Simulations Laboratory in Physics Distance Education

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Introduction

Distance learning has been popularized in recent years because of the fast development of computer systems and the spreading Internet connectivity. One of the major restrictions for distance learning in physics education is the difficulty of laboratory activities. One way to overcome these difficulties is to use simulation programs running on a Web browser instead of requiring hands-on experiments.

Computer simulations can play a crucial role in distance physics education because they can provide a vehicle for "interactive practice" [1]. "Interactive practice" can enable the student to respond to new and changing information in ways which closely approximate real-life situations. This type of instructional experience can produce a depth of learning which is difficult to achieve with other modalities.

Simulations have a special place in learning technologies because they are interactive and because they allow experimentation and discovery learning of multi-faceted skills in a close to real-world environment. Like most skill development, computer simulations benefit from preparation, guidance, coaching, and debriefing to optimize the learning experience. The ability to deliver these simulations online makes them a powerful alternative or supplement in physics education.

The purpose of this paper is to present the recent development of a Simulation Physics Laboratory created for student from engineering courses of University of Rousse and to explore the role that computer simulations can play in distance physics education.

Priorities of computer simulations

The term "computer simulations" has been defined in different way as follows:

- A computer model of a real-life system or process represented in an abstracted or scaled-down form. Users of computer simulations may interact with other people or with elements of a simulated environment. Computer simulations can be powerful tools for analyzing, designing, and interacting with complex systems or processes. Well-designed computer simulations provide a model of those elements most relevant to the immediate learning objective. In addition, "they inform the instructor and the learner of aspects of the real-life system or process that have been simplified" or eliminated [2, 3].
- Effective computer simulations are built upon "mathematical models" in order to accurately depict the phenomena or process to be studied [4].
- At the same time, "computer simulations have been found to be most effective for learning when unimportant aspects of the real-life situation or process are eliminated from the simulation" [5].

Computer simulations can be incorporated into a wide variety of distance education situations. The use of computer simulations in distance education is a relatively new phenomena and

research in this area is limited. The main priorities of computer simulations in physics education have been defined as follows:

- Computer simulations provide a method for checking our understanding of the real world by modeling the structure and dynamics of a conceptual system or a real environment. They facilitate "interactive practice" of real-world skills by focusing on essential elements of a real problem or system [2].
- Computer simulations can "communicate complex and technical scientific information" similar to interactive museum exhibits [6].
- A well-designed computer simulation can engage the learner in interaction by helping the learner to predict the course and results of certain actions, understand why observed events occur, explore the effects of modifying preliminary conclusions, evaluate ideas, gain insight and stimulate critical thinking.
- Computer simulations can also provide the learner with "feedback throughout the learning process" [5].
- Because "computer simulations are flexible and dynamic", they can guide the learner in the achievement of specific learning goals [7].
- Finally, computer simulations permit the learner to experience or experiment with problems that would be too dangerous or expensive to explore in reality.
- The facility to "explore hypothetical scenarios and test hypothesis" makes computer simulations an important tool in science education [8].
- Through the use of "Java applets" computer simulations can now be delivered over the Web making them a viable component in the distance learning experience [5, 9].
- Computer simulations do have distinct disadvantages compared with other modalities. First, because computer simulations are often used with "problem-based learning" methods, they stimulate learners to immerse themselves in a problematic situation and experiment with different approaches [2].
- This type of learning may require significantly more time than other methods of instruction. Second, research has shown that, without coaching, the learner gains little from "discovery learning" from computer simulations [4, 2]. Third, constructivists argue that computer simulations "oversimplify the complexities of real-life situations", giving the learner a "false understanding" of a real life problem or system [2].
- Finally, development of computer simulations may involve extensive planning and require significant investment of labor and financial resources.

The use of computer simulations in distance education have been illustrated by seven simulation projects [4-5, 10-14].

