ARCHITECTURE AND APPLICATION OF KNOWLEDGE ASSESSMENT SYSTEMS: AN OVERVIEW

ZINĀŠANU VĒRTĒŠANAS SISTĒMU ARHITEKTŪRU UN PIELIETOŠANAS IESPĒJU APSKATS

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Computer-assisted assessment, assessment system, student model, intelligent support, adaptivity

1. Introduction

Knowledge assessment is an integral part of the learning process. However, it is a very time and effort consuming activity in the traditional learning process, because it demands from the teacher to prepare assessment tasks or questions, to conduct assessment activities, to check and evaluate students' works, to provide feedback. This is the reason for the development of computer-assisted assessment systems. The mentioned systems are used, on the one hand, to detect students' knowledge and skills, but, on the other hand, to regulate teaching and learning process on the basis of informative and tutorial feedback generated automatically by the system.

The key factor of successful application of any computer-assisted assessment system is the level of its intelligence and adaptivity. Intelligence mainly refers to the intelligent analysis of solutions provided by students, but the adaptivity is related to the adaptive presentation of assessment content. Students have different needs and these differences should also be taken into account through providing an individualized approach to each student. Otherwise, a unified assessment style can have a negative impact on the assessment process by leading to worse results. Therefore, developers should provide an appropriate level of intelligence and adaptivity in their computer-assisted assessment system.

The paper is organized as follows. Section 2 explains the concept of computer-assisted assessment and describes systems of objective and subjective testing in brief. The advantages and drawbacks of computer-assisted assessment systems are presented in Section 3. Section 4 discusses the general architecture of a computer-assisted assessment system. Section 5 is devoted to the intelligent and adaptive support in computer-assisted assessment systems. The student model used as a basis for the implementation of adaptivity is described in Section 6. Section 7 presents a concept map based knowledge assessment system developed at the Riga Technical University. The paper ends with Conclusions.

2. Concept of computer-assisted assessment

According to [1] computer-assisted assessment is a common term for the use of computers in the assessment of student learning. However, today there is a variety of other widely used terms such as e-assessment, Internet-based assessment, online assessment, Web-based assessment, etc. Actually, all of them mean the same, that is, the application of computers or, more precisely, of a computer-based assessment system to knowledge assessment activities. In [2] the following tasks of computer-assisted assessment systems are mentioned:

- the delivery of assessment tasks and results to students;
- assessments taken in whole or part on computer;
- computer marking of assessments;
- electronic collation and transfer of grades and assessment data;
- electronic delivery of training and support materials.

Computer-assisted assessment systems can be used for initial, formative and summative assessment. Initial assessment, as a rule, is performed at the beginning of the learning process in order to gather diagnostic and prognostic information concerning students' knowledge and skills. Formative assessment is carried out during the instruction in order to obtain information about the regulation of the teaching and learning process, to identify obstacles that can be found in the learning process and to detect topics that need to be reinforced. Summative assessment takes place at the end of learning with aim to determine students' achieved level of knowledge and skills in a given domain [3, 4].

According to [5] the same term „computer-assisted assessment" is defined narrowly and refers to the use of computers in assessment, encompassing delivering, marking and analysis of assignments or examinations, as well as collation and analysis of data gathered from optical mark readers. This definition clearly distinguishes two basic forms of computer-assisted assessment which exist nowadays:

- systems, where students submit their works or answers using a computer that further makes their analysis and evaluation;
- optical mark readers, which scan, interpret and evaluate paper forms of tests completed by students through the marking answers on test questions.

The first mentioned basic form of computer-assisted assessment can be divided into systems providing objective testing and systems supporting subjective testing [6]. Systems based on objective tests are the most widespread systems of computer-assisted assessment. They offer the student a set of questions, answers to which are pre-defined [5], in other words, assessment is not subjective, because no judgment has to be made on the correctness of an answer at the time of marking [7]. Thus, in such systems the student is offered a question and he/she inputs an answer. The system compares the entered answer with the answer defined by the teacher and provides the feedback to the student. There are different types of questions, but the main ones are the following [3]:

- multiple choice questions (students are asked to select one answer from a list of possible answers);
- multiple response questions (students are asked to select any number of answers from a list of possible answers);
- graphical hotspot (students are asked to select areas of the screen by moving a marker to the required position or filling in a block in a particular position linked to a graphic illustration on a specially designed paper answer sheet);
- text/numerical questions (students are asked to input text or numbers in the particular field using the keyboard).

Computer-assisted objective testing systems vary significantly in their functional complexity. Simple systems act as authoring tools providing the possibility for the teacher to construct questions manually. Complex testing systems are able to create questions automatically on the basis of the dynamically selected learning content provided by the teacher. Such systems combine various techniques of natural language processing to construct questions. In most cases these systems are also able to process students' answers that are given in a free text form [8, 9].

