QUALITY ESTIMATION OF E-LEARNING SYSTEMS

Pavel Vorobkalov, Valerij Kamaev

Abstract: Existing approaches to quality estimation of e-learning systems are analyzed. The "layered" approach for quality estimation of e-learning systems enhanced with learning process modeling and simulation is presented. The method of quality estimation using learning process modeling and quality criteria are suggested. The learning process model based on extended colored stochastic Petri net is described. The method has been implemented in the automated system of quality estimation of e-learning systems named "QuAdS". Results of approbation of the developed method and quality criteria are shown. We argue that using learning process modeling for quality estimation simplifies identifying lacks of an e-learning system for an expert.

Keywords: e-learning, adaptive learning systems, quality estimation.

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Introduction

Education is one of the major problems of a government. Modern learning process becomes more and more complicated. E-Learning systems are widely used in education. The result of learning with the help of such systems to a great extent depends on the quality of these systems. Thus, the most important tasks in this area are to create tools that could estimate quality of e-learning in order to provide learners with qualitative learning materials. These tools might also help e-learning systems developers to find out system lacks during development process.

E-learning system presents learning materials to a user and then estimates his knowledge. Many modern e-learning systems tend to use adaptation technologies for improving learning process. An adaptive learning system is an e-learning system which takes into account some features of each learner, and then composes a learning strategy according to these features. Changes made by adaptive system during learning process could concern both sequences of learning concepts and content and layout of each page. An adaptive system is supposed to response for learning strategy and advices given to a user during learning, thus quality of learning process directly depends on adaptive models, methods and mechanisms used in the system. With built-in adaptation mechanisms e-learning system becomes more complex and results of learning could be unpredictable. Therefore problems of quality estimation of advanced e-learning systems, choice of adaptation mechanisms, finding-out the reasons of a low learning efficiency are urgent for developers of such systems.

Related Work

Two approaches for quality estimation of e-learning systems are used: the approach "as a whole" and the "layered" approach.

The idea of "as a whole" approach is based on considering system as a "black box" and estimating the values of general quality criteria (performance, security, etc.). The result of using this approach is one overall criterion value so it's hard to find out and distinguish the reasons of insufficient quality and lacks of the system. So after applying "as a whole" approach advanced analysis of the results must be performed.

Modern process of e-learning system development follows a spiral model of software life cycle where the initial stages such as analysis and design are emphasized. Incomplete development tasks at each stage of a spiral lead to lacks of the system on any architecture level. Using "as a whole" approach is expedient at a stage when a system is completely implemented, but during development of a system it is hardly applicable. Therefore the

approach that would allow quality estimation of e-learning systems on different life-cycle stages was required. New "layered" approach that focuses on quality estimation of e-learning systems is offered in [1]. Human-computer interaction process in e-learning system in the "layered" approach is divided into several various steps (so-called layers) which are estimated separately. The following advantages of using the "layered" approach can be revealed: it provides data about functioning of separate components of a system; it can be used at any development stage of a system. The lacks which could complicate application of the "layered" approach, are: dependence on internal mechanisms of a system; difficulty of interpretation of quality values from the point of view of a tutor.

Learning Process Modeling

Actually the aim of "layered" approach is to present e-learning system as a "white box" and to clarify reasons of different adaptation decisions applied in learning systems. But that decomposition does not show details of learning process and every time when the "layered" approach is applied additional analysis of e-learning system behavior should be performed. By learning process we mean the process of interaction between learner and e-learning system. For simplifying quality estimation process it is necessary to develop a universal model for a wide class of e-learning systems, including adaptive systems.

When describing a concept of quality of e-learning system pragmatic point of view must be taken into account, i.e. the result of learning should be considered as the major criterion of a system quality. If students are appeared to have insufficient knowledge of e-learning course after using the e-learning system it must be considered that this system is of a low quality. So learning statistics should be reflected in the learning process model. Model should also support simulation of learning process for individual student to help expert when analyzing adaptation decisions of the system.

Two parameters of learning process are chosen for learning process model:

- learner knowledge level;
- learning duration.

By learner knowledge level we mean current knowledge level of a learner which must be measured by e-learning system during learning process. Learning duration means shows how effectively learning time is being spent.