Philosophy of the simulation laboratory concept

One of the basic ideas in this concept is that the lab exercises are configured in such a way that the students can carry out the exercise autonomously, as individuals, or in small groups of 2 or 3 students. Achieving this renders a series of possibilities concerning improving the didactic level of the lab exercises as well as the practical organization of these. The listing below shows examples of improvements that the concept will render.

Didactic improvements

- Allow the student to choose own pace

- Improve the possibilities for the student to repeat parts of the lab exercise which were less clear to him/her.
- Improve student involvement through enabling a choice of lab exercises
- Stimulate the student to work and solve problems independently

Practical improvements

- Enable assisting personnel to spend more time on guiding the students in the interpretation process rather then the execution of the lab exercise itself
- Make it possible for students to choose the date and time when they carry out the lab exercise
- Improve the maintainability and further development of the lab exercises

Reasons for using simulation laboratory

Simulations are very efficient tool, but many experiments are of historical importance, and the classical experimentation tools must exist in the real laboratory. There are several reasons for using simulation lab exercises:

- The students may find the computer assisted demonstrations more attractive.
- The traditional laboratory tools aged, broke down or disappeared. Now, many tools can be replaced by one single hardware and the respective virtual instrument, thus this is a cost efficient way.
- The students may find it attractive to face with things of their everyday life – in another aspect.
- The visibility of experiments becomes better, reliability will be improved. An easier overview can be obtained, there are less "black boxes", because the operation of the instrument is well known.
- Experiments can be "downloaded" through the Internet, if necessary.

Simulation laboratory structure and realization

A variety of technologies may be used to create computer simulations [4-5, 10-14]. We used Web based technology. Web pages were created by Microsoft FrontPage and Microsoft Photo Editor. The main page of laboratory is presented in Fig.1.

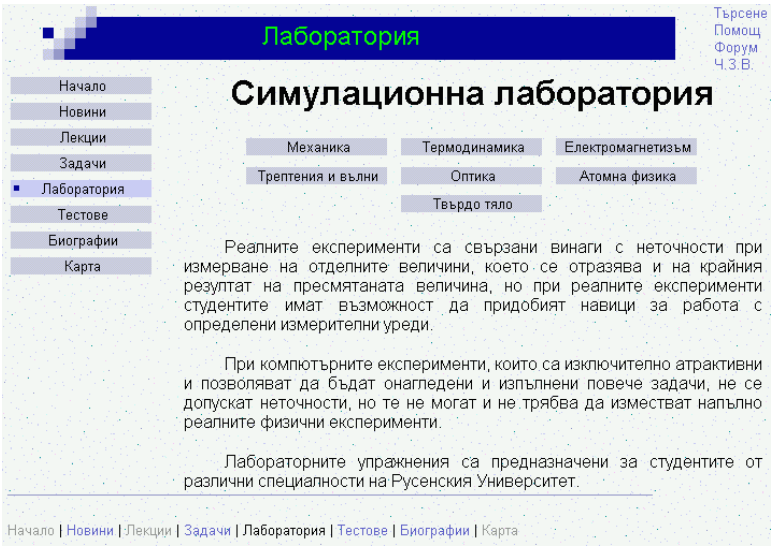

Fig.1.
Simulation Laboratory
- main page

The core of the simulation laboratory are 18 Java applets visualizing phenomena from Mechanics (2), Thermodynamics (1), Electromagnetism (5), Oscillations and waves (6), Optics (2), Atomic and Nuclear physics (1) and Solid state (1).