Systems of subjective testing can assess students' submitted works for content, style, originality, etc. [6], for example, e-rater [10], c-rater [11], Auto-marking [12], and Atenea [13]. As a rule, they are based on essays and free text responses and use methods of artificial intelligence, especially natural language processing.

3. Advantages and drawbacks of computer-assisted assessment systems

In general, the use of computer-assisted assessment systems provides a number of advantages [3, 6, 14, 15, 16, 17]:

- a wide range of topics can be tested quickly;
- large groups of students can be assessed quickly;
- provision of the potential for frequent assessments and, as consequence, the regular monitoring of the progress of students;
- a variety of media (images, video, audio, etc.) can be included in assessment questions or tasks;

- extensive feedback can be provided to teachers through various diagnostic reports;
- decrease in time needed for supervising and marking of assessments;
- greater flexibility regarding place and time of assessment;
- elimination of any prejudices in relation to students;
- instant feedback to students;
- reduced mistakes in comparison with human marking;
- results can be automatically entered into administration systems.

Despite of all advantages computer-assisted assessment systems have also drawbacks [3]**:**

- implementation of an assessment system can be costly and time-consuming;
- difficult to reproduce freedom of paper examination – e.g. scanning exercises to choose which to make;
- assessors need training in assessment design, IT skills and examinations management;
- students require adequate IT skills and experience of the assessment type;
- good system maintenance is required to avoid downtime during examinations.

Considering objective testing the following advantages can be identified in addition to the already mentioned advantages of computer-assisted assessment systems:

- it is easy enough to define questions, because a wide experience is accumulated in the development of knowledge assessment systems based on objective tests;
- objective testing can be used for initial, formative and summative assessment, as well as for other kinds of assessment, for example, self-assessment.

Moreover, one of the most promising advantages of the application of computer-assisted assessment systems based on objective tests seems to be the possibility of automatic bidirectional translation of questions and answers from one language to other language(-s), as it is implemented in the computer-assisted assessment system Atenea [18]. Thus, it allows an assessment system to be used by students and teachers from different nationalities, because the author of a course simply writes the questions in his/her own language (for example, in Latvian) and the student (for example, an English speaker) receives the question translated automatically into English, writes the answer, and the system automatically translates it into Latvian and compares it against the teacher's answer.

However, systems of objective testing have the following drawbacks:

- objective testing does not allow the student to offer original answers, so there are restrictions on knowledge and skills which can be assessed. According to [7, 17] such systems allow evaluation only of the first four levels in widely accepted in pedagogy Bloom's taxonomy [19], which includes three levels of lower order skills (knowledge, comprehension, and application), and three levels of higher order skills (analysis, synthesis, and evaluation). In [7] this assertion is said to be erroneous, but it is pointed out that designing test questions to assess higher order skills can be time consuming and requires skills and creativity;
- objective testing assesses only factual knowledge instead of student's understanding about their interconnectedness and significance in the learning course;
- objective tests encourage students guessing.

Subjective testing, in turn, provides the following advantages [20, 21]:

- it allows the student to offer original answers and judgments, to demonstrate ability to organize knowledge and express opinions, thus, higher order cognitive levels can be assessed;
- students can display a broader range of knowledge about a particular topic;
- students less likely to guess.

Systems of subjective testing use methods of artificial intelligence, especially natural language processing. This fact is the reason for the main drawbacks of such systems: dependency on a subject and natural language, as well as complex structure and functional mechanisms. Moreover, the use of essays and free text responses for systematic assessment is a questionable issue due to a high cognitive load for students. Other drawbacks are the following [20, 21]: limitations of the extent of content covered by assessment and more subjective assessment due to the taking into account such factors as style and originality of assignments.

4. General architecture of a computer-assisted assessment system

In general computer-assisted assessment systems are designed to be used by three types of users – an administrator, a course instructor (a teacher) and a student. The administrator updates records of courses, instructors and students and also gives access rights to both instructors and students. The course instructor organizes curriculum, designs tasks and views assessment results. The student takes published tests or performs tasks [22, 23].

The analysis of computer-assisted assessment systems intended both for objective and subjective testing shows that almost each system has its own architecture [24, 25]. From our point of view there are two main reasons for such architectural differences. Firstly, each computer-assisted assessment system has its own behavioral model. Secondly, each developer has its own preferences on dividing system functionality into structural units.

Trying to recap information about available architectures and their similarities a general architectural model of a computer-assisted assessment system has been developed. It is presented in Figure 1.

