USING MBIUI LIFE-CYCLE FRAMEWORK FOR AN AFFECTIVE BI-MODAL USER INTERFACE

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Abstract: Decision making theories seem very promising for improving human-computer interaction. However, the actual process of incorporating multi-criteria analysis into an intelligent user interface involves several development steps that are not trivial. Therefore, we have employed and tested the effectiveness of a unifying life-cycle framework that may be used for the application of many different multi-criteria decision making theories. The life-cycle framework is called MBIUI and in this paper we show how we have used it for employing a multi-criteria decision making theory, called Simple Additive Weighting, in an affective bi-modal educational system. More specifically, we describe the experimental studies for designing, implementing and testing the decision making theory. The decision making theory has been adapted in the user interface for combining evidence from two different modes and providing affective interaction.

1 INTRODUCTION

Decision making theories are rather promising for knowledge-based software. However, multi-criteria analysis has not been used adequately in intelligent user interfaces, even though user-computer interaction is, by nature, multi-criteria-based. The actual process of incorporating multi-criteria analysis into an intelligent user interface is neither clearly defined nor adequately described in the literature. Furthermore, Hull et al. (2002) point out that as the systems become more complex, their development and maintenance is becoming a major challenge. This is particularly the case for software that incorporates intelligence. Indeed, intelligent systems are quite complex and they have to be developed based on software engineering approaches that are quite generic and do not specialise on the particular difficulties of the intelligent approach that is to be used.

For this purpose a life-cycle framework have been developed for the incorporation of a multi-criteria theory in an Intelligent User Interface (IUI). This framework is called MBIUI (Multi-criteria Based Intelligent User Interface) life-cycle framework (Kabassi & Virvou 2006) and involves the description of a software life-cycle that gives detailed information and guidelines about the experiments that need to be conducted, the design of the software, the selection of the right decision making theory and the evaluation of the IUI that incorporates a decision making theory.

MBIUI life-cycle framework is based on the Rational Unified Process (RUP) (Jacobson et al. 1999). RUP is clearly documented and easily used due to its clarity. For this purpose RUP seems quite suitable for the development of knowledge-based systems. Indeed, RUP's rationale has also been adapted in other methodologies for knowledge-based systems, e.g. ADELFE (Bernon et al. 2003).

In this paper, we test the effectiveness of this framework by applying it for the development of an affective bi-modal user interface. The particular interface is called Edu-Affe-Mikey and is an affective educational user interface targeted to first-year medical students. Emphasis has been given on the application of the MBIUI life-cycle framework for the application of a multi-criteria decision

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making method for combining evidence from two different modes in order to identify the users' emotions. More specifically, the Simple Additive Weighting (SAW) (Fishburn 1967, Hwang & Yoon 1981) has been applied in the educational user interface for evaluating different emotions, taking into account the input of the two different modes and selecting the one that seems more likely to have been felt by the user. In this respect, emotion recognition is based on several criteria that a human tutor would have used in order to perform emotion recognition of his/her students during the teaching course.

A main difference of the proposed approach with other systems that employ decision making theories (Naumann 1998; Schütz & Schäfer 2001; Bohnenberger et al. 2005; Kudenko et al. 2003) is that the values of the weights of the criteria are not static. More specifically, the values of the criteria used in the proposed approach are acquired by user stereotypes and differ for the different categories of users. Stereotypes constitute a common user modelling technique for drawing assumptions about users belonging to different groups (Rich 1989; 1999). In our case, user stereotypes have been constructed with respect to the different emotional states of users that are likely to occur in typical situations during the educational process and their interaction with the educational software and represent the weight of the criteria.

The main body of this paper is organized as follows: In section 2 we present and discuss the MBIUI life-cycle framework. In sections 3 and 4 we present briefly the experimental studies for requirements capture and analysis. Section 5 describes the design of the affective bi-modal educational application and section 6 its main characteristics. In section 7 we present and discuss the results of the evaluation of the multi-criteria model. Finally, in section 8 we give the conclusions drawn from this work.

