

The use of E-olymp Internet Portal in Programming Competitions

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Abstract. E-olymp Internet portal was created to engage the students of higher education institutions and secondary schools to participate in programming contests, as well as to improve the quality of training future specialists in the information technology and programming areas.

Keywords: distance learning, programming competitions, online judge system.

1. Introduction

In times of transformations to information society, one of the nation's challenges is the training of specialists with relevant competencies, in particular preparing professionals in the area of computer science. Programming as a subject of study includes learning of various programming languages, algorithmic problems, program testing techniques, as well as work with data structures.

While training a specialist, distance learning systems play an essential role in the learning process, that includes sets of organizational, telecommunication, academic and scientific resources. Recently the distance learning has become a prominent part of the higher education system. It enables to select a convenient time, place and learning style for every student; improve their skills, acquire a profession in off-work hours; pursue higher distance education for people deprived of the possibility to receive traditional one. One of such systems dedicated to the distance learning programming is E-olymp Internet portal (www.e-olymp.com).

The Internet portal allows to facilitate the work of teachers and tutors in preparing for programming competitions, provide an opportunity for gifted students to work independently, to develop and exchange experience with like-minded students from different regions. The use of the portal provides an occasion to form and select qualified personnel who are able to arrange professional trainings for students – future teachers in the sphere of information technology, mathematicians and programmers.

E-olymp is considered to be a practice and a contest platform, like Topcoder, USA-CO, Codeforces, Codechef.

2. Functionality of E-Olymp Portal

E-olymp Internet portal was developed by Ivan Franko Zhytomyr State University, the Department of Applied Mathematics and Computer Science with the financial support of the Ministry of Education and Science of Ukraine in 2007. Over time, the functionality of the portal has been constantly improved. The portal administrators are:

- Mykhailo Medvediev – Assistant Professor at ADA University.
- Sergey Zhukovskiy – Senior Lecturer at Ivan Franko Zhytomyr State University.

The E-olymp portal helps the teachers of informatics and instructors of programming to deliver the elective courses and organize trainings and competitions. It allows pupils and students to prepare for olympiads independently, for instance, to solve thematic problems, to check their solutions without teacher participation, to compare the level of their knowledge and skills with the level of other pupils and students, which, in turn, creates ambition for victory and stimulates upgrading the skills and knowledge in this area.

So far, the portal supports four languages (Ukrainian, Russian, English and Azerbaijani), that allows to attract participants from different countries to programming competitions.

While developing the E-olymp system, the project team strived to make it user-friendly, fast and accessible to wide range of users. That is why the online judge system was made in the form of a website available on the Internet.

Nowadays E-olymp system supports the compilation of solutions in one of the following programming languages: Pascal, C/C++, Java, Python. It is possible to run personal or team competitions by ACM ICPC (International Collegiate Programming Contest) rules, as well as by IOI (International Olympiad in Informatics) rules. The overall rating of Internet portal users and participants of competitions is maintained. A forum with the opportunity to discuss competitions and individual tasks is supported. It is possible to form groups, where you can hold your own set of competitions. Precisely in the groups the distance summer and winter schools are held. In the groups the courses on programming languages, algorithms and data structures for university students are delivered.

The database information is processed using the Internet portal services. Any interested person can take part in competitions once registered in the system, or simply can check his solutions to the problems, which statements are available in the website database.

After testing the problem's solution, the participant's rating is recalculated. It is calculated using two parameters: the number of completely solved problems and the number of points scored. This is due to a different level of users and rules of official competitions. It should be reminded that by the rules of school programming contests,

the rating is calculated by the number of points obtained depending on the number of passed test cases. And by the rules of the student ACM ICPC competitions, the winner is the one who solved the largest number of problems completely. A problem is considered to be solved completely, if it has passed all the test cases proposed by the jury members. With the same number of solved problems, the time is taken into account. Penalty time is charged for every unsuccessful attempt.

