Automatic generation of emotions in tutoring agents for affective e-learning in medical education

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A B S T R A C T

Web-based education is particularly appropriate for remote teaching and learning at any time and place, away from classrooms and does not necessarily require the presence of a human instructor. The need for time and place independence is even greater in some cases, such as for medical instructors who are usually doctors that have to treat patients on top of their tutoring duties. However, this independence from real teachers and classrooms may influence negatively the students who may feel deprived of the benefits of human–human interaction. In this paper we describe a novel approach for incorporating affective characteristics into e-learning through an authoring tool. The authoring tool incorporates and adapts principles of a cognitive theory for modeling possible emotional states that a tutoring agent may use for educational purposes. Medical instructors may use this authoring tool to create their own educational characters that will interact affectively with their students in the e-learning environment.

1. Introduction

Medical students have many learning and training obligations, ranging from clinical work at hospitals to reading theory and doing coursework. A similar situation is faced by medical instructors who are usually doctors that have to treat patients on top of their tutoring duties. In view of these obligations, the technology of mobile computing can assist considerably the medical educational process, since both students and instructors may have access to educational software applications from anywhere at anytime through handheld devices of mobile phones. However, this independence from real teachers and classrooms may affect the educational process in a negative way because as Coleman (1995) points out, how people feel may play an important role on their cognitive processes as well. As it is also stated in Falout, Elwood, and Hood (2009), negative affective states of learners can negatively influence their attitudes and behaviors, degrade classroom group dynamics and teacher’s motivation, and result in long-term and widespread negative learning outcomes. At the same time, teachers could overcome difficulties in students' management by knowing the affective states of their students (Hwang & Yang, 2009).

Our main scope is to address these problems by providing an authoring tool for medicine that constructs animated medical agents with emotional interaction capabilities, thus rendering human–computer interaction for e-learning more human-like. Medical instructors may use this authoring tool to create their own educational characters that will interact with their students in the medical e-learning environment. Agents may be parameterized in many aspects, the way they speak, the pitch, speed and volume of their voice, their body-language, their facial expressions and the content of their messages.

Additionally, for educational purposes, agents may express specific emotional states and this capability is based on the incorporation of the OCC (Ortony, Clore, & Collins, 1990) cognitive model of emotions, proposed by Ortony et al. (1990). The novel system that we developed encapsulates an affective authoring module that relies on the OCC theory for modeling possible emotional states of users–students as well as for proposing tactics to medical instructors in order to improve the interaction between tutoring agents and medical students. Through the incorporation of the OCC model, the system may suggest that a tutoring agent should express a specific emotional state to the medical student for the purpose of motivating her/him while s/he learns. Consequently, the agent may become a more effective teacher, reflecting the instructors’ vision of teaching behavior.

In many cases it would be extremely useful to have such facilities in handheld devices, such as mobile phones rather than desktop or portable computers so that additional assets may be gained. Such assets include device independence as well as more independence with respect to time and place in comparison with web-based education using standard PCs. This is certainly the case for medical education due to the heavily loaded schedule of doctors–instructors and medical students. At the current state, there are not many mature mobile authoring systems, since the technology...
of mobile computing is quite recent and has not yet been used to
the extent that it could. The resulting educational system, Mobile
Medical Tutor (MMT) deals with the problem of facilitating the
medical instructor in the educational software management.
Moreover, MMT makes use of the desktop application, which is de-
signed in a way that can support the emotional state of learners for
educational purposes, based on a cognitive model (Alepis, Virvou,
Many researchers believe that the future of e-learning in medical
education will move towards more personalized learning sup-
ported by a range of new technologies (Larvin, 2009; Sandars &
Haythornthwaite, 2007).