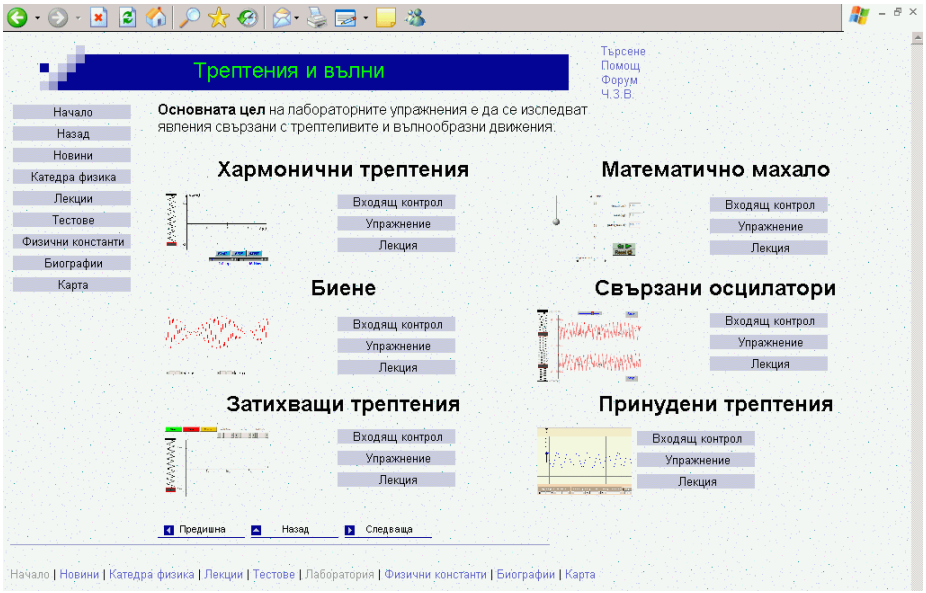

Fig.2. Part "Oscillations and waves"

Because most standard applets are written with English controls and instructions, students with limited knowledge of the English language might have problems understanding the basic concepts governing the applet`s behaviour. For our purpose some of the text in the applets has been translated in Bulgarian. Experiments in Simulation Laboratory are: Motion on inclined plane; Elastic and inelastic collision; Ideal gas; Ohm's law; Charge particle in electric and magnetic field; Hall` effect; Magnetic hysteresis; Electromagnetic induction; Harmonic oscillations; Mathematical pendulum; Beating; Coupled oscillators; Damped oscillations; Forced oscillations; Light diffraction; Light interference; Photo effect; Fermi` level in semiconductors with impurities. These simulation experiments have analog in real laboratory experiments in University of Rousse.

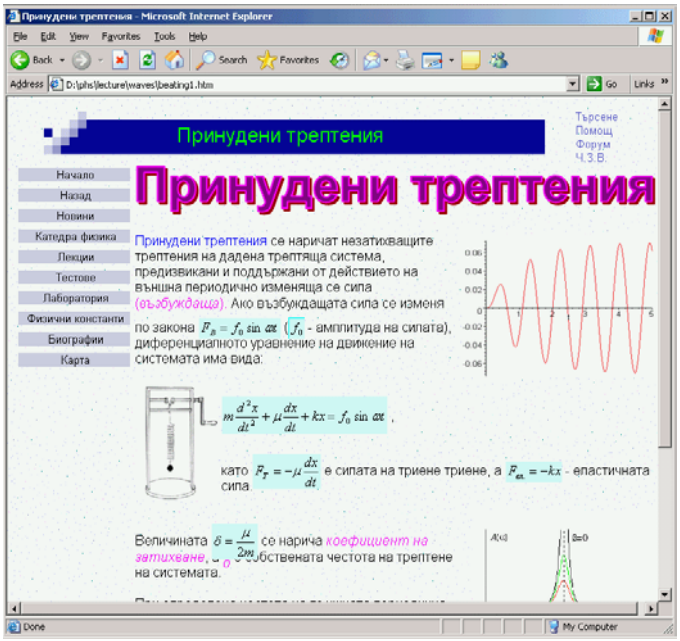

Fig.3. Forced oscillations – theoretical part

The lab exercises include some important parts: theoretical introduction and analysis of physical phenomenon, which is demonstrated in simulation laboratory; entry test; tasks, which students must execute; detailed measuring process description and the applet used in simulation and measuring process. Theoretical introduction and analysis of physical phenomenon is a very important part of simulation laboratory. When student do not know the theory of physical phenomenon, shown in simulation experiment, it will be only a computer game. The text of theoretical introduction and analyses must be very short and brief. Students must be very quickly introduced to the basics of physical phenomenon, because they usually do not hold enough concentration and are not patient when working at Internet.

