Emotionally Intelligent Interactive Agents for Delivering Information about User Affective Profiles

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Abstract – **The paper describes an approach to the design of emotionally intelligent interactive agents for information delivery in psychological domains. Descriptions of the user's mental states are based on the affective profiles built according to the standard test in psychiatry and clinical psychology Emotions Profile Index. To achieve believability the agents are capable of conveying emotional, verbal and non-verbal signals. Fuzzy decision-making paradigm is used to formalize the agent's behavior. Defining the agent's utility function over the results of the psychiatric interview, the agent's personality and the social context we are able to cover the subject-agent and psychiatrist-agent forms of interaction.**

I. INTRODUCTION

There is a general agreement that emotion and personality are essential to achieve believable behavior in AI applications that use animated agents as virtual characters for entertainment [1], as tutors in pedagogical software [2] or for presentation tasks [3].

Virtual characters might have impact on the users and motivate their responses or increase learning abilities in tutoring applications [4]. Animated agents composed of multimedia elements are able to present relevant information in more appealing way and to convey gestures and emotional signals that might have effect on user attitudes.

Besides emotions and personality verbal and nonverbal behaviors are some of the key issues that have to be addressed in creating virtual believable characters [5]. Coordinated verbal and nonverbal conversational behaviors convey the semantic and pragmatic content of the information through different modalities. Accentuating certain words, intonation and gestures synchronized with the spoken utterances of the artificial agents serve to reinforce the meaning of the speech. The propositional goals that make the content of the conversation might be realized with different linguistic styles, which might express agent's character and personality as Walker and colleagues argue [6]. The agents should be able to coordinate their communicative and expressive behavior. Also they have to cooperate with the users, by sharing speaking turns with them and introducing topics of their interest in order to be considered as a conversationally competent.

Several works describe human-computer interfaces with conversational believable agents. Pelachaud and her colleagues developed conversational embodied agent for information delivering in medical domain, whose beliefs and goals change during the conversation with the user [7]. The dialog is also influenced by the social context of the conversation [8] and the agent is able to hide emotions that are not appropriate for the situation. Bickmore and Cassell [9] built a real estate agent REA, an interactive agent able to converse with users in real time, to recognize non-verbal cues and to share speaking turns with the users.

Other important aspect to enhance the believability of animated agents is a social role awareness that determines the emotion expression and behavioral reactions according to the social context [10]. For example, when interacting with the patient the agent psychiatrist has to behave according to the norms and standards appropriate for the situation. The behavior is different when presenting a subject diagnosis to a psychiatrist or psychologist. In a particular social setting the social distance between the participants and the power that an agent's role has over other roles determine the appropriate behavioral and communicative conventions.

Recognizing user emotions and personality is one of the key issues in building emotionally intelligent interactive systems. Conati [11] proposes a probabilistic model, based on Dynamic Decision Networks to infer user's emotions during the interaction with educational game. Other works focus on the assessment of a specific emotion, such as anxiety in pilots [12] or stress in car drivers [13].

This paper introduces our approach to the design of believable animated agents for presenting information about the user's mental health and emotional characteristics. Important property of the animated agents is the capability to engage in affective communication with users according to their personality and the social context. Our affective user-modeling component is based on standard psychological test Emotions Profile Index (EPI) [14]. User profiles are built during the user's initial interaction with the application.

For the audio-visual implementation of the virtual agents we use the programmable interface of the Microsoft Agent package that includes several predefined characters [15]. The package has a speech recognizer and text-to-speech engine and offers a limited number of animations.

Agent's presentations are formulated as informative paragraphs and are taken from the predefined knowledge base. To communicate information and feelings in an ordered and structured way we propose multimodal user-agent interface.

The same message can be conveyed by a variety of expressions and the agents have to choose the right expression for a linguistic situation according to their personality and social role awareness. For example, an extrovert agent will use more direct speech and expansive gestures in comparison with an introvert agent.

The application provides limited explanations within constrained situations and competent descriptions of the attributes of the emotional profile and the impact that they have on the user's emotional state.

We use the fuzzy decision-making paradigm [16] [17] to formalize the agent's behavior and define the utility function over the results of the psychiatric interview, social context and agent's personality.

The application is implemented in web-based environment. JavaScript code is used to control the Microsoft Agent characters and Java to implement the affect modeling component.