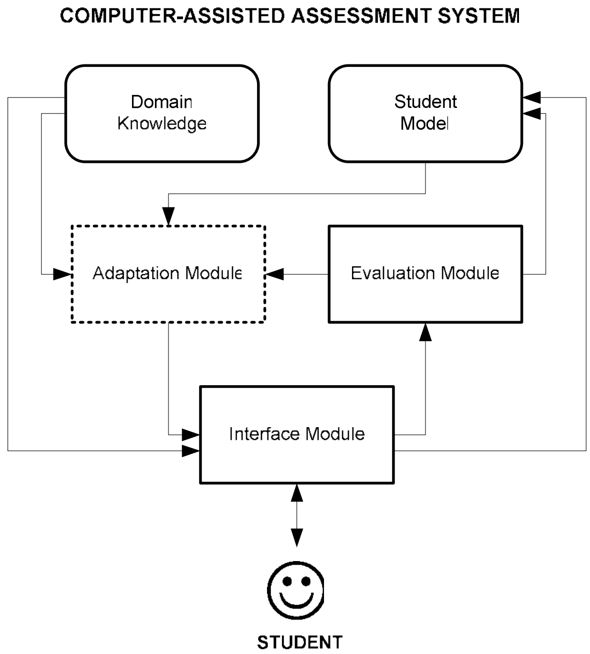

Fig. 1. General architecture of a computer-assisted assessment system

The architecture above incorporates the following structural units:

1. *Interface (or Interaction) Module* that is responsible for the provision of interaction between a user and the system. The main tasks of this component are the following: to present tasks and feedback, to activate the other modules according to the student's actions, to collect data concerning the student's observable behavior and to update the student model with the newly acquired information. The interface module passes student's solutions to the evaluation module for their evaluation. If the student set some preferences regarding the interface and behavior of the system the interface module also stores these parameters in the student model.
2. *Adaptation Module* that is responsible for the selection of tasks suitable for a particular student taking into account the student's level of knowledge, skills and preferences. Adapted tasks from the adaptation module are passed to the interface module for their presentation to the student.
3. *Evaluation (or Diagnostic) Module* that is responsible for the evaluation of student's solutions and generation of feedback. The mentioned module is the brain of the computer-assisted assessment system because it provides the intelligent solution analysis [26] that is discussed in the next section in detail. Evaluation results are used further mainly to update knowledge level in the student model. Results of each completed task are also passed to the adaptation module

and to choice the next assessment tasks. They are also passed after each task to the adaptation module for the selection of the next assessment task.

4. *Domain (or Expert) Knowledge* which stores all possible questions and solutions defined by the teacher. Domain knowledge is passed to the adaptation module to adapt assessment tasks to the student needs before assessment takes place, and to the interface module to show the student the correct solutions after assessment is completed.
5. *Student (or Learner) Model* which stores information about a student such as general information, knowledge level, preferences, etc. The student profile is passed further to the adaptation module to adapt assessment scenario to the student needs.

The adaptation module is depicted by dash line in figure 1 because this component is an optional and there are systems which do not provide adaptivity to a particular student and, therefore, offer the same assessment scenario for all students regardless their level of knowledge and skills and preferences, i.e., such systems are not able to generate individual assessment plans.

5. Intelligent and adaptive support in computer-assisted assessment systems

The analysis of computer-assisted assessment systems shows that there are two important features of such systems – level of intelligence and level of adaptivity. A system is called to be intelligent if it uses principles and methods of artificial intelligence [26] (such as the processing of natural language, knowledge representation, inference mechanisms and machine learning) in its structure and operation. In turn, adaptivity is defined as the capacity of the system to change behavior automatically without a deliberate action on the user's part [27]. The adaptivity and intelligence are features of high importance due to the fact that students have different needs and these differences should also be considered in computer-assisted assessment through the provision of an individualized approach to each student. Otherwise, if a unified assessment style does not match the style of a particular student it can have negative impact on assessment process by leading to worse results [28]. Therefore, in order the assessment process implemented through the use of a computer-assisted assessment system to be effective an intelligent and adaptive approach should be applied. Computer-assisted assessment systems become more flexible and useful for students with different preferences and learning needs by incorporating a certain level of intelligence and providing a certain level of adaptivity.

According to [26] intelligence is concerned with the intelligent solution analysis and the intelligent problem solving support. Unlike systems which do not incorporate intelligent solution analyzers and, as a result, are capable of telling only whether the student's solution is correct or not, systems performing the intelligent solution analysis can tell what is wrong or incomplete and which missing or incorrect pieces of knowledge may be responsible for the error. The intelligent problem solving support concerns with the provision of intelligent help during the problem solving process and the generation of tutorial feedback to the student both during the assessment process and at the end of it. The intelligent help can be given in forms of hints or leading questions relevant to the current situation in problem solving, Its main task is to allow the student to activate his/her thinking processes in order to obtain the correct solution of a task. In turn, tutorial feedback can be directed towards filling in gaps in knowledge simultaneously with the knowledge assessment by providing pieces of relevant learning material or towards facilitation of further direction of learning.

