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Prototype of Multiagent Knowledge Assessment System for Support of Process Oriented Learning

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Abstract-**The paper describes a multiagent concept map based system that has been developed for learners' knowledge assessment in process-oriented learning. At the meta-level it consists of an intelligent agent for assessment of learners' current knowledge level and a group of human agents, i.e. learners who are communicating with this agent. The paper presents the architecture of the system in terms of modules, their functions and interaction, giving the special attention to the intelligent assessment agent, which at the moment is composed of communication, knowledge evaluation, interaction registering, and expert agents. It also includes an example of system's performance, which is accompanied by screen shots, and test results of the intelligent knowledge assessment system in four different learning courses.**

I. INTRODUCTION

Nowadays when information age starts to replace industrial age modern organizations realize that knowledge is their most important asset. As a consequence a new type of intellectual work, the so-called knowledge work, emerges. It is obvious that teaching and learning processes also should be changed for the purpose of more effective turning of information into knowledge.

Efforts to provide more effective and flexible teaching and learning process from the point of view of learning place, time and pace using rapidly growing information and communication technology have lasted already some decades. During this time a huge amount of systems and environments have been developed, and a broad set of terminology has appeared including such terms as computer-based learning, distance learning, e-learning, Internet-based learning, online learning, and Web-based learning, for which according to [1] an umbrella term is technology-based learning. However, regardless of significant achievements in the field of technology-based learning the main disadvantage of known systems is their insufficient adaptability to the acquired knowledge level and skills of a particular learner, as well as his/her demands towards feedback and help.

New hopes for better solutions emerged about thirty years ago when the first intelligent tutoring system SCHOLAR [2] was developed, having given an origin to the successor systems of such kind (SOPHIE [3], BUGGY [4], WEST [5], LISP Tutor [6], GUIDON [7], etc.). Intelligent tutoring systems using methods and principles of artificial intelligence in their architecture and operation provide the most suitable learning for learner's abilities, knowledge, characteristics and needs. They store knowledge about problem domain, teaching strategies, and learners [8]. Today a new direction in their development is related with the application of intelligent agents [9], [10], [11], [12], which provide simplicity of analysis, implementation and maintenance of systems and also improve such aspects of their performance as reliability, computational efficiency, robustness, responsiveness [13], etc. Agents have such properties as autonomy, reactivity, proactivity, social capability, capabilities of learning and reasoning, adaptability, and mobility. They are able to act in complex dynamic environments performing tasks entrusted to them [14]. All the abovementioned properties are desirable for intelligent tutoring systems. It is the main reason why agent technology has recently become especially popular in the development of such kind systems.

Generally, intelligent tutoring systems have many tasks: monitoring of learner's actions and responding to them appropriately, selection and presentation of learning material, ensuring of feedback and help, adaptation of teaching strategy, and assessment of learner's knowledge level [14]. However, analysis of available publications reveals that such issues as continuous assessment of learner's knowledge and skills, as well as more sophisticated tools for support of teaching and learning process to satisfy the growing demands of a teacher and a learner have not met enough attention from the developers of intelligent tutoring systems. The paper presents a multiagent intelligent system which gives a teacher an opportunity to assess learners' knowledge level at each stage of the learning process, and to use assessment results for analysis of quality and suitability of learning material, for changing teaching methods timely, and promoting a learning course towards achievement of desirable characteristics of learners' knowledge.

The remainder of this paper is organized as follows. Section II presents such underlying concepts of the developed system as process oriented learning and concept maps. The architecture of the system from the point of view of used technologies as well as modules and their functions together with the scenario of interaction between the system and their users are described in Section III. Section IV introduces the intelligent agent of learner's knowledge assessment, which comprises the core of the system. Section V gives attention to the results of the system testing in four different learning

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courses. Some related works are discussed in Section VI. Finally, Section VII presents conclusions and outlines some directions for future work related to the further development of the system.

II. UNDERLYING CONCEPTS OF THE SYSTEM

Qualitative teaching and learning process is characterized by the fact that it is based on strengths of a learner and compensates his/her weaknesses. It may be achieved by a systematic assessment of learner's knowledge level and use of results for changing the teaching methods and the learning content timely in order to achieve desirable knowledge characteristics. Thus, assessment focuses on process of knowledge acquisition and becomes its integral part promoting process-oriented learning.