2. Related work

In the last decade, education has benefited a lot from the ad-
vances of web-based technology. Indeed, there have been many re-
search efforts to transfer the technology of ITSs and authoring tools
over the Internet. An important review (Brusilovsky, 1999) has
shown that all well-known technologies from the areas of ITS have
already been re-implemented for the web. Indeed e-learning is not
panacea in medical education. It has disadvantages as well. These
disadvantages include social isolation, up-front costs, and technical
problems. As it is stated by Cook (2007), web-based learning is
purported to facilitate individualized instruction, but this is cur-
cently more vision than reality. Some important assets in e-learn-
ing include platform-independence and the practical facility that is
offered to medical instructors of authoring e-learning courses at
any time and any place. A remedy for these problems may lie in
rendering human–computer interaction more human-like and
affective, especially in educational software. To this end, the incor-
poration of speaking, animated agents in the user interface of edu-
cational applications can be very important.

The presence of animated, speaking agents has been considered
beneficial for educational software (Chua & Lee, 2008; Johnson,
Rickel, & Lester, 2000; Lester et al., 1997). Hence, there have been
many educational applications that incorporate animated peda-
gogical agents in their user interfaces (Chua & Lee, 2008; Glavinić,
Rosić, & Zelić, 2008; Rist, André, & Müller, 1997; Sun & Li, 2008).
However, medical instructors that will use an authoring tool
should not necessarily be computer experts and should be helped
to develop sophisticated educational applications in an easy and
cost-effective way. In Hwang and Yang (2009) a distance learning
system has been developed that identifies affective states of users
through capturing face images. This system accurately identifies
negative affective states but does not elicit other emotional states
for pedagogical reasons. The authors of Zatarain-Cabada et al.
(2008) have developed an authoring tutoring system for distance
and mobile learning. This system recognizes and classifies learning
characteristics of learners but does not incorporate affective inter-
action modules. Another research effort has been made in Van Vel-
sen (2008) where an authoring tool called Naratoria is presented.
This authoring tool allows non-technical experts in the field of dig-
ital entertainment to create interactive narratives with 3D graphics
and multimedia, but also does not recognize nor generate emo-
tional states.

However, as yet there are no authoring tools that provide
parameterization in user–computer affective interaction, such as
speech-driven, affective animated agents that incorporate a highly
sophisticated cognitive model for affective interaction. As Picard et.
al. point out in Picard et al. (2004), the extension of cognitive the-
ory to explain and exploit the role of affect in learning is in its in-
fancy. The present authoring tool provides the important facility to
medical instructors to develop and author medical tutoring sys-
tems that incorporate speaking, animated agents who can be
parameterized by them in a way that reflects their own vision of
teaching behavior in the resulting applications.

3. General architecture of MMT

In this section the general architecture of MMT is described. It
should be emphasized that the educational application is meant
to assist the overall medical educational process. For this purpose
we have improved the communication of instructors and students
by incorporating mobile technology, while the basic concepts of
programming for educational purposes are retained.

As we can see in Fig. 1, the main architecture of MMT consists of
the main educational application, a database, mobile devices and
personal computers.

In particular, the main application is installed either on a public
computer where both students and instructors have access, or
alternatively each particular user may retain a copy on his/her
own personal computer. A simple overview of using the main
application is shown at Section 4, where the use of MMT by

Fig. 1. Communication between Instructors, Students and the educational application.
students is described and illustrated examples of use are also given. The underlying reasoning of the system is based on the student modeling process of the educational application. The system monitors the students’ actions while they use the educational application and tries to diagnose possible problems, recognize goals, or even record permanent habits and errors that are made repeatedly. The inferences made by the system concerning the students’ characteristics are recorded in their student model that is used by the system to offer advice adapted to the needs of individual students and presented by the affective agents. The database of MMT is used firstly store all the necessary information that is needed for the application to run and secondly to keep analytical records of the performance of all the students that use the educational application. Mobile pages provide medical instructors with the appropriate interface for their interaction with the main application through their mobile phones, or PDAs with mobile support.

Considering mobile interaction, mobile web-pages can contain as many server-side forms as necessary, whereas normal web pages can contain only one. This is quite important because it renders the mobile pages more effective and also it may reduce wireless communication costs. Mobile controls are implemented to automatically paginate content according to the specific device and keep the paged data on the server until requested by each user.

