Adapting OCC theory for affect perception in educational software

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Abstract

Educational software has been the object of continuous research globally. It has been widely acknowledged that computer assisted applications, which are made for educational purposes can be very beneficial for the students. In order to do that, such software has to be structured in such a way as to be highly adaptive and individualised to the needs of each student. The latest findings in this field of research show that, one important aspect of students in such software applications is affect (Goleman 1995). As a result affective user modeling is becoming essential. This paper describes how the Ortony, Clore & Collins (1988) cognitive theory of emotions can be adapted in an educational game, in order to model students' emotions while they learn. The system's inferences about students' emotions are used to adapt interaction to each individual student's needs.

1 Introduction

As researchers seeking to create intelligent applications began to realise the importance of emotions in attention, planning, learning, memory, and decision-making, there has been an increasing interest in building emotionally intelligent interactive systems that are equipped to express emotions, and even be able to capture or sense real human emotions (Picard 1997). There are several emotion models available for emotion synthesis (Roseman, Antoniou, & Jose, 1996; Sloman, 1999). However, Ortony, Clore and Collins (1988) developed a computational emotion model, which is often referred to as the OCC cognitive theory of emotions, which has established itself as the standard model for emotion synthesis.

One of the challenges in building emotionally intelligent systems is recognizing user emotional states. Humans use different sources of information to assess a person's emotions, including causal information on both context and the person's relevant traits, as well as symptomatic information on the person's visible bodily reactions (Zhou & Conati 2003). However, this information is often incomplete and even contradictory, making emotion assessment a task riddled with uncertainty. A computer attempting to recognize users' emotions will inevitably face the same problem.

Most of the research about implementing an emotion theory concerns the use of emotions for making more lifelike, believable and pedagogical agents for interactive systems. Emotions are an essential part of the believability of embodied characters that interact with humans (Elliott, 1992; Koda, 1996; O'Reilly, 1996). Breemen and BartNeck (2002) have created a simplified model of the OCC theory as to give the opportunity to their mobile phone character eMuu express possible emotional states about downloading mp3 songs. All of the above cases implement an emotion theory for being able to express emotions through their animated character/agents. However, the above projects have not used the OCC theory for the perception of the emotional state of the real user.

There are some studies that are focusing on detecting emotions of the users but are mainly referring to restricted environments and specific conditions. For example a model that uses fuzzy rules to assess anxiety in combat pilots is described in Hudlicka & McNeese (2002). Due to the specificity of the modelling task, the model does not need to deal with the high level of uncertainty involved in modelling affect in less constraining interactions, like those generated by educational games. However, there are a few research projects that are using an emotion theory to sense the emotional state of the user. For example Conati and Zhou (2002) are using the OCC theory explicitly for recognising user emotions for their educational game prime climb. The model relies on a Dynamic Decision Network (DDN) to probabilistically integrate information on both the possible causes of affective reaction and its observable effects. It does so by representing how game events relate to students' goals, and is trying to find possible affective states (6 states from the OCC model) that depend on the satisfaction or not of these goals. However, their work focuses on the relationship of students' goals with their interaction features during the game.

On the other hand, in our research we are focusing on how the goals and standards of the students', which are connected to their interaction features, are related to their emotional states and we are giving a way to calculate the intensity of these emotional states.

In view of the above, in this paper we introduce an adaptation of part of the OCC theory of emotions model that links students' reactions to events and reactions to actions of agents, which take place during the use of an educational game, with their goals and standards while using the game. These reactions are mainly students' observable behavioural characteristics and measurable cognitive characteristics that are the result of their interaction with the game. In order to recognise important students' emotions and provide appropriate feedback we use these characteristics, which are reactions to events and actions of agents, as intensity variables for the emotional state of the user that is found from the adaptation of the OCC model. So, our main contribution is to be able to measure the intensity of an emotion in order to find out if it really occurred. In our case we are able to model 12 different emotional categories of the Ortony, Clore & Collins cognitive theory of emotions.

The educational application that has been used as a test bed for our research is a Virtual Reality game for teaching English. This educational software uses the adaptation of OCC theory to model user emotional states while interacting with a virtual reality game, which typically provokes a wealth of emotions to users. This paper extends previous work (Virvou & Katsionis 2003), by using the adaptation of the OCC theory about the cognitive structure of emotions. Also it provides a method of calculating the intensity variables that affect possible emotional states.

