Simulation of Affective Student-Tutor Interaction for Affective Tutoring Systems: Design of Knowledge Structure

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Abstract: – Almost half a century intelligent tutoring systems have been developed towards imitating the learning process of a student and a tutor interaction in a one-to-one tutoring situation. However, the gap for this kind of systems still exists in showing the adaptation skills possessed by human-tutors, particularly, the systems lack emotional intelligence. The paper presents conceptual architecture of agent-based affective tutoring system for the simulation of human-tutors' and students' interaction using multi-agent approach for representation of involved parties. Such simulation would allow assessing the effectiveness of selected teaching approach on student's emotional state, behaviour, and learning progress. Since ontologies play an important role in the agent interaction, the design and usage of knowledge structures necessary for ITS functioning including emotion ontology are considered in this paper as well.

Key-Words: – Intelligent Tutoring Systems, Emotions, Tutoring Adaptation, Agents, Ontologies, Simulation

1 Introduction

In recent years, information and communication technology has become an important part of educational systems. Intelligent tutoring systems (ITSs) are intended to support and improve the learning process in certain problem domain, considering student's knowledge and individuality as in "one-to-one" tutoring. At the same time, ITSs can be considered as knowledge-based systems possessing domain knowledge, knowledge about techniques for student modeling, and pedagogical knowledge regarding teaching strategies. However, an explicit representation of knowledge necessary for ITS functionality is still a challenging task.

In the end of 90's, a new field started to evolve – affective computing (AC) which was aimed at building computer systems able to determine user's emotions and respond accordingly [1]. Developers of intelligent tutoring systems also started to incorporate AC ideas in the behavior of these systems due to close relationship between emotions and learning. This can be considered a starting point of new ITSs generation – affective tutoring systems (ATSs) able not only to support the learning process but also to recognize student's emotions, respond to them by adapting tutoring process, and show emotions of the tutoring system itself using animated pedagogical agents.

However, students have different personalities, characteristics, needs, knowledge background, preferences, learning styles, and emotions that can influence his/hers learning. From the tutor's perspective, his personality, the way of teaching, appearance, etc. can affect an efficiency of teaching and learning process as well. But how to know, which will be the most effective tutor's personality and a way of teaching for particular student to positively influence student's emotional state, motivation, interest, behavior, and learning progress? To answer this question, the simulation of human-tutors' and students' interaction using multi-agent system (involving tutor agents and student agents) is proposed in this paper to test different teaching ways, different teaching material representation methods, etc.

The structure of the paper is as follows. Section 2 provides a short description of intelligent tutoring systems and the usage of agents in the development of ITSs, as well as the role of emotions in the learning process is explained and different ontology models describing emotions are discussed. In Section 3, some issues regarding tutoring adaptation to student's emotions are discussed and a conceptual architecture of agent-based affective tutoring system is introduced to simulate human-tutor and student interaction. Finally, conclusions and future research directions are given at the end of the paper.

2 Related Work

We have divided the related work into three subsections. First part gives a brief description of intelligent tutoring systems and their architecture, as well as explores suitability of multi-agent approach for the development of ITS's components and explains ontology role in the context of multi-agent systems and agent interaction. Second part focuses on the existing problems regarding ITS's adaptation capabilities, particularly, on the lack of emotional intelligence. Third part reviews different ontology models describing emotions for the further usage in the agent-based affective tutoring system.

2.1 Intelligent Tutoring Systems, Agents, and Ontologies

Intelligent tutoring systems are adaptive computer systems based on the theory of learning and cognition. ITSs emulate a human-tutor and provide benefits of one-on-one tutoring. ITSs are intelligent systems because their architecture and functionality are typically based on principles and methods of artificial intelligence. Such systems allow providing more natural learning process by adapting a learning environment (content, feedback, navigation, etc.) to the characteristics of a particular student. Adaptation is possible because of traditional architecture and incorporated knowledge that include [2]:

- a student diagnosis module collecting and processing information about the student (his/her learning progress, problem solving behavior, psychological characteristics, etc.) and a student model that stores this information;
- a pedagogical module responsible for implementation of the teaching process and a pedagogical model storing teaching model and strategies;
- a problem domain module able to generate and solve problems in the problem domain and a domain model storing knowledge what must be taught to the student;
- an interface module managing interaction among the system and the student through different devices.

The modern approach in the field of artificial intelligence is related to an agent paradigm [3]. Many systems for learning purposes have adopted agent paradigm to explore the interaction and dynamic changes related to the learning and teaching process. Agents are able to simulate adaptive behavior, respond to changes, plan, predict, reason, learn, and operate in dynamic environments. The common practice is to combine several agents in a single system as a result forming a multi-agent system where agents interact and cooperate together to reach goals that single agent would not be able to achieve alone. Taking into account agent capabilities, multi-agent architecture is appropriate for development of ITS due to the following reasons: [2]:

- ITS plans the learning process and communication with the student;
- ITS performs multiple, different tasks, including student's monitoring and reacting to his/her behavior, student's knowledge assessment, choosing of learning material and tasks, provision of feedback and help, adaptation of teaching strategies, etc.;
- system's behavior and operations are changing with each student's action in ITS and the system must demonstrate reactive behavior;
- system collects information about the student and must consider his/her cognitive, psychological, and affective characteristics in order to adapt the learning process;
- the system architecture is composed of several components where each of them has a set of quite independent functions. However, all components must interact in order to achieve the common goal – adapted tutoring for a particular student.

