The overview of software for computer simulations in profile physics learning

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Abstract. The paper deals with the possibilities of using specialized (virtual labs and simulators, software for natural process simulation) and general (programming languages and libraries, spreadsheets, CAS) software in school researches.

Such software as virtual labs, software for natural process simulation, programming languages and libraries in school researches can be used to simulate phenomena that cannot be learned in a school lab (for example, for modeling a radioactive decay or for demonstrating the states of relativistic mechanics). Also, virtual labs in school practice are usually used in those cases where students cannot perform an experiment in real labs. For example, it is convenient for distance learning.

The using of programming languages and libraries in physics learning research requires both students' physics research competencies and programming competencies. That is why using this software in physics classes can hardly be recommended. However, programming languages and libraries can become a powerful tool for the formation and development of research competencies of physics students in extracurricular learning activities.

The implementation of the spreadheets and the CAS in school physics researches is the easiest and has its benefits.

Keywords: profile physics learning, physics research, CAS, spreadsheets, virtual labs, virtual simulators, programming languages and libraries, software for natural process simulation.

1   Introduction

Valerii I. Seldiaev [11] classifies the possibilities of using a computer in physics labs. He emphasizes that there are many experiments that cannot be performed without computer (studying the kinematic characteristics of motion caused by the gravity, the conditions of spark discharge occurrence etc.). Furthermore, Seldiaev defines the main methods of ICT using in educational studies:

a. using the computational experiment in conjunction with the lab experiment;
b. using the computational experiment only;
c. using ICT tools in the set of measuring equipment.

Donald R. Hamann states that the most traditional methods of ICT using in physics researches are automation of computing and physics processes modeling ("numerical analysis" or "imitation" [5, p. 240]).

Richard Phillips Feynman proposed to generalize "step by step" calculations in the form of a table to determine the orbits of the planets [4, p. 170-171]. He proposed to use the tables of squares, cubes, and inverse quantities to simplify mathematical calculations. Feynman emphasized that even in this case, the implementation of such calculations manually requires a lot of time. That is why it can be useful to solve such tasks with the use of a computer as a tool of computing automation [4, p. 173].

2   Discussion and results

Charles W. Misner examined the possibilities of using spreadsheets in physics researches. Using spreadsheets provides the ability to automate the data processing [12], mathematical and logical actions; provides the opportunity of numerical solving of equations, of submitting data in the form of charts. The most common modern spreadsheets are Microsoft Excel Online, LibreOffice Calc Online, KSpread, Kingsoft Spreadsheets, Google Sheets [13], Gnumeric.

According to Misner, the main advantage of spreadsheets is their possibility to combine text and numeric data. It makes the execution of similar "routine" actions (such as reports writing) easier [8, p. 396]. Moreover, the researcher notes that the range of physics problems that can be solved via spreadsheets is much wider (these tasks are also more complex) than the range of problems for which the spreadsheets were created. First of all, spreadsheets in physics are used for calculations and building additional charts and diagrams. Misner described main features of spreadsheets using for calculations in physics: "a high ratio of design time to run time and the need for small amount of data" [8, p. 395].

The spreadsheets in profile physics learning can be used in studies that require the processing of homogeneous data arrays and their generalization in charts. The examples of such studies are the research of the process of discharging the capacitor and determining its capacity, determining the temperature coefficient of metal resistance, studying the efficiency of the electric source, studying the correlation between the resistance of semiconductors and temperature, studying the volt-ampere characteristics

