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THE SET OF AGENTS FOR THE MODELLING OF LEARNER'S EMOTIONS IN INTELLIGENT TUTORING SYSTEMS

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ABSTRACT
The paper presents a detailed set of intelligent agents for the modelling of learner's emotions in intelligent tutoring systems. Functions and interaction of the agents, the overall decision making process and the involvement of the agents in the affective loop of an intelligent tutoring system are described. The most widespread categories of inputs for the determination of a learner's emotional state are identified as well.

KEY WORDS
Intelligent agents, intelligent tutoring system, emotions

1. Introduction

Emotions are an integral part of human beings. They influence various aspects of our life, inter alia perception of a person by other individuals, relationships with people, professional activities, as well as the learning process. Learning takes place through a complex interplay between both cognitive and affective dimensions [1]. From our own experience and psychological studies we know that different emotions have different impact on outcomes of our activities. In relation to the learning process positive emotions allow for efficient acquisition and creation of knowledge, while negative emotions reduce and inhibit knowledge retrieval and memory [2]. So it is necessary to take into account emotions of the learner both in the traditional learning process and in technology-based educational applications. In the latter case this necessity is more significant because the familiar learning environment and live contact with the teacher and other learners are replaced by a lifeless machine.

Intelligent tutoring systems are promising technology-based educational applications due to their high level adaptability to the learner. The modelling of learner's emotions provides two main advantages for systems of a such kind: a) it allows adaptation of the learning process not only to cognitive characteristics of the learner, but also to his/her affective state; b) it allows inducing of necessary emotions to the learner in order to promote more effective learning. The system becomes more flexible and adaptive, as well as comes closer to the implementation of the more natural learning process.

The agent paradigm is one of the leading research directions in the development of intelligent tutoring systems during the last several decades. It offers a good solution for the implementation of the architecture of such systems. The reason is that the agent technology allows the creation of autonomous entities called agents which have such properties as reactivity, proactivity, capabilities of socialization, learning and reasoning, adaptability, and mobility. They are capable to act in complex dynamic environments and to perform tasks entrusted to them [3]. The integration of multiple agents produces an easy maintainable, extensible and robust modular architecture of a system. However, the usage of agents for the modelling of learner's emotions is weakly investigated.

The paper presents results of the theoretical research conducted with the aim to identify a set of intelligent agents for the modelling of learner's emotions in intelligent tutoring systems. The structure of the paper is the following. Section 2 defines the concept of an intelligent tutoring system and presents a general set of intelligent agents for the development of such systems. Section 3 discusses the notion of an emotionally intelligent tutoring system and identifies an affective loop which involves the system and the learner, as well as specifies the most widespread categories of inputs which can be used for the determination of a learner's emotional state. The set of agents for the modelling of learner's emotions in an intelligent tutoring system, their interaction, functions and involvement in the previously identified affective loop are described in Section 4. Conclusions are given at the end of the paper.

2. Intelligent Tutoring Systems and Agents

Intelligent tutoring systems are adaptive and intelligent computer systems which are based on the theory of learning and cognition, emulate the human teacher and try to provide benefits of one-on-one tutoring [4]. They store three basic kinds of knowledge: domain knowledge, pedagogical knowledge, and knowledge about the learner. The knowledge types determine three main parts of the general system's architecture: the expert module, the pedagogical module, and the student diagnosis module, accordingly. Intelligent tutoring systems are the most promising kind of educational software, because on the basis of the mentioned types of knowledge and usage of methods of artificial intelligence they are able to adapt the learning process (sequence of knowledge units and tasks,

content, detail level, feedback and help) to different characteristics (psychological, cognitive and affective) of a particular learner.

One of the leading research directions in the development of intelligent tutoring systems during the last several decades is the agent paradigm (for example, [5, 6, 7]). Agents are able to perceive their environment through sensors and to act upon the environment through effectors [8]. In our previous work [3] we have developed a possible set of agents which comprise the architecture of an intelligent tutoring system (Figure 1). Within the offered architecture the psychological agent is responsible for the modelling of learner's affective characteristics alongside with psychological characteristics. However taking into account last research in the field of the modelling of emotions this agent demands further revision and extension what we present in Section 4.