Additionally, Internet services such as e-mail and SMS sending are used in order to deliver messages from and to medical instructors and their students during their interaction with MMT. E-mail messages usually include progress reports of medical students. In contrast, SMS messages are shorter and are used by both medical instructors and students for other purposes such as unexpected changes in programmed courses and tests, to send scores for particular examinations, etc.

4. Overview of the system

Medical students can use MMT to learn through courses that are relevant to their medical studies and to test the knowledge they have acquired. The students’ basic interaction with the system may be accomplished by using a personal computer connected with the main MMT server. Fig. 2 illustrates the main form of the educational application on a desktop computer.

While using Medical Mobile Tutor from a desktop computer, students are able to retrieve information about a particular course.

In the example of Fig. 2 a medical student is learning anatomy. The information is given in text-form while at the same time an animated agent reads it using one of the available speech engines. Students can choose specific parts of the human body and the available information is retrieved from the system’s database.

Similarly, medical students are able to take tests that include questions–answers, multiple-choice, etc., corresponding to the medical theory. The animated agent is present in these modes too to make the interaction more human-like and to assist medical students by providing help adapted to their needs and clarifications of difficult situations or when students are confused. Fig. 3 illustrates the interaction between a medical student and MMT, while the student is answering a question in a test. Students’ scores in the given tests are recorded and stored in the system’s main database and can be viewed remotely and asynchronously by medical instructors.

5. Affective tutoring agents

The tutoring agent of the user interface is a cartoon-doctor. The cartoon-doctor is an animated agent who can move around the tutoring text and can show parts of the theory that a student is expected to read. It has also incorporated features of human body-language. It may show patience while the student reads the theory, boredom if the student is not responding to the system, wonder if the student makes an unexpected move, etc. The cartoon-doctor’s behavior is programmatically controlled by an underlying mechanism that relies on the OCC theory, described in the next section.

Medical instructors may choose from 27 available speech engines that the system incorporates. These speech engines are synthesizers that produce different voices. The system also offers the facility to parameterise these voices by changing the pitch, speed and volume, as illustrated in Fig. 4. Thus, the resulting tutoring system may use the voices differently in different contexts to show enthusiasm, when the student is doing particularly well, to imitate whisper, when it judges that the student needs help, or even to show anger when the student is consistently careless and does not pay any attention to the educational system.

As an example of voice parameterization, by increasing the pitch and also the speed and volume of the speech we have the effect of a more “angry” tone of speaking. This may also be achieved by selecting an appropriate speech engine. We may have a special speech engine that always synthesizes speech with an angry tone. Additionally, a medical instructor may use the form illustrated in Fig. 5, which provides more specific and detailed controls. In this particular form, instructors also have the ability to set the exact pronunciation of words by using phonemes.

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**Fig. 2.** The main form of the application.

**Fig. 3.** A medical student is taking a test.
The educational system incorporates built-in tools, to which only medical instructors have access. These tools help the instructors modify the behavior of the characters further, with the agents’ emotion generation facility as the final objective. Not only can the medical instructor command the educational agent to say something under certain circumstances, but s/he can also add commands in the text that will be spoken, in a way that the agent may seem to express a specific emotional state. These commands are understood by the system and are interpreted into changing speech attributes, body movements, facial expressions, etc.

The incorporation of the OCC theory provides a key function in helping the human instructor select “suitable”, pedagogical behaviors for the tutoring agent in cases of student–agent interaction. Alternatively, a medical instructor has to manually associate events such as successful answering to questions with specific commands to agents, programatically modulating the agent’s behavior. This part of the authoring process can also be brought off by the use of the instructor’s mobile device. An example of the mobile interaction is illustrated in Fig. 6. Medical instructors are able to connect to the system database with their wireless device, either mobile phone or mobile Pocket PC simply by entering the corresponding URL into their mobile device.