2 MBIUI LIFE-CYCLE FRAMEWORK

MBIUI life-cycle framework is based on RUP, which gives a framework of a software life-cycle that is based on iterations and maintains its phases and procedural steps. However, RUP does neither specify what sort of requirements analysis has to take place nor what kind of prototype has to be produced during each phase or procedural step. Such specifications are provided by our MBIUI framework concerning IUIs that are based on multi-criteria theories.

According to MBIUI framework, during the inception phase, the requirements capture is conducted. During requirements capture, a prototype is developed and the main requirements of the user interface are specified. At this point the multi-criteria decision making theory that seems most promising for the particular application has to be selected. This decision may be revised in the procedural step of requirements capture in the phase of construction.

According to MBIUI, in the inception phase, during analysis, two different experiments are conducted in order to select the criteria that are used in the reasoning process of the human advisors as well as their weights of importance. The experiments should be carefully designed, since the kind of participants as well as the methods selected could eventually affect the whole design of the IUI. Both experiments involve human experts in the domain being reviewed.

The information collected during the two experiments of the empirical study is further used during the design phase of the system, where the decision making theory that has been selected is applied to the user interface. More specifically, in the elaboration phase, during design, the user modelling component of the system is designed and the decision making model is adapted for the purposes of the particular domain. Kass and Finin (1989) define the user model as the knowledge source of a system that contains hypotheses concerning the user that may be important in terms of the interactive behaviour of the system.

In the elaboration phase, during implementation, the user modelling component of the system as well as the basic decision making mechanisms are developed. As a result a new version of the IUI is developed which incorporates fully the multi criteria decision making theory.

In the construction phase, during testing, the IUI that incorporates the multi-criteria decision making theory is evaluated. The evaluation of IUIs is very important for their accuracy, efficiency and usefulness. In MBIUI, evaluation is considered important for two reasons: 1) the effectiveness of the particular decision making theory that has been used has to be evaluated 2) the effectiveness of the IUI in general has to be evaluated. In case the version of the IUI that incorporates a particular decision making theory does not render satisfactory evaluation results with respect to real users and human experts, then the designers have to return to requirements capture, select an alternative decision making model and a new iteration of the life cycle takes place. In transition phase, during testing, the decision making model that has been finally selected is evaluated and possible refinements of that model may take place, if this is considered necessary.

3 REQUIREMENTS CAPTURE

In the inception phase, during the procedural step of requirements capture the basic requirements of the system are specified. For this purpose we conducted an empirical study. Due to the difference of an affective bi-modal user interface from common user interfaces, the main aim of the particular experiment was to find out how users express their emotions through a bi-modal interface that combines voice recognition and input from keyboard.

50 users (male and female), of the age range 17-19 and at the novice level of computer experience participated the experiment. The particular users were selected because such a profile describes the majority of first year medical students in a Greek university that the educational application is targeted to. They are usually between the age of 17 and 19 and usually have only limited computing experience, since the background knowledge required for medical studies does not include advanced computer skills.

These users were given questionnaires concerning their emotional reactions to several situations of computer use in terms of their actions using the keyboard and what they say. Participants were asked to determine what their possible reactions may be when they are at certain emotional states during their interaction. Our aim was to recognise the possible changes in the users' behaviour and then to associate these changes with emotional states like anger, happiness, boredom, etc. After collecting and processing the information of the empirical study we came up with results that led to the design of the affective module of the educational application. For this purpose, some common positive and negative feelings were identified.

The results of the empirical study were also used for designing the user stereotypes. In our study user stereotypes where built first by categorizing users by their age, their educational level and by their computer knowledge level. The underlying reasoning for this is that people's behaviour while doing something may be affected by several factors concerning their personality, age, experience, etc. For example, experienced computer users may be less frustrated than novice users or older people may have different approaches in interacting with computers, comparing with younger people. Younger computer users are usually more expressive than older users while interacting with an animated agent and we may expect to have more data from audio mode than by the use of a keyboard. The same case is when a user is less experienced in using a computer than a user with a high computer knowledge level. In all these cases stereotypes were used to indicate which specific characteristics in a user's behaviour should be taken to account in order make more accurate assumptions about the users' emotional state.

4 ANALYSIS

According to MBIUI, during analysis, two different experiments are conducted. The first experiment aims at determining the criteria that are used in the reasoning process of the human advisors and the second aims at calculating their weights of importance.