Majority of modern e-learning systems use semantic nets to represent a subject domain. Therefore use of net for modeling learning process should simplify interpretation of simulation results. We have analyzed different models that could be interpreted as net: finite state machines, Markov chains, Petri Nets. As a result colored stochastic Petri nets have been chosen because of the following reasons:

- Petri net model is event-based model, so it could easily represent learning process events such as concept and test completion;
- Petri net model could be easily extended;
- Visualization of Petri net simulation process can help expert to analyze learning process;
- Places, transitions and arcs of Petri net could be interpreted in learning process context.

Data collected during testing groups of learners by e-learning system is used as the input for simulation model. A place of Petri net is interpreted as a concept of a subject domain. Movement of tokens represents a progress in users' learning. Each transition corresponds to a step of learning process. Firing of transition is interpreted as learning task completion. Saying "learning task" we mean any type of a task user should perform during learning process: completing tests and exercises.

For modeling complex learning processes with student cooperation we use color component of Petri net token to identify each student role. For representation of a learner knowledge level we extended Petri net token with the attribute "knowledge level". It allows tracking learner results on each step of learning process simulation. Tokens are divided into two classes: tokens of the first class are in places which correspond to currently learned concepts; tokens of the second class are located in places learned previously (see Figure 1).

These Petri net extensions allow seeing which concepts are already learned and which are in progress in any moment of learning process for each learner.

Two random variables are bounded to each transition: firing time of transition, delta of a learner knowledge level after transition. These values are determined according to statistical data about learning process collected in the considered e-learning system. It is supposed that the data have been acquired adequately. So, for example, measuring time the system should take into account only time of active work in a system, i.e. when a user makes a different sort of action (moves mouse cursor, scrolls the learning content).

Each transition must have only one input place, and two or more output places. One of output positions always corresponds to a unique input place as it is necessary for us to mark the given place as it had been learned. Other output places correspond to alternatives of continuation of a learning process. The token corresponding to currently learned concept is located only in one of such output places randomly. Thus statistical probability distribution of possible continuation of learning process is taken into consideration.

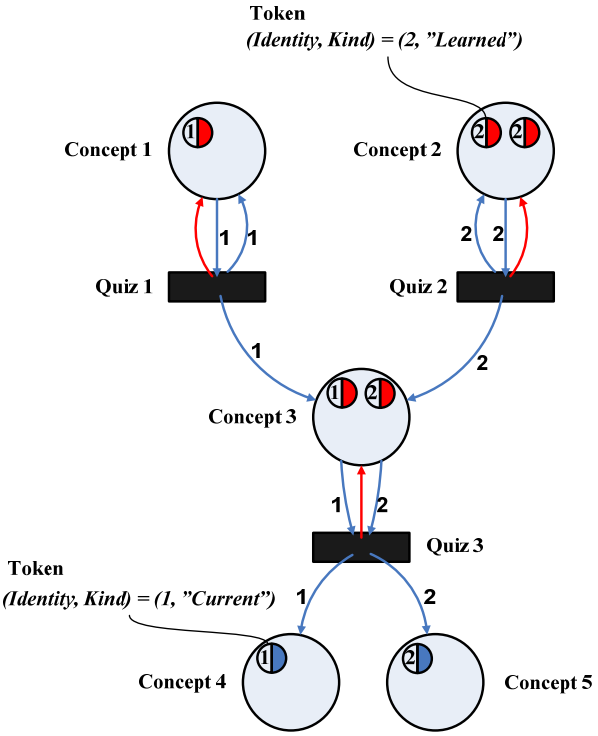

Figure 1: Learning process model based on Petri net

Quality Estimation

The suggested method of quality estimation of e-learning systems includes the following steps:

- Calculate apriori quality criteria of e-learning system.
- Analyze results of apriori quality estimation and modify appropriately e-learning system.
- Collect data about studying of students using e-learning system.
- Build learning process model based on collected data.
- Identify course concepts with insufficient quality.
- Calculate detailed quality characteristics of identified concepts and find out reasons of insufficient learning quality.
- Modify e-learning course.
- Test modified learning course and verify changes.

We have developed a set of criteria to estimate learning process model built for an e-learning system. These criteria can be divided into three groups: based on Petri net topology metrics; based on statistical characteristics of Petri net transitions; based on learning process simulation results.

Criteria based on Petri net topology metrics include the following ones:

- number of places in Petri net;
- number of transitions in Petri net;
- number of arcs in Petri net;

- number of all possible routes;
- number of all possible routes to number of places ratio;
- connectivity of Petri net.

Criteria based on statistical characteristics of Petri net transitions:

- average level of concept knowledge;
- integration of concept in e-learning course;
- level of connectivity between concepts of learning.