6. Incorporation of the OCC cognitive model of emotions

An expected contribution of the proposed medical system is to affect positively the educational process in general. More specifically, the system should motivate medical students for the purpose of learning more efficiently and also more enjoyable. In Soldato and Boulay (1995) it is suggested that a tutoring system must react with the purpose of motivating distracted, less confident or discontented students, or sustaining the disposition of already motivated students. Elliott, Rickel, and Lester (1999) believe that tutoring agents will be more effective teachers if they display and understand emotions. However, even if new multimodal capabilities like 3D-graphics and speech synthesis have made pedagogical agents more human-like, there is also a great need in determining “how” (what exactly should the pedagogical agent do) and “when” (in which situation) a pedagogical agent should act/behave in each part of the tutoring process.

In view of the above our system incorporates an affective authoring module that relies on the OCC theory (Ortony et al., 1990). The system uses the OCC cognitive theory of emotions basically for modeling possible emotional states of users–students as well as for proposing tactics to the instructors for improving the interaction between the educational agent and the student while using the educational application. Through the incorporation of the OCC, the system may suggest that the pedagogical agent should express a specific emotional state to the student for the purpose of motivating her/him while s/he learns. Accordingly, the agent becomes a more effective teacher.

In OCC theory, emotional states arise from cognitive models that measure positive and negative reactions of users to situations consisting of events, agents and objects. Correspondingly, events match user goals that are key elements in the OCC theory.

Tables 1 and 2 illustrate representative parts of the intensity variables concerning user input actions and application events that
are used by the system’s adapted OCC emotion model in order to propose an apposite for each case emotional state for the pedagogical agent. The variables illustrated in Tables 1, 2 have been specified in our own implementation and adaptation of the OCC model into the resulting educational application. The application’s user interface is multi-modal, thus it is possible for the system to monitor and record user actions such as speed of typing through the keyboard as well as low voice volume through the microphone etc. The following pseudo-code derives from the OCC model and makes estimations for the intensity of the emotional states that the model examines.

\[
\text{IF}(\text{EMOTION}(i)\text{-POTENTIAL}) > (\text{EMOTION}(i)\text{-THRESHOLD}) \text{ THEN }
\text{SET}(\text{EMOTION}(i)\text{-INTENSITY}) = (\text{EMOTION}(i)\text{-POTENTIAL})
\text{ ELSE IF}(\text{USER.ACTION(i)}\text{-VALUE}) < (\text{USER.ACTION(i)}\text{-MIN})
\text{ THEN }
\text{SET}(\text{SIGNIFICANCE}) = (\text{USER.ACTION(i)}\text{-VALUE}) - (\text{USER.ACTION(i)}\text{-MAX})
\text{ ELSEIF}(\text{USER.ACTION(i)}\text{-VALUE}) > (\text{USER.ACTION(i)}\text{-MAX}) \text{ THEN }
\text{SET}(\text{SIGNIFICANCE}) = (\text{USER.ACTION(i)}\text{-VALUE}) - (\text{USER.ACTION(i)}\text{-MIN})
\text{ ELSE SET(SIGNIFICANCE) = 0 }
\]

Subsequently, each user action with a value of significance other than zero adds a value of emotion potential to one or more emotional states. User actions as well as events of interaction that are correlated with changes in emotional states provide the reasoning mechanism of the OCC model with sufficient information in order to make assumptions for each user’s potential emotion. However, these assumptions can be characterized as “plausible”, since the system does not try to support them by multi-modal or physiological data from the users. The main reason for this is because the educational system’s main purpose is to support the educational process by recognizing and producing pedagogical situations and not to comprehensively examine the users’ emotional states. For example, if a user is answering correctly to subsequent questions in a test, the system’s reasoning mechanism could hypothesize that this user is happy and should also impact positive remarks by a tutoring agent. However, in our example for other external and undefined reasons, the objectively correct emotional state of the user may differ considerably.

The proposed authoring system integrates the OCC model by including a subset of five basic emotional states, namely happiness, sadness, anger, fear and surprise. A diagram of the simplified OCC model considering the five basic emotional states is illustrated in Fig. 7. Each time an event is triggered through a user input action, the incorporated mechanism proposes a behavior for the tutoring agent, which is correlated with the above mentioned emotional states. As it has been shown in Section 5, a medical instructor may approve the proposed tactics for the tutoring agent’s behavior.