In process oriented learning a teacher divides a learning course into some stages. The notion of a stage is not strictly defined and it can be any logically complete part of a learning course, for example, a chapter or a topic. At the end of each stage the teacher makes assessment of learner's knowledge level. Methods of assessment depend on the teacher and specificity of the learning course. Assessment in the proposed system is based on the notion of concept maps.

Concept maps are a specific kind of mental model and a method for representation and measuring of individual's knowledge [15]. They are universal enough, as may be visualized using nodes and arcs that represent concepts and conceptual links, respectively. In the developed system two types of conceptual links are used. Important conceptual links show that relationships between the corresponding concepts are considered as important knowledge in a given learning course. Less important conceptual links specify that relationships between the corresponding concepts are considered as desirable knowledge in a given learning course. An example of a concept map for the learning course "SQL Fundamentals" is given in [16].

Thus, using the developed intelligent system a teacher prepares a corresponding concept map for each stage of the learning course, specifies one or several initial concepts and publication date of the map (date when a concept map will become accessible for learners), and makes knowledge assessment at the end of each stage (Fig. 1).

It is important to note how a concept map for each stage is formed. It is prescribed that learners should acquire a certain set of concepts at the first stage of a learning course. These concepts and relationships between them are included into the first concept map of the learning course. At the second stage new concepts are taught. A teacher adds these concepts to the concept map of the first stage, but doesn't change the relationships among already existing concepts. Thus, a concept map of each stage is not anything else than extension of a concept map of the previous stage. A concept map of the last stage displays all concepts in the learning course and relationships between them as it is shown in Fig. 2.

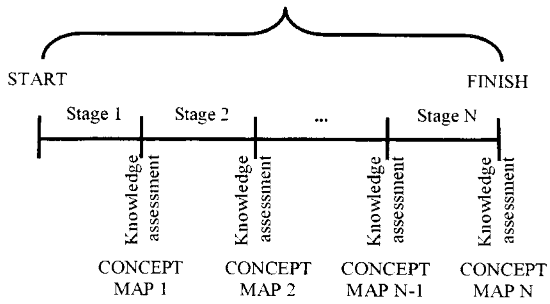

Fig 1. Use of concept maps in process oriented learning for learners' knowledge assessment.

III. SYSTEM'S ARCHITECTURE AND OPERATION

The developed intelligent system consists of an intelligent agent for assessment of learners' current knowledge level and a group of human agents, i.e. learners who are communicating with this agent.

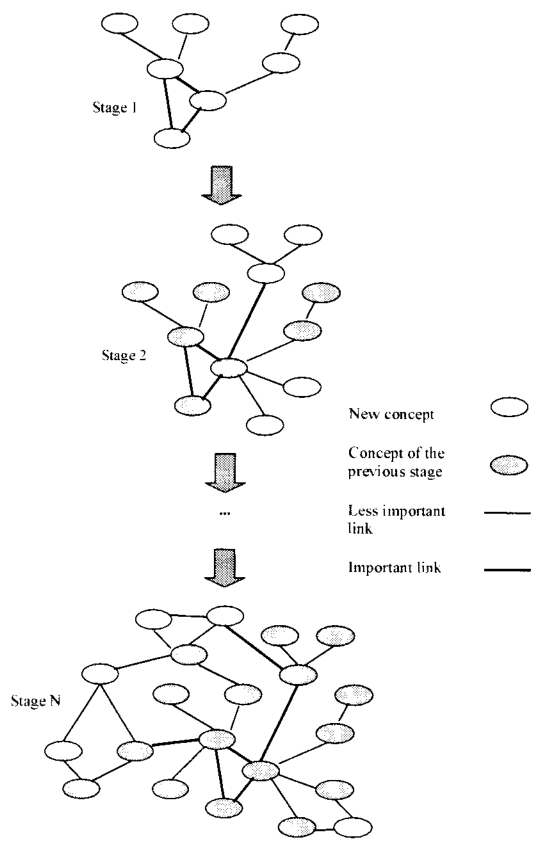

Fig. 2. Formation of a concept map at each stage of a learning course.