During the portal activity since September 2009:

- More than 70,000 users registered.
- More than 9,000 problems uploaded to the portal.
- More than 5,000,000 submissions checked.
- More than 1000 user groups created.
- A large number of trainings and official competitions have been organized. For example, official competitions at schools and universities, regional and national competitions in Ukraine and Azerbaijan, mirrors of ACM ICPC and IOI programming contests, international student programming competitions, summer and winter programming schools (Sevastopol 2011–2013, Kharkiv 2009–2013, Qafqaz university 2011–2015).

In many universities of Azerbaijan (including ADA University) the following courses are offered to students using the groups of E-olymp system: Programming Principles (C/++, Java, Python), Data Structures, Design & Analysis of Algorithms, Object Oriented Programming. Groups enable the teacher to automate the verification process of writing programs by students. For example, every semester the author of this article teaches classes in 3 groups, each of them has more than 30 students. Each week, each student must solve about 10 problems. Thus, during a semester (14 weeks), the teacher should check for correctness about $3 * 30 * 10 * 14 = 12,600$ programs. This is not possible without automation!

3. Types of Problems Presented on the E-Olymp Portal

E-olymp portal contains large number of elementary problems in various topics, enabling to use them for a wide range of school teachers and university instructors in their basic programming courses. Exactly these problems teach the students to work independently: how to write properly the first program, how to enter the input data, what data type to use in the program, how to get the correct result. E-olymp system motivates the student in such work, because user immediately sees the answer of the online judge system after submitting the code (Accepted, Wrong Answer, Time Limit). Step by step, the student learns topics such as data input/output, linear programs, processing the digits of the number, conditional statement, loops, one-dimensional and two-dimensional arrays, strings, functions, bit operations, mathematical functions. Each of these topics in turn is divided into subtopics. For example, the set of problems related to the topic “linear integer array” with division into subtopics (problem numbers are given from E-olymp online judge) is given below:

- Elementary problems # 904, 7843, 7844, 8679, 8680.
- Sum of array elements # 919, 7829.
- Minimum / maximum in array # 914, 917, 928, 1952, 7831, 7832, 7845, 7849.
- Second minimum / maximum in array # 5059, 7834.
- Read array till the end of file # 8358, 8684, 8685.
- Average of array elements # 2238, 7368, 7833.
- Shift the array elements # 922, 4760.
- Reverse the array elements # 1460, 2098, 3935.

The next class of problems can be found at regional olympiads. In order to solve them successfully, students must have sufficient knowledge of basic algorithms from such topics as number theory, dynamic programming, combinatorics, computational geometry, graph theory, recursion, sequence processing, greedy algorithms, sort and search, string processing, data structures (Clifford, 2008; Cormen *et al.*, 2009; Weiss, 2012).

At national championships and international competitions (such as ACM ICPC or IOI), the knowledge of advanced algorithms is required. For example, one of the favorite topics at these contests is complex data structures and techniques for their processing, such as Range Minimum Query, Lowest Common Ancestor, Segment tree, Fenwick tree, Decart tree, SQRT decomposition. Below, for example, given the set of problems from the topic “segment tree” with division into subtopics:

1. Single update:
 - Sum of elements in given range # 2941, 4255, 4484, 4496.
 - Minimum/maximum in given range # 695, 2911, 3838, 4482.
 - Prefix/suffix sum # 2906, 2907, 4504, 4510.
2. Multiple update:
 - Sum of elements in given range # 1994, 2304, 2307, 2939.
 - XOR operation # 2905.
 - Additional data structures in the vertices # 3866, 5084.
 - Multiple operations # 752, 3984, 7761.
3. Persistent segment tree # 2955.
4. Two dimension segment tree # 861.
5. Dynamic segment tree # 3252, 7488.

Below we’ll review some problems of advanced level, for which solutions require to implement smart algorithmic ideas. The numbers of the problems are given from E-olymp system.

