MONAP-II: the analysis of quality of the learning process model

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Abstract

The main topic of this paper is the analysis of quality of the learning process model for skills of algorithmic nature. This model is realized by intelligent tutoring system (ITS) authoring tools MONAP-II. The model is evaluated from the points of adequacy (precision) and convergence (reliability). The correlation of the basic parameters of the model is reflected. It is shown in which way human-teacher can tune didactic properties of designed ITS by changing parameters of the model. MONAP-II contains subsystem of learning process modeling for more precise and valid tuning of the model as soon as didactic experiment realization. This subsystem allows human-teacher to inspect internal states of the learning process.

1. Introduction

The effectiveness of intelligent tutoring systems (ITS) in many respects depends on quality of learning process models realized in these systems for learning process control.

Baker in his paper [1] marks out three basic contexts for considering models in present researches in the area of artificial intelligence in education (AIEd):

– model as scientific tool,
– model as component of an educational artifact,
– model as basis for design of computational artifacts for education.

This paper considers the model of learning process realized in *MONAP-II* from points of all of the contexts listed above (to a greater or lesser extent).

On the one hand when evaluating *MONAP-II* on meeting the requirements that are made for computational models we have investigated its behavior in different educational situations. These investigations are on the basis of the experiments with parametrical tuning of the learning process model, determination of the correlation between different parameters, and detection of the forms of these parameters influence on the properties of the overall model. It has been very useful in such investigation the built-in subsystem of learning process modeling (it was described in details in [2]) allowing by varying parameters of the model the evaluation of quality of *MONAP-II* as the system of AIEd.

On the other hand the papers describes educational artifact, to be more precise, authoring tools for ITS design. The learning process model is the key component of architecture of ITS designed by means of *MONAP-II*. This component is responsible for effective learning process control, and, in the final analysis, in many respects, for the success of learning process.

Finally, while different components of *MONAP-II* were developed, the structure of the model frequently caused making of one or another design decision. Both figures in the paper demonstrate it very illustratively. So both on the stage of definition if model parameters (fig. 1) and on the stage of learning process modeling (fig. 2) human-teacher interacts with he screens, whose functionality was imposed by functional structure of learning process model.

2. *МОНАП-II*: brief review

Authoring tools for ITS design of MONAP family were described in the number of journal papers and conference reports. The most detailed formalization of didactic principles, which the system is based on, as well as description of its practical implementation made in [3]. The last version of *MONAP-II* authoring tools is characterized by the mechanism making the overall process of ITS design easer for human-teacher who is not the expert in the area of computer-based learning [4].

The learning process in *MONAP-II* is considered as a monitored and controlled process of learning task solving. Using of the Bayesian approach to the student's knowledge identification, processing of student's results during the specified number of learning steps for abnormal termination control (in the case when learning process is not effective) and making the prediction of student's mastering state provide the taking into account the history of learning, what is the basis for adaptive learning organization.

Figure 1 demonstrates the initial stage if ITS design by means of *MONAP-II* authoring tools. On this stage human-teacher provide tuning of the basic parameters of an ITS's learning control model.

By determining these parameter human-teacher is expressing his conception about the way, how the process of learning control should be conducted. Thus, depending on specified values of parameters ITS takes one or another "personal" features of human-teacher from "patient" and "tolerant" to "strict" and "exacting".

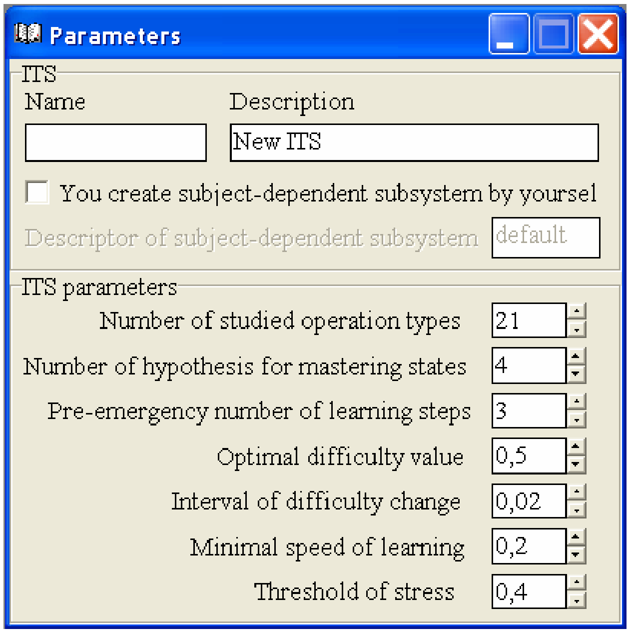

Figure 1. Parameters of learning process model.