of the semiconductor diode (Figure 1). It is also advisable to use spreadsheets to process the results of series of identical experiments [16], which is relevant for the most of school workshops.
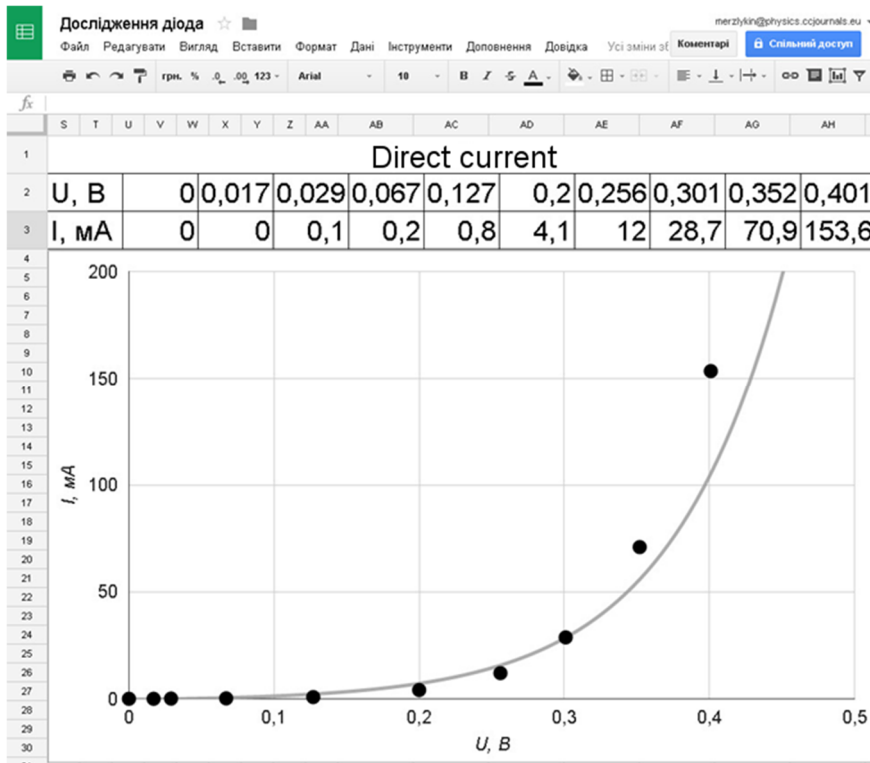

Fig. 1. Example of Using Google Spreadsheets for the Studying of Semiconductor Diode

Donald R. Hamann emphasizes the significant potential of problem-oriented programming languages, such as MACSYMA and ALTRAN. Nowadays the common name of such software is the computer algebra systems (CAS). The main purpose of this software is the performance of mathematical operations and transformations of algebraic expressions given in a symbolic form. Moreover, most of modern CAS provide the ability to numerical problem solving, to work with matrices, to process the data arrays. The most of modern CAS also support the ability to display data in a graphical form. The most common modern CAS are CoCalc [7], MATLAB Online, MapleCloud, Mathcad, Scilab on Cloud [9], Maxima Online, Wolfram Mathematica Online, Yacas Online.

At school CAS can be used to solve the same problems as spreadsheets. However, their use for researches, which require the work with a large amount of mathematical abstractions (such as vectors) is the most effective. The examples of such researches are the study of body balance under the action of several forces in, finding the center of

