

NOTES

The Basic Principles of Building an Ergonomic Component of Automated Training Systems

Nina Kalinina

Novosibirsk State University,
Novosibirsk, Russian Federation

Nina Kostyukova

Institute of Computational Mathematics
and Mathematical Geophysics, Russian Federation

In recent years, in view of the transformation in education in the Russian Federation, it has been necessary to introduce different technical facilities and new educational methods into the educational process. An introduction of training systems into the educational process concerns every educational method. New methods use various results from such fields as pedagogy, psychology, cybernetics, mathematics, and linguistics. Automated training systems consist of 3 components: informational, didactic, and ergonomic. This paper considers 2 components: didactic and ergonomic. They provide maximum learning with minimum energy consumption on the part of the trainee, in acceptable working conditions. As an example, this paper considers educational systems of calculus mathematics and mathematical geophysics realized in the Novosibirsk State University and Institute, Russian Federation.

ergonomic didactic fatigue efficiency intensity monotony activity
training systems teaching management

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Correspondence and requests for reprints should be sent to Nina Kostyukova, Institute of Computational Mathematics and Mathematical Geophysics, Russian Academy of Science, Academician Lavrentyev Avenue, 6, 630090, Novosibirsk, Russian Federation. E-mail: <nina@rav.sccc.ru>.

1. INTRODUCTION

Ergonomic and didactic aspects are rather important in automated training systems (ATS). Ergonomics considers the intensification of all forms of teaching. Under conditions of normal, optimum intensity of teaching there is no physical, intellectual, or nervous overload; natural human labor and perceived requirements are satisfied. Moreover, working time, energy, and strength are spent rationally; work capacity and health are maintained; there is no monotony or fatigue.

To intensify a student's training it is necessary for

- a system of didactic methods, techniques, and facilities to be developed;
- the most effective forms and conditions of organizing a student's activity to be determined;
- training methods and techniques to be acquired by teachers.

An intensification of pedagogical activity involves providing the most favorable working conditions, decreasing fatigue, assisting in opening creative abilities, and increasing efficiency.

Training systems should be designed to intensify the educational process, the teacher's and the student's individual activities (an increase of the teacher's qualifications and the student's erudition), and collective activity.

The following tasks are the basic components of ATS:

- to create a methodology of multiterminal directory systems, operation software for information systems with user's terminals;
- to develop materials on mathematical modelling of communication;
- to analyse parameters of survivability;
- to create mathematical model algorithms of both structural analysis and synthesis;
- to develop a program complex, which consists of an automated training system, an encyclopaedia, a toolkit for realizing practical employment and laboratory work, a manual for designing and analysing communication.

1.1. Didactic and Ergonomic Components of the Project

As the project is designed to automate research and to create new models of training (which are necessary for long-distance education), the didactic and ergonomic aspects are very important. In this paper estimating the efficiency

of ATS and new software is considered. The training system should offer an opportunity in a dialogue mode to change ways of displaying information on the screen, to create various models, to register the characteristics of work pace. This creates preconditions that allow researching individual features of a person (memory, recognition, attention) at work in laboratory conditions as close as possible to real ones.

The use of computers brings new elements to traditional lecturing, namely,

- visual presentation of information on screens in a form convenient for recognition;
- audio and visual images that are easy to remember, assist thinking and creating certain associations in students;
- the possibility to repeatedly refer to lecture material with the help of various indexes and references;
- the possibility to receive hard copies of lecture material.

The comparison of the evaluation of the efficiency of the training system can be based on either training according to a standard model or training with the help of another automated system in which the way of presenting material and the form of interaction between the student and teacher essentially differ.

1.2. Ergonomic Estimation of an Information Model

The task of designing an information model can be divided into three subtasks:

- choosing a way, kind, and volume of presented information;
- forming and optimizing a set of typical means of displaying information;
- designing and optimizing the sign alphabet.

The listed tasks are solved with experimental methods.

2. METHOD

The conception of the psychological-pedagogical theory of teaching should be used when creating ATS. The process of automated training can be brought to the process of perceived activity management. There are different

approaches to classifying perceived activity. Three levels can be distinguished:

- the trainee gets a general concept of the study object;
- the trainee acquires basic subject ideas to such an extent that he or she can analyse different actions;
- the trainee can apply acquired information in practice; and the trainee can draw conclusions and find correct solutions of new problems.

So, the model of automated training should accomplish the functions listed, whereas ATS should provide these three levels of perceived activity management.

The first level of management is the teaching process, which proceeds according to the prescribed algorithm, without checking acquired knowledge. The second one is management of perceived activity with constant checking of the quality of understanding of new material and accomplishment of necessary corrections. On the last level of perceived activity management a combination of the first and second levels should be used.

When developing ATS it is necessary to define accurately the content of three basic didactic questions:

- What is taught?
- Who is taught?
- How is the teaching done?