3. Emotionally Intelligent Tutoring Systems

According to [9], an affective computational system must have a few of the following capacities: recognize, express, or possess emotions. An emotionally intelligent tutoring system [10], in turn, is defined as an intelligent tutoring system which includes functional capabilities able to (1) know learner's emotions, and (2) induce emotions to the learner in order to improve his/her performance. So, such system needs to achieve the following conditions: know the current emotional state of the learner, determine the impact of an action on the learner's emotional state and select the most advantageous emotional state of a learner to enhance his performance.

We extend the notion of an emotionally intelligent tutoring system by identifying an affective loop (Figure 2) which involves the tutor (the system) and the learner. First of all the system through sensors perceives the current emotional state of the learner from one or several sources, for example, face and/or speech. After that features relevant to the determination of the learner's emotion, for example, face features (shape and displacement of eyes, eyebrows, etc.) and/or speech features (pitch and duration of the utterance, etc.), are extracted from the information received from the sensors. Further the features are classified with an intent to obtain one of the pre-defined emotional categories. The identified emotional category is interpreted in terms of its influence on the learning process and further learner's activities in the educational environment. At the next step the system selects a pedagogical action (or actions) which can be directed towards one of two aspects: to change the emotional state of the learner, for example, frustration or boredom, if its influence on the learning process is considered as negative, or to maintain the emotional state of the learner, such as enthusiasm or confidence, if it has a positive effect on the learning process. Moreover, an emotion which the system (more precisely an animated pedagogical agent) will express must be selected taking into account the current emotional state of the learner, the chosen pedagogical action and the goal of system's influence on the learner. After that the animated pedagogical agent expresses its emotion and implements the pedagogical action. The loop repeats.

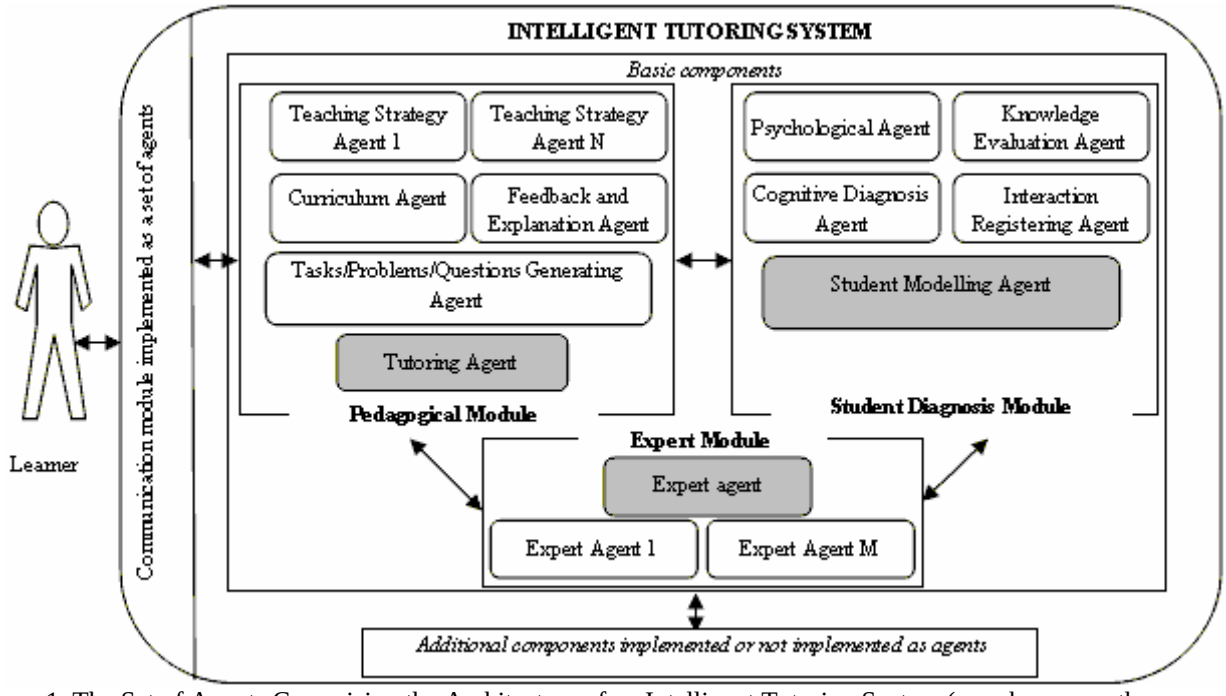

Figure 1. The Set of Agents Comprising the Architecture of an Intelligent Tutoring System (grey boxes are the managing agents in each of the components)