In the next section we describe the affective user modeling component and the rule-based methodology for expert's refinement of the profiles. Then we present the conceptual and formal model of the agent's behavior. Our approach is illustrated by an example that shows the principles of role-based psychiatrist-agent and subject-agent interaction. We end the paper with a brief discussion and conclusions.

II. USER AFFECTIVE PROFILE

User modeling component builds the affective profile according to the standard test in psychiatry and clinical psychology Emotions Profile Index. This instrument uses the idea that personality traits are mixtures of two or more primary emotions [14]. For example, personality trait cautious includes expectancy and fear as two main emotional components, and affectionate includes acceptance and joy.

EPI assesses the user affective state based on a partial ordering scheme of personality traits: adventurous, affectionate, brooding, cautious, gloomy, impulsive, obedient, quarrelsome, resentful, self-conscious, shy, and sociable.

The emotional dispositions, such as fear, anger, joy, sadness, acceptance, disgust, expectancy and surprise, represent the user's affective state. We characterize the user's affective state as a mixture of different emotions and use fuzzy linguistic labels to express the scores of the emotional scales measured with the psychological test.

The term set T(A)={high, medium, low} is used for the linguistic variable A that represents the score of the emotional scale.

The user-modeling component infers user's emotional state and presents the appropriate interpretation in the form of expert explanations, or offers a diagrammatic view of the results. One type of a user profile is shown in Fig. 1.

Expert explanations of the emotional profile are obtained using the affective modeling system and consulting experts. In our affective modeling system they are formed by merging fragments of texts activated by fired fuzzy rules.

Besides emotions, we consider that personality is essential for a virtual character that has to exhibit a believable behavior and to predict future behaviors of the user. Personality influences person's goals and behaviors and determines person's adjustment to the environment. Personality traits predispose people to behave consistently