The following scenario describes interaction between the system and its two users: a teacher and a learner. The teacher using the system creates concept maps for each stage of a learning course and defines their characteristics (initial concepts and publication date). During knowledge assessment the learner gets a structure of a concept map, which corresponds to the learning stage. At the first stage it is an empty structure with very few initial concepts defined by the teacher. In the subsequent stages new concepts are included in addition with those, which the learner has already correctly inserted during the previous stages. In both cases the set of concepts, which should be inserted into the structure of the concept map is given to the learner. After finishing the concept map, the learner confirms his/her solution and the intelligent assessment agent makes its analysis, comparing concept maps of the learner and the teacher on the basis of five patterns described in Section IV. The intelligent agent saves the final score of comparison and the learner's concept map in a knowledge base, and gives feedback to the learner about correctness of his/her solution. At any time the teacher has an opportunity to examine concept map completed by the learner and his/her score. Fig. 3 displays the described scenario.

Modules of administrator, teacher and learner make the system's architecture. Their names display a category of system's users for which the module provides a set of functions. The modules interact sharing a common database, which stores data about teachers and their learning courses,

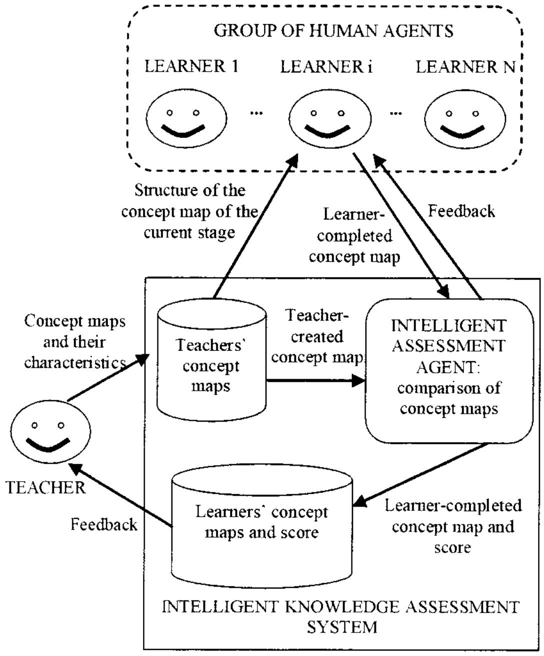

Fig. 3. The scenario of the system's operation.

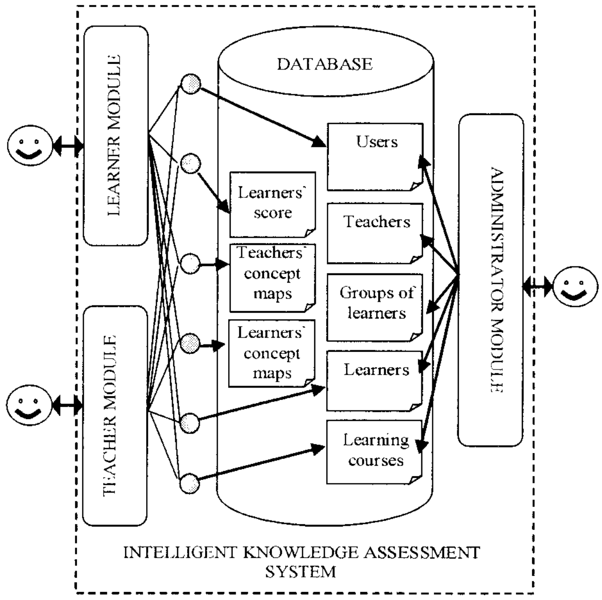

Fig. 4. The architecture of the system.

learners and groups of learners, teacher-created and learner-completed concept maps, learners' final score and system's users (Fig. 4).The administrator maintains the system and his/ her primary responsibilities are to manage data about users, learners and groups of learners, teachers and learning courses, using such functions of the administrator module as data input, editing, and deleting.

The teacher's module supports the teacher in the development of concept maps and of examining of learners' final score. Its main functions are the following: automatic providing of information on learning courses taught by the teacher and on learners studying a particular learning course, automatic providing of information about maximum score, the publication status and date of a particular concept map within a chosen learning course, tools for developing, editing and deleting concept maps, and tools for examining of learner-completed concept maps and score, as well as for deleting the results.

Graphical user interface is used for concept map development and editing. The teacher draws on a working surface using tools for concept inserting and linking them by two types of links (Section II). When the teacher creates the first concept map in a particular learning course, he/she can freely add and delete concepts and links. However, if he/she creates a concept map of the next stage, he/she can freely operate only with elements of already not published maps of the previous stages.