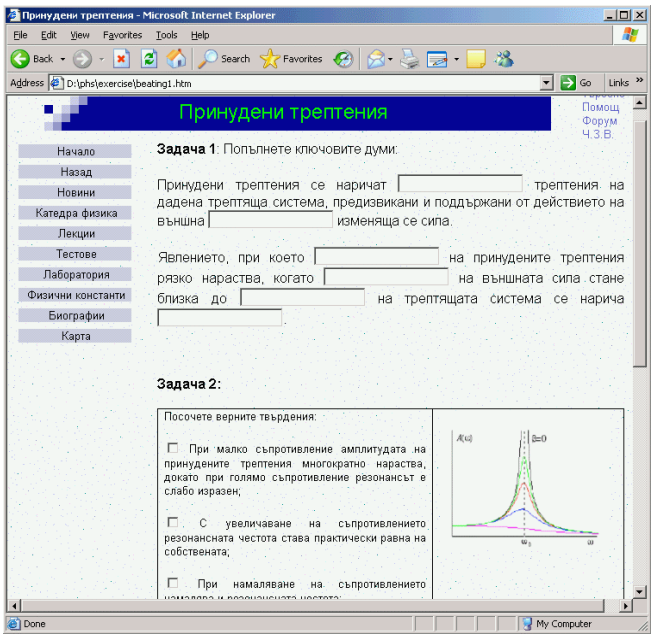

Fig.4. Forced oscillations - entry test

Figs. 3, 4, 5 and 6 are examples for theoretical part, entry test, tasks, which students must execute, detailed measuring process description and the applet used in simulation [15] and measuring process in the case of simulation exercise “Forced oscillations”, respectively.

