

13/1 (2015), 73–80

tmcs@math.klte.hu
http://tmcs.math.klte.hu

Teaching
Mathematics and
Computer Science

How to use our own program evaluation system to streamline teaching computer programming

SÁNDOR KIRÁLY and SZILVESZTER SZÉKELY

Abstract. During computer programming contests the use of automatic evaluation systems is becoming more and more frequent. In said systems the contestants are allowed to submit their source code that will be evaluated with the results reported back to them. According to this report the contestant can realise for what test cases his program works properly and for what cases does it fail. This kind of on-line evaluation system is used for example in the International Olympiad in Informatics (IOI), in the final round of the Nemes Tihamér National Programming Competition, and in the Selection Competition for IOI in Hungary. A contest management system can be used for other purposes apart from this singular example. A well-developed evaluation system can foster not only the teaching of computer programming and the preparation of students for programming contests but the teacher’s work as well.

Key words and phrases: computer programming, program evaluation system, contest management system, ruby on rails.

ZDM Subject Classification: B10, C70, D50, D60, P50, Q70, U70.

1. Introduction

Teaching programming in secondary schools in Hungary is getting more difficult because of the decreasing number of lessons and therefore proper preparation for the different competitions is almost impossible. [1]

After the initial steps of the teaching process computer programming students reach the point where they can solve simple problems without help by using the selected programming language. After being made aware of the basic algorithms

the next step is practice. After this, studying harder algorithms, solving problems based on these algorithms is the next necessary step. The developed software requires thorough testing, because the question is whether the student’s software can give the correct results for every input. The evaluation of programs is even more critical in the case of solving more difficult tasks.

According to the traditional method the student develops his program to solve the problem and tests it with his own data. If deemed correct by the student it will be sent to his teacher who also tests it with his own test data that includes all the corner cases and is large enough. Then the student will get a report about the results of the evaluation. If the program does not work properly it can be modified in awareness of the test data that caused the incorrect output. Then the process can start over again. Following this procedure the program developed to solve the problem will be finished after 1-2 days or, in worst case scenario, after 1 week.

To reach the first place in the National Secondary School Competition (OKTV) or in the Nemes Tihamér Competition even a very talented student has to solve a lot of problems and has to walk along the above mentioned path. This process can be shortened by giving the input data along with the task description to the student beforehand, therefore leaving the teacher out of the testing cycle. But this may not be beneficial methodologically as test cases are also not available during the competition. The best way of preparation for the contests is solving the problems of the previous years of these or similar competitions. [2]

Solving the problems that were in the final rounds of the competitions is not enough in itself since memory and execution limits are given for the tasks that invalidate suboptimal solutions in terms of efficiency. So to reach the maximal score, the optimal solution is required from the young programmer which also means his program is not allowed to exceed these limits. That is the reason why it is considered particularly important that students have a chance to use an evaluation system during the preparation period and not only in the competition.

2. Contest management systems

In the traditional programming competitions (ACM, IOI, CEOI, Nemes Tihamér, IOI Selection Competition) different contest management systems are used. In the case of the latter two contests the software can be reached at the address biro.inf.elte.hu.



Figure 1. Contest manager

These software solutions are used in the following way: before the competition starts contestants are given an account to the system to be able to submit their source codes. After compiling the code these websites inform the students about the execution result of the uploaded program in each test case. It can be correct, wrong, it can exceed time or memory limits or throw an exception. The report also includes the points scored. Aware of the result the student can decide whether he corrects the code or begins to solve the next problem. At the end of the competition students know their own points and the outcome of the contest can be announced immediately.

These programs work on the following principle: they compile the source code and execute it with different test data. Based on the resulting output file they can decide whether the student’s program wrote the correct answer and they can grade it. [3]

How could we develop a similar program and use it in education and in preparation for the programming competitions?

3. Creating our own evaluation system and its workings

As IT teachers in secondary schools can write computer programs developing this kind of program is not a hard task. Only a computer to act as the server is necessary.