Table 1
Input Categories for the Determination of a Learner's Emotional State

Category	Sub-category (if any)	Examples of features	Sources
Educational environment	Learner's actions within the environment and their characteristics	Difficulty of the performed action, student reaction time, navigation in the application, absence of an action, action unrelated to the educational application, chosen options, request or refuse help	11, 12, 13
	Events within the environment	End of the test, types of made mistakes, correct/incorrect answer/solution, usefulness of help	12, 13, 14
	Characteristics	Level of difficulty of a task	14, 15
Face and head	Face	Shape and displacement of eyes, eyebrows, nose, mouth, mouth corners, lips, checks, forehead	14, 15, 16, 17,18
	Eyes	Pupil size, blink rate and duration, saccadic data (occurrence rate, length and velocity), gaze duration and fixations, eyelid's degree of openness	19, 20, 21, 22
	Head	Likelihood of nod, likelihood of shake	14, 18
Spoken language	Content	Speaks using exclamations, speaks words from a specific list of words showing an emotion	12, 22, 23
	Characteristics	Pitch, duration and intensity of the utterance, silence, phonetic features	12, 24, 25
Posture	-	Net pressure, prior and post change, reference change, net pressure change, net coverage, net coverage change	11, 14, 21
Physiological signals	-	Electromyography, facial electromyogram, finger temperature, finger pulse transmission, finger pulse amplitude, heart rate, systolic and diastolic blood pressure, respiration activation, respiration period, respiration depth, skin conductance, skin temperature, pulse transit time, pulse volume amplitude, electro-oculogram, electrocardiogram, general somatic activity	12, 21, 26, 27,28, 29
Haptic cues	Usage of the keyboard	Typing speed (normally, quickly, slowly), using of BkSp or Delete keys, hitting of unrelated keys, user does not use the keyboard	12
	Usage of the mouse	Mouse pressure	21, 30
Written language	Content	Speech act	11, 13
	Characteristics	Length of an answer, verbosity of the student	13

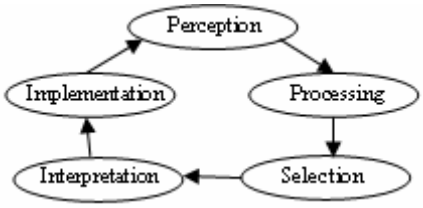

Figure 2. The Affective Loop of an Intelligent Tutoring System

On the basis of the investigation of a broad scope of research papers in the field of the emotion recognition and modelling we have defined the most widespread categories of inputs which can be used for the determination of a learner's emotional state (Table 1).

4. Agents for the Modelling of Emotions in Intelligent Tutoring Systems

Taking into account the results of the theoretical research presented in Section 3 we have developed a set of agents for the modelling of learner's emotions in an intelligent tutoring system (Figure 3). The great part of agents in the communication module manages a particular sensor, for example, video camera, posture seat, microphone, etc. The main task of these agents is to receive raw data from the sensor and to extract from them features which are used for the determination of the learner's emotional state. According to Table 1 features can be very different and multiple. Therefore an input of a particular agent is raw data from the sensor and an output is a set of features which further are sent to agents-classifiers in the student diagnosis module.

Features of face, head, eyes, posture and spoken language can be received from a unique sensor. For example, such features of the face as a shape and displacement of eyes, eyebrows and mouth are extracted from video of only one camera. In turn, in order to receive data about various physiological signals different devices are used for different signals. For this reason we have defined multiple Physiological Signals Processing Agents. Each of them manages a particular device which simultaneously can be used for capturing of several signals.

Two agents, the Spoken Language Processing Agent and the Written Language Processing Agent, are displayed by a dotted line. These agents are necessary and can be implemented only in the case if the system provides interaction in the form of natural language dialogue. Other agents can be implemented without any restrictions.

The Written Language Processing Agent and the Environment Monitoring Agent do not have external devices (sensors) attached to them. The first of them captures dialogue in a special field of the system's user interface. The second agent manages interface tools such as buttons, menus, input fields, panels, etc.

The agents of the communication module after the extraction of necessary features send them to the agents-classifiers of the student diagnosis module which carry out the following functions: receipt of the extracted features, classification of the features, integration of results of particular classifiers in order to get more exact prediction of the learner's emotional state, storing of the results both of the classification and the integration, as well as transferring of the predicted emotional state to the Emotional Modelling Agent. Thus an input of these agents is features extracted by the data processing agents of the communication module, and an output is a prediction of the learner's emotional state on the basis of a particular group of features.

