 \leq e_i \leq 1$ in the case of single emotions and $-1 \leq e_i \leq 1$ in the case of emotion pairs.

The (normalized) emotion impulse vector is a vector describing the impulse, force, on the emotional state. This emotion impulse vector is similar to the emo-

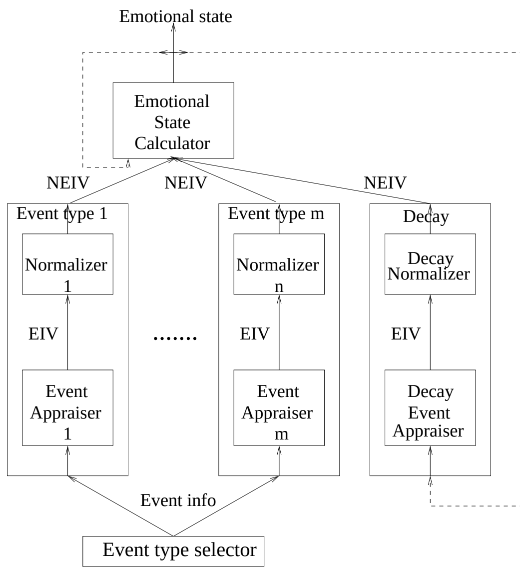

Figure 5: *The SHAME architecture. An incoming event is classified by the event type selector which sends the event, based in this classification to the appropriate event appraiser. the Event Appraisers calculates an emotion impulse vector (EIV) which is normalized to a normalized emotion impulse vector (NEIV) by the Normalizers. These normalized emotion impulse vector serves as input for the Emotional State Calculator which calculates the new emotional state given the emotion impulse vector and the old emotional state. This feedback of the old emotional state is represented by the dashed line.*

tion potential discussed in Section 3. This emotion impulse is used by the emotional state calculator to calculate the new emotional state and is of the form $\langle ei_1, ei_2, \ldots ei_n \rangle$ where ei_i is the emotion impulse for the emotion pair corresponding to e_i. Again we assume that $0 \leq ei_i \leq 1$ in the case of single emotions and $-1 \leq ei_i \leq 1$ in the case of emotion pairs.

In the first phase the emotional meaning of an event is appraised, i.e. determining the emotional effect (impulse) of the event on the emotional state. This is done by determining the type of the event. Based on this event type an event appraiser is selected. Each (relevant) event type has exactly one corresponding event appraiser. Then, secondly, the event, together with relevant event information is sent to the event appraiser. This event appraiser calculates, based on the event information, the emotional impulse of the event. This is stored in the emotional impulse vector.

The event appraisers appraise the emotional impulse of the event in a qualitative way and the normalizers form an interface between the emotional state calculator and the event appraisers, in such a way that, firstly, the emotional state calculator can treat all event appraisers in a uniform way and, secondly, it makes the emotional state calculator *domain independent*. The normalizers should form the interface between the domain dependent event appraisals and the domain independent emotional state calculator, hence the event appraisers and normalizers are domain specific.

A special event is the *internal decay event*, which models the decay of emotions over time, i.e. temporal phenomena. Again the normaizers for the decay event appraiser serves the purpose of treating it as a regular event. These decay events occur after a fixed amount of time and depend on the previous emotional states.

The functionality of the emotion state calculator (*ESC*) is to calculate the new emotional state (New ES) given the old emotional state (Previous ES) and the normalized emotional impulse vector (*NEIV*). Since the *ESC* is, in our view, domain independent it needs to be developed only once. An option is to implement it by a neural network, cf. Figure 6 which should be trained in a supervised way on data elements of the type (*NEIV*, *Previous ES*, *New ES*), where *New ES* is the desired new emotional state given the emotion impulse vector*NEIV* and the old emotional state *Previous ES*. These training data should be generated by hand at forehand and determines the dynamics of the emotional state. Since this dynamics should depend on the personality, character, of the agent, this personality should be taken into account when determining the desired emotional state for the elements of the training data set, this must be consistent with the desired emotional personality of the agent. In order to keep the networks relatively small we opted for a separate neural network for each component of the emotional state. These neural networks for each component can be kept relatively small and therefore the less training data is needed compared to the case in which the emotional state calculator is implemented by one large neural network. Of course we could implement the emotional state calculator by an Elman network [Elman, 1990], which can learn temporal phenomena. But then again we will need a large network and hence a lot of training data, also due to feedback loops in the Elman network.

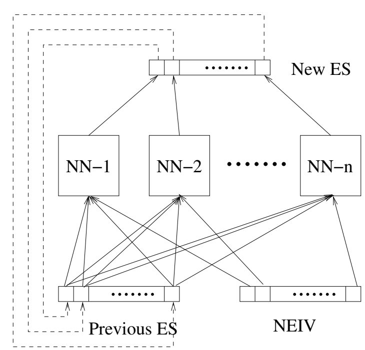

Figure 6: *The architecture for the emotional state calculator (ESC).*

The event appraisers must be constructed by hand. For INES one could use the emotion potential generates discussed in Section 3.

5 Conclusions and Future Work

In this paper we introduced the Intelligent Nursing Education System (INES), which is a intelligent agent based tutor system which allows for multi modal interaction through a haptic device, an expressive face, text and speech, etc. Affect plays in important role in tutor systems and therefore the INES system is endowed with a simple emotion component. Extensions of the emotion component have been discussed, but still there is a long way to go before the tutor agent in the INES system can be called a "believable" agent [Ortony, 2003].

5.1 Future work

In the future we want to pursue three research directions. At first we want to extend and refine the emotional model of the tutor agent, using the SHAME architecture, as described in Section 4. At second one of the goals is to equip the tutor agent with the well-known BDI-model [Rao and Georgeff, 1991]. But the current BDI-models do not take into account emotions. Therefore they have to be extended with emotions. This means that we have to specify how agents use their emotional state for deliberating which goal(s) to select and which plans / actions to execute. This in turn implies that we need to represent emotions in an adequate way such that it is possible to reason about emotions, or rather about the emotional states an agent may be in, together with its effects on the agent's actions. At third we want to incorporate learning in the tutor agent, more specific we want to study how reinforcement learning [Sutton and Barto, 1998] can be used to increase the performance of the tutor agent. Already Rolls [2003] showed that emotions can function as punishment and rewards for instrumental conditioning. This indicates that emotions can be used as reinforcement signals and gives rise to the possibility of using emotions in the context of reinforcement learning.

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