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REPORTS

International Olympiads in Informatics in Kazakhstan

Artem IGLIKOV[1], Zaza GAMEZARDASHVILI[2],
Bakhyt MATKARIMOV[3]
[1]*Kazakh-British Technical University*
59 Tole bi str., 050000 Almaty, Kazakhstan
[2]*Tbilisi Free University*
Microdistrict 1, Nutsubidze str., 0183 Tbilisi, Georgia
[3]*Nazarbayev University*
Kabanbay batyr ave 53, 010000 Astana, Kazakhstan
e-mail: artem.iglikov@gmail.com, gam_zaza@yahoo.com, bakhyt.matkarimov@gmail.com

Abstract. The Republic of Kazakhstan will host the International Olympiad in Informatics and Asia-Pacific Informatics Olympiad in 2015. Organization of the on-site International contest is a challenging task owing to the various scientific, technical, organizational, and even political issues. This paper discusses the Kazakhstan experience of hosting International programming contests from the viewpoint of the technical and scientific committee. We will briefly cover issues of contestant's workplace preparation, overview our testing system, and define some challenges in problemset preparation.

Key words: IOI, ICPC, APIO, IZhO, EOI/VKOSHP, scientific committee, CMS.

1. Short Overview

In Kazakhstan, a single State enterprise called the Republican Scientific Practical Centre "Daryn" (Republican Scientific Practical Centre "Daryn") of the Ministry of Education and Science (Ministry of Education and Science of the Republic of Kazakhstan) bears responsibility for organizing the National Olympiads in all subjects for secondary school students. Before 2003, we had only one programming contest – our Daryn-organized National Olympiad in Informatics for secondary school students. In 2003 our College and University students began participating in the ACM ICPC, on the base of al-Farabi National State University and Nazarbayev University.

During the last decade the number of programming problem solving contests in Kazakhstan has dramatically increased with many educational and scientific organizations offering various competitions in programming and information technologies. Many Kazakhstan Universities opened annual programming championships, among them Kazakh-British Technical University, Suleyman Demirel University, al-Farabi National State University, International IT University, and Nazarbayev University. University championships are ACM ICPC-style and open for secondary school students who compete in and often win them. In fact, ICPC and IOI activity joined together and in just a few years demonstrated commendable results – in 2007, Kazakhstan students reached the World final of ICPC and, independently, won gold medals level at IOI.

To date, Kazakhstan has created and hosted two ongoing International Informatics Olympiads for secondary school students:

– Since 2005, the International Zhautykov Olympiad (IZhO) has conducted competitions for secondary school students organized by the Ministry of Education and Science, Daryn, and O. Zhautykov Republican Specialized Physics-Mathematics Secondary Boarding School (O. Zhautykov Republican Specialized Physics-Mathematics Secondary Boarding School). The International Zhautykov Olympiad (International Zhautykov Olympiad) welcomes secondary school teams to compete in Mathematics, Physics, and Informatics (Informatics debuted in 2009). Each team comprises seven students (contestants); a student competes individually in only one subject. Contest rules are close to those of the top World Olympiads, i.e., IMO, IPhO, and IOI. Medals are allocated individually, and a weighted sum formula yields the total team score. Winning teams receive valuable prizes, like modern laptops for every contestant of the team (independent of his individual result).
– Since 2009, the Saint Petersburg National Research University of Information technologies, Mechanics and Optics (IFMO), Daryn, and K. Satpayev Kazakh National Technical University conduct the Eurasian Olympiad in Informatics. EOI is actually the All-Russian Team Olympiad in Programming for schoolboys (VKOSHP) (All-Russian Team Olympiad in Programming for Schoolboys), hosted in Almaty, Kazakhstan. This is an ACM ICPC style contest and traditionally carried out within the single week with ACM ICPC Northeastern European Regional Programming Contest for high school students. It is hosted by Saint Petersburg and Barnaul in Russia, Tbilisi or Batumi, Georgia, or Erevan, Armenia, Tashkent, Uzbekistan, and Almaty, Kazakhstan. Before 2009, Kazakhstan students participated VKOSHP at the Saint Petersburg, Barnaul, and Tashkent sites, several times winning the championship at Tashkent site, and once at Barnaul site.

Kazakhstan students will join the Asia-Pacific APIO starting from 2012.