4.1 Determining Multiple Criteria

Decision making theories provide precise mathematical methods for combining criteria in order to make decisions but do not define the criteria. Therefore, in order to locate the criteria that human experts take into account while providing individualised advice, we conducted an empirical study.

The empirical study should involve a satisfactory number of human experts, who will act as the human decision makers and are reviewed about the criteria that they take into account when providing individualised advice. Therefore, in the experiment conducted for the application of the multi-criteria theory in the e-learning system, 16 human experts were selected in order to participate in the empirical study. All the human experts possessed a first and/or higher degree in Computer Science.

The participants of the empirical study were asked which input action from the keyboard and the microphone would help them find out what the e-motions of the users were. From the input actions that appeared in the experiment, only those proposed by the majority of the human experts were selected. In particular considering the keyboard we have: a) user types normally b) user types quickly (speed higher than the usual speed of the particular user) c) user types slowly (speed lower than the usual speed of the particular user) d) user uses the backspace key often e) user hit unrelated keys on the keyboard f) user does not use the keyboard.

Considering the users' basic input actions through the microphone we have 7 cases: a) user speaks using strong language b) users uses exclamations c) user speaks with a high voice volume (higher than the average recorded level) d) user speaks with a low voice volume (low than the average recorded level) e) user speaks in a normal voice volume f) user speaks words from a specific list of words showing an emotion g) user does not say anything.

4.2 Determining the Weights of Importance of the Criteria

During requirements capture the main categories of the users and emotions were identified. As a result the main stereotypes were designed. For the design of the body of the stereotype we have used the results of the empirical study described in section 4.1, in we categorized users' input actions in terms of the two modes of the bi-modal system. These actions would indicate possible changes in a user's emotional state while s/he interacted with the system. However, in order to identify the weights of the criteria (input action) another experimental study was conducted.

More specifically, 50 medical students were asked to use Edu-Affe-Mickey, which incorporated a user modelling component. The user modelling component recorded all users' actions as a filter between the user and the main educational application. Then these actions were classified by the six and seven basic input actions in regard to the keyboard and the microphone respectively.

Table 1: Values for the stereotypic weights for the emotions of happiness and anger concerning input from the keyboard.

Using the keyboard			
Emotion of happiness		Emotion of anger	
input action	weight	input action	weight
k1	0,4	k1	0,11
k2	0,4	k2	0,14
k3	0,1	k3	0,18
k4	0,05	k4	0,2
k5	0,05	k5	0,25
k6	0	k6	0,12

The results of the empirical study were collected and analyzed. The analysis revealed how important each input action is in identifying each emotion. Therefore, the weight of each criterion (input action) for all emotions were identified and the default assumptions of the stereotypes were designed.

Tables 1 and 2 illustrate the values of the weights for two opposite (positive/negative) emotions, namely the emotion of happiness and the emotion of anger. Variables k1 to k6 refer to the weights of the six basic input actions from the keyboard, while variables m1 to m7 refer to the weights of the seven possible input cases concerning interaction through the microphone. We may also note that for each emotion and for each mode the values of the weights have sum that equals to 1.

Table 2: Values for the stereotypic weights for the emotions of happiness and anger concerning input from the microphone.

Using the microphone			
Emotion of happiness		Emotion of anger	
input action	weight	input action	weight
m1	0,06	m1	0,19
m2	0,18	m2	0,09
m3	0,15	m3	0,12
m4	0,02	m4	0,05
m5	0,14	m5	0,12
m6	0,3	m6	0,27
m7	0,15	m7	0,16

5 DESIGN

In MBIUI the design of the running application is mainly concerned with the design of the user model and is divided into two major parts with respect to the application of a multi-criteria decision making theory: 1) design decisions about how the values of the criteria are estimated based on the information of the user model and 2) design of the embedment of the actual multi-criteria theory that has been selected into the system.

The input actions that were identified by the human experts during the first experimental study of analysis provided information for the actions that affect the emotional states that may occur while a user interacts with an educational system. These input actions are considered as criteria for evaluating all different emotions and selecting the one that seems more prevailing. More specifically, each emotion is evaluated first using only the criteria (input actions) from the keyboard and then only the criteria (input actions) from the microphone. For the evaluation of each alternative emotion the system uses SAW for a particular category of users. According to SAW, the multi-criteria utility function for each emotion in each mode is estimated as a linear combination of the values of the criteria that correspond to that mode.