Two kinds of information on learners' results are available: a learner-completed concept map with mistakes and incorrect places displayed on it, and a text pointing out learner's data, learning stage, and final score comparing with maximum score.

The learner's module includes the following functionality: automatic providing of information on learning courses studied by the learner, and on concept maps within learning courses (stage, status of publication, and learner's score), tools for completion of concept maps provided by the teacher, and tools for viewing the feedback after the learner has submitted his/her solution.

Feedback given to the learner comprises information on concepts not inserted into a map, incorrectly connected concepts, and final score. In the current version of the system the learner does not have an opportunity to see a correct concept map or to perform a task once again.

The system has been developed using the following tools: Borland JBuilder 9.0., JGraph, PostgreSQL DBMS 8.0.3, and JDBC drivers for PostgreSQL. Fig. 5 shows the architecture of the system from the point of view of used technologies.

Such system functions as the development of a new concept map by the teacher and examining of learners' results, as well as concept map filling by the learner in the form of use case diagrams are given in [16].

IV. Intelligent Assessment Agent

The intelligent agent who makes assessment of the learner's current knowledge level is a core of the system's intelligence and the basis of the learner's module. The developed prototype of this agent at the moment consists from four agents (Fig. 6).

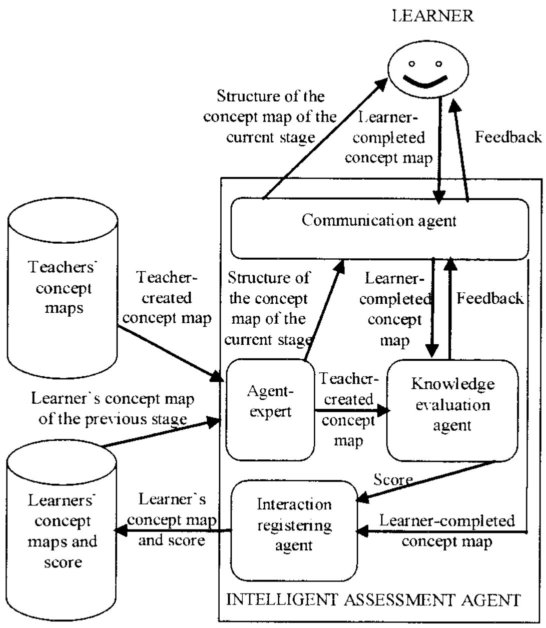

Fig. 6. The architecture of the intelligent assessment agent.

The communication agent perceives the learner's actions on the working surface, i.e. concepts inserting into and removing from the structure of a concept map, and clicking on the buttons of solution submission and window closing. It is also responsible for visualization of a structure of a concept map, which is received from the agent-expert, and for the output of feedback coming from the knowledge evaluation agent. After the learner has confirmed his/her solution, the communication agent delivers the learner-completed concept map to the knowledge evaluation agent. This agent compares the concept maps of the learner and the teacher on the basis of recognition of five patterns of learner's solutions described below, and generates a feedback, which is delivered back to the communication agent. The interaction registering agent receives the learner-completed concept map from the communication agent and results of its comparison with the teacher-created concept map from the agent of knowledge evaluation, and stores them in a database. The agent-expert forms a structure of a concept map of the current learning stage on the basis of the teacher-created concept map and learner's concept map of the previous stage. The formed structure is delivered to the communication agent for its visualization on the working surface. The agent-expert also delivers a teacher-created concept map to the agent of