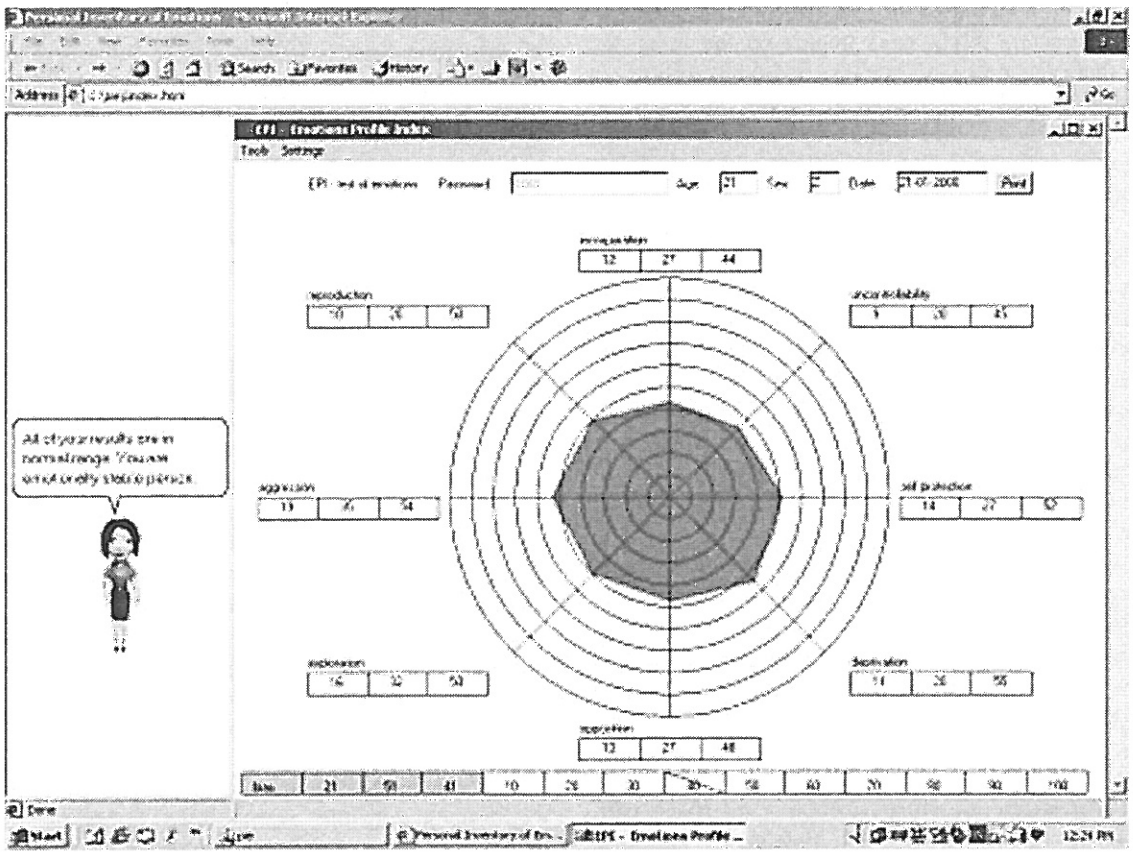

Fig. 1. Representation of the user affective profile

in situations and they remain stable over a period of time. In psychology, emotions are defined as focused on particular events, while personality is more diffuse and indirect.

In our approach, we follow the Costa and McCrae's Five-Factor Model of personality [18] where traits are structured as five dimensions: neuroticism, extroversion, openness, agreeableness and conscientiousness. For example, using personality traits, an extrovert person might be described as affectionate, sociable, assertive, trusting, person who likes excitements and carefully selects right words when speaking. By contrast, the introvert person is reserved, skeptical, seldom seeks company, and rather stays in the background instead of being assertive. Person with high level of neuroticism, or negative emotionality is worried, quick to anger, often sad and prone to stress. Low level of neuroticism is associated with personality resistant to stress, calm and slow to anger. Conscientious person is well organized, driven to succeed, focused on work and careful as opposed to flexible person, who is unorganized, casual about obligations, spontaneous. Openness is connected with intellectual curiosity, imagination and openness to new values.

We use the partial ordering of the personality traits to infer the user's personality. For example, personality traits as cautious, brooding, obedient or altruist contribute to the evaluation of the person as agreeable or disagreeable.

Users perceive the same dimensions of personality in virtual agents as in humans. They generally prefer cooperative and outgoing agents to those that are competitive and withdrawn. Interesting fact is that similar personalities to user's own personality are liked more than the dissimilar ones [19].

A. Rule-Based Refinement of the User Profile

EPI is used for initialization of the user affective profile. The user model might be modified using fuzzy rules.

Emotional state is described with linguistic labels for the fuzzy variables <R, I, N, S, D, O, E, A> denoting emotional categories reproduction, incorporation, orientation, protection, deprivation, rejection, exploration and destruction, respectively.

Fuzzy rules with the following general pattern are used for updating of the profile:

if x_1 is A_1 and ... and x_n is A_n or ... then y is B,

where A_i and B are linguistic variables from the universes of discourse U and V respectively, x_i is an instance in the universe U corresponding to membership value $\mu_{Ai}(x_i)$, y is an instance in V with membership value $\mu_B(y)$.

Condition part of the rule might, for example, include events from the application where EPI is used for the assessment of the user emotional state. Action part might specify new values for the attributes in the user model or might activate other rules.

The process of fuzzy inference is formalized with fuzzy automaton:

$$FA=(I,S,O,f,\lambda),$$

where I is a set of input linguistic variables, S is a set of automaton's internal states and O is a set of output linguistic variables.

Transition function f is defined as $f: SxIxS \rightarrow \{0,1\}$ and output function λ as $\lambda: SxIxO \rightarrow \{0,1\}$, where:

$f(s_i,i_p,s_j)=1$ if there is link from state s_i to s_j, and
$f(s_i,i_p,s_j)=0$ in other cases, and
$\lambda(s_i,i_p,o_p)=1$ if o_p is the output at state s_i when input is i_p and $\lambda(s_i,i_p,o_p)=0$ otherwise.

The fuzzy automaton has to be deterministic. That is, for a given input and current state there is only one next state and output. So, some constraints are imposed: function f has value 1 for exactly one next state s_j being in state s_i when the input is i_p and λ has value 1 for only one output o_k being in state s_i when the input is i_p.

To obtain next states the automaton computes max-min operations from the current state and inputs.

Let current input x has membership values

$$I=[\mu_{i1}(x),\ldots,\mu_{ip}(x)],$$

for every input linguistic variable i_k and S is the current state of the automaton distributed over several states, where the degree of activation of the states is defined with value in the interval [0,1].