It is possible to conclude that systems of subjective testing are mainly intelligent systems because they perform not only the analysis of text in natural language through the use of corresponding methods of artificial intelligence, but also checking of matching of the text to criteria corresponding to the content, style, originality and identification of reasons of mismatching. In turn, the greater part of objective testing systems are not intelligent because they do not provide the intelligent solution analysis and the intelligent problem solving support. The mentioned systems typically compare the student's submitted answer with the teacher's predefined answer without the identification of the reasons of the mismatching between the mentioned answers, as well as the provision of very simple feedback in form of short sentences pointing out whether the answer is/ is not correct.

In other knowledge assessment systems [8, 28, 29, 30, 31] both previously mentioned terms - the intelligent solution analysis and the intelligent problem solving support - can be closely related. If a system is not able to perform the intelligent solution analysis then no tutorial feedback or individualized help can be generated.

The adaptivity in computer-assisted assessment systems refers mostly to the adaptive presentation of assessment content and means the ability of a system to generate an individual assessment scenario (tasks sequence). If a system is not adaptive then for all students the same assessment scenario is applied. In contrast, an adaptive computer-assisted assessment system [18, 30, 31] provides an individual assessment scenario for each student taking into account student's prior knowledge level, preferences and already given solutions.

Objective testing can be adaptive. In this case the terms „computer adaptive assessment" or „computer adaptive testing" are used. In adaptive testing questions of knowledge assessment are adjusted to the learner's knowledge level. In most cases the widely known Item Response Theory (IRT) is used to generate an individual assessment scenario. In accordance with IRT selection of the next question depends on answer given to the previous question (-s). The procedure is described in [32] in detail. At the beginning of the assessment the student receives a question of average difficulty. If he/she gives a wrong answer, he/she receives a less difficult question. Otherwise, the student receives a more difficult question. This process continues until the predetermined test termination criteria have been met. In such an approach each student receives a unique set of questions, which allows more accurate determination of his/her achievement level. Thus, students at a low achievement level are not required to respond to questions that are very difficult and far beyond their achievement level, but students at a high achievement level are not required to answer questions that are too simple for them.

In [30] the system's ability to support an individualized approach is divided into adaptivity and adaptability. Adaptivity requires the system to automatically adapt to the student's current level of domain competence and other similar attributes, whereas adaptability requires the system to provide suitable interfaces by which the student can customise the system according to his own preferences.

The intelligent and adaptive support in computer-assisted assessment systems can be achieved by the use of a student model which is discussed in the next section in detail.

6. Use of the student model in computer-assisted assessment systems

Student or learner modelling is related to the task of keeping a record of many aspects of a student. This record is called a student (or a learner) model. The student model reflects specific characteristics of the student and thus it is used as the main source of the adaptive behavior of any computer-assisted assessment system [18, 24, 28, 33].

The information held is the student model is divided into domain dependent information or *dynamic information* that changes during the assessment process and domain independent information or *static information* that is constant through the assessment process. Regarding the domain dependent information the student model keeps information about the student's knowledge level, the student's errors, the student's behavior during his/her interaction with the system (number of help asked, frequency of errors made, time of response, etc.). The domain independent information is the general information about the student such as the username, the profession, student's favorite feedback components and knowledge units (i.e., definition/description, example, image), last time/date the student logged on/off, etc. The student model is dynamically updated during the student's interaction with the system in order to keep track of the student's "current state".

Information about the student can be obtained from different sources:

- from user-filled forms at the initial stage of the use of the system when the student is asked to answer a questionnaire about his/her personal data and preferences; in some cases psychological tests can be applied in order to get information about student's preferred learning style;
- from student observable behavior when he/she works with the course (e.g., pages visited, time spent in each page, navigation path followed, chosen options, etc.);
- from results concerning solving of practical problems and tasks;
- from the observations of the student through the use of different sensors [34, 35, 36].

Thus the process of the acquisition of information about the student can run in different modes [33]: passive (when the system infers the model of students without explicit help from them), active (when students may be asked questions by the system to assist it) or interactive (when students play an active role in the development and maintenance of their own model).
Student models can be classified according to different factors. The available classifications are summarized in Table 1 [22, 37, 38].