7. Evaluation

Software that is meant to help the educational process can be considered successful if it is approved by human instructors and is educationally beneficial to students. For this reason an evaluation study was conducted among 50 first-year students of a medical school and 10 medical instructors. Both students and instructors were selected randomly from the whole medical department. After the participants were selected they were given a short interview concerning their computer knowledge and skills. The evaluation study of MMT concerned two levels:

1. Usefulness level. In this level, the usefulness of the affective interaction of the resulting educational system was evaluated.
2. User friendliness level. In this level, the user friendliness of the affective interaction of the resulting educational system was evaluated.

A sample of the questions that were asked to the medical students and their instructors is the following:

Concerning the first level of the evaluation:

1. How do you rate the usefulness of the affective interaction in the educational application?
2. How do you rate the usefulness of the tutoring agent?
3. Do you think that the emotional-interaction features helped you during the educational process?
Concerning the second level of the evaluation:

1. Do you prefer using your mobile phone, rather than a PC for the interaction with the application? If yes/no what did/didn’t you “like” most?
2. Did you consider the resulting educational application attractive? If yes, what did you like about the application?

During the evaluation of the proposed educational system we observed that most of the asked medical students were enthusiastic about using the affective educational system. More specifically, as they reported, they experienced an interaction that was more human-like, rather than the usual apathetic user-computer interaction. On the other hand most of the medical instructors stated that using MMT as an accessional educational tool could help them sufficiently during the whole educational process.

Figs. 8–10 illustrate representative results of the evaluation study. More specifically, Figs. 8 and 9 concern medical instructors opinions for the usefulness level of the affective educational application and also the usefulness of the alternative mobile maintenance of their lessons. Additionally, Figs. 10 and 11 illustrate the scores of the 50 medical students that participated in the evaluation study. These students scored both for the degree of usefulness and the degree of user-friendliness of MMT. Their scores take values from 0 indicating that the resulting system was not useful at all (correspondingly not user friendly), up to 5 indicating that the resulting system was found to be very useful (correspondingly very user friendly) to them.

As a result of this evaluation study, medical instructors and students appreciated both the affective and mobile features of the educational system MMT. The affective tutoring agents were considered very user-friendly by students who also had previous computing experience. However, one very important finding came up from medical instructors who were not familiar with computers. Mobile facilities were preferred by them, as an alternative way of...
interaction that could also save them precious time in their tight schedule. This derived from the fact that most of these medical instructors, who did not have much experience in using computers, owned a mobile phone and therefore knew how to use it. Furthermore, the incorporation of the OCC cognitive model of emotions into the educational system provided the underlying reasoning mechanism that is needed by highly sophisticated educational applications to become more user-friendly to their users and thus more positive in pedagogical terms. These reasons also made the affective interaction “more attractive” and “accepted” by the majority of medical students.

8. Conclusions

In this paper we have described an affective mobile educational system that incorporates mobile technology in order to assist medical instructors and students with many learning and training obligations. The authoring tool provides an important facility to medical instructors for the creation of their own affective tutoring characters, who can respond emotionally to medical students during their interaction. Based on each student’s interaction, goals, achievements and mistakes and the OCC theory for modeling the cognitive structure of human emotional states, the system proposes specific emotional states for the tutoring agent as tactics in supporting the educational process. In this way, the tutoring characters that are speaking, animated agents may represent the teaching behavior of the human medical instructor who is in charge of the remote lessons. Medical students, who are going to use the educational applications, will have a user interface that is more human-like and affective. Thus they may feel less deprived of the absence of human instructors in medical e-learning.

As a next step we are planning to combine our system with face detection and facial expression analysis modules, developed in Virvou, Tsihrintzis, Alepis, Stathopoulou, and Kabassi (2007) and Tsihrintzis, Virvou, and Alepis (2008) by our research group, that address the problem of emotion perception of users through their facial images. In this way, adaptivity in the affective educational system is going to improve and the resulting application is expected to become more user-friendly and attractive.

References