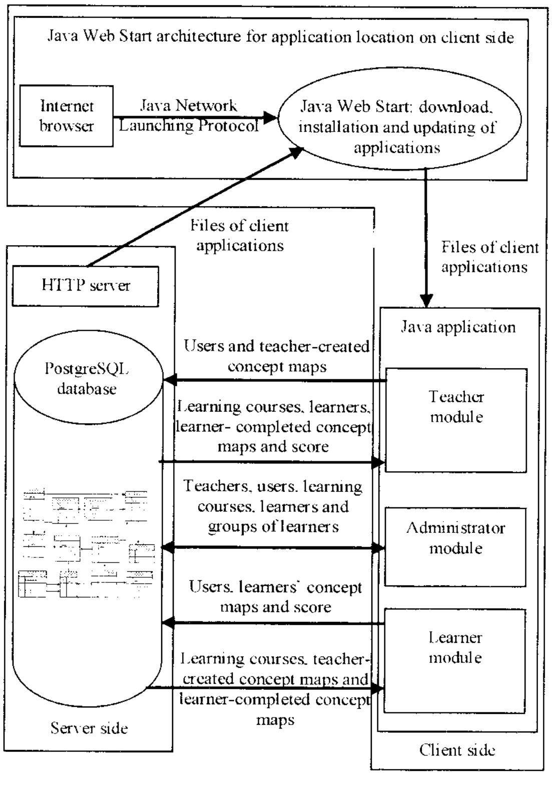

Fig. 5. The client/server architecture of the system.

knowledge evaluation for its comparison with a learner-completed concept map.

The knowledge evaluation agent is capable to recognize five patterns of learner solutions. It is based on assumption, that the fact that the learner understands presence of relationships between concepts has the primary value, while the type of link and the place of concepts within the general structure of a concept map are secondary things. Thus, the learner solutions, which the agent is capable to distinguish are the following (Fig. 7):

Pattern 1. Learner has related concepts in accordance with a standard map of the teacher. In this case the learner receives 5 points regarding every important link and 2 points regarding every less important link.

Pattern 2. Learner has defined a relationship, which does not exist in a concept map of the teacher. In this case he/she does not receive any points.

Pattern 3. Learner has defined a relationship, which exists in a standard map, the type of link is correct, but at least one of concepts is placed in an incorrect place. In this case the learner receives 80% from maximum score for that link.

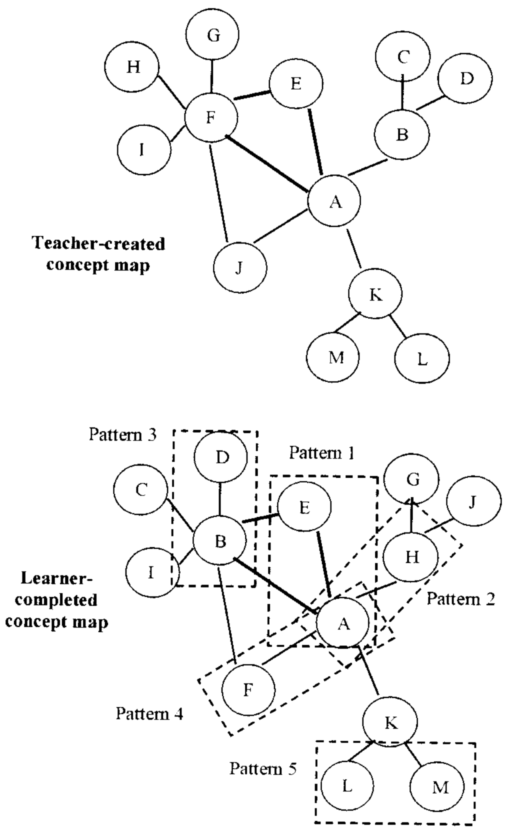

Fig. 7. Patterns of learner's solutions which can be recognized by the knowledge evaluation agent.

Pattern 4. Learner has defined a relationship, which exists in a standard map, the type of link is wrong, and at least one of concepts is placed in an incorrect place. The score received by the learner is 50% from maximum score for a correct link.

Pattern 5. A concept is placed in a wrong place, but its place is not important. The learner receives maximum score for a corresponding link.

V. Testing of the System

The operation of the developed system has been tested in four learning courses of different types (both engineering and social sciences). Seventy four students have been involved in the testing process. After testing students were asked to complete a questionnaire. Each questionnaire had fifteen questions, seven of them were devoted to the evaluation of system's performance and eight questions were related to the used approach based on concept maps. As a result sixty three questionnaires have been processed.

Let's consider an example from testing of the system. Fig. 8 displays a teacher-created concept map for a learning course "Systems Theory Methods". The concept map has two initial concepts – *Systems Theory* and *Systems Concepts* - which color on the working surface differs from the color of other concepts. The teacher has specified twenty relationships: twelve of them are important and eight are less important conceptual links. Fig. 8 also shows the main buttons, which the teacher can use for the development of concept maps.