Table 1

Classifications of student models

Classification factor	**Group**	**Description**
1. Openness	1.1. Open	The model is shown to students or instructors. In this way, students may get actively involved in their diagnostic process by looking at how they understand the concepts in the learning domain. Besides, educators can be provided with more feedback about their students' knowledge assimilation state and help them to improve it.
	1.1.1. Inspectable	The model is shown to instructors and/or students but they are not allowed to modify it.
	1.1.2. Editable	The model is built and kept by the assessment system, but instructors and/or students are allowed to modify its content.
	1.1.3. Negotiated	The model is agreed between the assessment system and the student that freely interacts with it through a dialogue.
	1.2. Closed	The model is shown neither to instructors nor to students as the aim is just to modify the behavior of the assessment system in order to be adapted to the student.
2. Representation of domain knowledge	2.1. Overlay	The student model is a projection of the domain model, i.e. the student knowledge is considered as a subset of the domain knowledge.
	2.2. Bug	The bug model is based on a library of possible mistakes that could be made up by the student.
	2.3. Perturbation	The perturbation model is a hybrid model that involves the concepts of the overlay and bug model together.
	2.4. Constraint-based	Opposite to the previous models, it does not compare the student's knowledge to the domain knowledge. It rather focuses on correct knowledge by checking if all the constraints of a certain domain are satisfied by the student.
3. Granularity	3.1. One student	The main goal of the model is to capture information from a particular student.
	3.2. Group of students	The model represents general information about a group of students.

According to [31] storing all the information in the student model in standardized formats allows for alternative externalizations of the student models and sharing of the information with other systems. Student models are thus reusable by different assessment and teaching systems and other applications. Different applications could interpret and portray the available data differently.

7. RTU concept map based knowledge assessment system

One of the techniques which can be used in subjective assessment is concept maps. Concept maps are widely applied for the assessment of students' higher order cognitive skills. Concept mapping stimulates students to articulate and externalise their actual state of knowledge. It is also a creative activity, in which the student must exert effort to clarify concept meanings in a specific domain knowledge by identifying important concepts and establishing relationships among them.

Researchers from the Department of Systems Theory and Design of the Faculty of Computer Science and Information Technology of Riga Technical University have been developing the concept map based knowledge assessment system [39, 40] already for three years. It allows the teacher to assess student's knowledge regularly, that is, at each stage of the study course, and to use assessment results for the analysis and the improvement of learning content and teaching methods. At the same time the student can use the system for knowledge self-assessment in order to control and to keep track of his/her own learning progress.

The system is used in the following way. The teacher creates one or more concept maps for a study course. The process of the creation of a concept map consists from the specification of relevant concepts and relationships among them. Teacher's created concept maps serve as a standard against which the students' concept maps are compared. During knowledge assessment the student solves a concept-map based task using initially given concepts and links. Maps created by students show how well students understand the learning material. After the student has submitted his/her solution, the system compares the concept maps of the student and the teacher, identify student errors, calculates the student's score and generates feedback which is delivered back to the student [41].

The concept map based knowledge assessment system incorporates the following two features related to the adaptivity: firstly, the degree of task difficulty automatically increases if the student has reached the teacher's specified number of points in the current assessment task, and secondly, automatic provision of such type of concepts' explanations which the system recognizes as the most suitable for the student taking into account student's characteristics. In turn, the adaptability is implemented by the following features: manual reduction of the degree of task difficulty by the voluntary request from the student during the solving of the task, automatic checking of the correctness of the student's created proposition by the voluntary request from the student during the solving of the task, automatic insertion of the student's selected concept into the right node within the structure of the concept map by the voluntary request from the student during the solving of the task and, finally, manual selection of the preferred type of concepts' explanations.

The concept map based knowledge assessment system includes also some intelligent features which are related to the intelligent analysis and evaluation of students' concept maps. The system uses a new algorithm that has been developed specially for the intelligent comparison of student's and teacher's concept maps [40]. It is not based only on the isomorphism of both graphs, but is sensitive to the arrangement and coherence of concepts taking into account such aspects as the existence of a relationship, locations of both concepts, the type and direction of a relationship, the correctness of a linking phrase, etc. Application of this new algorithm is a discriminative feature of the system in comparison with other systems based on concept maps.

However, despite the intelligent nature of the evaluation process not all potential is used in the provision of informative and tutorial feedback to the students after the analysis of the solution. At present the generated feedback includes the overall student's score and the score for each composed proposition indicating whether or not a proposition is composed correctly and if not then what exactly is erroneous. But such a feedback is not really informative enough to clearly identify student's misconceptions and to direct future learning. Therefore, there are plans to enrich the feedback by performing the transition from the closed student model to the open student model. Information stored in the student model will be externalized with the aim to show the student how well he/she understands the concepts from the domain. Thus, a new version of feedback will additionally include the following information presented in a graphical format: student's results in comparison with other peers, statistic (percentage) on how well the student masters each concept presented in a map and finally recommendations to go to the next assessment task or probably to go to revision of the relevant

learning material. Thus, a new format of the feedback can be used by the student in order to regulate successfully his/her individual learning process.
The current version of the system has been already experimentally evaluated in 7 learning courses with the participation of 149 students. Students positively evaluated the chosen approach to the knowledge assessment as well as the functionality of the system. But despite of fact that the system has already reached the certain level of maturity and has been used successfully in practice future enhancement of the system related to the system's intelligence and adaptivity should be done in order to make the system even more useful.