An interaction between agents is a defining characteristic to reach previously mentioned ITS's goal. One of the ways to initiate and maintain interaction among agents is their participation in communication that enables agents to base their decisions on more complete knowledge of overall situation. Effective interaction and communication among agents requires three fundamental and distinct components [4]: a common language; a common understanding of the knowledge exchanged; the ability to exchange whatever is included in the first two components. An explicit representation of knowledge is an essential task to ensure ITS functionality and usage of domain knowledge, knowledge about the student, and pedagogical knowledge related to teaching strategies and methods for domain knowledge transfer. In the context of multi-agent systems, ontologies play an important role in agent interaction by providing shared representation of domain knowledge and concepts that agents need to use during the communication. Ontology typically consists of hierarchical arrangements of the classes describing the major concepts in the domain and subclasses corresponding to more specific concepts under a particular class. Furthermore, the properties of the classes and subclasses (description of the features and attributes) can be specified together with all relevant restrictions [5].

In the field of intelligent tutoring systems, ontologies appeared in Japan in the mid-90's [6]. The literature analysis shows that ontologies in ITSs have been applied for different purposes. In some ITSs, ontologies are used for all ITS's components to provide formalization of all necessary knowledge, however, the more common approach is the usage of ontologies in only one (or two) of components. The most frequently ontologies have been developed to represent problem domain within ITSs [7, 8, 9]. Regarding pedagogical knowledge, ontologies are used to describe teaching strategies and tactics [10], learning theories [11], learning objects, e.g. learning objective, teaching method, delivery type, assessment type, and assessment outcome [12], recommend personalized learning content [9]. The information about the student is also represented using ontologies within ITSs [13, 14]. Also for the representation of the ITS interface or communication module, interface ontologies have been proposed [9, 15].

2.2 Intelligent Tutoring Systems and Emotions

As mentioned at the beginning, the ITS-based learning process is very similar to the process when a student and a tutor interact in a one-to-one situation, which, according to Benjamin Bloom [15], is an ideal condition for learning. Therefore, an effective intelligent tutoring should simulate what good human-tutors do when implementing individualized instruction. Although it is considered that developed ITSs are capable to adapt teaching process similar as human-tutors do, there is still a gap between perfect adaptation skills and current developments. The main reason for this gap is considered the ITS's lack of an emotional intelligence [17]. It is important to add that understanding emotions is quite a complicated process even for humans because each emotional state has its own reasons and current emotions may affect person's further behavior. However, tutors can evaluate emotional states of the student with a rather high reliability on the basis of facial expressions, body language, tone of voice, and speech content. Consequently, experienced human-tutors can adapt the teaching process taking into account the student's knowledge level, emotional state, and behavior during learning.

Previous studies have shown that emotions can influence various aspects of human behavior and cognitive processes, such as attention, long-term memorizing, decision making, understanding, remembering, analyzing, reasoning, and application of knowledge in task solving [18, 19]. Emotional states such as confusion, curiosity, interest, flow, joy, boredom, frustration, and surprise have become particularly relevant in learning and can influence student's problem solving abilities and even leave impact on willingness to engage in the learning process, as well as they can affect motivation to learn [20]. As a result, the field of affective (or emotionally intelligent) tutoring systems started to evolve by integrating ability to recognize student's emotions and to respond to them by adapting tutoring process and showing emotions of the tutoring system itself using animated pedagogical agents into the traditional intelligent tutoring system [21].

Functionality of affective tutoring systems requires inclusion of not only already previously listed knowledge regarding students, problem domain, and pedagogy but also a common representation and understanding of emotions. In terms of agent-based ITSs, an explicit emotion representation enables agents to imitate possible student's reactions during the learning process and to express them to pedagogical agents (tutors). Pedagogical agents, in turn, can recognize reason and act on emotions by changing tutoring situation accordingly, adapting pedagogical activities, as well as expressing its own emotions. Emotion ontology is discussed in the next section as knowledge representation scheme used in the development of agent-based affective tutoring system.

2.3 Emotion Ontology

Wide spectrum of different ontology models describing various emotions have been developed during the past years. The models vary from point of view of formalization, underlying psychological theory and abstraction level. The meaning of emotion in spite of long research and heated discussions is still very vague and as a result there is no consensus of what emotions really are. As [22] notes, in the field of affective computing the lack of common understanding of emotions' nature often leads researchers to choose definition which fits for a specific task. Therefore, many propositions of emotion description have been introduced.