In the next section it is shown how changing of these parameters influences on properties of the model and consequently on quality of learning process.

3. Evaluation of learning process model

Learning process as such and, accordingly, the effective learning control are the multiple-factor, feebly-formalized processes. At present there is no "ideal" theory of learning and consequently there are no quantitative characteristics (estimated values) of an "ideal" learning process. In another words nobody can, for example, provide quantitative assessment of the required degree of coincidence for values of output parameters of the learning process model and the modeled object (human-teacher). In this connection analysis of learning process model is on principal qualitative in nature.

The customer of adequacy is one of the main requirements for models. The model regards as adequate if it reflects the properties of object with acceptable precision. The precision is defined as a degree of coincidence between meanings of output parameters of model and object. For analyzed model the output parameter is the learning process control.

In object as well as correspondingly in model it is possible to distinguish two following main components of learning process control:

- assessment of student's knowledge;
- forming of learning task on the basis of knowledge assessment.

An assessment of student's knowledge provided by learning model in the general case can be more reliable, than the grade is put down by human-teacher as in the first case the factor of subjectivity is absent. In connection with this it is necessary to distinguish objective and subjective aspects of student's knowledge assessment and learning process control.

3.1. Objective evaluation of adequacy

Impartially adequacy (precision) of students' knowledge assessment, which is implement by the described learning model, is reached by the following manner.

It is well known, that efficacy of functional inspection of knowledge is considerably higher than control on the basis of student's end answer. The method of knowledge identification, implemented in ITSs designed by means of *MONAP-II*, is invariant to the number of types of studied operations. In other words, there is the objective possibility to raise the precision of knowledge assessment up to acceptable level at the expense of increase of refinement of learning activity decomposition to component operations (parameter "*Number of studied operation types"* fig. 1).

Model uses the coefficient of prediction of learning [3], which is dynamically calculated according to the results of each leaning step. It allows model to take into account the individual learning effect of all diagnostic reports (error reports, comments, explanations). Such mechanism also increases the precision of student's knowledge assessment.

The great deal of existing learning models practically does not consider "abnormal situations", which are arisen by outward influences regarding student and learning process ("noises"). This is explained by complexity of modeling of pointed influences. Not taking into account of such a "noises" can fundamentally decrease adequacy of learning model with respect to the real learning process. Described model contain a special parameter "*threshold of stress*" (fig. 1), which is intended for averting of false emergency termination of learning.

Besides, for such purpose it is necessary to know values of probabilities of correct using of all types of operations during *pre-emergency number of learning steps*. Thus one more mechanism for taking into account the history of learning process (in other words, providing adequacy of learning model as a system of learning process control) is implemented.

Together with indicated mechanism the taking into account of learning history in implementation of learning tasks' difficulty stabilization is also impartially directed to providing adequacy of developed learning model.

3.2. Subjective evaluation of adequacy

Along with the objective aspect of precision of student's knowledge assessment and learning control the subjective aspect of precision (the model precision from the point of view of human-teacher) is implemented as follows.

The converging of knowledge assessments providing by the model and human-teacher can be reached by choosing of corresponding dimension of rating scale. The dimension of rating scale is determined by the *number of hypothesis for mastering states* (fig. 2).

In connection with the fact that the output parameter of the model and the object (human-teacher) is not the assessment of student's knowledge but the control of learning process on the basis of this assessment, the central problem is not the proper minimization in mismatching of ratings but the minimization of differences in learning process control that caused by described mismatches. At the human-teacher's point of view mismatching of ratings may be expressed as the rating of student's knowledge that is carried out by the model either set as too high or set as too low. In the case when human-teacher think that the rating is given too high it is necessary to lower the value of optimal difficulty level to lessen difficulty of forming task to the next learning step and corresponds with student's knowledge. Otherwise, when the rating is given too low it is necessary to increase the value of optimal difficulty level.

The described method of minimization of mismatching consequences in the assessments of student's knowledge between learning model and human-teacher is only one approach to provide the adequacy of the model. Together with this method the necessary (acceptable) adequacy of learning process control may be provided by the way of flexible variation of values of all another parameters of discussed model. Thus, for example, when changing the value of minimal speed of learning and pre-emergency number of learning steps it is possible to change conditions of abnormal termination of learning process. Also, when changing the number of hypothesis for mastering states it is possible to change requirements for final mastering state, i.e. the conditions of successful finishing of learning process and so on. At the same time it is necessary to say that adequacy of discussed model as a system of control of learning process may be reached only if human-teacher principally agrees with the main didactic principles, which are in the basis of this model.