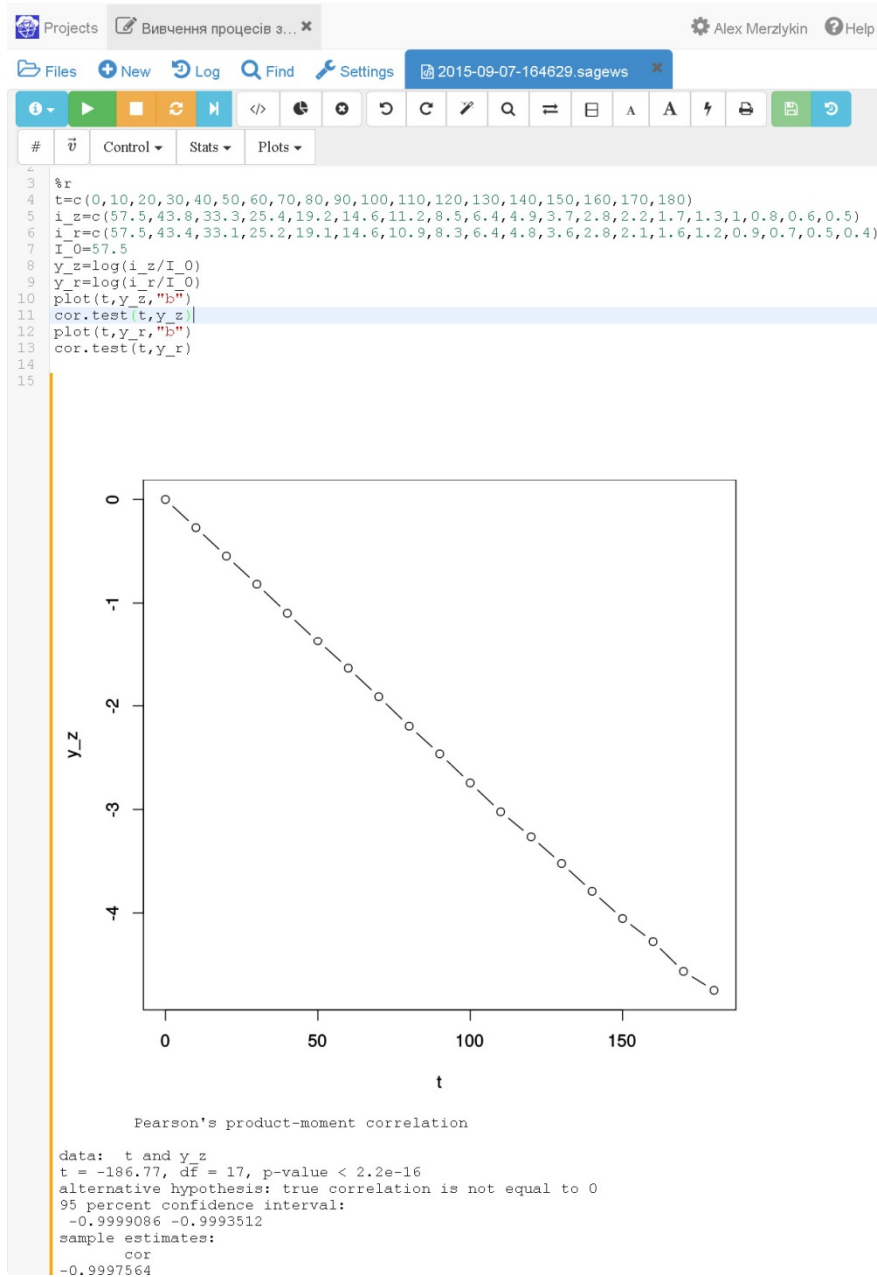mass of the flat body. Moreover, CAS can be used for statistical data processing (Figure 2).

Fig. 2. Using CoCalc in studying the processes of charge and discharge the capacitor

Donald R. Hamann considers contemporary (Fortran, C, ALGOL, Pascal) and prospective programming languages and libraries separately [5, p. 248-251]. We will use the term "programming languages" for definition of the complex of programming languages as is (character system for writing algorithms) and its translator (compiler or interpreter). A programming language translator, along with a text editor, debugger, profiler, file and object management, set of specialized libraries for a given programming language, etc. can be combined into an integrated programming environment.

In this definition, the programming languages and libraries together are the tool of implementing any algorithm as a computer program. The ways of data presenting can be diverse (text, charts, video, audio, multimedia, database, etc.). That is why programming languages can be considered as the universal tool at all stages of physical research [14].

It should be noted that the using of programming languages and libraries in physics learning research requires both students' physics research competencies and programming competencies. That is why using this software in physics classes can hardly be recommended. However, programming languages and libraries can become a powerful tool for the formation and development of research competencies of physics students in extracurricular learning activities.