From the psychology perspective there are two main directions regarding origin of emotions: the bodily feelings (supported by feeling theories) and cognition (supported by appraisal theories) [23]. Most of existing ontology models support one particular theory which belongs either to feeling or appraisal theories, or try to connect both directions. The significant amount of work has been dedicated to the creation of generic ontology that does not rely on single emotion theory but instead organizes emotions on a higher level. A very solid step towards such ontology is EMO (Emotion Ontology) - one of the richest and most generic knowledge structures which classify a lot of emotions independently from any emotion theory [23]. The EMO ontology is based on BFO (Basic Formal Ontology) upper ontology which defines general terms and OMD (Ontology of Mental Diseases) ontology which describes basic terms regarding human mental health. The HEO also is a generic ontology; however, it takes a different approach [24]. Instead of reorganizing concepts so that they would not confirm any particular theory HEO describes most of the popular emotion theories. In addition, a lot of effort has been put to create generic ontology for more specific purposes, such as EmotionsOnto for the description of emotion responses [25].

As mentioned before, there are ontology models which are based on one emotion theory and serves for one task. Psychological theories come from inherently non-formal science so they are not formalized very well or are not defined formally at all. In contrast, computer science tends to formalize everything. This has led to the fact that some psychological theories that are formalized, e.g., OCC model (categorizes emotions into three classes depending on elicitation factor [26]) or PAD model (allows assigning numerical value to every emotion using three coordinates: Pleasure, Arousal, Dominance [27]), are used a lot – mostly because it is easy to use these models rather than them being the best or the richest.

One of examples for such task ontology is OLA which uses OCC-based ontology to predict student's emotions during test [28]. The Japanese Emotion Ontology is based on PAD model and can be used in creating realistic interactive characters [29]. There are also some ontology models that consider several basic emotions (the most used theory of this kind is Ekman's theory according to which six basic emotions exists: anger, sadness, joy, disgust, surprise and fear [30]). For example, in [31] four emotion theories are combined to categorize all emotions into 8 groups for sentiment analysis in Twitter. In [31], basic emotions are also used together with application-specific secondary emotions. The EmOCA ontology is based on two factor theory which maps primary emotions onto secondary emotions and belongs to previously mentioned feeling theories [33]. Two of the latter developments are created for affective context analysis.

From the formal point of view, most of ontology models are strictly formal with rather well defined classes and properties, such as EMO [23] or EmotionsOnto [25]. In [24] various emotion theories are connected via properties. Most of ontology models have been described in OWL [34] which is Semantic Web standard for knowledge formalization. Some models, such as EmOCA [33], are described using RDF - another standard used for data exchange on web [35]. Japanese Emotion Ontology extends OWL by using EmotionML which is special markup language for description of emotions [36].

By researching various models of emotion ontology, it can be concluded that structure and formalization level of emotion ontology differs depending on the task and domain. Emotions are complex mechanisms thus there is no consensus on one psychological theory for emotion emergence. Since different needs regarding semantics and formalization of emotions for various tasks exist, it is doubtful that there can be common application ontology for all systems. Different needs emerge due to several reasons which have no connection to ambiguity of emotion. First of all, for some domains, rich model of emotions does not make sense, e.g., in emotion detection from facial expressions it is technically impossible to distinguish small nuances, while for others, such as believable human simulation, ability to model various emotional details is crucial. Secondly, for some tasks it is needed to categorize emotions by basic emotion (i.e., define synonyms), while for others it is more important to infer new knowledge (i.e., the cause of emotion) from the ontology.

In the context of affective tutoring systems, emotion ontology should be adapted to learning purposes. Since learning process is closer to the second type of tasks (inference of new knowledge), ontology can serve as a mean for understanding emotion causes so that ATS could take actions to adapt tutoring situation to student's emotions.

3 Agent-Based Affective Tutoring System

In this section, main challenges regarding tutoring adaptation to students' emotions are discussed, as well as a conceptual architecture of agent-based

ATS for the interaction simulation between human-tutors and students is designed. Simulation is used for the assessment of selected tutoring style on student's emotional state and learning progress before system's use in real conditions. Emotion ontology is used as one of components to represent common knowledge between agents.

3.1 Adaptation Issues in Affective Tutoring Systems

Currently, many ITSs are rebuilt to include capabilities for the emotion recognition, emotion modeling and tutoring process adaptation [37, 38, 39], however, greater focus has been directed to detection and classification of student's emotions. Thus, relatively little attention has been paid to a problem how to adapt tutoring to a student's emotional state [40, 41].