2 The OCC cognitive theory of emotions

The OCC (Ortony, Clore, & Collins, 1988) model has established itself as the standard model for emotion synthesis. A large number of studies employed the OCC model to generate emotions for their embodied characters, and lately there are some studies, like our case, that are using it to model user emotional states. This model specifies 22 emotion categories based on valenced reactions to situations constructed either as being goals of relevant events, as actions of an accountable agent (including itself), or as attitudes of attractive or unattractive objects. It also offers a structure for central intensity variables, such as the desirability of an event, the praise-worthiness of an action of an agent and the appealing-ness of an object, which determine the intensity of the emotion types. It contains a sufficient level of complexity and detail to cover most situations that an emotional interface character might have to deal with.

As mentioned previously, the OCC model divides the concerns of an agent into goals, standards, and attitudes.

Goal-based emotions: In order to determine the intensities of emotions pertaining to the success or failure of goals, the OCC model uses several variables depending upon the context of the situation. Specifically, the variables used depend on whether the event is unconfirmed, confirmed or disconfirmed, whether the event was anticipated, and whether it happened to the agent itself or someone else. Under the OCC model, unanticipated confirmed goal successes and failures for one's self generate the "Well-Being" emotions category of *joy* and *distress*. Anticipated goal effects for our-self generate the "Prospect-Based" emotions category. In an unconfirmed state they generate *hope* and *fear*. In a confirmed state, hope and fear will turn to *satisfaction* or *disappointment*, respectively, and in the disconfirmed state fear and hope become *relief* and, for lack of a better term, *fears-confirmed*. When evaluating how the goals of others have been affected the "Fortune-Of-Others" emotions category is triggered. Goal successes will generate *happy-for* or *resentment*, and goal failures will generate *gloating* or *pity*, depending on whether the agent in question is liked or disliked by the agent experiencing the emotion.

Standards-based emotions: The degree of judged praiseworthiness or blameworthiness of the action of an agent is implemented as the result for an effected standard. Standards are responsible for what the OCC model terms "Attribution" emotions. When responsibility for an action is attributed to one's self, *pride* or *shame* will result. When attributed to an external agent, these turn to *admiration* or *reproach*.

Attitudes-*based emotions:* The degree to which an object is considered appealing or unappealing is modeled. Attitudes are responsible for what the OCC model terms "Attraction" emotions resulting from effects upon preferences. They come only in two varieties under the OCC model, *love* and *hate*.

3 The virtual reality educational application

What we have created is an educational application for teaching English orthography and grammatical rules, which operates as a virtual reality game. This educational game is called VIRGE (Virtual Reality Game for English). In particular, VIRGE incorporates an advanced user model that keeps track of students' cognitive and behavioural characteristics, and makes assumptions about possible emotional states. Students have the opportunity to play a 3D game, similar to the commercial ones, which enables them to learn while playing. Such gaming applications, which typically provoke a wealth of emotions to users, can become an advanced test bed for affective states.

VIRGE invites the culture of computer games for creating a language tutoring system that can be very engaging, motivating and cross-cultural. In the case of language tutoring systems the use of computer games may additionally provide a cultural internationalisation and wide acceptance of these systems. The environment of a game plays a very important role for its popularity. Griffiths (1995) found that the machine's "aura" typified by characteristics such as music, lights, colours and noise was perceived as one of the machine's most exciting features for a large part of the population questioned.

The environment of VIRGE is similar to that of the most popular virtual reality games, which has many virtual theme worlds with castles, corridors and dragons that the player has to navigate through and achieve the goal of reaching the exit. The main similarity of VIRGE with computer games lies in their use of a 3D-engine. However, VIRGE unlike commercial computer games of this kind is not violent at all and is connected to an educational application. In VIRGE, one must fight one's way through by using one's knowledge. However, to achieve this, the player has to obtain a good score, which is accumulated while the player navigates through the virtual world and answers questions concerning English spelling.

Another part of the adventure of the game is that the player may come across certain animated agents. There are three types of animated agent, the advisor, the guard (who acts as a virtual enemy) of a passage and the student's companion. The animated agent, who acts as an advisor and has the form of a female angel, along with the virtual world of the game, is illustrated in Figure 1 and appears in situations where the student has to read new parts of the theory or has to repeat parts that s/he appears not to know well. In addition, virtual advisors are responsible for showing empathy to the students and help them in managing their emotions while playing and answering questions. The game itself may motivate students but it may also cause disappointment and distress each time a student does not perform so well as s/he would like or expect.