8. Conclusions

Computer-assisted assessment systems provide real advantages in comparison with traditional paper-based assessment process, because they can save time and efforts needed to prepare assessment tasks, to conduct assessment activities, to check and evaluate students' works. Probably the most valuable feature of computer-assisted assessment systems is their ability to provide informative and tutorial feedback at the end of the assessment process. This feedback is generated automatically by the system and is based on pre-defined pedagogical rules. The feedback can be used successfully by the student to direct future learning, thus, increasing the efficiency of individual educational process.
Other valuable feature of computer-assisted assessment systems is their ability to conduct adaptive assessment according to the characteristics and needs of a particular student. This option is hardly or even not achievable in traditional assessment. Adaptivity ensures that the individualized approach will be applied to each student, thus making the assessment process equally useful for different students.
However, the development of a computer-assisted assessment system able to provide an appropriate level of adaptivity and to generate qualitative tutorial feedback is a hard work, because complex interdisciplinary researches should be done in order to understand what level of intelligence and adaptivity is required in a computer-assisted assessment and how they should be achieved.

References

1. What is Computer Assisted Assessment? [Electronic resource] / University of Leicester, 1999. – http://www2.le.ac.uk/Members/rjm1/talent/book/c3p2.html – 01.10.2008
2. Computer Assisted Assessment: The future, right here, right now [Electronic resource] / SQA, 2004. – http://www.sqa.org.uk/files_ccc/Computer_Assisted_Assessment_article.pdf – 03.10.2008
3. Computer-assisted assessment. Using computers to design and deliver objective tests [Electronic resource] / 2004. – http://etudeedl.free.fr/annexes/assess.pdf – 03.10.2008
4. Aguilar G., Kaijiri K. Design Overview of an Adaptive Computer-based Assessment System // Interactive Educational Multimedia. – 14, 2007, P.116-130.
5. General CAA topics [Electronic resource] / Computer-Assisted Assessment (CAA) Centre, 2002. – http://www. caacentre.ac.uk – 01.10.2008
6. Using CAA to support student learning [Electronic resource] / Seale J., Learning Technology and Support Network, 2002. – http://www.alt.ac.uk/docs/eln004.pdf – 01.10.2008
7. Introduction to computer-assisted assessment [Electronic resource] / Bull J., University of Wolverhampton, 2003. – http://asp2.wlv.ac.uk/celt/download.asp?fileid=44&detailsid=200008 – 05.05.2006
8. Gütl C., Dreher H., Williams R. E-TESTER: a Computer-based Tool for Auto-generated Question and Answer Assessment // Proceedings of ELEARN 2005. – Vancouver, 2005. – P.2929-2936.
9. Aguilar G., Gomez A., Kaijiri K. Learners and Knowledge: A New Personalization Factors Perspective for Adaptive Computer-based Assessment Systems // Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2007. – Chesapeake, VA: AACE, 2007. – P.2143-2148.