Problem #4516. Trees in the garden (www.e-olymp.com/en/problems/4516, *XX All-Ukrainian informatics olympiad*). The undirected weighted graph is given. The vertices of the graph are trees in the garden, the edges are paths between them. The garden was so large that one gardener was unable to take care of it. It was decided to divide the garden into two parts. Certain trees will be assigned to the first part, and the rest to the second. One part of the garden may remain empty. Each of two gardeners will take care of his part of the garden by walking along the paths connecting the trees of his part only.

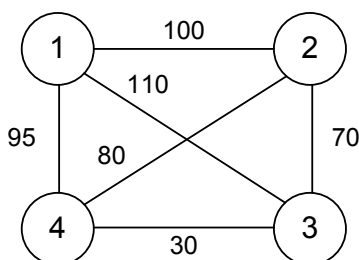
You must divide the garden in such way that the length of the longest path between a pair of trees belonging to the same part is minimum.

Solution. In this problem we need to assign to each tree one of the two gardeners who will take care of it.

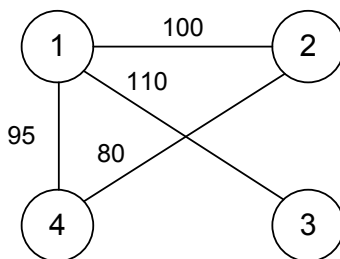
Let us consider the following subtask: is it possible to divide the trees between two gardeners in a such way that there are no paths (along which each gardener will walk separately) with the length greater than x . If we know the answer to this question, then we can search the minimum value of x (the answer to the problem), for which such partition exists using binary search.

Let us draw a graph where the edges of the length greater than x are only available. If such graph is bipartite, then each set of trees will be maintained by one of the gardeners. And none of the gardeners will have at their disposal the paths longer than x .

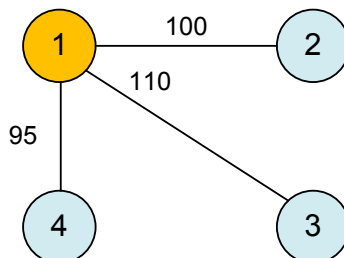
Example. Let us consider the following graph:



Let us try to divide the garden trees between two gardeners in a such way that there are no paths of length strictly greater than $x = 70$. For this purpose, take in the graph only the edges of size greater than 70 and check if it is bipartite:



This graph is not bipartite. Let us consider the graph with $x = 80$. This graph is bipartite:



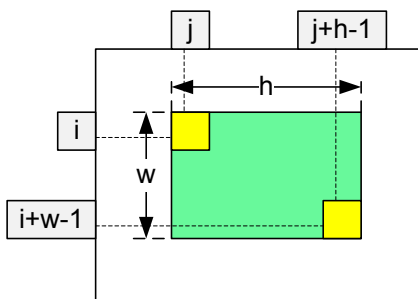
It can be observed that when $x < 80$, the graph with edges of weights greater than x always contains a cycle of odd length (1 – 2 – 4). Therefore, the answer is 80.

Problem #3535. Vasya and matrix (www.e-olymp.com/en/problems/3535). Vasya has a rectangular matrix with n rows and m columns with non-negative integers in the cells. For a given integer k find a submatrix of maximum area in which the sum of all numbers does not exceed k . The submatrix is a rectangular area of the matrix.

Solution. Let a be an input rectangular matrix. Let us create a two-dimensional array dp of the same size, where $dp[i][j]$ equals to the sum of numbers in submatrix with opposite vertices $(1, 1)$ and (i, j) . Its cells can be recalculated by the formula:

$$dp[i][j] = dp[i-1][j] + dp[i][j-1] - dp[i-1][j-1] + a[i][j]$$

Let us consider the submatrix of the array a of size $w \times h$. Let its opposite vertices have coordinates (i, j) and $(i+w-1, j+h-1)$.