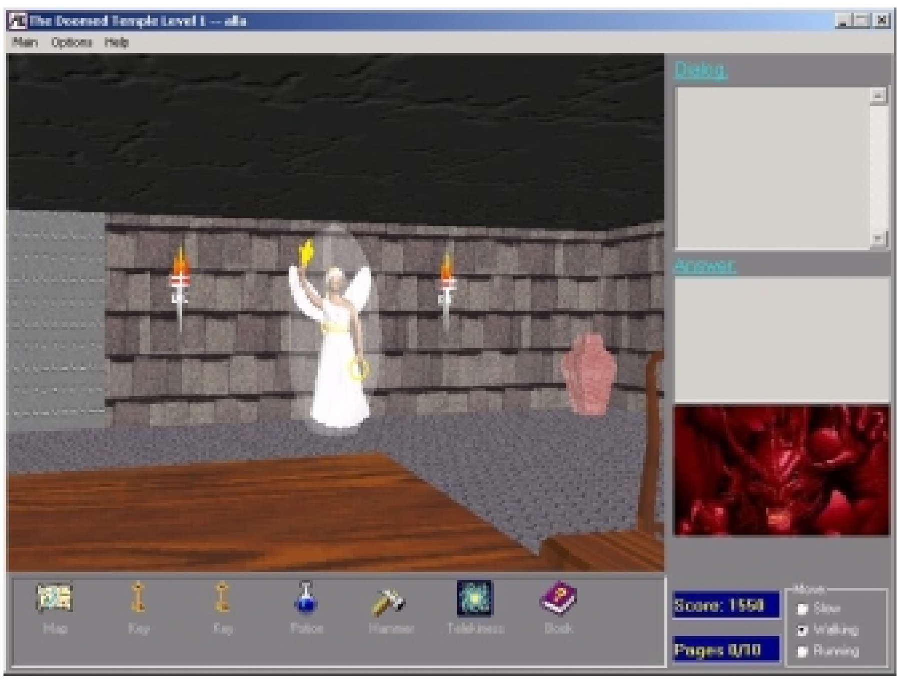

Figure 1: The advisor agent.

The virtual enemy agent is a dragon guard outside every door in the virtual worlds of the game that opposes himself as an obstacle on the student's course during the game. The animated agent who is acting as a virtual enemy is responsible for asking questions to students. Finally the virtual companion, who has the form of an elf, appears in cases where the student has given an answer, either correct or wrong, or has made a mistake repeatedly. Then the virtual companion appears, and makes some remarks in a casual way as if a friend was talking to the student. The existence of the virtual companion has been considered quite important by many researchers for the purpose of improving the educational benefit of tutoring systems and promoting the student's sense of collaboration.

4 Affect perception

As we mentioned above the latest scientific findings indicate that emotions play an essential role in decision-making, perception, learning and more. They influence the very mechanisms of rational thinking. According to Picard (1997), if we want computers to be genuinely intelligent and to interact naturally with us, we must give computers the ability to recognise, understand, and even to have and express emotions. To support this need in the case of our educational game, in VIRGE there exist agents that as part of game playing generate tailored interventions aimed at stimulating the student to learn from the game. However, in order to be more accurate in our interventions, and in order to avoid interference with the high level of engagement of users that is a key asset of educational games, these agents take into account the players' emotional states.

In order to identify these emotional states of the OCC theory of emotions, we introduce an adaptation of part of the theory's model that links students' reactions to events and actions of agents, which take place during the use of an educational game, with their goals and standards while using the game. These reactions are mainly students' observable behavioural characteristics and measurable cognitive characteristics that are the result of their interaction with the game. Additionally, we use these students' characteristics, which are reactions to events and actions of agents and are connected to their goals and standards, as intensity variables for the emotional state of the user that is found from the adaptation of the OCC model.

4.1 Students' goals and standards while using the educational application

At first we were able to record some of the students goals and standards while using the virtual reality educational game and came up to the following:

Students' goals while playing with the virtual game: We have identified 6 high-level student goals for our educational application. We managed to do that by having the students complete some questionnaires at their first contact with the virtual game, and by watching them play afterwards. There also existed some other goals that either had lower significance or at most times were not common for the majority of the students. From these 6 goals, there were 3 concerning anticipated events, those that the OCC model refers to as *Prospect Relevant* and that affect the "Prospect Based" emotional category (*hope, fear, satisfaction, fear-confirmed, relief, disappointment*). The other 3 concerned unanticipated events, those that the OCC model refers to as *Prospect Irrelevant* and that affect the "Well Being" emotional category (*joy, distress*).