Providing students with cognitive and affective support is generally recognized as an important condition for successful learning. Nevertheless, more research is needed that would allow to explain how both types of support may be included in tutoring strategies and how to implement them in ITSs as part of the pedagogical module. Traditionally, the pedagogical module is ITS component that imitates the human-tutor and determines appropriate tutoring strategies, adapts the tutoring process (chooses the next topic and its presentation type, tasks to solve and their difficulty, type of assistance and feedback, etc.) depending on the curriculum, student's cognitive needs, and abilities. Moreover, this module plans and manages interaction with the student [42].

It should be noted that there is no "one-size-fits-all" strategy in tutoring because students have different personalities, characteristics, needs, knowledge background, preferences, learning style, etc., as well as emotions that can influence his/hers learning [43]. In [44] authors have even found that students with different learning styles prefer different pedagogical support when learning in a one-to-one educational environment. Therefore every student should have different tutoring approach that would allow ensuring the knowledge acquisition and maintenance of the optimal emotional state for the particular student. Many ITSs make decisions that are inappropriate for the student in terms of their profile, personality and emotional characteristics (due to inconsistencies in the presentation style, an inadequate level of content or strategy to address tutoring situation) thus negatively influencing student's performance during the learning [12].

3.2 Conceptual Architecture of Agent-Based Affective Tutoring System

In general, multi-agent systems offer several benefits which are useful in the development of long term adaptive systems. Affective tutoring system can be considered as a long term adaptive system if it follows students during several courses rather than few tasks within one learning session. In this case, a system has to model student in a believable manner as well as store the previous knowledge structure and behavior of the student. First of all, multi-agent approach allows building a dynamic and easily changeable system (several students and tutors can be added). Secondly, students' agents are autonomous units which are able to "experience" emotions and exhibit student-like behavior. This property enables student simulation before content adaptation for a real student. Finally, in a system with clearly defined roles (e.g. several students and corresponding tutors) the agent mechanisms allow the design of the system to be more intuitive [45].

To support both emotional and cognitive aspects, the architecture of multi-agent based affective tutoring system is proposed that includes shared emotional ontology between pedagogical agents and student agents (see Fig.1.). Adaptation of the tutoring process is planned through the creation of personalized emotional pedagogical agent for the particular student (student agent) based on student's characteristics. Each student learns better with particular type of tutors because they also have their own personality, the way of teaching, appearance, etc., that can affect an efficiency of teaching and learning process [46].

Usage of the agent-based system allows simulating human-tutors and students as an interaction between agents where each agent represents a tutor or a student. Similar idea regarding student simulation within ITS has been expressed also in [47, 48], however, student's emotional state is not considered as an important factor during the agent interaction. In our proposed system, the simulation of agents' interaction will be used to evaluate the effectiveness of selected pedagogical agent and its teaching approach (used tutoring strategies) on student's emotional state, behavior and learning progress. Thus the planned multi-agent agent-based affective tutoring system will be implemented as a simulation system to carry out experiments needed to test different teaching methods, techniques and pedagogical approaches, different learning material representation techniques and different ordering of material contents to see how these decisions affect behavior of student's agent.