Results of International Zhautykov Olympiads, National Olympiad, APIO, and VKOSHP/EOI are taken into account together to select Kazakhstan team to IOI. The Country report on various programming competitions in Kazakhstan will be presented in subsequent publications.

2. Contest Environment

One of the most important tasks in hosting a big contest is the construction of a contest technical environment that is familiar to all contestants and additionally performs well under high loads.

2.1. *Ideal Conditions*

To prepare an ideal contest environment, one would need:

- precisely equivalent computers: the environment should have enough computers for all contestants plus reserves for failures and the testing system;
- networking and printing: all computers must be connected to network;
- power, backup and restore: system should be stable under power and other faults;
- time to work: whole system must be available and reserved for at least one week before contest;
- permissions: the technical committee must have full system access, i.e., permission to modify hardware, to format hard drives, and reinstall the operating system and other software;
- software: there should be a reliable ready-to-work Testing and Contest management system (CMS);
- knowledge and experience: the technical committee must have good knowledge of operating system and contest system administration.

The contest problem set does not appear in the above list as it includes only technical issues. Let us consider problem set as scientific issue, since task preparation is not yet completely automated.

If all these conditions are met, then there will be a chance to run contest ideally. Technical committee staff starts preparation before the contest with enough time, cleans all computers, installs the proper operating system, prepares the workspace for contestants, prepares testing system, runs several load tests, checks all computers, runs sample contests, generates reports, etc. All the best!

2.2. *Reality*

The reality usually is different from the ideal above. Olympiads in Informatics in Kazakhstan are usually held in Universities. These Universities have offered a number of computers in one or several collocated laboratories, all computers on a unified network, and sometimes even servers and printers! But actually:

- Nobody will give full control to these computers to the technicians of the Olympiad, because there are system administrators there, and they do not want strangers to take control over their systems. In the best case, they will help you with some problems.
- Nobody will even talk about reinstallation of operating system. It's not a problem to reinstall the system before the Olympiad. The problem is to restore original

system after the Olympiad. And because there are usually classes just a day before the contest and on the next day after, they cannot lose time (a day or two) on reinstalling hundreds of computers.
- There is no possibility to reserve computers for several days before the process since the computers are in ongoing use by students.
- Sometimes there is even no possibility to reinstall operating system on jury computers used for testing.
- All universities primarily use Windows-family installations for their education process.
- There are only a few people in the technical committee, and all of them are working or studying. So we just don't have a free week for setting up all things.

These problems can be solved in different ways. Some universities propose using thin clients for virtual machines on their server cluster (but you need to be sure, that the performance of the cluster will be enough for hundred or more contestants). Some universities already have all needed software on contestant computers (but there is also other software and teaching materials available on these machines). Some universities, of course, simply don't have the needed software.

A committee survives in these conditions (like starting to work only 12 hours before contest) only by having all software ready and completely automated scripts for installation and setup. Scripting and tools like Sysinternals (Windows Sysinternals) are very helpful. One more very helpful feature is that at the moment all compilers that are used in the Olympiad (MinGW C/C++, Java, FPC), all IDE's, and other tools for Olympiad (CodeBlocks, Eclipse, FreePascal, Far Manager) do not actually require explicit installation process. It's enough to unpack them in some folder and to put shortcuts on the desktop. So we often created a self-extracting archive with everything needed and just downloaded it to all computers and run once.

Having enough time, a special windows account for contestants created. It has limited access to the system, for example, it cannot access to any other software and documents that was already installed to the computer before the Olympiad. Now contestants have limited access to computer resources that will not needed during the contest.

2.3. *Testing System*

One big challenge is that of grading the contestant solutions. A number of testing systems are now available for use, e.g., PCMS2 (NRU ITMO PCMS2 CMS), eJudge (Ejudge CMS Home Page), or others. All of them have different features: some of them work only on Linux (but we cannot reinstall operating system), some of them require huge administration experience; some of them do not support IOI rules. In the Kazakhstan quarterfinals of ICPC, we used PCMS2. Many Universities use eJudge for training and championship. For our National and International Zhautykov Olympiads, we created our own testing system. Every test system has an invoker module, responsible for executing contestant code and checking runtime limits. In our system we are using invokers running under the Widows OS family, from PCMS2 and from the testlib package of Saratov State University, Russia (Testlib).