Criteria based on learning process simulation results:

- average student knowledge level;
- rate of correct adaptation decisions.

The method is invariant under internal mechanisms of estimated e-learning system. The restrictions of the method are the following ones: an estimated system should use the net model of a subject domain that is typical for natural-science and technical disciplines; the system should record time of learning of each concept and knowledge level for each student.

The process of identifying course concepts with insufficient quality is shown in Figure 2. Transitions in model are arranged by ascending of a ratio “delta of a knowledge level” / “time of learning”. Transitions with minimal ratio are considered to be problematic. Upgrade of corresponding concepts should be made for elimination of these problems. After fixing the errors new test group is expected only to learn part of course that contains modified concepts. The results of studying upgraded concepts define new values of transitions’ attributes. If these results are higher than previous, we can predict results of complete learning process.

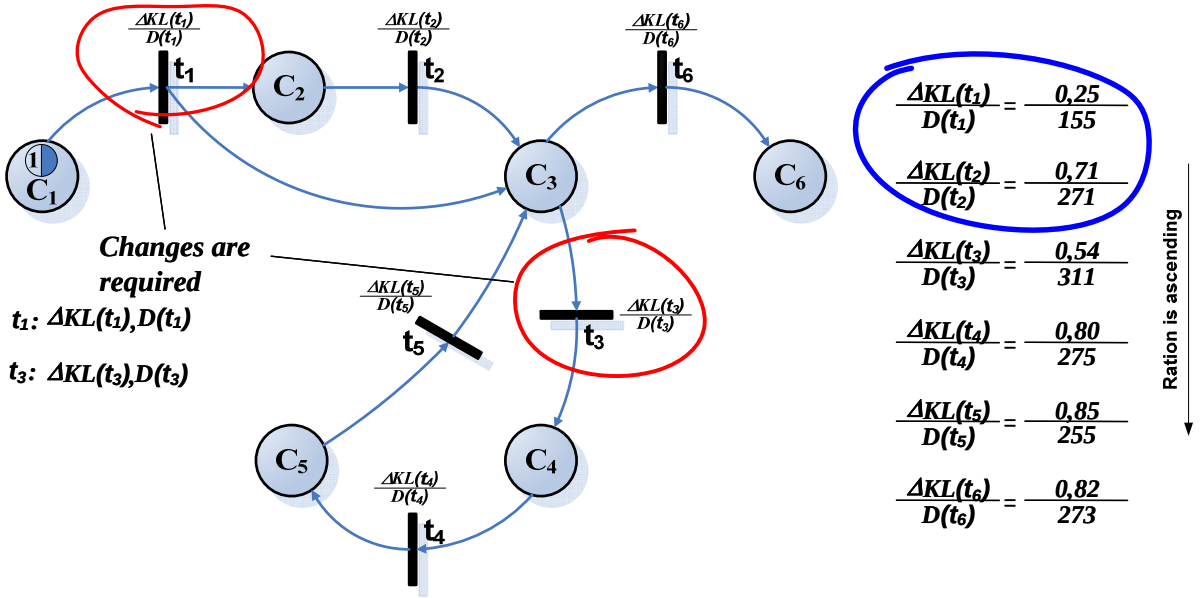

Figure 2: Process of identifying course concepts with insufficient quality

Experiments

Apriori criteria can be applied only on early development stages of a system, so for their approbation we needed the information about development process of any e-learning system. We have got an opportunity to approbate apriori criteria during development of the adaptive system with adaptation model based on Bayesian net, which was developed at CAD department of Volgograd State Technical University (Russia).

A set of learner characteristics in a learner model and a set of adaptation techniques were composed to measure a learner model adequacy. Inferences of each learner characteristic were estimated, and as a result an incompleteness of developed learner model was revealed. To fix the lack of information about a learner a few learner characteristics have been proposed to be included into learner model.

Estimation of learner model responsivity of learner knowledge level has shown that learner model based on Bayesian net takes into account stability of learner results during adaptation process. As a learner results stability grows then the next learner marks inference become smaller. But if a learner shows instable results model becomes responsible again. Actually that fact shows that Bayesian model handles contradictory data correctly.

Learning process modeling could be done if the system is already developed. For approbation learning process model we used our automated system of quality estimation QuAdS. We estimated e-learning system CALMAT [2] and adaptive learning system "AHA!" [3].

The estimation of quality of e-learning system CALMAT has been performed in collaboration with Katrin Hartmann (Glasgow Caledonian University, GCU, Scotland). CALMAT is used in GCU to teach math.