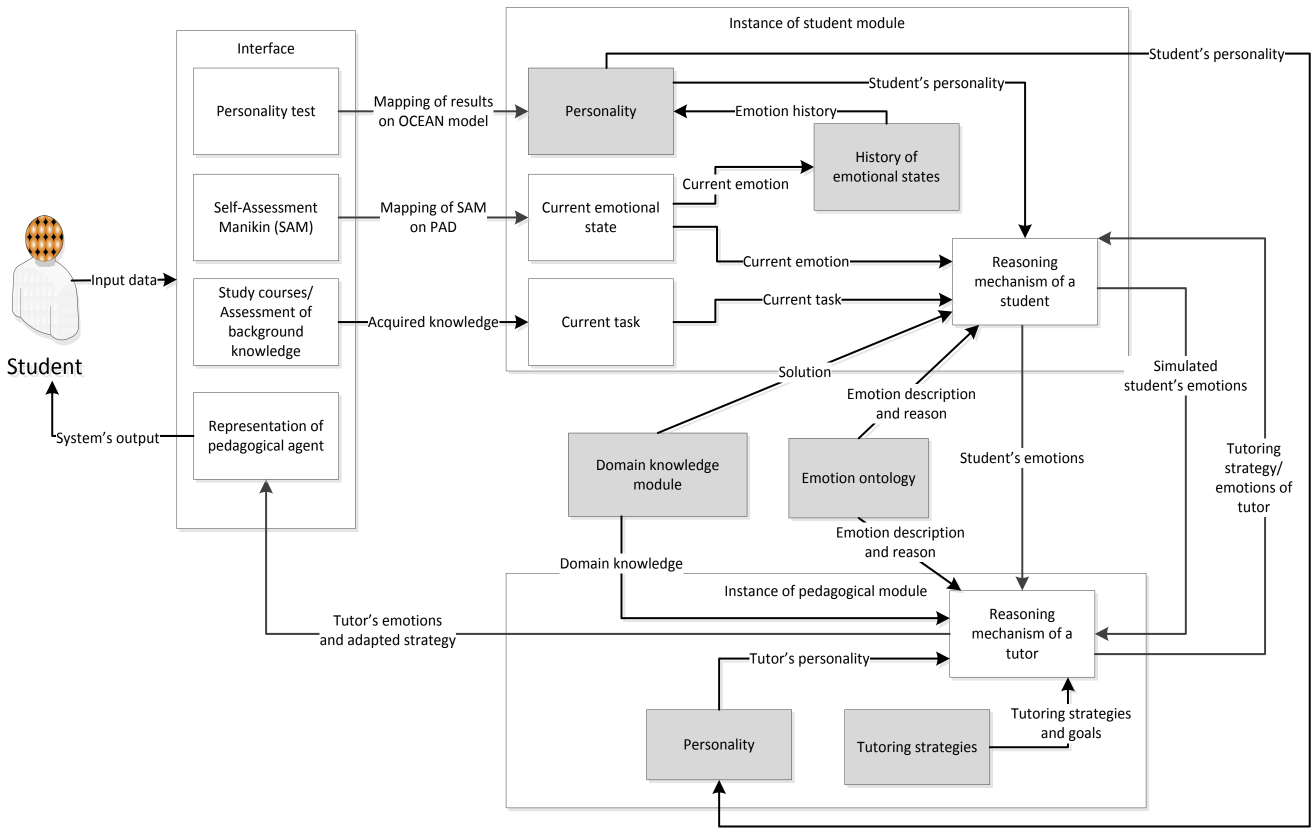

Fig.1. Conceptual architecture of multi-agent based affective tutoring system

The system will consist of two types of intelligent agents: student agent and tutor agent. The interface and domain knowledge module will be implemented as passive components without complex reasoning capacity. Design of multi-agent systems is usually organized into two levels, namely, a micro and macro level [45]. Generally, a micro level consists of the development of individual agent architecture, reasoning processes, etc., while design of a macro level is concerned with the development of agent inclusion into one system, i.e., communication protocols and semantics for common understanding. We propose to split the knowledge structure of the system into micro and macro levels which means that there are some common knowledge, such as emotions ontology, and some private knowledge for each agent. In Fig.1, components that hold knowledge are colored grey.

We wanted for the system to be as non-invasive, as possible, however, although there are some ideas for student emotion assessment from action history in [28] we found that the model acquired from similar methods is too simple for generating believable behavior. Also, the model acquired from facial expression recognition allows focusing mainly on the so-called basic emotions. A few attempts have been to model more complex emotions, however, the accuracy level is still considered to be too low [49]. We propose to use Self-Assessment Manikin (SAM) [50] which would be based on self assessment of the student after a task or block of tasks. SAM can be then mapped on PAD model – the idea and method for linking both models is described in [51]. After that, PAD model can be mapped on OCC as a result acquiring (a) particular emotion and (b) the reason of the emotion which can be inferred from OCC. The mapping of both models is used in ALMA – a layered model of affects implemented on virtual student and tutor [52]. The bodily feelings are not considered, as we only have inputs from human-computer interface.

Shared emotion ontology should be used so that both involved parties (student and tutor) would understand the emotions of each other. Understanding student's emotions and eliciting factors of student's emotions, would allow tutor agent to learn and as a result adapt better. Partly usable ontology for our case might be the one described in [28] as long as a suitable inference mechanism for our task is developed.

Also, none of emotion ontologies allows reflecting personality type of an agent and how the personality type influences emotions. For modeling student's personality, we propose to use Five-Factor Model (or OCEAN model) [53], which is commonly used model for creating personality for agents (see, e.g., [54]). Personality will be formed as a combination of OCEAN parameters, for this purpose a test have been developed [55]. The test will be used to start working with the system, later on correcting personality according to the history of student's actions.

According to the determined student's personality, an appropriate pedagogical agent will be selected with the initial personality, behavior, and teaching style that influence agent's reasoning mechanisms. There are defined some tutor's instructional roles (e.g., mentor, tutor-expert, motivator, etc.) in [46] to examine the effectiveness of specific agent design features on learning outcomes. However, there is no clear understanding regarding functionality of various tutor roles as well as a link between student's personality and tutor's role [56].

The simulation and decision making will be done in reasoning mechanism. The main task of student reasoning mechanism is to generate emotion and according behavior. During agent interaction, emotional responses, behavior and reasoning expressed by student's agent will be used as a feedback for the tutor's behavior adaptation, including changes in assigned initial personality, teaching style, emotional characteristics, etc. Tutor reasoning mechanism will have following tasks: (1) to distinguish between simulated and real response from the student, (2) to choose appropriate tutoring strategies, (3) to determine whether the results acquired from student's agent are satisfactory.