Here are some benefits of our CMS:

- The programmer, who designed and wrote the system, is always a member of the technical committee, so problems can be fixed very quickly, and if the jury sees that it would be nice to have some feature, it can be implemented very quickly.
- Almost all parts of the system are cross-platform or potentially cross-platform (because we have used it only on Windows OS, some parts just have no adaptation for other systems), so we don't need to reinstall computers for installing the testing system.
- The system uses shared folders for distributing tasks between machines, it doesn't create any TCP connections, and so even if there is a firewall, or some limitations on the network, it will have no problems (and debugging is much easier, too).
- All system modules are very independent, so it's not a problem to reboot an invoker or add new invoker on the fly.
- The big part of the system (user interface generation and logic for tasks distribution) is written in PHP, so fixes and upgrades can be made very quickly (even during the contest).
- The invoker's part is written in plain command shell language, so preparing invokers involves just setting up compilers and running a command to install invoker scripts.
- Importantly, the system fully tests solutions during the contest, so current results are always visible to jury and are almost immediately available after the contest.

The first version of the system was written for Kazakhstan National Olympiad in Informatics. It was incrementally developed over three years to have all features of a modern scalable contest testing system: support of multiple invokers, presenting results during the contest, printing, processing clarification requests, accounts for observers and other cool things. The system is currently used in National and International Zhautykov Olympiads.

3. International Zhautykov Olympiad

When Andrey Lopatin was IZhO Jury member we used his TestSys testing system. From him we learned many interesting tricks; one of them was how to avoid possible network connections between contestant's computers. The trick based on the feature of TCP/IP protocol stack, tested for Windows OS family – it is not required for computer and default gateway to be in same subnet. Every computer is isolated in its own subnet, having to send packages to default gateway to communicate with other computers. The contestant cannot change network setting without administrative privileges, so all network communications controlled by default gateway which is also testing system interface server.

The technical conditions of IZhO were far from ideal. In the first years there were too many different types of computers and network cabling problems; currently there are no administrative privileges on software and hardware. Sometimes we divided students into two groups, foreign and ours, and give our guests the better workspaces. Despite these troubles, we did not get negative assessment from contestants. The practice shows that a strong student needs very little to work and win – just a working compiler and availability of the submit interface! We often observed that Kazakhstan student seated at the worst workstations won the contest.

4. Eurasian Olympiad in Informatics

The EOI exploited almost ideal conditions – all necessary hardware with necessary permissions was allocated. IFMO representatives of the scientific and technical committee are present on every VKOSHP site, and the contest environment is identical everywhere except the contestant computers and testing server. VKOSHP uses the IFMO PCMS2 testing system. PCMS2 supports several distributed testing servers, so every site is in fact autonomous. EOI carried out the best traditions of Russian programming competitions. Every technical task is automated, starting from operating system install and test and finishing with diploma printing.

5. Challenge of Creating Problem Set

One of the features of the Zhautykov Olympiad is a wide distribution of contestant skill level and experience. Even though this contest is an International one, it's not of IOI challenge. So, a smaller number of countries participate and those who do participate sometimes do not send the strongest contestants. The contest entrants span the range from IOI gold medallists to beginners. If we target a problem set to the stronger participants, the beginners will have zero points, which would quite probably reduce their motivation. If we target the problem set to the weakest participants, the contest will not be interesting for stronger ones. One main requirement is to avoid the situation where the number of full score results exceeds the limit of the number of gold medals.

Thus it is quite challenging for the jury to create a problem set that will be interesting for all categories of participants and at the same time will allow fair evaluation of the winners. Though several first contests always included a problem that can be fully solved by a beginner, last year we had no such problem, but almost all problems we used had easy subtasks for 30 or even 50 points that could be solved with naïve algorithms. We think that having easy subtasks is more interesting for both types of participants than having one easy problem. Because the easy problem can be solved in the beginning of the contest even by a non-experienced contestant, and after this he or she will do nothing for the remaining four hours. With several easy subtasks, a contestant will be able to show different skills and gain more satisfaction, because he was not counting flies for several hours.

5.1. *Sample Tasks of the International Zhautykov Olympiad*

Below are some example problems of past contests.

Problem B from year 2009. The contestant needed to find a bridge nearest to the given two vertices in a graph. Solution of this problem assumes solving standard graph problems:

1. Find minimal distances from two given vertices to all other vertices.
2. Find all bridges in graph and choose one of them, for which robots arrival time is minimal possible.

The effective solution of this problem assumes use of Dijkstra's algorithm ($O((N + M) * \log(N))$, for example, implemented with heap data structure) for finding distances and based on depth-first-search $O(N + M)$ algorithm for finding bridges in graph.