Figure 3 shows the user interface of the computer program for demonstrating Faraday's law in a cloud-based GlowScript environment created with use of Python programming language and Visual Library [15].
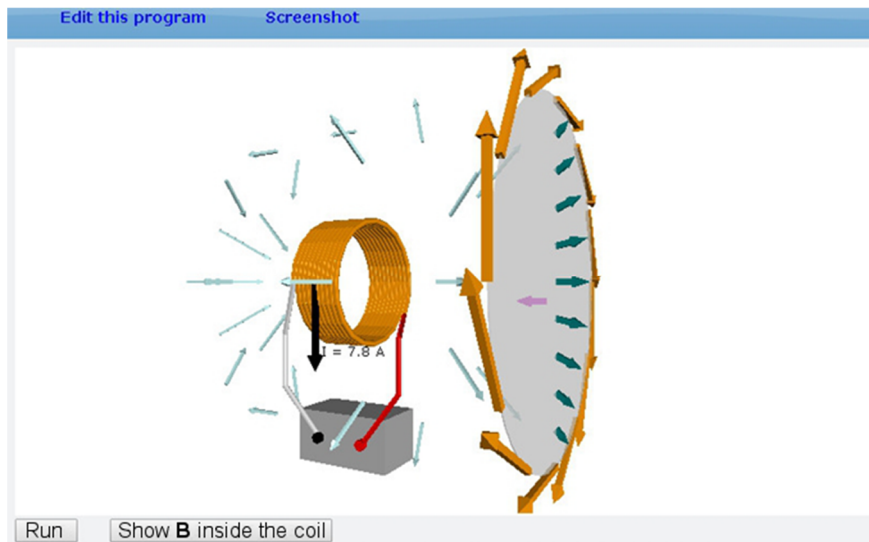

Fig. 3. User interface of computer program for demonstrating the Faraday's law

Virtual labs are a narrow class of software that is designed to simulate the process of natural research [10]. Using virtual labs involves working with virtualized objects of a

real physical laboratory. Virtual labs may involve the creation of the user's experiments or researches, pre-designed by the authors of the virtual lab or by the teacher. The purpose of students' work at the virtual lab is to process an experiment using the appropriate set of virtualized devices and performing measurements.

The virtual lab designed by Gregory Bothun, Sean Russell and Amy Hulse is the part of Oregon's Physical Education Resources package and is a collection of Java applets available on the University's website. Research in the virtual lab, according to the authors, is intended to give students an access to the data that simulates a real physical experiment. According to Gregory Bothun, it was previously planned to use a virtual lab for students of non-science specialties (their Physics course does not involve lab works). Later it turned out that the Java applets were downloaded thousands times per month and became popular at physics classes in high schools. Every research in the virtual lab consists of two parts: in one of them students work with computer models of devices, and the other one reflects the lesson plan. The virtual lab includes both studies which can be and cannot be provided in the conditions of the physics lab (Figure 4).
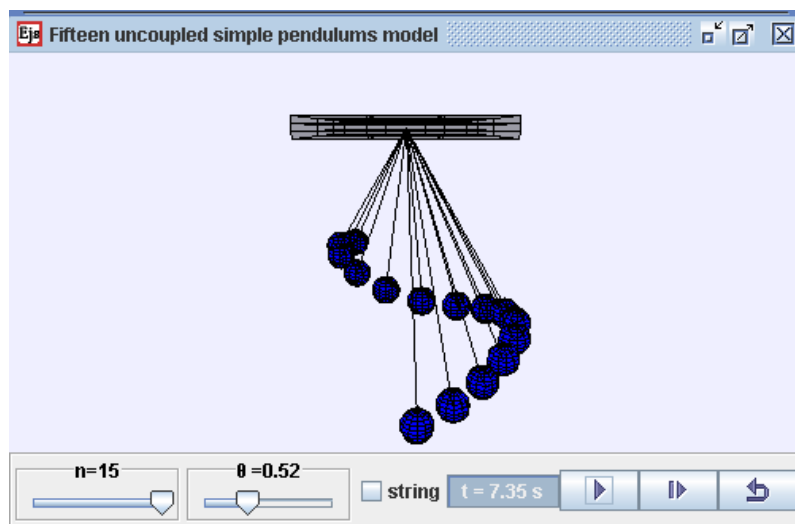

Fig. 4. Wave pendulum simulated by Easy Java / Javascript Simulations (EjsS) of the Open Source Physics Project

You can use improperly most of the equipment in this virtual lab. In this case, the equipment will "virtually" fail, and the sound message will notify user [1]. It provides the ability to use the part of the described virtual lab as a virtual simulator for the use of physical equipment.