The map was presented to students in the form depicted in Fig. 9. The offered structure of the concept map corresponds to the first stage of knowledge assessment in the learning course. Therefore it contains only initial concepts. Other concepts are placed in the bottom part of the working surface as it is shown in Fig. 9. The student can manipulate them using concept inserting and removing buttons.

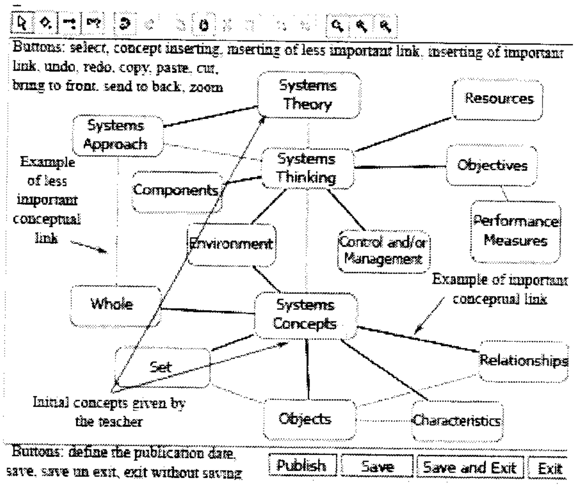

Fig. 8. A teacher-created concept map for the first stage of the learning course "Systems Theory Methods".

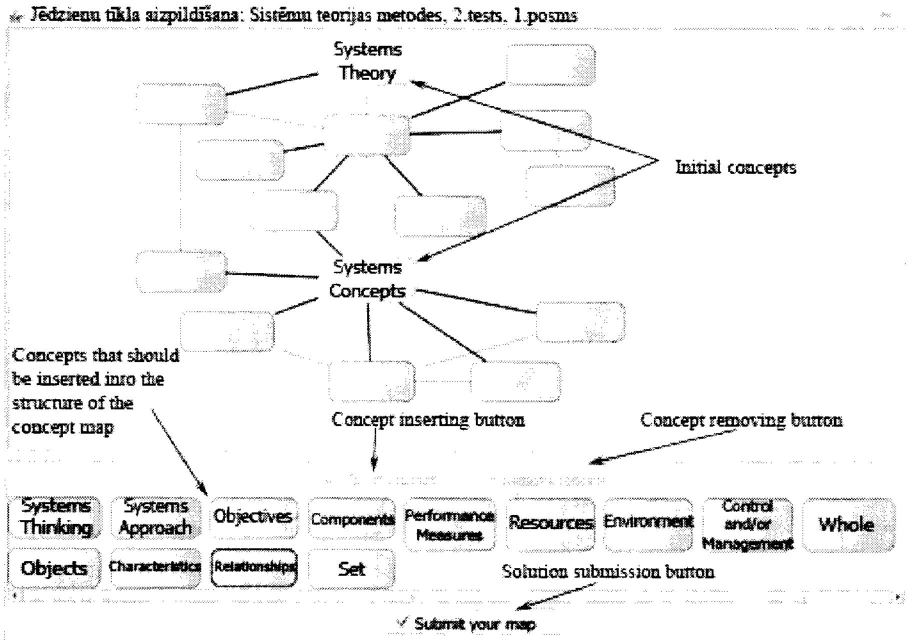

Fig. 9. Structure of the concept map offered to the student.

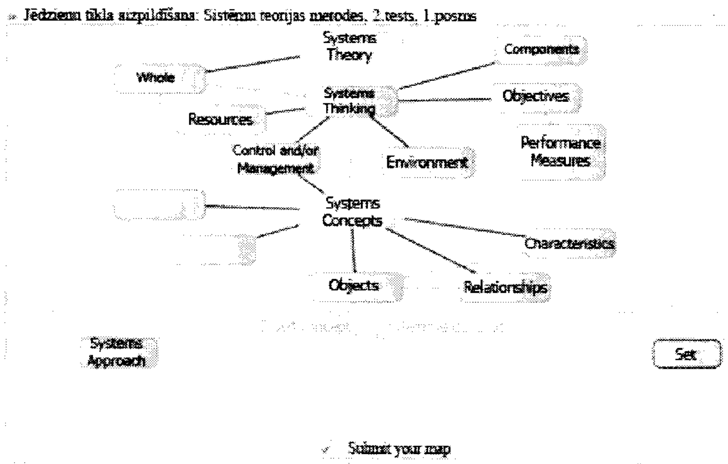

Fig. 10. The student-completed concept map.