Estimated learning course "Statistics" for medicine and biology specialties contains 10 concepts (see learning score statistics in Table 1). Quality estimation of learning course "Statistics" revealed that the last three concepts are scored lower than the others because they are disconnected with preceding concepts (see Figure 3), i.e. we have located the bottlenecks of the course.

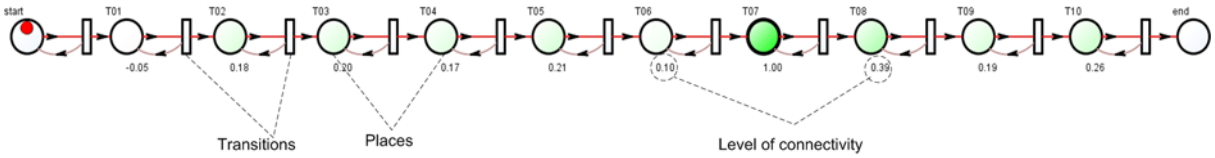

Figure 3: Visualization of learning process model built in QuAdS. Level of connectivity of learning course concepts with concept T07 ("Probability")

Table 1: Students' knowledge level of CALMAT learning course "Statistics" (number of students - 51)

Concept	Average score (maximum 100)
T01	93
T02	94
T03	71
T04	81
T05	78
T06	95
T07	87
T08	69
T09	75
T10	69

For estimation of adaptive mechanisms we used a free learning environment "AHA!". Learning course "Fundamentals of computer-aided control systems" which has been developed on CAD department in Volgograd State Technical University was implemented as an adaptive learning course in "AHA!". Information about learning process in "AHA!" learning system is collected in open format, so we could build learning process model. Results are shown in the Figure 4.

After that each adaptation strategy was analyzed (e.g. see Figure 5). Performed analysis allowed to correct learning course in such a way to exclude insufficient quality strategies.

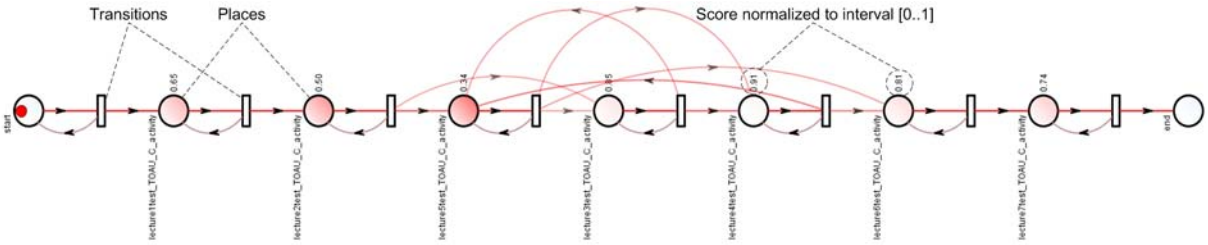

Figure 4: Visualization of learning process in AHA. Learning process model for learning course 'Fundamentals of computer-aided control systems' in "AHA!" system

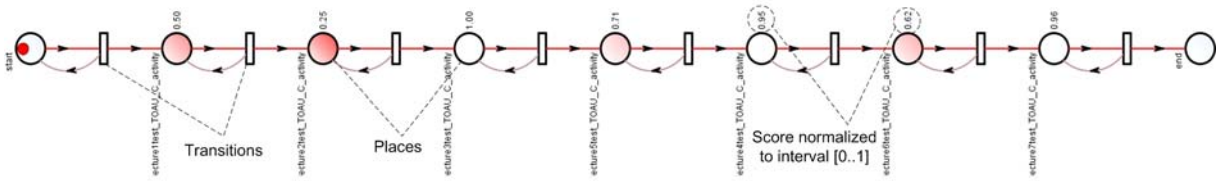

Figure 5: The most effective adaptation strategy of learning course in "AHA!" system

Conclusions and Future Work

The suggested method of quality estimation of e-learning systems using simulation of learning process and developed quality criteria of e-learning systems can be used during design and development of e-learning systems and for e-learning systems certification purposes. The method covers wide class of e-learning systems based on net models. Learning process model can help expert to perform e-learning process analysis and to deduce learning course mistakes. The method and criteria were successfully applied to estimate quality of existing e-learning and adaptive systems.

The future work is to expand a set of quality criteria and to create e-learning development framework with integrated tools for quality estimation.

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