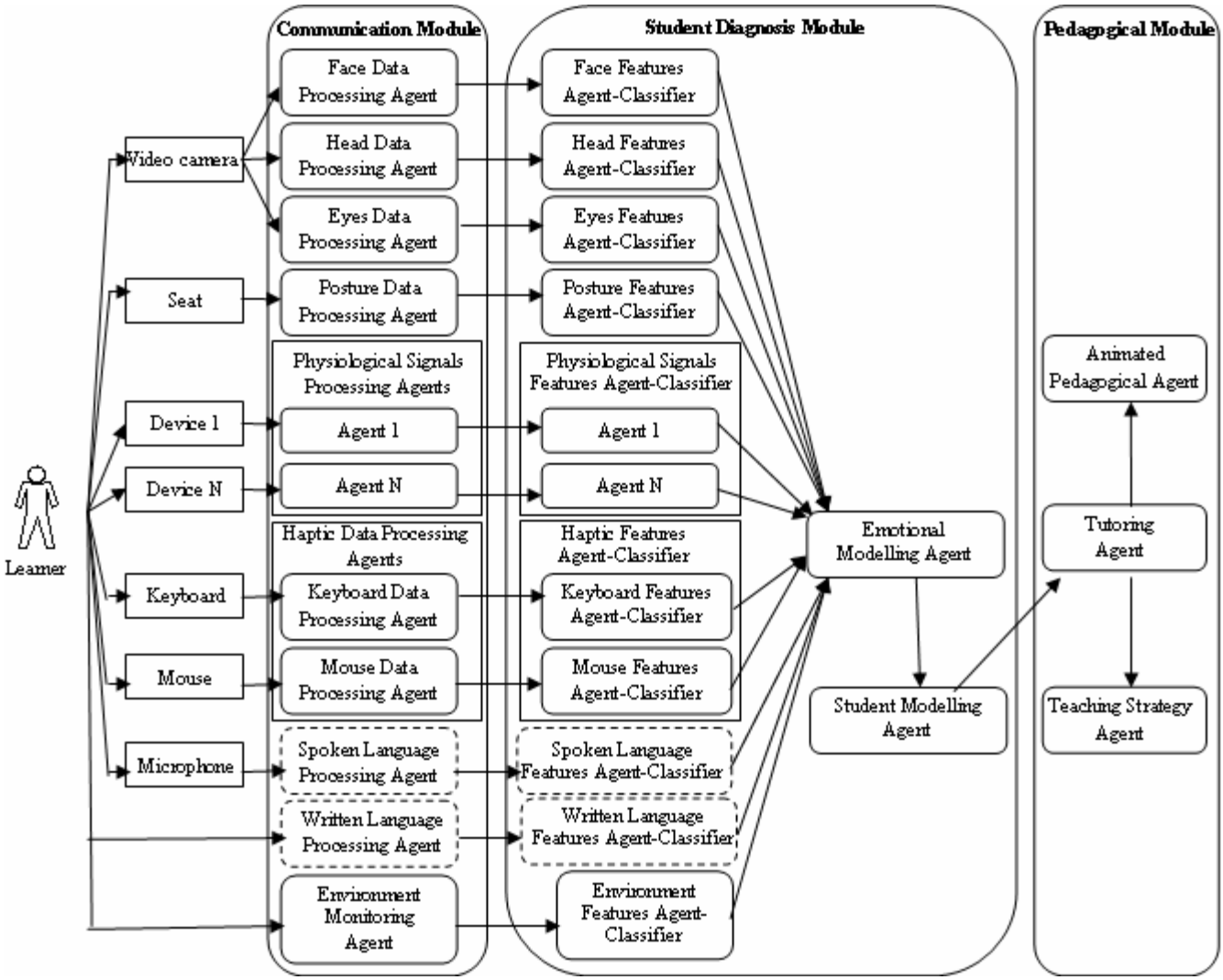

Figure 3. The Set of Agents for the Modelling of Learner's Emotions in Intelligent Tutoring Systems