Fig. 10 shows the student-completed concept map. The student has inserted the majority of the concepts into the structure of the concept map. However, two concepts - *Systems Approach* and *Set* - have not been inserted. Comparing Fig. 8 and Fig. 10, it is possible to see, that arrangement of concepts in the student-completed concept.map differs from their arrangement in the teacher's map.

The feedback, which was given to the student is represented in Fig. 11. The student has received 48 points from 76 possible. On the left part of the window the list of concepts that have not been inserted is shown. It comprises two concepts corresponding to the concept map depicted in Fig.

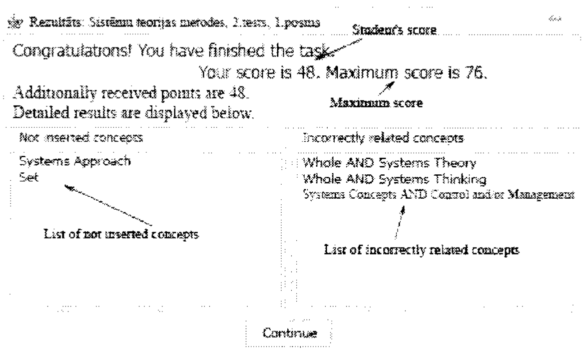

Fig. 11. Feedback received by the student.

10: *Systems Approach* and *Set*. On the right part of the window pairs of incorrectly related concepts are displayed: *Whole* AND *Systems Theory*, *Whole* AND *Systems Thinking* and *Systems Concepts* AND *Control and/or Management*.

For the second stage the teacher added new concepts and links to the concept map, and the map was offered to the student in the form displayed in Fig. 12. Fig. 12 clearly shows how the developed intelligent agent assessed the student's solution. Some concepts were exchanged by places as their place was correct, but differed from the place specified by the teacher. Two concepts - *Whole* and *Systems Approach* - were thrown off downwards as they were completely incorrectly placed. One link was marked as wrong because the place of the concept *Control and/or Management* related by it was incorrect. At the same time this concept was correctly related to another concept - *Systems Thinking*.

The analysis of the questionnaires revealed that the students positively evaluated the chosen approach to knowledge assessment, as well as functionality and user interface of the system. Table 1 displays some important questions and the summary of answers given by students.

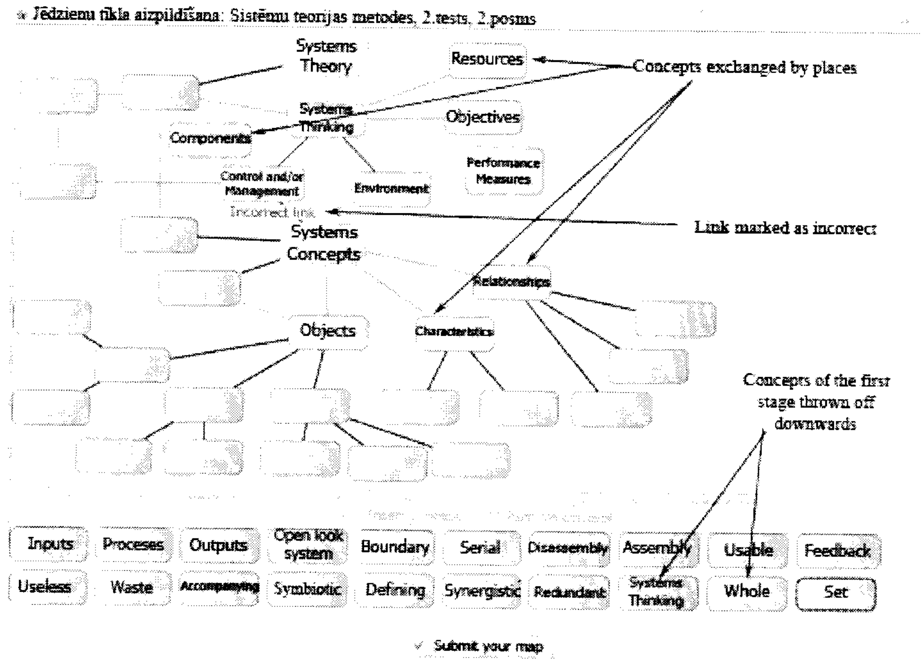

Fig. 12. The concept map of the second stage offered to the student.