The system developed by the authors of this article is coded in Ruby with the help of the Ruby on Rails framework and runs on the school server computer under a Linux based operating system. [4, 5]

The data of students, contestants, uploaded programs, types of tasks, and the submissions are stored in a database while the actual source code files, inputs and outputs are stored in a folder hierarchy.

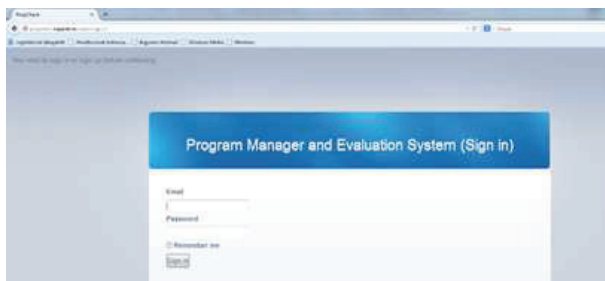


Figure 2. Contest manager

When the teacher wants to make a task available for the students the first step is to select a category (or create a new one) and then store the task in the database. To perform this currently they need to execute commands in the Ruby on Rails command line and give the name, category, and description of the task. This results in the system creating the folder structure for the task. Then the teacher has to upload the input, output, and score files along with the documents that contain the description of test cases and the solution PDF. This can be accomplished in a variety of ways including over FTP or with scp. The final version is to use an online interface that does not require backend access and allows teachers to upload “taskballs”. These would be archives that contain all the necessary information and are easily created by hand or by an editor.

The submitted programs are executed (after the compilation) in a sandboxed environment, default memory and execution time limit taken into account and enforced but these constraints can be changed for each task. Students are informed about the memory and execution time their submissions use up while if they overstep the limits an error message is presented for them.

The users of the system are put in categories therefore only the tasks assigned to them can be viewed except for the administrator. For each task input and output files are available and are used by the default grader to decide the correctness of the submitted program. For each test case different points can be awarded. If more than one solution exists for an input file then instead of the default grader another grader program written in an arbitrary programming language has to be uploaded by the administrator. The submitted programs can be written in an arbitrary language the only restriction being that a compiler or interpreter must be available for it. These conditions met adding support for a language only involves writing a module that can handle the compilation and execution of said language. The other parts of the system and the sandbox are

language agnostic. Current support includes C/C++, C# and Java as these are the ones most frequently used in competitions and in classes.

Students who take part in the preparation get an account to the web site that hosts several tasks of Nemes Tihamér, OKTV, IOI Selection Contest, IOI, and CEOI from the past 15 years but it can evaluate any task solution program after uploading their input and output data files. [6] As a result, it is suitable for the evaluation of homework in tertiary education or even performing local competitions but can be used to check programs of basic algorithms as well.

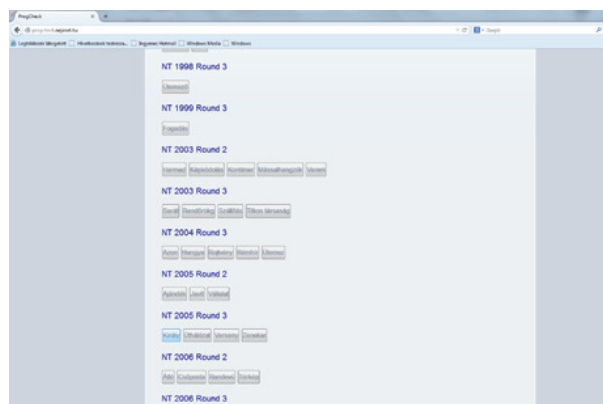


Figure 3. Uploading in the system

After signing in to the system students submit their solutions being aware of the task name then get the result of the evaluation: for which test cases they are awarded points. If the system can compile the program then the answer can be: right, wrong, time or memory limit exceeded or run time error. Except for the first case the aspiring programmer can download both the input and output files and in each case the description of the test data. Using these data students can correct their software without help. Students are also informed about the execution time of each test case (Figure 4.) but cannot compare their data (point and execution time) with other students' data. All the uploaded solutions are stored in the system so the teacher may follow and supervise the submitted versions for a given problem.