10. Burstein J., Leacock C., Swartz R. Automated evaluation of essays and short answers // Proceedings of the 5th International Computer Assisted Assessment Conference. – Loughborough, 2001. – P.41-53p.
11. Leacock C., Chodorow M. C-rater: scoring of short-answer questions // Computers and the Humanities. – 37 (4), 2003, P.389-405.
12. Sukkarieh J.Z., Pulman S.G., Raikes N. Auto-marking: using computational linguistics to score short, free text responses // Proceedings of the 29th Annual Conference of the International Association for Educational Assessment. – Midland, 2003. - 15 p.
13. Pérez D., Alfonseca E., Rodríguez P. Application of the BLEU method for evaluating free-text answers in an e-learning environment // Proceedings of the Language Resources and Evaluation Conference (LREC-2004).- Lisbon, 2004. - 4 p.
14. JADE Based solutions for knowledge assessment in eLearning Environments [Electronic resource] / Anghel C., Salomie I., TILAB & University of Limerick, 2003. – http://jade.tilab.com/papers/ EXP/Anghel.pdf – 03.10.2008
15. What is computer aided assessment and how can I use it in my teaching? [Electronic resource] / Lambert G., Canterbury Christ Church university college, 2004. – http://www.canterbury.ac.uk/ support/staff-development/brochure/computer-aided-assessment.asp – 01.10.2008
16. Computer aided assessment-the pros and cons [Electronic resource] / The Learning Technology Development Unit, Learning and Information Services, 2000. – http://www.herts.ac.uk/ ltdu/learning/caa_procon.htm – 10.12.2007
17. The use of computers in the assessment of student learning [Electronic resource] / Mogey N., Watt H., Learning Technology Dissemination Initiative, 1996. – http://www.icbl.hw.ac.uk/ltdi/ implementing-it/cont.htm – 01.10.2008
18. Authoring of Adaptive Computer Assisted Assessment of Free-text Answers / Alfonseca E., Carro R. M., Freire M., Ortigosa A., Perez D., Rodriguez P. // Educational Technology & Society. – 8, 2005, P.53-65.
19. Bloom B.S. Taxonomy of educational objectives. Handbook I: The cognitive domain. – New York: David McKay Co Inc., 1956. – P.207.
20. Module III: Objective and Subjective Tests and Construction of Test Items, Advantages/Disadvantages [Electronic resource] / University of Minnesota, 2008. –http://www. nursing.umn.edu/Preceptors/evaluation/Module3/advantages.html – 01.10.2008
21. Designing Test Questions [Electronic resource] / The University of Tennessee at Chattanooga, 1998. – http://www.utc.edu/Administration/WalkerTeachingResourceCenter/FacultyDevelopment/ Assessment/test-questions.html – 01.10.2008
22. Lukashenko R., Vilkelis M., Anohina, A. Deciding on the Architecture of the Concept Map Based Knowledge Assessment System // Proceedings of the International Conference on Computer Systems and Technologies (CompSysTech'08). – Gabrovo, 2008. – P.V.3-1-V.3-6.
23. Marinagi C.C., Kaburlasos V.G., Tsoukalas V.T. An architecture for an adaptive assessment tool // Proceeding of the 37th ASEE/IEEE Frontiers in Education Conference. – Milwaukee, 2007. – P.T3D-11-T3D-16.
24. COMPASS: an adaptive web-based concept map assessment tool / Gouli E., Gogoulou A., Papanikolaou K., Grigoriadou M. // Proceedings of the First International Conference on Concept Mapping – Pamplona, 2004.
25. Adapting Assessment Goals to the Student's Profile [Electronic resource] / Georgouli K., T.E.I. of Athens. – http://www.emis.de/journals/AUA/acta7/Georgouli.pdf – 03.10.2008
26. Brusilovsky P., Peylo C. Adaptive and Intelligent Web-based Educational Systems // International Journal of Artificial Intelligence in Education. – 13,2003, P.156-169.
27. Thévenin D., Coutaz J. Adaptation and plasticity of user interfaces // Proceedings of the Workshop on Adaptive Design of Interactive Multimedia Presentations for Mobile Users. – Barcelona, 1999.– 7 p.
28. Adaptive Assessment in Web-Based Learning / Wen D., Graf S., Lan C.H., Anderson T., Kinshuk C., Dickson K. // Proceedings of the IEEE International Conference Multimedia and Expo 2007. – Beijing, 2007. – P.1846-1849.

29. Aguilar G., Gomez A., Kaijiri K. Question model for intelligent questioning systems in engineering education // Proceedings of the Frontiers in Education Conference, 2001. – Washington: IEEE Computer Society, 2001. – P.T2B-7- T2B-12.
30. Application of Adaptivity in Quiz Systems [Electronic resource] / Kinshuk C. – http://www.col.org/pcf3/Papers/PDFs/Cheng_Kinshuk.pdf – 01.10.2008
31. Lazarinis F., Retalis S. Analyze Me: Open Learner Model in an Adaptive Web Testing System // International Journal of Artificial Intelligence in Education. – 17, 2007, P.255-271.
32. Computer adaptive assessment [Electronic resource] / Castle Rock Research Corp., 2005. – http://www.castlerockresearch.com/caa/Default.aspx – 01.10.2008
33. Adaptive Computer Assisted Assessment of free-text students' answers: an approach to automatically generate students' conceptual models, PhD thesis [Electronic resource] / Perez-Marin D., Universidad Autonoma de Madrid, 2007 – http://orestes.ii.uam.es/dperez/tesisDianaPerezMarin.pdf – 01.10.2008
34. Hartley D., Mitrovic A. Supporting learning by opening the student model // Proceeding of the 6th International Conference on Intelligent Tutoring Systems ITS 2002. – Biarritz, 2002. – P.453-462.
35. Nkambou R. Towards affective intelligent tutoring system // Proceedings of the Workshop on Motivational and Affective Issues on ITS at the 8th International Conference on Intelligent Tutoring Systems. – Taiwan, 2006. – P.5-12.
36. Kapoor A., Picard R.W. Multimodal affect recognition in learning environments // Proceedings of the 13th Annual ACM International Conference on Multimedia. – Singapore, 2005. – P.677-682.
37. D'Mello S., Picard R.W., Graesser A. Toward an affect-sensitive AutoTutor // IEEE Intelligent Systems.- 22 (4), 2007, P.53-61.
38. Labidi S., Sergio N. Student modelling and semi-automatic domain ontology construction for Shiecc // Proceedings of the 30th ASEE/IEEE Frontiers in Education Conference, 2000. – P.F1B/14 - F1B/18.
39. Anohina A., Grundspenkis J. Prototype of Multiagent Knowledge Assessment System for Support of Process Oriented Learning // Proceedings of the 7th International Baltic Conference on Databases and Information Systems. – Vilnius, 2006. – P.211-219.
40. Anohina, A., Pozdnakovs D., Grundspenkis J. Changing the Degree of Task Difficulty in Concept Map Based Assessment System // Proceedings of the IADIS International Conference "e-Learning 2007". – Lisbon, 2007. – P.443-450.
41. Vilkelis M., Anohina A., Lukashenko R. Architecture and Working Principles of the Concept Map Based Knowledge Assessment System // Proceedings of the 3rd International Conference on Virtual Learning. – Constanta, 2008 (in print).