Prospect Relevant

- Being Correct
- Avoid Mistakes
- Finish Quickly

Prospect Irrelevant

- Have Fun
- Avoid Confusion
- Learn

Students' standards while playing with the virtual game: There are 4 important student standards for our educational application. By asking the students what they are expecting from themselves and the virtual game, after they had used it for a while, we were able to conclude to 2 standards concerning the students' actions, and 2 more that concerned the agents' actions. These standards concerning *self agent* and *other agent actions* are those that according the OCC theory affect the "Attribution" emotional category (*pride, shame, admiration, reproach*).

Self Agent Actions

- Be a very good student
- Not being a bad student

Other Agent Actions

- Being Helped
- Not Being Disturbed

4.2 Behavioural and cognitive characteristics of students

Our educational application takes into account the history of answers of students and constructs a student-model for each one of them. It also monitors closely the actions of students, and it updates the individual student model for every student-player while they play the game. The student characteristics that are being modelled concern cognitive characteristics of students (answers' results - errors) as well as behavioural characteristics while learning (user actions/ characteristics), which can be connected to their emotions.

While students use the educational game there exist some certain observable behavioural characteristics that are reactions to events or actions of agents and can be connected to their goals and standards for the game. Some of these characteristics can be tracked down by the students typing and mouse movements while playing with the educational application. There are other inferences that can be drawn depending on the time, which has played a very important role in our measurements, that they spend before and after making some actions. Additionally, there are behavioural characteristics of the students that are connected to the use of specific game features by them.

The way these students' behavioural characteristics, that are connected to students' goals and standards, are linked to OCC theory's emotional states and are used as intensity variables of the emotions is shown below:

- *Mouse movements*: Mouse movements without any obvious intent in the virtual reality space of the game that might mean that the student is confused. This characteristic is connected to the Prospect Irrelevant goal of the student "Avoid Confusion" and can lead to the emotion of *Distress*.
- *Speed of answering*: The time that it takes to the student to answer a question. In the case this time is very small it might mean that the student is having a good time playing and answers quickly to see more, so is connected to the Prospect Irrelevant goal of the student "Have Fun" and can lead to the emotion of *Joy*. For the same case the time is connected to the Prospect Relevant goal of the student "Finish Quickly" and can lead to the emotion of *Satisfaction*. On the opposite case that this time is really high then this can reveal the student's hesitation to answer and is connected to the Prospect Relevant goal of the student "Avoid Mistakes" and can lead to the emotion of *Fear*.
- *Use of (advisor, companion) agent*: How often the student uses the advisor agent and asks the help of the companion agent or not. If the student uses really often these agents then this behaviour is connected to the student's Prospect Irrelevant goal "Learn" and can lead to the emotion of *Joy*. For the same case this characteristic is connected to the standard of the student for Other Agent Actions "Being Helped" and can lead to the emotion of *Admiration*. On the contrary if the student does not use these agents, that might mean he does not like them and their actions, is related to the standard of the student for Other Agent Actions "Not Being Disturbed" and can lead to the emotion of *Reproach*.
- *Use of map*: How often the student uses the inventory's map. This characteristic, that shows that the student uses the map if he feels lost, is connected to the student's Prospect Irrelevant goal "Avoid Confusion" and can lead to the emotion of *Joy*.
- *Use of inventory*: The way that the student uses the inventory (keys, potions etc.). Such behaviour reveals that the student understands the game features of the game and likes using them. So is connected to the student's Prospect Irrelevant goal "Have Fun" and can lead to the emotion of *Joy*. Also specifically for the case of keys that mean that student will continue without making a mistake for a question he did not know this characteristic is connected to the student's Prospect Relevant goal "Avoid Mistakes" and can lead to the emotion of *Relief*.

The above kind of evidence based on the students' behavioural characteristics is combined with evidence on the students' degree and quality of knowledge of the parts of the lessons that are examined during the game. During the students' interaction with the educational application there are some measurable cognitive characteristics that can be measured. These mainly rely on the correctness or not of the students' answers. Therefore for each question asked, the system examines the correctness of a student's answer and if the answer is incorrect it performs error diagnosis. The system also tries to estimate the severity of an error (i.e. whether it was an accidental slip or whether it was due to a persistent misconception).