In view of the above, for the evaluation of each emotion taking into account the information provided by the keyboard is done using formula 1.

$$\boxed{em_{1e_1 1} = w_{1e_1 k1}k_1 + w_{1e_1 k2}k_2 + w_{1e_1 k3}k_3 + w_{1e_1 k4}k_4} \\ \boxed{+ w_{1e_1 k5}k_5 + w_{1e_1 k6}k_6}$$

(Formula 1)

Similarly, for the evaluation of each emotion taking into account the information provided by the other mode (microphone) is done using formula 2.

$$\boxed{em_{1e_1 2} = w_{1e_1 m1}m_1 + w_{1e_1 m2}m_2 + w_{1e_1 m3}m_3 + w_{1e_1 m4}m_4} \\ \boxed{+ w_{1e_1 m5}m_5 + w_{1e_1 m6}m_6 + w_{1e_1 m7}m_7}$$

(Formula 2)

$em_{1e_1 1}$ is the probability that an emotion has occurred based on the keyboard actions and $em_{1e_1 2}$ is the probability that refers to an emotional state using the users' input from the microphone. $em_{1e_1 1}$ and $em_{1e_1 2}$ take their values in [0,1].

In formula 1 the *k*'s from *k1* to *k6* refer to the six basic input actions that correspond to the keyboard. In formula 2 the *m*'s from *m1* to *m7* refer to the seven basic input actions that correspond to the microphone. These variables are Boolean. In each moment the system takes data from the bi-modal interface and translates them in terms of keyboard and microphone actions. If an action has occurred the corresponding criterion takes the value 1, otherwise its value is set to 0. The *w*'s represent the weights. These weights correspond to a specific emotion and to a specific input action and are acquired by the stereotype database. More specifically, the weights are acquired by the stereotypes about the emotions.

In cases where both modals (keyboard and microphone) indicate the same emotion then the probability that this emotion has occurred increases significantly. Otherwise, the mean of the values that have occurred by the evaluation of each emotion using formulae 1 and 2 is calculated.

$$\boxed{\frac{em_{1e_1 1} + em_{1e_1 2}}{2}}$$

The system compares the values from all the different emotions and determines whether an emotion is taking effect during the interaction.

As an example we give the two formulae with their weights for the two modes of interaction that correspond to the emotion of happiness when a user (under the age of 19 and novice with respect to his/her computer skills) gives the correct answer in a test of our educational application. In case of $em_{1e_1 1}$ considering the keyboard we have:

$$\boxed{em_{1e_1 1} = 0.4k_1 + 0.4k_2 + 0.1k_3 + 0.05k_4 + 0.05k_5 + 0k_6}$$

In this formula, which corresponds to the emotion of happiness, we can observe that the highest weight value correspond to the normal and quickly way of typing. Slow typing, 'often use of the backspace key' and 'use of unrelated keys' are actions with lower values of stereotypic weights. Absence of typing is unlikely to take place. Concerning the second mode (microphone) we have:

$$\boxed{em_{1e_1 2} = 0.06m_1 + 0.18m_2 + 0.15m_3 + 0.02m_4 + 0.14m_5 + 0.3m_6 + 0.15m_7}$$

In the second formula, which also corresponds to the emotion of happiness, we can see that the highest weight corresponds to *m6*, which refers to the 'speaking of a word from a specific list of words showing an emotion' action. The empirical study gave us strong evidence for a specific list of words. In the case of words that express happiness, these words are more likely to occur in a situation where a novice young user gives a correct answer to the system. Quite high are also the weights for variables *m2* and *m3* that correspond to the use of exclamations by the user and to the raising of the user's voice volume. In our example the user may do something orally or by using the keyboard or by a combination of the two modes. The absence or presence of an action in both modes will give the Boolean values to the variables *k1…k6* and *m1…m7*.