4 Conclusion

In the paper, intelligent tutoring systems and their architecture are shortly described, as well as a multi-agent approach in the ITS development is discussed. Currently, an assumption is that there still exists a gap for ITSs regarding adaptation skills and capabilities possessed by human-tutors, particularly, the lack of emotional intelligence. Therefore, the influence of emotions on the learning is explained and different ontology models describing emotions are reviewed to analyze their possible usage in the ATS development.

The interaction simulation between tutor and students using multi-agent approach (involving pedagogical agents and students' agents) is proposed to evaluate the effectiveness of different teaching strategies, teaching styles and different sequences of teaching material on student's emotional state, interest, knowledge acquisition, behavior and learning progress. Emotion ontology is included as one of the additional system's components to improve ITS adaptation skills and incorporate common understanding of emotions between agents. A multi-agent approach allows building a dynamic and easily changeable system as well as simulating students as autonomous agents with ability to "experience" emotions and demonstrate student-like behavior. This property enables simulation of a tutor and a student (and their interaction) before tutoring adaptation to a real student thus allowing assessing the effectiveness of pedagogical agent's behavior.

Future work will be focused on a detailed design of agents' architecture and interaction mechanisms, including development of agents' functionality, behavior and communication principles using interaction protocols. In addition, an ontology-based hierarchical structure of pedagogical model will be developed to ensure dynamically adapted tutoring process based on students knowledge and emotions. Pedagogical ontology will be built to represent domain-independent pedagogical knowledge covering concepts related to content planning, delivery planning and tutoring decisions considering also emotional factors. Development of such ontology will contribute to the creation of general purpose ATS shell that can be used for teaching different problem domains.

Currently, the emotion acquisition is proposed based on student's self-assessment, his/her personality analysis and interaction with the system. However, after successful simulation of a tutor and a student interaction, emotion detection step can be extended through integration of sensors for affective data acquisition, e.g. facial expressions. This improvement would contribute to the development of less intrusive affective tutoring system for the student.

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References:

[1] W. Picard, *Affective Computing*. MIT Press, Cambridge, 1997.

[2] S. Petrovica, A. Anohina-Naumeca, "Design and Implementation of Agent Interaction Mechanisms for Emotionally Intelligent Tutoring Systems", *Scientific Journal of Riga Technical University (5. series). Applied Computer Systems*, Vol.13, 2012, pp 44-53.

[3] R.M. Viccari, P.A. Jaques, R. Verdin, "Preface", *Agent-Based Tutoring Systems by Cognitive and Affective Modeling*, 2008, pp. xiii-xxxiii.

[4] Y. Shoham, K. Leyton-Brown, *Multiagent Systems - Algorithmic, Game-Theoretic, and Logical Foundations*, Cambridge, UK: Cambridge University Press, 2009.

[5] E. Oguejiofor, R. Kicinger, E. Popovici, T. Arciszewski, K.A. de Jong, "Intelligent Tutoring Systems: An Ontology-Based Approach", *International Journal of IT in Architecture, Engineering and Construction*, Vol. 2, No. 2, 2004, p. 115-128.

[6] V. Graudina, "An Overview of Ontology Usage in Computer-Based Tutoring Systems", *ICTE in Regional Development: Annual Proceedings of Vidzeme University College*, 2007, pp.70-77.

[7] W.R. Murray, "Intelligent Tutoring Systems for Commercial Games: The Virtual Combat Training Center Tutor and Simulation", *Proceedings of the 2nd Artificial Intelligence and Interactive Digital Entertainment Conference*, 2006, pp. 66-71.

[8] H.-S. Chung, J.-M. Kim, "Ontology Design for Creating Adaptive Learning Path in -Learning Environment", *Proceedings of the International MultiConference of Engineers and Computer Scientists*, 2012, pp. 585-588.

[9] B. Vesin, M. Ivanovic, A. Klasnja-Milicevic, Z. Budimac, "Protus 2.0: Ontology-Based Semantic Recommendation in Programming Tutoring System", *Expert Systems with Applications*, Vol.39, No.15, 2012, pp. 12229-12246.

[10] R.A. Sottilare, H.K. Holden, "Motivations for a Generalized Intelligent Framework for Tutoring (GIFT) for Authoring, Instruction, and Analysis", *Recommendations for Authoring, Instructional Strategies and Analysis for Intelligent Tutoring Systems (ITS)*, 2013, pp. 1-9.

[11] Y. Hayashi, J. Bourdeau, R. Mizoguchi, "Using Ontological Engineering to Organize Learning/Instructional Theories and Build a Theory-Aware Authoring System", *International Journal of Artificial Intelligence in Education*, Vol.19, No.2, 2009, pp. 211-252.

[12] S. Wang, "Ontology of Learning Objects Repository for Pedagogical Knowledge Sharing", *Interdisciplinary Journal of E-Learning and Learning Objects*, Vol.4, No.1, 2008, pp. 1–12.