The way these students' cognitive characteristics, that are connected to students' goals and standards, are linked to OCC theory's emotional states and are used as intensity variables of the emotions is shown below:

- *Error frequency*: The percentage of errors among the answers given to all the questions so far. If the student has made a high degree of errors for his answers so far, then this characteristic is related to the standard of the student for Self Agent Actions "Not being a bad student" and can lead to the emotion of *Shame*.
- *Error persistent occurrence*: Consecutive errors for the last questions or for a specific orthography or grammatical rule. This characteristic is connected to the Prospect Relevant goal of the student "Being Correct" and can lead to the emotion of *Disappointment*.

- *Correct answers frequency*: The percentage of correct answers among the answers given to all the questions so far. If the student has made a high degree of correctness for his answers so far, then this characteristic is related to the standard of the student for Self Agent Actions “Be a very good student” and can lead to the emotion of *Pride*.
- *Correct occurrence*: Consecutive correct answers for the last questions. This characteristic is connected to the Prospect Relevant goal of the student “Being Correct” and can lead to the emotion of *Satisfaction*.

4.3 Adapting the OCC theory

During the two previous sub-sections we were able to identify students’ goals and standards during their interaction with our educational software. Additionally we have tracked down some observable behavioural characteristics and measurable cognitive characteristics that are reactions to events and actions of agents, either for self-agent or the application’s agents, and are connected to students’ goals and standards. These characteristics are the intensity variables for the desirability of an event and the praise-worthiness of an action of an agent, so are linked to the intensity of the corresponding emotions according to the OCC cognitive theory model.

Our adaptation of the OCC theory uses a big part of the OCC emotion model (Ortony, Clore, & Collins, 1988) to map the numerous events and actions to emotional states and their intensities (see Figure 2). The subsection chosen from the OCC model focuses on the Prospect Based, Well-Being, and Attribution emotional categories of the original OCC model. All of the above characteristics either behavioural or cognitive are used as intensity variables to draw inferences about the possible emotional state of the student.

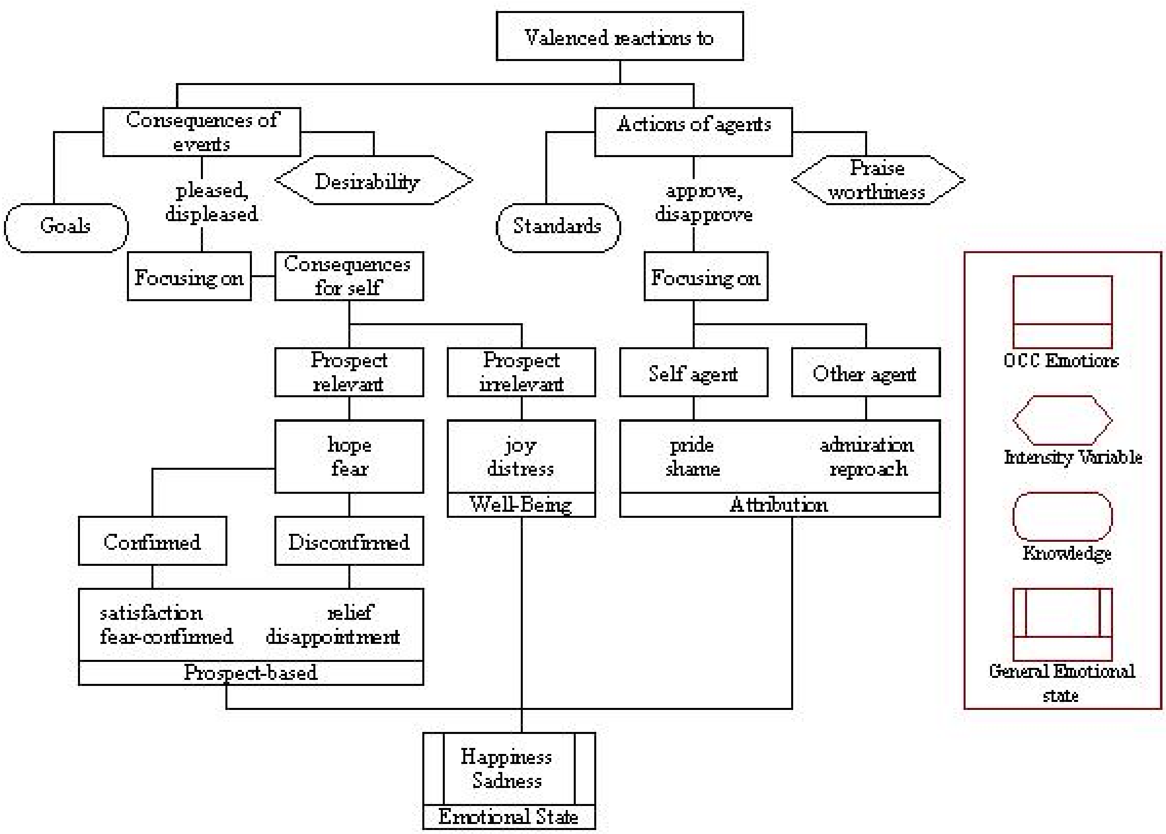

Figure 2: The adaptation of part of the OCC model for the educational game.