The first question determines the goals and content of teaching, the second—the object of teaching, the third—the method of teaching. To accomplish the first question of what is taught, a model of the subject should be developed, to accomplish the second—a model of the trainee, and for the third one—a model of perceived activity management. The principles of the development of such a model are considered in the work of Kostyukova and Kvashnin (1995). We should mention that dissipated and directional informational processes can be distinguished. In the dissipated informational process, information from the source (in our case from ATS) is directed straight at the trainees, whether they understand it or not. In the directed informational process, information from the source is directed at a concrete trainee taking into account of his or her individual peculiarities. Teaching programs (in ATS it is a logically combined set of quantifiers of teaching information, assigned to the forming of required aggregate of a trainee's knowledge and skills in the subject, in the human-computer

dialog mode) can be linear and multilevel. A linear teaching program consists of fixed consistency shots identical for every trainee. ATS should be supplied with a special adaptive human-computer dialog. The goal of this dialog guiding in ATS is to provide adaptation to the trainee's parameters, in order to create the most convenient working conditions. Every user is represented by a vector of parameters, determined by its peculiarities (the model of the trainee). There is a limited number of groups, in which trainees are grouped according to similar parameters. That is why adaptation is provided within every group of users.

The main tasks of the dialog are the choice of a dialog, the choice of the dialog's structure, reorganization of the dialog's structure in order to adapt it to the user's needs. The dialog's management on the level of different topics and sections is based on the determination of the optimal consistency of the study of signal topics, in other words, of training systems. In ATS technical aesthetics—rationality of forms and color solution—should be realized.

2.1. Estimation of Practical Work

First, it is necessary to list parameters used to estimate the students' activity. Data on each of the parameters are formed by associating the results of the examinations that were given at different times to different groups of students. To estimate parameters, which are continuous values, it is possible to use the Wilcoxon criterion. To estimate discrete parameters it is possible to use the Student criterion. Second, it is necessary to plan the experiment correctly. Trainees are divided into two equal groups. The first group is experimental (training will be conducted through the new automated system). The second group is a control group (training will be conducted by a traditional method or on a known automated system). The constant conditions in the experiment must be the academic performance of the trainees, structure training, syllabus, laboratory, course and test work, day of the lecture, and the teacher. Third, it is necessary to be able to process statistically the results of the experiment.

2.2. Estimation of Progress

The progress of a group can be estimated with the formula

$$Y = \frac{1}{mn} \sum_{j=1}^n \sum_{i=1}^m c_{ij}, \quad (1)$$

where c_{ij} —estimation received by student j for the i kind of work; n —number of students; m —number of estimated kinds of work. Depending on the technique used the estimation of training can be written down as follows:

$$\begin{aligned} X_a &= Y_1 - Y_2 && \text{absolute parameter,} \\ X_e &= Y_1/Y_2 && \text{efficiency ratio (relative parameter),} \end{aligned}$$

where Y_1 , Y_2 —progress in the first and second techniques respectively, calculated from Equation 1. If in a pedagogical experiment it is impossible to divide participants into equal experimental and control groups, it is necessary to correct the difference of average numbers.

2.3. Estimation of Fatigue During Training

The model of controlling the educational information processing is described by the formula

$$Z(t) = \delta(1 - e^{t\lambda}), \quad (2)$$

where $Z(t)$ —volume of information in SUTs (semantic unit of the text), presented to the student in time t .

$$\dot{Z}(t) \Big|_{t=0} = 0;$$

δ —parameter of a model that determines a maximum quantity of information remaining in the memory of a person during continuous training; λ —parameter of a model describing a trainee's fatigue. $T = 1/\lambda$ —time, for which the speed of processing information decreases in e time. To define δ and λ we differentiate Equation 2 on time. Then, having performed a number of

analytical transformations and using the method of least squares, we calculate λ and u ($u = l n \delta \lambda$).

3. RESULTS

3.1. Example of Construction of Training System

3.1.1. VOLNA

In ICMMG (the Institute of Computational Mathematics and Mathematical Geophysics at the Russian Academy of Science) on the basis of a complex of mathematical models the VOLNA electronic textbook is developed. While designing the electronic textbook the following issues were solved: the purpose and contents of training, the method of training, trainees, the level of the trainees' abilities.

While developing the system a lot of emphasis was put on convenience and ergonomics. The intellectual interface of the system contains superfluous software, which allows choosing a certain level of comfort.

The ergonomic maintenance of the electronic textbook is aimed at increasing system efficiency (the trained-training program) at a minimal use of the resources of the student and maximum satisfaction with the contents of work. This maintenance is based on the realization of the ergonomic requirements: composite structure, rationality of the forms, information expressiveness.

The student has an opportunity to allocate independent stages of mastering the material. He or she can decide to move up to the next level or skip some.