3.3. Evaluation of Reliability

The next main requirement, which is set up to models, is reliability (convergence). The model regards as reliable if a minimal errors in determination of input data do not lead to large dispersion of calculus results, i.e. the convergence to solution is provided. Input data for described model, and potential sources for errors, are knowledge about student, knowledge about control of learning process and knowledge about subject domain of learning.

For any allowable input data the discussed model provides the decision making which is contained in termination of the learning process (abnormal or successful) or in the determination of properties for learning task for next step that will be adequate to student's knowledge level.

When modeling the learning process any quantitative evaluation of concept like "inaccuracy" bears a subjective character. When the same distances in the determination of input data may be interpreted by one human-teacher as immaterial the others may consider them as essential. Consequently the requirements of model convergence must be integrated with the requirements of its openness, i.e. the model must have the following property. If distance in input data is interpreted by human-teacher as "inaccuracy" then they have to be ignored by model, otherwise the model have to sufficiently (adaptively) react on them. The demanded property in *MONAP-II* is provided by the way of parametric tuning of model.

In the case when the source of an inaccuracy is knowledge about the student, the acceptable level of convergence may be reached, for instance, by following manner.

It is known that when the Bayesian approach is used the sensitivity to the start a priori distribution of hypothesis decrease when the amount of sampling is increased. In that way, the increasing of number of operations in the texts of tasks leads to the following result. The inaccuracy in a priori knowledge assessment of student do not influence so hard to the a posteriori assessment of his knowledge (the knowledge assessment provided in accordance of learning results). For further increasing of convergence of student's knowledge identification, and consequently in the decision that the model is made, the number of hypothesis of mastering states may be decreased. The pointed decreasing of dimension of rating scale results in that the range of distance in knowledge assessment by entered mastering states rises.

Knowledge of human-teacher about learning process control is presented in model in the form of the set of values of input parameters. The character of influence of inaccuracy on the pointed values of parameters to the convergence is diverse and illustrated by following examples.

If the value of such parameter as a number of hypothesis of mastering states in the particular implementation of the model differ from its value in another and at the same time the values of hypothesis are sufficiently large in the context of its admitted region then the influence of pointed distances to the level of convergence does not large. In case when the values of this parameter are low it is possible that differences between them can lower the level of convergence. The similar statements are true also for pre-emergency number of learning steps. The deterioration of convergence, which is caused by distance in optimal difficulty values in different implementations of model, is minimized by increasing of value of interval of difficulty change. The raise of the interval of difficulty change and the number of pre-emergency steps increase the level of convergence.

Knowledge of human-teacher about the learning domain are presented in the model by means the components of ITS's knowledge bases, where didactic properties of learning tasks are formalized. Conducted investigation of the learning domain properties, invariant to the content of learning [5] allows to characterized influence of inaccuracy in pointed knowledge on the convergence of learning process model as follow:

- changing of the number of studied operation types influence essentially on the convergence of learning process model;
- the level of convergence does not depend on the sorting of learning task according to their difficulty level inside of one class of learning tasks, which is characterized by the specific set of studied operation types;
- the smaller the number of existing classes of learning tasks is the higher the level of convergence of learning process model is;
- the bigger the number of learning tasks belonging to the one class is the higher the level of convergence of learning process model is.

Thus, given examples vividly demonstrates that human-teacher can determine and set by himself the required levels of adequacy and convergence for learning process control.

4. Modeling

Baker in his paper [1] marks that one of the main problems, which should be solved for ITS to be widely applied in the real school education, is the problem of closeness of these system.

In another word, first of all, when ITS organize the learning process it practically does not allow human-teacher to influence on the process of making the decision about one or another learning action for the next learning step. The above section has shown that MONAP-II provides human-teacher with the broad sphere of action on tuning the parameters of the learning process model.

Secondly, there is not many ITS's which realize subsystem of explanation helping human-teacher (who is not the expert in the area of computer-based learning) to answer on the student's possible question: «Every time I do/say X it does/says Y (to me); why does it do that? I don't understand what it's getting at, what it wants from me?" [1]. In our opinion, the next step on the way of providing ITS with maximum openness is the realization of mechanism that allow inspection of their internal states of learning process, comparison predictable and real student's results and conduct on this basis the correction of system's decision (if it is necessary). MONAP-II has such a mechanism. Subsystem of learning process modeling (which is described in details in [2]) is presented on the figure 2. With the help of this subsystem human-teacher can investigate the properties of the model for realizing general regularities, which are in the basis of the learning process control, implemented by *MONAP-II.* Also this subsystem can be used for didactic experiments conduction and correction of designed ITS properties according to the results of these experiments.