The next state S' is computed as fuzzy composition

$$S'=S^{\circ}\max[\min(\mu_{i1}(x),f(s_i,i_1,s_j)),..,\min(\mu_{ip}(x),f(s_i,i_p,s_j))$$

User affective profile might be modified to include evidence from psychiatrists. The experts might add a rule that is inconsistent with the rest of the rules. Analyzing the process of fuzzy inference using fuzzy automaton may help in detecting undesirable and ambiguous situations. That is, this representation can be used as a basis for a tool, which will discover conflicting results.

III. CONCEPTUAL MODEL OF THE AGENT

The agent is assumed to have a mental model consisting of different kinds of entities, including emotions, personality traits, goals and motivations. We concentrate on those entities that are important for affective communication. The concept of user-agent interaction is illustrated in Fig.2.

The agent is able to display two social emotions i.e. emotions that are felt for another person. Sorry-for and happy-for are driven by an empathic attitude and are elicited by undesirable and desirable events, respectively. The agent's goal "desiring the good of others" is related to an empathic attitude.

Information delivery manager operates on a knowledge base allowing the agent to recognize the user's emotional state and to formulate a description of the mental health.

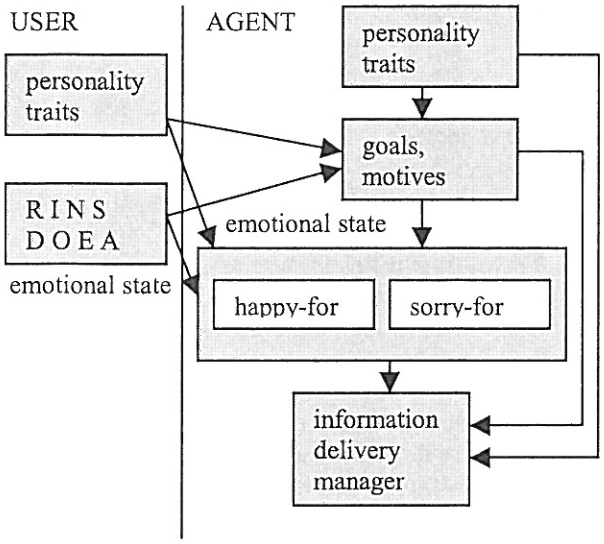

Fig. 2. Agent's mental model in the multimodal interaction with the user

The animated agent displays the information by uttering one or a set of predefined paragraphs from the knowledge base, and uses pointing gesture and facial expressions defined by the animations "pleased" and "sad". Facial expressions and gestures are limited to predefined animations of the Microsoft Agent package.

Our aim is to model believable agents that react differently to similar situations according to their personality and social role awareness. Social roles put constraints on agent's behavior and emotion expression.

To model adequate behaviors according to social conventions we define conceptual characters conscientious and compassionate. The role of the character is associated with certain goals and behaviors. The goal of the conscientious agent is to provide detailed explanations about the subject's affective state and mental health when interacting with the psychiatrist. Compassionate agent assigns higher importances to goals "give advice" and "express empathy", which are appropriate in interactions with the subjects.

A.Framework for Selecting Adequate Behavior

To exhibit social competence, an agent ought to possess the ability to select adequate behaviors. The process of selection depends on the evaluation of the situation and on the desirability of the possible outcomes.

We use fuzzy decision-making techniques [16] [17] to formalize the agent behavior.

The agent's utility function is defined over the results of the psychiatric interview, the agent's personality and the social context. By varying the utility function agents with different characters can be defined.

We define two characters to cover the subject-agent and psychiatrist-agent forms of interaction:

- compassionate agent that will assign higher importance to expressions of empathy and giving advice, and
- conscientious agent that will value more the actions offering detailed explanations of the results about the mental health of the user.

The decision-making situation is represented with the 3-tuple (S,C,W) where:

$S=\{S_1, ..., S_n\}$ are decision alternatives,
$C=\{C_1, ..., C_k\}$ are decision criteria, and
$W=\{w_1, ..., w_k\}$ are weights assigned to the decision criteria.

Agent utility function determines the importances assigned to the decision criteria.

Let $\{s_{i1},...,s_{ik}\}$ are evaluations for the alternative S_i over all the criteria. The methodology suggested by Yager [16] [17] to find the unit score of the alternative S_i is as follows

$$S_i=\min(g(w_1,s_{i1}), g(w_2,s_{i2}), ... , g(w_k,s_{ik}))$$

where g is maximum t-conorm $g(w_r,s_{ir})=\max\{1- w_r,s_{ir}\}$.