3.1.2. *Modern tasks of organization and methodology of ergonomic bases for an information and fact retrieval system*

The objectives and scope of an information and fact retrieval system for a geophysical class of objects are described in this section. Problems of the organization of the ergonomic bases of the system are formulated. The system is formulated. The ergonomic component of the system is considered.

An information and fact retrieval system for a geophysical class of objects is developed as hardware means in theoretical studies of processes of elastic wave propagation when predicting natural resources.

This work is developed using the following:

- A new numerical method for calculating seismic fields on the basis of a combination of finite integral transformations along one spatial coordinate with finite difference techniques along the other spatial coordinate and with respect to time.
- Calculation of synthetic wave fields on the basis of the main peculiarity of efficient algorithms enables taking into account all the effects (such as inhomogeneous, surface, non-ray, channel, diffracted, volume, and other types of wave) arising when the field is propagating in complex elastic and acoustic media allowing for absorption, anisotropy, and so forth.

3.1.3. *FABULA system*

The FABULA system is intended for solving transformation and optimization problems of Boolean algebra. Let us consider its ergonomic component, which is included in the interface part of the system. The interface supplies interaction with the user. It ensures user commands are received and displays information given by the system: the results of work, error messages, and tips. When designing the system major attention was paid to user interface. Among computer algebra systems there are different types of user interface. Many systems, especially those that were developed a rather long time ago, support dialog on the level of the command line. This is not very convenient now.

Some systems have a type of interface called blackboard. The display looks like a classroom blackboard, and the user can “write” his or her command in any place of the blackboard. The results of the system are presented in the free space of the display. Moreover it does not matter what kind of results they are: formulas, graphics, or other.

When analysing such systems as REDUCE, MACSYMA, Derive Algebra, muMATH, it was decided that the best way to represent user interface was to represent them as windows interface. Its structure corresponds to the integrated environment of the program’s development. It allows inputting programs into text editors and it makes it possible to keep information during the calculations. Access to it is quite quick. This choice was made because information is one-dimensional, in other words, it consists of strings of characters. We should not represent fractions and draw graphics. All our objects go in a string.

The main elements of a display interface. They are edit fields, history windows, status line, menu bar.

The output of programs: edit fields. The edit field is a simple text editor. It is intended for input and modification of user programs. This text editor is full-screen and supports ordinary edit commands. At the end of an input of the current part of a program, the user can send it for interpretation and after its execution look through the results. The history windows serve this purpose.

History windows. They are intended for keeping, viewing, and choosing all user queries and results within the current session. Every text input by the user and then sent to the interpreter is added to the history window. All answers of the system, in other words the results of the work of the program, are put into the history window too. If it is necessary the user can look through all this information and move some needed strings to the edit field. This is convenient when you want to use the results of the system's work or modify an already executed part of the program. There can be a few history windows, in which case information is input into the active one. You can make any window you want active. As in one session there can be a lot of information, there is no sense in keeping it all in on-line storage. That is why all the information is stored in a disk file and only the small part that is represented in the window is kept in the window buffers. Every window is supplied with such a file, which is called a history file. This file is indexed by the numbers of strings. The indexes are kept in special index files. Indexes and buffers make access so rapid that there are no any delays when viewing the contents of the window.

Controlling the system: menu and status line. The status line shows the current state of the system and gives short tips, depending on the context. It gives the user information about available memory and gives the number of the active history window. The menu bar provides access to the menu system, which makes administrating the system possible. There is an alternative way to administer the system—hot keys that are assigned to the menu commands used most often. The head menu system consists of four submenus: Window, Files, Interpreter, Fragments. In the File menu there are groups of commands for working with history windows, for exiting the system, and for changing the current directory. In the Window menu commands for working with windows are grouped. Commands for moving between an active history window and an edit field, and for clearing the edit field are related to them. Moreover, here standard window operations are grouped, such as maximizing a window, changing its size and position, displaying windows as a cascade or tiles, listing windows, closing windows. In the Interpreter menu there is only one command—execute. When activating

the interpreter and using this command, the whole content of the edit field is given for interpretation and it duplicates the active history window. The result of the correct operation of the program is displayed in the active history window. If during a syntactical analysis or execution of the program an error is found, then the user receives information about this mistake in an error message and the number of the string where it happened. The Fragments menu includes commands dealing with string fragments and history windows. By a string fragment we understand a marked part of a text. You can hide the marking of the strings, delete a marked fragment from the history fragment, or copy it into the edit field. In addition to the short tips in the status line, the user has a wide hypertext system of context-dependent references about the interface.

4. CONCLUSIONS

To successfully perform the task of creating a highly effective training system it is necessary to take into account a number of ergonomic factors:

- Features of the student's work with mathematical models;
- The student's individual features (high-speed parameters differ from one another);
- The need for lecturers to create certain associations supporting the process of memorizing.

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