Virtual simulators are the software that is similar to virtual laboratories. The main difference between these two classes of software is their purpose. Using virtual simulators mainly involves working with virtualized devices as is, but not with the "scheme" of the whole experiment. Virtual simulators can be used for students' familiarization with the devices used in research. Often the virtual lab and the virtual

simulator are the same software. Thus, virtual simulators simulate physics equipment, while virtual labs simulate physics research.

Virtual simulators in a school physics research should be used at the preparatory research stage to provide to students the opportunity to familiarize themselves with the equipment which is used in the research (Figure 5). This is especially useful for students who have to work with devices they have never used before.
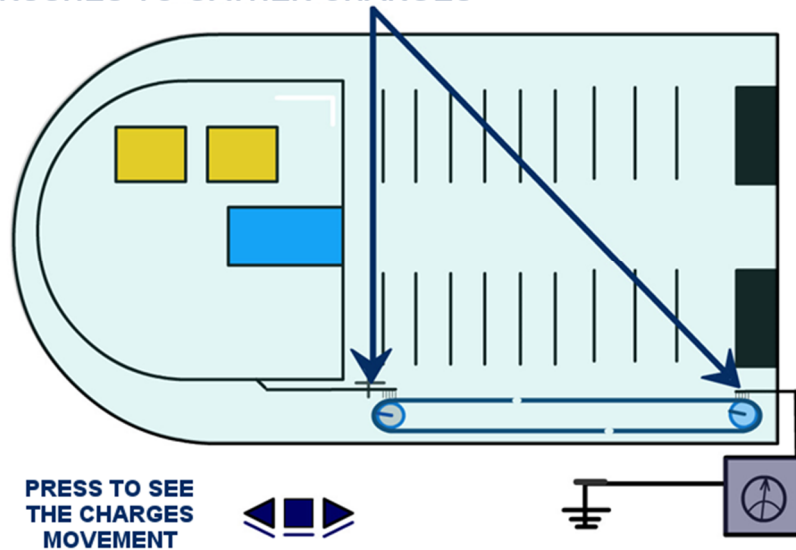

Fig. 5. Introduction to electrostatic ion accelerator on the site of the Institute of High Technologies of Kyiv Taras Shevchenko National University

The using computer simulations can extend the content of school curriculum because any natural phenomenon can be modeled using a computer. Donald R. Hamann states that there are three factors of the successful application of numerical modeling: "analytical simplification based on well-known physical theory, good algorithm and successful graphical representation of results" [5, p. 247]. The article [6] presents a number of models, which using in the educational process, according to the authors, is more effective than the real demonstration of physical phenomena.

Software for natural process simulation is similar to virtual labs. In virtual labs, students use ready-made models of natural phenomena, while in software for natural process simulation, they have to create these models by themselves. It requires a higher level of abstraction, deeper understanding of the processes and mathematical modeling skills. Developing computer models with this software takes a lot of time, so it is advisable to organize such activities within the framework of a research project. At the same time, complete virtualization of lab work using this software goes beyond the scope of physics learning.