The OCC theory of emotions suggests that for the purpose of finding out if an emotion really occurred to an individual there is a need for the specification of a specific value for its intensity variables that is called the threshold value. If the potential value of an intensity variable of an emotion is lower than its threshold value then the individual is not considered to experience the emotion. Otherwise the intensity of the emotion experienced is the difference between the value of the intensity variable of the emotion and its threshold value. An example of the calculation of the intensity of a JOY emotion according to the OCC theory is shown below.

```
IF (JOY-POTENTIAL) > (JOY-THRESHOLD) THEN
  SET (JOY-INTENSITY) = (JOY-POTENTIAL) – (JOY-THRESHOLD)
ELSE
  SET (JOY-INTENSITY) = 0;
```

While performing affective student modelling in the educational game, we are able to measure the value of the intensity variables of emotional states that are the behavioural and cognitive characteristics of the students. As a result, we have used the OCC theory to find out which of these characteristics of each student, either behavioural or cognitive, among the ones that are measured, have an intensity value greater than zero. So, in order to recognise the experience of a possible emotion, the game calculates the intensity of students' characteristics that can lead us to the intensity of the specific emotional state.

In order to find out which of the characteristics of each student, among the ones that are measured, have an intensity value greater than zero, and so play a role to his or her emotional state, we needed to calculate a threshold value for every characteristic and then find the intensity that it has. During the game the system keep track of characteristics of students by storing information about each player answers. Hence, we decided that the way we would calculate the threshold value of each characteristic in a specific moment was to calculate the mean value of this characteristic and add or subtract its standard deviation value. This decision was based on the fact that, in order to find if the intensity of a characteristic is greater than zero, it is important to know if it has a potential value that is out of its usual bounds for the particular student. For example, one particular student may generally be very slow in typing his/her responses to the system whereas another one may be very fast. For these two students the threshold value of the *Speed of answering* characteristic, which is related to the goals "Having Fun", "Finish Quickly", or "Avoid Mistakes" and their linked emotional categories of *Joy*, *Satisfaction* or *Fear*, is different and depends on their usual behaviour.

By performing these calculations we have two threshold values (High & Low) about each characteristic, one upper bound and one lower bound.

1) T. High = Mean Value + Standard Deviation
2) T. Low = Mean Value - Standard Deviation

So if the potential value of a characteristic is greater than the T. High value or lower than the T. Low value the system has a good reason to make some remarks about it. The intensity of the characteristic either positive or negative could result from the value of the following operations.

```
IF (VALUE) > (T. HIGH) THEN
   SET (INTENSITY) = (VALUE) – (T. HIGH)
ELSE IF (VALUE) < (T. LOW) THEN
   SET (INTENSITY) = (T. LOW) – (VALUE)
ELSE
  SET (INTENSITY) = 0;
```

In a similar way the system calculates the intensities for all of the characteristics, either behavioural or cognitive, of the students that have been included in the affective state representation and are the intensity variables for the desirability of events and the praise-worthiness of agents' actions. These intensities can give evidence for the experienced emotions of the user and give the system the opportunity to provide more detailed assistance. Additionally, this evidence of possible experienced emotions and their variables intensities can be combined together, separated into positive or negative emotional experiences, and provides us information for the general emotional state (see Figure 2) of the user, which could be either Happiness or Sadness.

5 Conclusions

In this paper we have described how observable behavioural characteristics of the students' actions, in conjunction with measurable cognitive characteristics of the students' knowledge of the domain being taught, can be connected to students' goals and standards while using an educational application. These students' characteristics are reactions to events and actions of agents, which take place during the game and are the intensity variables of students' goals and standards. The intensity of these reactions that generate from the students' characteristics can be used for drawing inferences for the student's emotional state while interacting with the educational application. Such inferences arise by evaluating the above intensities by using an adaptation of the OCC theory.

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