Then the sum of all numbers in the submatrix equals to

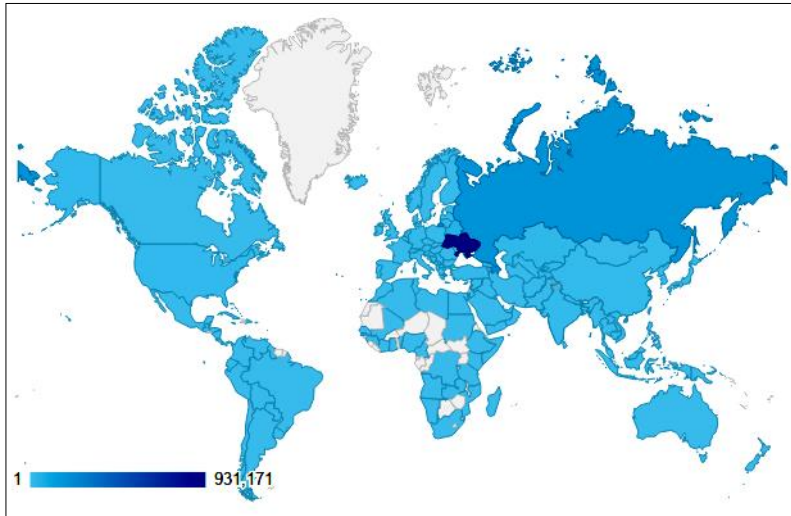
$$dp[i+w-1][j+h-1] - dp[i+w-1][j-1] - dp[i-1][j+h-1] + dp[i-1][j-1]$$

The problem is solved by exhaustive search. Let us run through all possible sizes of the submatrix $w * h$ and all possible left upper corners (i, j) of this submatrix. Within the constant time we can find the sum of numbers in this submatrix using the array dp . If the sum does not exceed k , then among all such submatrices we calculate the maximum of their areas. However, such search runs in $O(n^4)$ and can be improved to $O(n^3 \log n)$ using binary search by the width h of submatrix.

Let us fix the upper left corner (i, j) . Let $g(w, h)$ be the sum of numbers in the submatrix $(i, j) - (i+w-1, j+h-1)$. If w is fixed and h is treated as a variable, then $g(w, h)$ is a non-decreasing function relative to h (the array a contains non-negative integers). Using binary search we find the maximum value for h , for which $g(w, h) \leq k$.

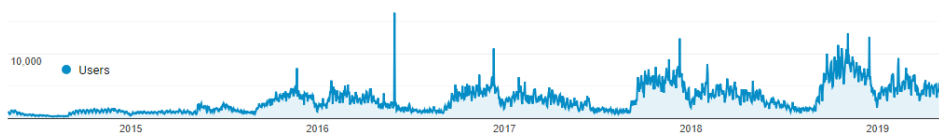
4. The Use of E-Olymp Portal

With the help of Google Analytics, we can see the statistics of problems submitted in the last three years:



The greatest number of students who use the E-olymp system are from Ukraine, Russia and Azerbaijan.

Over the last three years, the E-olymp system checks about 5,000 solutions every day. The peaks on the graph below correspond to online schools (competitions) when the large number of solutions are submitted. Minimums correspond to summer months, when students and pupils have holidays.



The following activities were run in groups of E-olymp system:

- Algorithms and data structures classes in Kiev branch of the Yandex School of Data Analysis, 2011–2015.
- Online summer and winter schools in Qafqaz University, Baku, Azerbaijan, 2011–2015.
- Summer school in Ukraine (Sevastopol) 2011–2013.
- Distance school in Ukraine “9 spiral turns” 2011–2015.
- Classes in programming languages, algorithms and data structures in Taras Shevchenko Kiev National University, 2009–2015.
- Lectures in programming principles 1 (C++), programming principles 2 (Java), data structures and algorithms in ADA University, Baku, Azerbaijan, since 2015.

The author of the article maintains the Facebook group “Competitive Programming Problems & Solutions”, where the theoretical material about algorithms is provided and training courses are run using the E-olymp system. Today the group has more than 2400 members.

5. Conclusion

The E-olymp portal is a convenient educational tool for preparing pupils and students for programming competitions. It can also be used in the further professional activities of a computer science teacher, encouraging to self-education and self-perfection.

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