5. Conclusions

MONAP-II authoring tools for ITS design have been considered. The special attention is gift to the quality analysis of learning process model realized in *MONAP-II.* This analysis has shown that the model meets the general requirements made for computational models, namely: adequacy (precision) and reliability (convergence). The correlation of the basic parameters of the model is reflected. It is shown in which way human-teacher can tune didactic properties of designed ITS by changing parameters of the model. MONAP-II contains subsystem of learning process modeling for more precise and valid tuning of the model as soon as didactic experiment realization. This subsystem allows human-teacher to inspect internal states of the learning process.

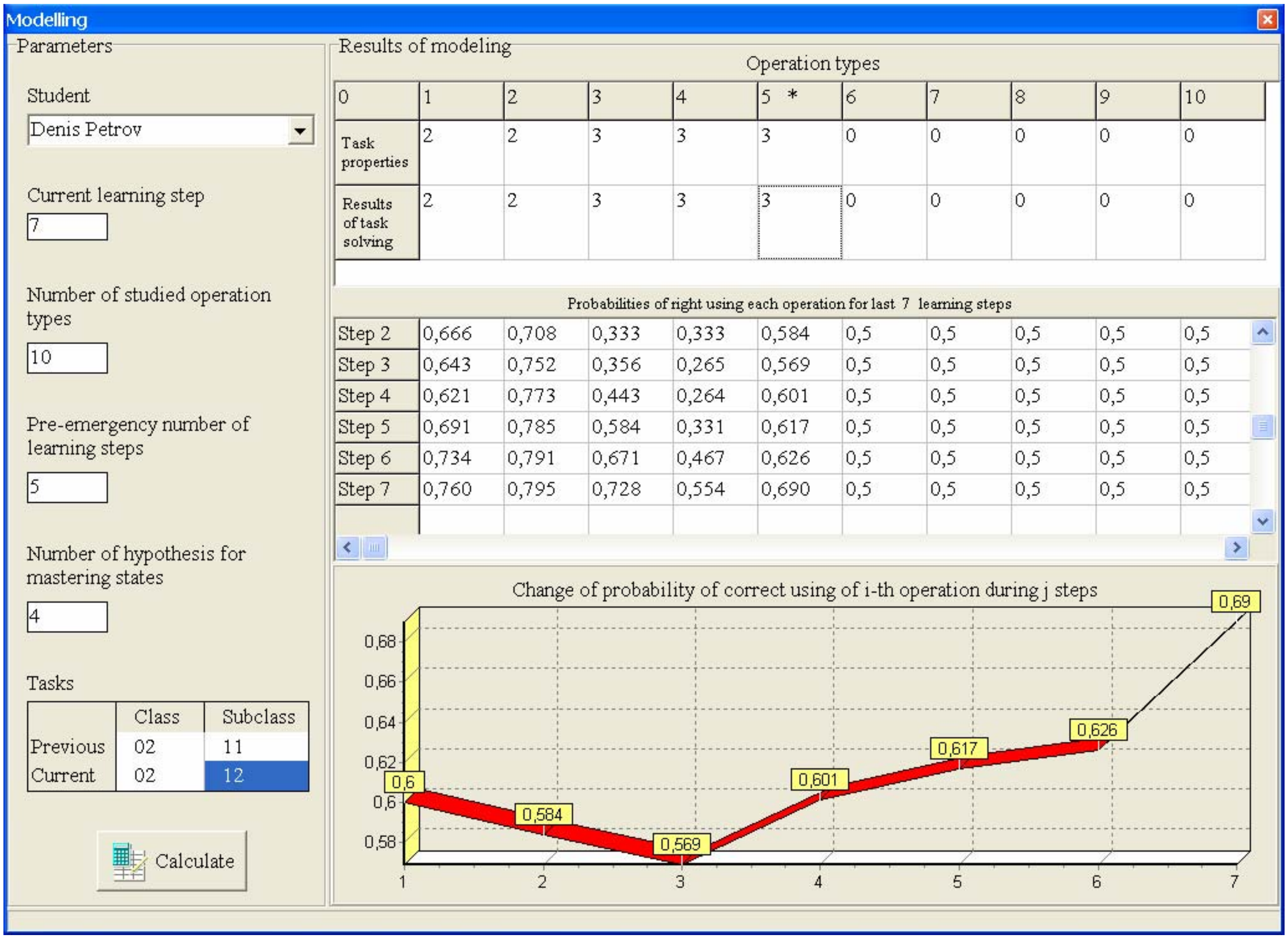

Figure 2. Modeling of learning process.

6. References

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