A possible situation where a user would use both the keyboard and the microphone could be the following: The specific user knows the correct answer and types in a speed higher than the normal speed of writing. The system confirms that the answer is correct and the user says a word like 'bravo' that is included in the specific list of the system for the emotion of happiness. The user also speaks in a higher voice volume. In that case the variables k1, m3 and m6 take the value 1 and all the others are zeroed. The above formulas then give us $em_{1e_1 1} = 0.4 * 1 = 0.4$ and $em_{1e_1 2} = 0.15 * 1 + 0.3 * 1 = 0.45$.

In the same way the system then calculates the corresponding values for all the other emotions using other formulae. For each basic action in the educational application and for each emotion the corresponding formula have different weights deriving from the stereotypical analysis of the empirical study. In our example in the final comparison of the values for the six basic emotions the system will accept the emotion of happiness as the most probable to occur.

6 IMPLEMENTATION

During implementation, in the elaboration phase the overall functionality and emotion recognition features of Edu-Affe-Mikey are implemented. The architecture of Edu-Affe-Mikey consists of the main educational application with the presentation of theory and tests, a programmable human-like animated agent, a monitoring user modeling component and a database.

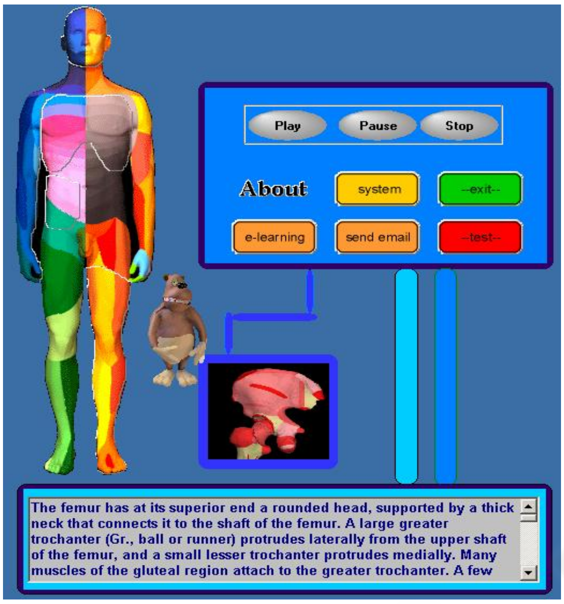

Figure 1: A screen-shot of theory presentation in Edu-Affe-Mikey educational application.

While using the educational application from a desktop computer, students are being taught a particular medical course. The information is given in text form while at the same time the animated agent reads it out loud using a speech engine. The student can choose a specific part of the human body and all the available information is retrieved from the systems' database. In particular, the main application is installed either on a public computer where all students have access, or alternatively each student may have a copy on his/her own personal computer. An example of using the main application is illustrated in figure 1. The animated agent is present in these modes to make the interaction more human-like.

While the users interact with the main educational application and for the needs of emotion recognition a monitoring component records the actions of users from the keyboard and the microphone. These actions are then processed in conjunction with the multi-criteria model and interpreted in terms of emotions. The basic function of the monitoring component is to capture all the data inserted by the user either orally or by using the keyboard and the mouse of the computer. The data is recorded to a database and the results are returned to the basic application the user interacts with. Figure 2 illustrates the "monitoring" component that records the user's input and the exact time of each event.

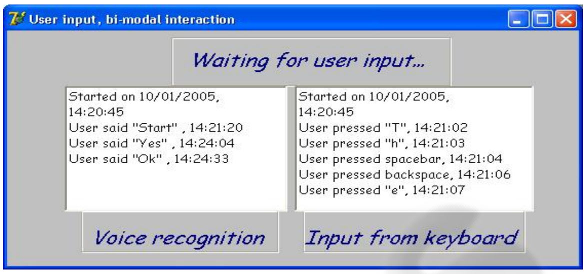

Figure 2: Snapshot of operation of the user modeling component.

Instructors have also the ability to manipulate the agents' behaviour with regard to the agents' on screen movements and gestures, as well as speech attributes such as speed, volume and pitch. Instructors may programmatically interfere to the agent's behaviour and the agent's reactions regarding the agents' approval or disapproval of a user's specific actions. This adaptation aims at enhancing the "affectiveness" of the whole interaction. Therefore, the system is enriched with an agent capable to express emotions and, as a result, enforces the user's temper to interact with more noticeable evidence in his/her behaviour.