[13] A. Yessad, C. Faron-Zucker, R. Dieng-Kuntz, M.T. Laskri, "Ontology-based Semantic Relatedness for Detecting the Relevance of Learning Resources", *Interactive Learning Environments*, Vol.19, No.1, 2011, pp. 63-80.

[14] M.A. Abbas, W.F.W. Ahmad K.S. Kalid, "Semantic Web Technologies for Pre-School Cognitive Skills Tutoring System", *ARPN Journal of Engineering and Applied Sciences*, Vol.10, No.23, 2015, pp. 17758-17765.

[15] P. Bakhtyari, "Automatic Feedback Generation – Using Ontology in an Intelligent Tutoring System for both Learner and Author Based on Student Model", *Proceedings of ICEIS 2006: Databases and Information Systems Integration*, 2006, pp. 116-123.

[16] B.S. Bloom, "The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring", *Educational Researcher*, Vol.13, No.6, 1984, pp. 4-16.

[17] N. Thompson, T.J. McGill, "Affective Tutoring Systems: Enhancing E-Learning with the Emotional Awareness of a Human Tutor", *International Journal of Information and Communication Technology Education*, Vol.8, No.4, 2012, pp. 75-89.

[18] S.D. Craig, A.C. Graesser, J. Sullins, B. Gholson, "Affect and Learning: An Exploratory Look into the Role of Affect in Learning with AutoTutor", *Journal of Educational Media*, Vol.29, 2004, pp. 241-250.

[19] B. Lehman, S.K. D'Mello, N. Person, "The Intricate Dance between Cognition and Emotion during Expert Tutoring", *Proceedings of 10th International Conference on Intelligent Tutoring Systems (Part II)*, 2010, pp. 433-442.

[20] N. Schwarz, "Emotion, Cognition, and Decision Making", *Journal of Cognition and Emotion*, Vol.14, No.4, 2000, pp. 440–443.

[21] M. Ochs, C. Frasson, "Emotionally Intelligent Tutoring Systems (EITS)", *Proceedings of the FLAIRS 2004 Conference*, 2004, pp. 251-256.

[22] J. Yan, D.B Bracewell, F. Ren, S. Kuroiwa, "The Creation of a Chinese Emotion Ontology Based on HowNet", *Engineering Letters*, Vol. 16, No. 1, 2008, pp. 166-171.

[23] J. Hastings, W. Ceusters, B. Smith, K. Mulligan, "Dispositions and Processes in the Emotion Ontology", *ICBO: International Conference on Biomedical Ontology*, 2011, pp. 71-78.

[24] M. Grassi, "Developing HEO Human Emotions Ontology", *Biometric ID Management and Multimodal Communication*, 2009, pp.244-251.

[25] R. Gil, J. Virgilli-Goma, R. Garcia, C. Mason, "Emotions Ontology for Collaborative Modelling and Learning of Emotional Responses", *Computers in Human Behavior*, Vol. 51, Part B, 2015, pp. 610 - 617.

[26] A. Ortony, G.L. Clores, A. Collins, "The Cognitive Structure of Emotions", *Cambridge, MA: Cambridge University Press*, 1988.

[27] J.A. Russell, A. Mehrabian, "Evidence for a Three-Factor Theory of Emotions", *Journal of Research in Personality*, Vol. 11, No.3, 1977, pp. 273–294.

[28] W. Eyharabide, A. Amandi, M. Courgeon, C. Clavel, C. Zakaria, J. C. Martin, "An Ontology for Predicting Student Emotions During A Quiz", *Proceedings of IEEE Workshop on Affective Computational Intelligence*, 2011, pp. 76-83.

[29] K. Kaneko, Y. Okada, "Building on Japanese Emotion Ontology from Knowledge on the Web for Realistic Interactive GC Characters", *Proceedings of 7th International Conference on Complex, Intelligent, and Software Intensive Systems*, 2013, pp. 735-740.

[30] P. Ekman, "Are there basic emotions?", *Psychological Review*, Vol. 99, No. 3, 1992, pp. 550-553.

[31] M. Sykora, T. Jackson, A. Brien, S. Elayan, "Emotive Ontology: Extracting Fine-Grained Emotions from Terse, Informal Messages", *IADIS International Journal on Computer Science and Information Systems*, Vol. 2, No. 2, 2013, pp. 106-118.

[32] K.I. Benta, A. Rarau, M. Cremene, "Ontology Based Affective Context Representation", *Proceedings of the Euro American conference on Telematics and information systems*, 2007, Article No. 46.

[33] F. Berthelon, P. Sander, "Emotion Ontology for Context Awareness", *Proceedings of 4th IEEE International Conference on Cognitive Infocommunications*, 2013, pp. 59-64.

[34] W3C, "Web Ontology Language", *available at https://www.w3.org/2001/sw/wiki/OWL*, 2013.

[35] W3C, "Resource Description Framework", *available at https://www.w3.org/RDF/*, 2014.

[36] W3C, "Emotion Markup Language (EmotionML) 1.0", *available at https://www.w3.org/TR/emotionml/*, 2014.