TABLE I
SUMMARY OF STUDENTS' ANSWERS

	Yes, and I like this idea	Yes, but I do not like this idea	No, I do not understand sense of concept maps	No, I do not understand how concept maps are developed at all	Other answer
Whether do you understand essence of concept maps?	65%	27%	3%	3%	2%
	Very difficult	Difficult	Easy	Very easy	
Whether it was difficult for you to fill concept maps?	8%	57%	33%	2%	
	Yes	No	Other answer		
Whether the filling of concept maps has helped you to understand teaching material better?	62%	36%	2%		
	Yes	Possibly	No	Other answer	
Would you like to use such method of knowledge assessment also in other learning courses?	28%	57%	13%	2%	

VI. Related Works

The idea to computerized concept mapping is not new at all. A number of commercial and non-commercial graphical software packages and tools already exist, for example, AXON Idea Processor (web.singnet.com.sg/~axon2000/), Inspiration (www.inspiration.com), Knowledge Manager (www.knowledgemanager.us/), SMART Ideas™ (www2.smarttech.com/st/en-US/Products/SMART+Ideas), IHMC CmapTools (cmap.ihmc.us), and others, which allow to capture and visualize ideas and knowledge. These products provide such functions as concept map construction, navigation and sharing, and can be used as a useful learning tool, but they do not assess created concept maps.

One of the powerful concept map based assessment tool is COMPASS (COncept MaP ASSessment tool) [17]. It is a Web-based system that provides assessment of the learners' knowledge level through various concept mapping tasks and supports the learning process generating the informative and tutoring feedback after the analysis of a learner's concept map.

The other example of assessment tool based on concept maps is described in [18]. It has two versions: one of them supports the task of filling in the blanks of incomplete structure of a concept map, other offers an opportunity to freely construct a concept map. Both versions provide evaluation and hint functions.

The developed system has two discriminative features in comparison to the mentioned tools. Both known systems consider assessment as a discrete event, while the system described in this paper supports process oriented learning and allows the teacher to extend the initially created concept map for the new stage of assessment. The second unique feature is an algorithm that compares the teacher's and learner's concept maps and is sensitive to the arrangement and coherence of concepts.

VII. Conclusions and Future Work

The paper describes the multiagent intelligent system for learners' knowledge assessment at each stage of a learning course. The underlying concepts of the system are process oriented learning and concept maps. The core of the system is the intelligent agent that is capable to recognize five patterns of learners' solutions. It is communicating with a group of human agents, i.e. learners and at the moment consists from four agents: communication, knowledge evaluation, interaction registering and expert agents. The operation of the developed system has been tested in four learning courses of engineering and social sciences. Experiments have shown the effectiveness of the developed tool for continuous assessment of learners' knowledge. The drawbacks also have been specified: poorly informative feedback to learners, lack of drag-n-drop facility as well as guidance how to perform the task, some problems regarding connection to the system. These drawbacks will be eliminated in future.

The main advantages of the developed system are defined by the Web-based application that allow to use it from any remote location with Internet connection, the convenient and clear graphical user interface both for learners and teachers, the support of process oriented learning and intelligent algorithm for comparison of learner's and teacher's concept maps.

The system has a good potential for further evolution. First, it is necessary to deepen the method of knowledge assessment. At present the system allows only to establish the fact that the learner understands the presence of relationships between concepts of problem domain. However, it does not allow to examine, whether the learner understands sense of a particular relationship. Thus, in future it is necessary to provide opportunities to specify not only concepts, but also the type of the link between them, i.e. to define semantics of the link, for example, "include", "is a part of", "consist of", and so on.

Second, it is possible to give the learner only the list of concepts instead of the structure of a concept map allowing the learner to create a concept map by himself/herself. Such approach provides an opportunity to follow the organization of learner's knowledge.

Third, it is necessary to increase intelligent abilities of the system, which at present are not high enough. It may be achieved by improving feedback given both to the learner and to the teacher. In future the system should summarize learners' solutions, in order to deliver statistics to the teacher about what concepts are incorrectly related more often, which ones remain not inserted at all, etc. Regarding the learner the system should generate the recommendations related to learning material that the learner should revise to fill gaps in his/her knowledge.

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