

# Virtual Laboratories in Physics with Autogenerated Parameters

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**Abstract.** The paper is devoted to a virtual laboratory system, which in particular can be used to test knowledge through research. The participant can prefer which tools to operate and what actions should be taken. For the most of the tasks, there are copious ways to obtain the correct solution. One of the most important features of the system that distinguish this one among other simulation packages and educational systems is the pseudo-random physical parameter generation technique. The technique supports constraints and relationships between variables. As a result, it provides correctness and equal complexity of the generated task. The system can be very complex and is highly customizable by internal script system executed on server-side. The system is used as a part of distolymp Learning Management System with about 40 thousand participants per year.

## 1. Introduction

Online Competition in Physics [1] provides a unique opportunity not only to test theoretical knowledge, but also the ability to apply this knowledge in practice. Checking the ability to conduct a physical experiment is achieved by means of virtual laboratories. This virtual laboratory is a computer simulation with virtual physical system and virtual measuring devices. The contest participants are given a set of tools which is necessary to perform the research. For the majority of tasks, there are various ways to obtain a correct solution. In order to solve the problem, an attendee of the Online Competition chooses the tools and makes decisions by himself. Moreover, those assessments check the attendee's ability to plan action that leads to a correct result among redundant conditions and obscurity of the system.

## 2. Distolymp Learning Management System

The developed system provides three types of assessments: tests, theoretical tasks and virtual experiments. Thus, tests check student's basic knowledge of the subject. The virtual experiments allow us to identify the most talented students, as they assume creative research approach. The software can be used both for simple tasks and for hard problems with complexity level which can be compared with the tasks of the final tour of the Online Competition in Physics. In such a way, once the Organizing Committee of the competition constructed quite a challenging task which was completely solved by only one of 930 participants of the final stage of the competition. The detailed description of the task and the solution are available here [2].



As it often happens in physical experiment (especially in a complex environment), it is not always easy to get the correct result from the first attempt. Thereupon, the attendee receives a feedback about whether he completed the task correctly or not. Then he can retry to solve the task again with some penalty. As a result, this feature tests the candidate's ability to correct his errors on the results of his activity. This is one of the most important features which distinguish distolym virtual laboratories from some other Open Online Courses.

### **3. The generation algorithm**

#### *3.1. Motivation*

First, all participants receive similar tasks, models and equipment. Thereupon the server generates some unique pseudorandom state of the system. Obviously, the generated problem should be correct and solvable. Another important criterion for the generation algorithm is the rule that the complexity of the generated assessments between various attendees should be equal. To accomplish such result, authors of the Learning Management System have developed a server-side system of physical parameter generation.

The parameter generation algorithm generates a pseudorandom set of input parameters according to given input constraints, calculates the constraints got other physical parameters corresponding to the generated set and repeats the process until all the constraints are satisfied.

The constraints can be divided into a number of categories:

- A pseudorandom value from a uniform grid
- A pseudorandom value from given set
- A result of function evaluation with already specified variables calculated by substitution into a formula

In order to optimize server load and extend capabilities of the LMS, some values are processed at the server side, while the other is processed at the client side.

#### *3.2. Accuracy measurements*

In the first version of the system we employed a fixed absolute error for checking the results. This approach, however, turned out to be problematic for our pseudorandom system if the generated dependent parameters differ by some magnitude, the calculated absolute error may be very inconsistent with the specified answer. As a consequence, there were a few times when the system rejected the nearly correct answers, and accepted solutions submitted by unfair participants.

Afterwards, the technique was improved with an algorithm which could specify the error for each interval of values. After all, it was decided to use the relative error. The part of source code and details of the algorithm are described in [3].

### **4. Client-side features**

BARSIC programming language [4] is used to develop client-side software of virtual laboratories. It is a Domain-Specific Language with some unique features. Client-side technologies are evolving so fast, so it is quite important to be always ready to a new frontend technology. For this and other reasons, source code of the virtual laboratories is reused by implementing an extensible syntax-directed translation system for different platforms such as J2SE, Android, JavaScript. To put it another way, it is not necessary to rewrite the entire implementation of client library, it is possible to rewrite only the user interface controls and graphical primitives, the behaviour will remain the same.

## Conclusion

Relying on our experience of organizing the Online Competitions in Physics for 10 years, it can be concluded that the implementation of virtual laboratories in Physics with server-side algorithm of generation of parameters contains a lot of advantages to test knowledge through research.

## References

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