7 TESTING

In construction phase, during the procedural step of testing, the final version of the system is evaluated. When a user interface incorporates a decision making theory, the evaluation phase plays an important role for showing whether the particular theory is effective or not. In MBIUI life-cycle framework it is considered important to conduct the evaluation of a decision making model by comparing the IUI's reasoning with that of real users. Therefore, in this experiment it is important to evaluate how successful the application of the decision making model is in selecting the alternative action that the human experts would propose in the case of a user's error. For this reason, it has to be checked whether the alternative actions that are proposed by the human experts are also highly ranked by the application of the decision making model. In case this comparison reveals that the decision making model is not adequate, another iteration of the life-cycle has to take place and another decision model should be selected. This iteration continues until the evaluation phase gives satisfactory results.

In view of the above, an evaluation study was conducted. Therefore, the 50 medical students that were involved in the empirical study during requirements capture were also involved in the evaluation of the multi-criteria emotion recognition system. More specifically, they were asked to interact with the educational software and the whole interaction was video recorded. The protocols collected were presented to the same users in order to perform emotion recognition for themselves with regard to the six emotional states, namely happiness, sadness, surprise, anger, disgust and the neutral emotional state.

The students as observers were asked to justify the recognition of an emotion by indicating the criteria that s/he had used in terms of the audio mode and keyboard actions. Whenever a participant recognized an emotional state, the emotion was marked and stored as data in the system's database. Finally, after the completion of the empirical study, the data were compared with the systems' corresponding hypothesis in each case an emotion was detected. Table 3 illustrates the percentages of successful emotion recognition of each mode after the incorporation of stereotypic weights and the combination through the multi-criteria approach.

Table 3. Recognition of emotions using stereotypes and SAW theory.

Using Stereotypes and SAW			
Emotions	Audio mode recognition	Recognition through keyboard	Multi-criteria bi-modal recognition
Neutral	17%	32%	46%
Happiness	52%	39%	64%
Sadness	65%	34%	70%
Surprise	44%	8%	45%
Anger	68%	42%	70%
Disgust	61%	12%	58%

Provided the correct emotions for each situation identified by the user himself/herself we were able to come up with conclusions about the efficiency of our systems' emotion recognition ability. However, one may notice that there are a few cases where the proposed approach had a bit worse performance in recognizing an emotional state (e.g. neutral emotional state). Possible reason is the fact that some emotional states, e.g. neutral emotional state, give little evidence to certain modes (e.g. the keyboard mode). For the same emotions, other modalities (e.g. the visual mode) may give us significantly better evidence. However, the combination of the two modes in the multi-criteria model increases significantly the accuracy of the proposed approach.

Although, success rates may look at a first glance lower than expected, we should underline the fact that emotion recognition is a very difficult task for human and their success rates are also quite low. Therefore, the results of the evaluation study offer evidence for the adequacy of the multi-criteria multi-modal model for emotion recognition.

8 CONCLUSIONS

In this paper, we have used a general framework, which provides detailed guidelines for the application of a multi-criteria decision making theory in an affective bi-modal Intelligent User Interface. This framework is called MBIUI life-cycle framework and was initially designed for incorporating a decision making theory in a user interface that helps users during their interaction with a file-store system.

In this paper we aimed at checking the effectiveness of this framework in order to apply a simple multi-criteria decision making theory in an adaptive bi-modal user interface. Indeed, the MBIUI life-cycle framework facilitates the application of the multi-criteria decision making theory by providing detailed guidelines for all experimental studies during requirements capture and analysis as well as testing.

The user interface presented in this paper is used for providing medical education to first-year medical students and is called Edu-Affe-Mikey. In this system, the multi-criteria decision making theory, SAW, is used for combining evidence from two different modes in order to identify the users' emotions. SAW is used for evaluating different emotions, taking into account the input of the two different modes and selecting the one that seems more likely to have been felt by the user. The particular user interface offers affective bi-modal interaction and for this reason differentiates from the other user interfaces. The fact that the particular framework can be used in interfaces that differ in many ways strengthens MBIUI's generality.

The affective bi-modal user interface has been evaluated and the results prove the effectiveness of the multi-criteria decision making theory for combining evidence from two different modes and perform emotion recognition.

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