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Lukašenko R., Anohina A. Zināšanu vērtēšanas sistēmu arhitektūru un pielietošanas iespēju apskats
Rakstā ir sniegts pārskats par datorizētām zināšanu vērtēšanas sistēmām. Datorizētas zināšanu vērtēšanas vispārīga definīcija ir dota un objektīvas un subjektīvas testēšanas sistēmu pielietošanas iespējas ir aprakstītas. Turklāt rakstā ir identificētas priekšrocības un trūkumi, kas attiecas gan uz datorizētu zināšanu vērtēšanu pašu par sevi, gan arī atsevišķi uz objektīvas un subjektīvas testēšanas sistēmām. Zināšanu vērtēšanas sistēmu vispārīga arhitektūra ir atspoguļota, norādot šādu sistēmu pamatkomponentes, to izpildāmas funkcijas un sadarbību. Rakstā ir pamatota nepieciešamība nodrošināt intelektuālu un adaptīvu atbalstu zināšanu vērtēšanas sistēmās un ir aprakstīti minētā atbalsta izpausmes veidi esošās sistēmās. Īpaša uzmanība ir veltīta studenta modelim, kas tiek izmantots, lai adaptētu sistēmu atsevišķa lietotāja vajadzībām. Ir definēti modelī glabātas informācijas pamatveidi un šīs informācijas iegūšanas avoti, kā arī ir piedāvāts apkopojums par studenta modeļa klasifikācijām, ņemot vērā dažādus kritērijus. Rakstā ir arī sniegta informācija par intelektuālu un

adaptīvu atbalstu uz jēdzienu tīkliem balstītajā zināšanu vērtēšanas sistēmā, kas tiek izstrādāta Rīgas Tehniskajā universitātē, kā arī ir identificēti minētās sistēmas turpmākas attīstības virzieni.

Lukashenko R., Anohina A. Architecture and application of knowledge assessment systems: an overview
The paper gives on overview of computer-assisted assessment systems. The general definition of computer-assisted assessment is provided and the application of objective and subjective testing systems is described. Moreover, advantages and drawbacks related both to computer-assisted assessment in general and to objective and subjective testing systems in particular are identified. The overall architecture of a computer-assisted assessment system in terms of components, their functions and interaction is presented. The necessity to provide intelligent and adaptive support in computer-assisted assessment systems is stated and kinds of the mentioned support in existent systems are described. Special attention is devoted to the student model that is used with the aim to adapt the system to the needs of a specific user. The basic kinds of information stored in the student model and their sources are defined, as well as the available classifications of the student model on the basis of different criteria are summarized. The paper also provides information on intelligent and adaptive support in the concept map based knowledge assessment system that has been developed at Riga Technical University, as well as identifies further development directions of the mentioned system.

Лукашенко Р., Анохина А. Обзор архитектуры и возможностей применения систем оценки знаний
Данная статья посвящена обзору автоматизированных систем, предназначенных для оценки знаний. Общее определение компьютерной оценки знаний приведено и применение систем объективного и субъективного тестирования описано. Кроме того, преимущества и недостатки, которые относятся как к компьютерной оценки знаний самой по себе, так и к системам объективного и субъективного тестирования в частности, идентифицированны. Общая архитектура систем оценки знаний с указанием основных структурных компонент, их функций и взаимодействия представлена. В статье обоснована необходимость обеспечения интеллектуальной и адаптивной поддержки в компьютерных системах оценки знания и описаны виды этой поддержки в существующих системах. Особое внимание уделено реализации модели студента, которая используется в целях адаптирования системы к нуждам конкретного пользователя. Определены основные виды информации хранящейся в модели студента и источники получения этой информации, а также предложено обобщение классификаций модели студента на основе различных критериев. В статье также приводится описание уровней интеллектуальной и адаптивной поддержки в системе оценки знаний основанной на использовании карт понятий и разработанной в Рижском Техническом Университете, а также намечены дальнейшие пути развития упомянутой системы.