For each task a solution file in PDF format can be enclosed that may help the students either improve or rewrite their programs. In case of failure he can ask for help from his teacher. Experience to date it has only occurred in case of ambiguous solution description.

The system stores all submissions so as a solution changes it can be kept track of.

4. The benefits of this software to foster teaching computer programming

After logging in to the system as an administrator the teacher can get reports about different submissions by different students. For example, after how many attempts the student made it to the final or the perfect solution in case of each task. All the submissions are stored hence with knowledge of the folder hierarchy the teacher can view both the results and the source code without logging in to the system as an administrator. Consequently the teacher can view the sources any time and advise students on how to correct or refactor their programs. If it is necessary an email about submissions with an attached file containing the results can also be sent. In the long run, teachers could analyse how often and how efficiently students were able to solve the different problems stored in the system. In awareness of these data the preparation for the competitions can be made more effective.

Besides, using this system is particularly useful as the teacher can focus on teaching algorithms since the evaluation and the correction can be performed automatically. Programs with bugs can be improved by the students using the downloadable test files. In case of totally wrong solutions after downloading the corresponding solution file that includes a solution in pseudo code and explanatory text students can even rewrite their programs without any help from the teacher.

The description of test cases gives further support for students hence systematic study of these tasks can play important role in students' development.

The system intentionally does not include task descriptions since all students learn at different speeds, have holding points in different places, and may not compete in every category. It is unfortunate if they try to solve problems when they are not aware of the appropriate knowledge. As a result, they receive task only on a personal basis. Those who work faster and can solve more and harder problems thus their development will be faster and may achieve greater success. This process can be enhanced and automated. In the finals, these students will be using the contest manager programs routinely, for example the one that can be found at biro.inf.elte.hu.

As of now, less than 15 students use this system to prepare for programming contests. Because of this the sample would be insufficient to conduct a survey

Case	Description	Time	Result	Score
Case 1	Egy lezármazási sor, több gyerek nem király	100 ms	result	6 / 6
Case 2	3 király útdő, több király lehetett van, utának nincs gyereke	100 ms	result	6 / 6
Case 3	Ac utódokat megvizsgálja valaki, lehetnek nem egymás sábj, költés gyerek	120 ms	result	6 / 6
Case 4	Több lezármazási sor, többéző is vannak lehetnek, 0 nem király gyerekek	110 ms	result	9 / 9
Case 5	Serkekek sem király a gyereke, lehetnek királyok	90 ms	result	5 / 6
Case 6	A gyerek az apa volt király	90 ms	result	4 / 6

Figure 4. The result of the submission

and compare the achievements of students who use the system with those who do not.

5. Summary

In this article, the means to foster and automate the teaching of computer programming and thereby make students skilled using our own evaluation system was expounded.

This system differs in several points from the online-systems used in different competitions. For each test case, in case of a wrong answer it makes the test data downloadable thus helping students find the bug in their programs. It also facilitates the checking of the code, creation of an own test plan since it makes the test plan developed by the task creators available. In case of an insufficient solution, giving the description of the solution plan makes possible the re-thinking and rewriting of the code by the student. All of this is done automatically and independently thus speeding up the practice and the development.

The teacher can follow the student’s work, follow the development process and seeing the results of the submission may as well help him. Utilizing the result of the submission and the source code the teacher can make his work more efficient which the next generation will benefit from as well.

References

- [1] http://dokumentumtar.ofi.hu/index_NAT_informatika.html, 2014.
- [2] S. Király, How to teach computer programming if our goal is the International Olympiad in Informatics, *Teaching Mathematics and Computer Science* **9**, no. 1 (2011), 13–25.
- [3] <http://biro.inf.elte.hu/>, 2014.
- [4] Ruby programming language, 2014, <https://www.ruby-lang.org/en/>.
- [5] Ruby on Rails web framework, 2014, <http://rubyonrails.org/>.
- [6] <http://nemes.inf.elte.hu/>, 2014.

SÁNDOR KIRÁLY and SZILVESZTER SZÉKELY
EGER
HUNGARY

E-mail: ksanyi@aries.ektf.hu

E-mail: szekelyszilv@gmail.com

(Received August, 2014)