[37] S.K. D'Mello, A.C. Graesser, "AutoTutor and Affective AutoTutor: Learning by Talking with Cognitively and Emotionally Intelligent Computers that Talk Back", *ACM Transactions on Interactive Intelligent Systems*, Vol.2, No. 4, 2012, pp. 23:2-23:39.

[38] N. Jaques, C. Conati, J.M. Harley, R. Azevedo, "Predicting Affect from Gaze Data during Interaction with an Intelligent Tutoring System", *Proceedings of the 12th International Conference on Intelligent Tutoring Systems*, 2014, pp. 29-38.

[39] M. Wixon, I. Arroyo, K. Muldner, W. Burleson, C. Lozano, B.P. Woolf, "The Opportunities and Limitations of Scaling Up Sensor-Free Affect Detection", *Proceedings of the 7th International Conference on Educational Data Mining*, 2014, pp. 145-152.

[40] S.K. D'Mello, N. Blanchard, R. Baker, J. Ocumpaugh, K. Brawner, "I Feel Your Pain: A Selective Review of Affect-Sensitive Instructional Strategies", *Design Recommendations for Adaptive Intelligent Tutoring Systems: Volume 2 – Instructional Management*, 2014, pp. 35-48.

[41] R. Sottilare., J. DeFalco, J. Connor, "A Guide to Instructional Techniques, Strategies and Tactics to Manage Learner Affect, Engagement, and Grit", *Design Recommendations for Adaptive Intelligent Tutoring Systems: Volume 2 – Instructional Management*, 2014, pp. 7-33.

[42] S. Petrovica, "Adaptation of Tutoring to Students' Emotions in Emotionally Intelligent Tutoring Systems", *Proceedings of Second International Conference on e-Learning and e-Technologies in Education*, 2013, pp. 131-136.

[43] S. Chaffar, C. Frasson, "Using an Emotional Intelligent Agent to Improve the Learner's Performance", *Workshop on Emotional and Social Intelligence in Learning Environments, in the 7th International Conference on Intelligent Tutoring Systems*, 2004, pp. 37-43.

[44] M. Ally, P. Fahy, "Using Students' Learning Styles to Provide Support in Distance Education", *Proceedings of the 18th Annual Conference on Distance Teaching and Learning*, 2002, pp. 1-5.

[45] M. Wooldridge, *An Introduction to Multi-Agent Systems*, John Wiley&Sons, 2009.

[46] A.L. Baylor, Y. Kim, “Simulating Instructional Roles through Pedagogical Agents”, *International Journal of Artificial Intelligence in Education,* Vol.15, No.2, 2005, pp. 95-115.
[47] V. Graudina, J. Grundspenkis, “The Role of Ontologies in Agent-Based Simulation of Intelligent Tutoring Systems”, *Proceedings of the 19th European Conference on Modelling and Simulation*, 2005, pp. 446-451.
[48] M. Spoelstra, E. Sklar, “Agent-Based Simulation of Group Learning”, *Multi-Agent-Based Simulation VIII: International Workshop, MABS 2007, Revised and Invited Papers*, 2008, pp 69-83.
[49] A. Adams, P. Robinson, “Automated Recognition of Complex Categorical Emotions from Facial Expressions and Head Motions”, *Proceedings of International Conference on Affective Computing and Intelligent Interaction*, 2015, pp. 355-361.
[50] M. Bradley, P. Lang, “Measuring Emotion: The Self-Assessment Manikin and the Semantic Differential”, *Journal of Behavioral Therapy and Experimental Psychiatry,* Vol. 25, No 1, 1994, pp. 49-59.
[51] J. Broekens, W.P. Brinkman, “AffectButton: A Method for Reliable and Valid Affective Self-Report”, *International Journal of Human-Computer Studies archive*, Vol. 71, No. 6, 2013, pp. 641-667.
[52] P. Gebhard, “ALMA – A Layered Model of Affect”, *Proceedings of the 4th International Joint Conference on Autonomous Agents and Multiagent Systems*, 2005, pp 29-36.
[53] R.R. McCrae, O.P. John, “An Introduction to the Five-Factor Model and Its Applications”, *Journal of Personality*, Vol. 60, No. 2, 1992, pp. 175–215.
[54] M. Tavakoli, M. Palhang, M. Kazemifard, “Three Levels of Information Processing: Improvement using Personality”, *Proceedings of 2014 Iranian Conference on Intelligent Systems (ICIS)*, 2014, pp. 1–6.
[55] J.P. Oliver, “The Big Five Project Personality Test”, *available at http://www.outofservice.com/bigfive/*, 2015.
[56] Y. Kim, A.L. Baylor, “Research-Based Design of Pedagogical Agent Roles: A Review, Progress and Recommendations”, *International Journal of Artificial Intelligence in Education*, Vol. 26, No. 1, 2016, pp. 160-169.