The formula represents an anding of the criteria satisfactions modified by the importance of the criteria.

After the evaluation of the alternatives the agent selects the alternative/s with the maximal value as the most desirable in the given situation.

Linguistic variables are used to represent the importance of the decision criteria and the degrees of appropriateness of the decision alternatives.

We use the same term set for the linguistic variables that represent the importance of the decision criteria and the appropriateness of the alternatives, and the same membership functions corresponding to each element in the term set.

The linguistic variables are translated into triangular fuzzy numbers to compute the arithmetic operations. The total integral value method is used to rank the decision alternatives [20]:

$$I(U)=1/2[\alpha c + b + (1-\alpha)a],$$

where $0\leq\alpha\leq1$ is the degree of optimism of the decision-maker, and a, b, and c are the lower, modal, and upper value of the triangular fuzzy number.

B. An Example

In this section we illustrate the methodology for selecting the appropriate agent behavior.

The decision criteria are defined as follows:

C={advice, explanation, empathy, personality}.

We consider only extrovert/introvert dimension of personality, which is important for affective social interaction.

Following term set of the linguistic variable importance is used for assessment of the decision criteria and decision alternatives:

T(importance)={High, Medium, Low}.

Let the affective profile under consideration belongs to a

person with certain pathological manifestations and let the following alternatives from the knowledge base are activated:

S1: This is a cautious and anxious person. The results show that this person is constantly worried of getting into troubles that she could not be able to overcome. Also this person is worried about what other people think or speak about her.

S2: There is a possibility for phobic and obsessive-compulsive behavior.

S3: It looks that you have some problems. Is that right? You have to visit a psychiatrist.

S4: For further analyses you have to consult a psychiatrist. Your results show anxiety and some other pathological problems.

The importances that compassionate agent assigns to the decision criteria are as presented in Table 1:

Table 1. Criteria importances for compassionate agent

C1 advice	C2 explanation	C3 empathy	C4 extrovert
M	L	H	H

The importances for the conscientious agent are presented in Table 2:

Table 2. Criteria importances for conscientious agent

C1 advice	C2 explanation	C3 empathy	C4 extrovert
L	H	L	H

The evaluations of the alternatives are presented in Table 3.

Table 3. Evaluations of the decision alternatives over the criteria

	C1	C2	C3	C4
S1	L	H	L	H
S2	L	H	L	H
S3	H	L	H	H
S4	H	M	M	M

The unit scores for the alternatives for conscientious and compassionate agents are given in Table 4.

Table 4. Unit scores of the alternatives for different agents

agent	S1	S2	S3	S4
compassionate	L	L	H	M
conscientious	H	H	L	M

As the results in Table 4 show the compassionate agent will display the alternative S3 together with emotion sorry-for. The alternative S4 is less suitable because of the low performance on the third and forth criteria. An extrovert agent carefully chooses words, so the alternative S3 is appreciated more than the alternative S4.

The conscientious agent will present detailed information to a psychiatrist about the pathological problems of the subject. The agent will display alternatives S1 and S2.

IV. CONCLUSION

The presented work models emotions and personality to enhance the believability of the agent behavior.

In addition to creating more natural and intuitive interfaces, animated agents may have positive and motivational effect on the user experience with interactive technologies.

The predefined characters of the Microsoft Agent package have limited number of animations. Because of their cartoon-style appearance they are not very suitable for our application. We intend to replace the characters by more expressive animated agents.

The affective user modelling is discussed in the context of the interaction with agent designed to improve the effectiveness of the human-agent interface.

In this paper we presented an approach for assessment of the user's affective state using standard test in psychiatry and clinical psychology Emotions Profile Index. We describe a rule-based refinement of the model by integrating evidence from additional sources such as expert opinions.

The affective profile is used by the fuzzy decision-making agent to generate and display information about the user's mental health. By varying the utility function we define different animated characters that react according to their personality and the social context.

The social role of an agent is associated with certain responsibilities, duties, rights, behavioral constraints and has influence on the emotion expression. By considering the social dimension we aim to achieve convincing behavior and to enhance the believability of the animated agents.

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