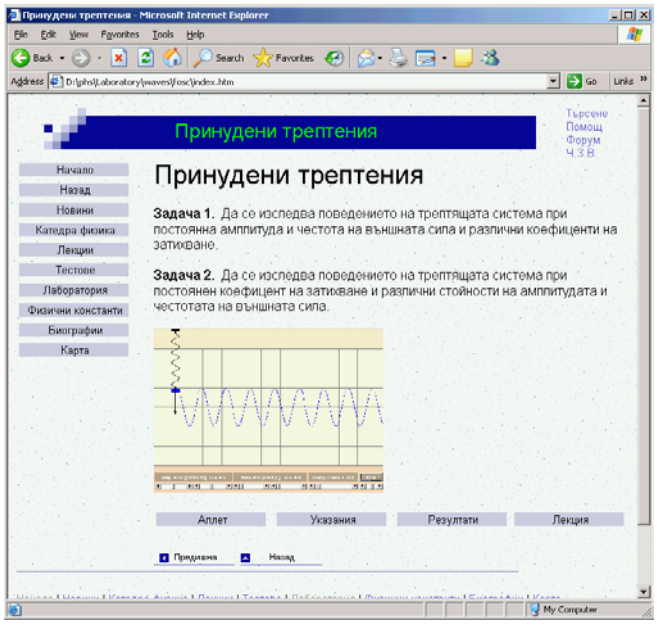

Fig.5. Forced oscillations - tasks

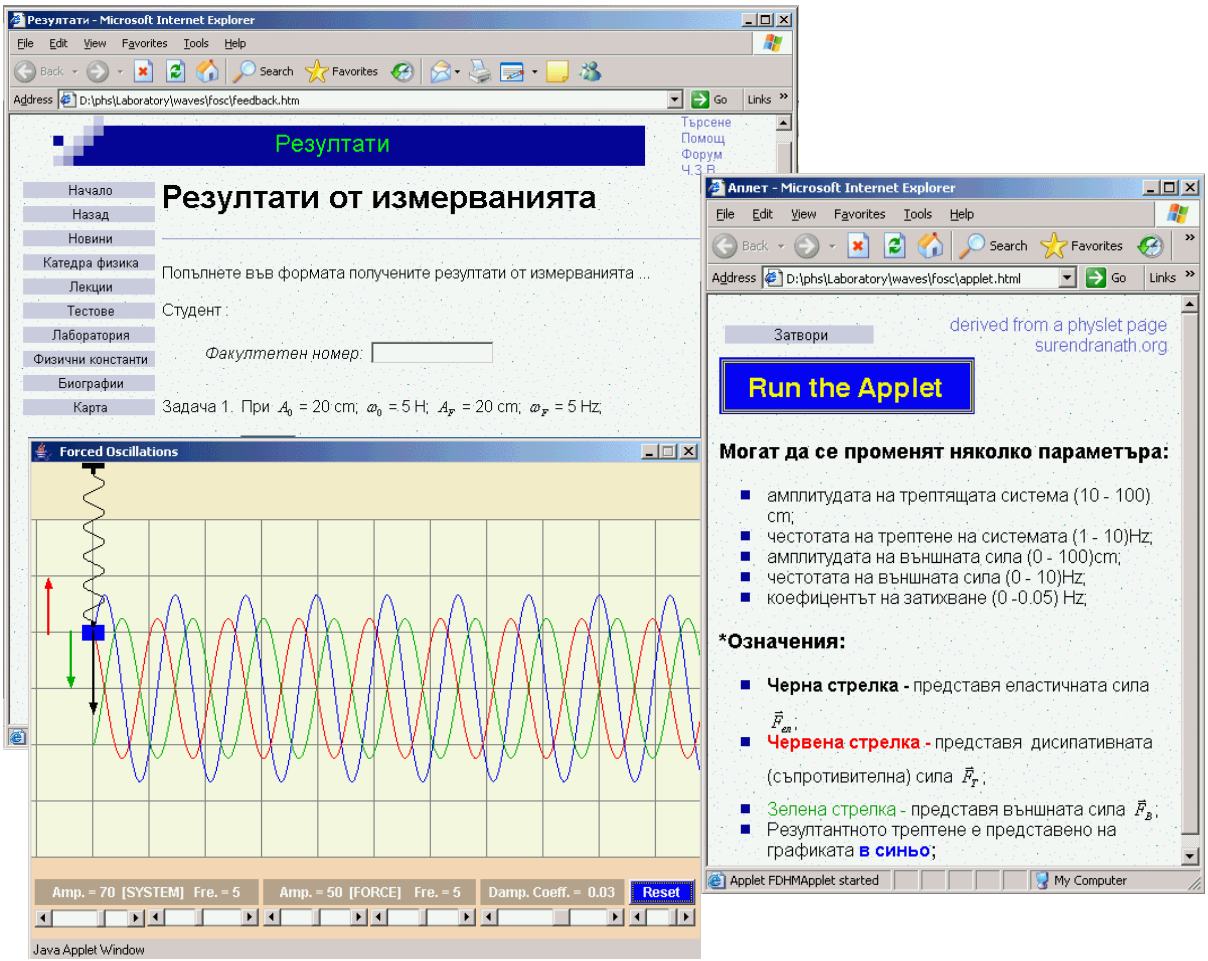

Fig.6. Forced oscillations – applet and results

A few of simulation experiments from the Simulation Laboratory have been presented during National Conferences connected with physics education in Bulgaria [16- 19].

Conclusions

The simulation laboratory sufficiently complement traditional method of education and follow the present trends of cheap education (especially expensive laboratory education) provide to obtain measured data alike as in classical laboratory. The laboratory exercises included in Simulation Laboratory can be used not only for distance education, but in addition of real laboratory experiments. A Simulation Laboratory may be used by the teacher to explain and demonstrate an experiment, before the student actually enters the real lab. It can also be profitably used by the distant learners, who have often scarce or null opportunity to access the laboratory in the university. Of course, when using simulation laboratories, it is important to bear in mind that the actual reality is inevitably more complicated than the virtual one, so everybody should be invited to try, whenever possible, home made experiments or to directly look at physical phenomena in nature. Although the simulation laboratories are very good as an educational addition, they could not recompense the classical education.

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