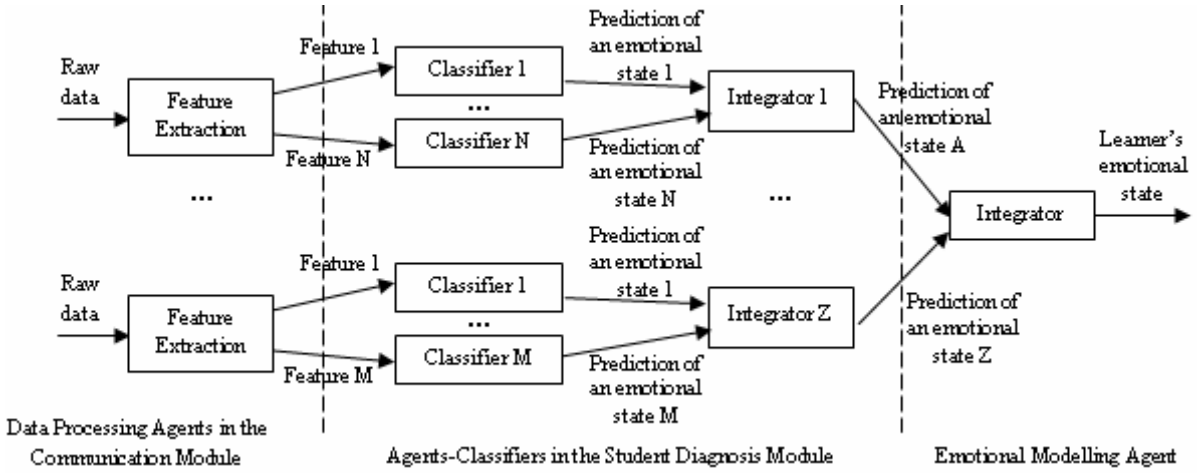

Figure 4. The Decision Making Process about the Learner's Emotional State

The Emotional Modelling Agent located in the student diagnosis module makes a final decision about the learner's emotional state by receiving the predictions of the learner's emotion from the agents-classifiers and by integrating them.

We consider that the agents-classifiers and the Emotional Modelling Agent should have their own knowledge base in order to store results of the previous classifications. It will allow them do not perform classification and integration each time when data processing agents send the information, but to use their own previous experience. For example, the Emotional Modelling Agent could use the early determined emotional state if it receives the same predictions from other agents.

Figure 4 displays the overall process of decision making. The structure of each group of agents in terms of an input, an output and the processing is shown. The decision making process corresponds to the decision level fusion of data.

The determined learner's emotional state is sent to the Student Modelling Agent alongside with the information from other agents of the student diagnosis module (Figure 1). The Student Modelling Agent transfers the received information to the Tutoring Agent which activates different agents in the pedagogical module. The Animated Pedagogical Agent and the Teaching Strategy Agent respond to the learner's emotional state. The Teaching Strategy Agent chooses the suitable strategy of learning. The Animated Pedagogical Agent, in turn, selects and expresses an emotional state. Their common goal is to maintain or to change the emotional state of the learner.

The involvement of the agents in the previously described affective loop (Section 3) is shown in Figure 5.

5. Conclusion and Future Work

The development of intelligent tutoring systems on the basis of the usage of intelligent agents allows for getting an easy maintainable, extensible and robust architecture. The paper focuses on the theoretical research directed towards the identification of agents which can be used for the recognition and modelling of learner's emotions. The main result of the research is the set of agents which are located in different modules of an intelligent tutoring system and identifies the current learner's emotional state. The agents implement the decision making chain starting from the receipt of raw data from sensors, extraction of features from them and finishing by the classification and integration of the features in order to get the current learner's emotion. Taking into account learner's emotions the system is able to adapt the learning process not only to cognitive characteristics of the learner, but also to his/her affective state.

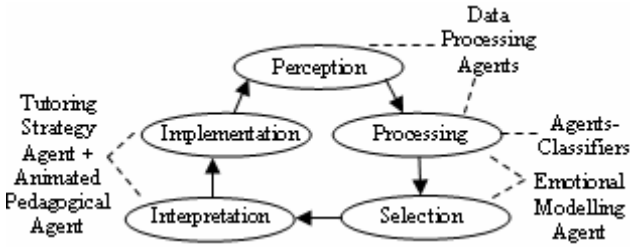

Figure 5. The Involvement of the Agents in the Affective Loop

The implementation of the complete set of agents can be very time consuming and expensive. Thus, the results of the research can be used as a guide for the selection of agents needed for certain domain or accordingly to the available resources and technologies. Some agents can be eliminated or the interaction between agents can be changed if necessary. However, our future work has two main directions: 1) specification of the detailed interaction mechanisms among the defined agents, and 2) implementation at least some of the agents, may be in collaboration with other research groups who have already developed and implemented agents for the emotion recognition and modelling.

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