Methods for describing models, which use the software for natural process simulation, can vary from a textual description (Figure 6) to the direct execution by means of a graphical interface [17].
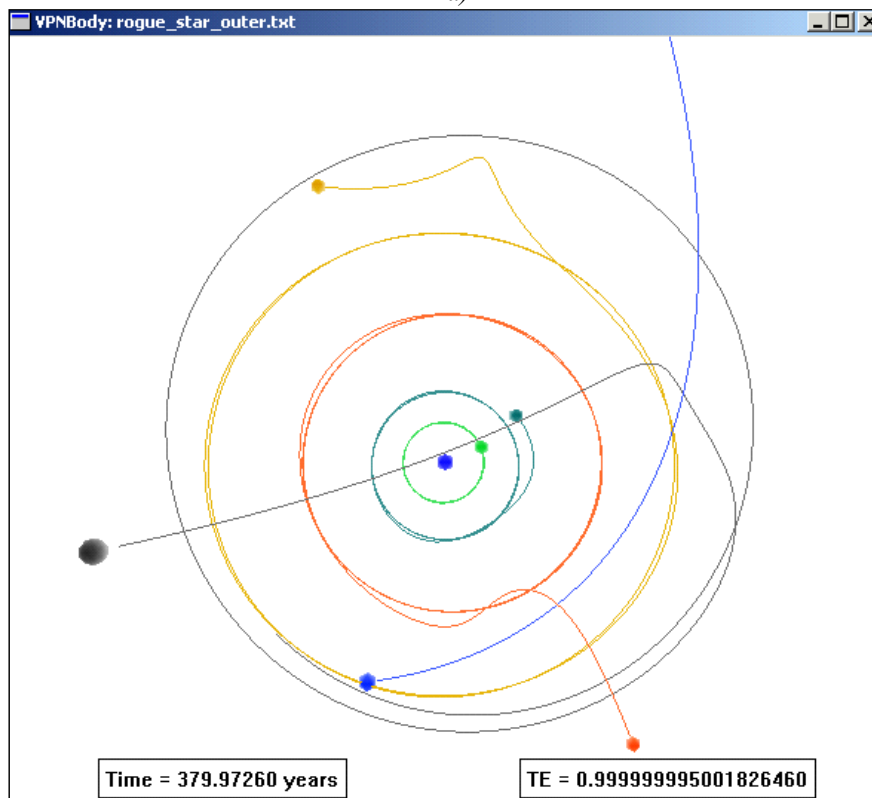
```
TIME_STEP 90 DAYS # крок моделювання
MAX_TIME 600 YEARS # повний час моделювання
METHOD Candy_Rozmus_Opt # метод інтегрування

OBJECT_DATA # опис об'єкту "блукаюча зірка"
  Name Rogue_Star
  Free
  MASS 1.50 SOLAR_MASSES
  COLOR 1 0.85 0
  Orbit_color 1 0.85 0.0
  POSITION -125 200 0 AU
  VELOCITY 0.325 0.0 0 AU/Yr
END_OBJECT_DATA

# опис інших об'єктів Сонячної системи (Сонця, планет)
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a)

b)

Fig. 6. The fragment of description the computer model of the process of the wandering star invading in the Solar system using VPNBody (a) and the results of simulation (b)

Marek Pawel Checinski proposes to use the FireFly (PC-Gamess) for calculating the properties of molecular structures and MacMolPlt for visualization the results of these calculations [2]. The author examines the basic features of both tools and makes recommendations on how they can be used. Francisco Esquembre points out that computer simulation tools have all the benefits of learning modeling and, in addition, help students to clarify the Physics concepts. The author also notes that the level of abstraction of the modeling tools can vary from the "pure programming" to the construction of high-level blocks. The choice of modeling tools is determined by the task. So Esquembre recommends using Modellus for simple models and Easy Java Simulations for more complex tasks [3, p. 17].

Consequently, software natural process simulation in relation to virtual laboratories is not a broader but a different class of the software that has its own specific purposes and ways of using. One of the possible approaches to the delimitation of this software is the classification given in Table 1.

Table 1. Classification of adjacent software by controllability of code and data

Software	Controllability of code	Controllability of data
Programming languages and libraries	The code is created by the user with the use of library objects; algorithms are created or used from the library	The data structures are determined by the user or by the author of the library; the data is entered by the user
Software for natural process simulation	The code can be created by the user according to the proposed interface or the ready-made program modules can be used.	The data structures are determined by the software engineer; the data is entered by the user
Virtual labs	The code is created by the software engineer	The data structures are determined by the software engineer; the data is entered by the user
Virtual simulators	The code is created by the software engineer	The data and its structure are determined by the software engineer

3   Conclusions

Such software as virtual labs, software for natural process simulation, programming languages and libraries in school researches can be used to simulate phenomena which cannot be learned in a school lab (for example, for modeling a radioactive decay or for demonstrating the states of relativistic mechanics). Moreover, virtual labs in school practice are usually used in those cases when students cannot perform an experiment in real labs. For example, it is convenient for distance learning. However, a comparison of the results of the study obtained in the natural research with the results obtained by means of the virtual lab can be useful. It can also be useful to compare the results of different models of the same phenomenon. Such comparisons can help students to understand the limits of the application of physics laws, to understand the

correspondence principle and the possibility of the existence of several adequate mathematical interpretations of the same phenomenon.

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