A hard problem C from year 2009. In this problem, we must check existence of the symmetry axis for the given set of points on the plane. Naive $O(N * N)$ solution check existence of symmetry axis for all pairs of points, assuming that they are mirror reflection and taking care that axis of symmetry may pass through one or more points in the set. Note that checking, if the given line is an axis of symmetry for given set of points, could be done in $O(N)$ time using a hash table.

Full score solutions assume to use linear time algorithms to find longest palindrome in cyclic sequence of objects. Note, that the symmetry axis, if exists, will pass through the centre of mass M of the given set of points. Now, let us consider the vectors from point M to each of the point of the set. If there is an axis of symmetry, then we can partition our vectors into two groups: for each vector X (not lying on the symmetry axis) from the first group, there is only one vector Y from the other group that has the same length and lying at the same angle as X from the symmetry axis, but in opposite direction. So, we can mark-up point vectors by unique identifier (using angles between pairs of consecutive vectors and their lengths), for example, sorting all vectors by angle and length and updating angles from absolute to relative cross points values. As result, we will get a circular sequence of vectors (circular string) that should be checked for being a cyclic palindrome-like one, i.e., if there is a symmetry axis, then reading the sequence of vectors in clockwise or opposite direction around symmetry axis gives the same result. In case of point set $\{(0, 1), (1, 0), (0, -1), (-1, 0)\}$, the cyclic sequence may look like $\{(90, 1), (90, 1), (90, 1), (90, 1)\}$ which contains four palindromes of length 3 (odd) and four palindromes of length 4 (even). To avoid consideration of cyclic palindromes, we might double initial sequence, i.e., make a new sequence with double size, containing the initial sequence twice. If the length of the longest odd/even palindrome in the new sequence is more than or equal to $N - 1/N$, then there exists in initial sequence a cyclic palindrome. Finding the longest palindrome in a string can be done in $O(N * \log N)$ or $O(N)$ with different algorithms.

An easy problem D from year 2009. In this problem, contestants had to calculate the Bth power of A modulo C for 64-bit integers A, B, C. The problem was targeted for weaker participants, so several solutions possible. The main issue of this problem is that even multiplication of two numbers when calculating the power can exceed the maximal value of 64-bit integer data type. So full score solution may use arbitrary precision arithmetic or the contestant can note, that it is possible to calculate product $X * Y$ as $X + X + \cdots + X$, replacing product by addition in the well-known fast-exponentiation algorithm. Jury noted that, despite enabling the Java programming language, contestants didn't submit solutions exploiting the *modPow* method of *BigInteger* class.

In problem E from year 2009, we have a number of watermelons, and we know their sizes W_0 at some point in time. Also we know the speed of growing S for each watermelon. The size of watermelon after K days can be calculated as $W_k = W_0 + S * K$. Given parameters of all watermelons, the contestant must find the heaviest watermelon on given days.

Naive approaches to solve this problem include an $O(N * M)$ solution which iterates through all watermelons for each request and choose the heaviest one. Another $O(N * N + M * \log(N))$ solution notes that there is not more than one segment of time when the given watermelon becomes the heaviest one, and we can find this moment by iterating through all pairs of watermelons, and then using binary search to find the heaviest one at given moment of time.

The full score solution requires $O((N + M) * \log(N)$ time where we can find the segment for being the heaviest for each watermelon in $O(N * \log(N))$ time. Note that the weight of the watermelon is the linear function of time. It could be represented as a line on the plane (time-weight). Then for each moment of time we have to find the topmost point of the given lines. It is obvious that this point's form convex polyline, which in fact is the intersection of half planes determined by given lines of watermelon's weight in time. There is a known algorithm for finding such intersection in $O(N * \log(N))$, using stack data structure. In the stack we will store vertices of a part of the convex polyline that we are constructing. Initially stack is empty. First step of algorithm is sorting lines by angle in ascending order. Then let us consider each line (half plane) by the order. Every half plane cuts a part of current polyline and adds one segment to it. To construct updated polyline we should remove points from the stack while they do not belong to added half plane and then add one point – the intersection of the last polyline segment left in stack and new line. At the end of the algorithm the stack will contain resulting polyline, and then we can use binary search to determine the heaviest watermelon at a given time moment.

Problem D from year 2013. This problem required the contestant to answer queries about a special graph. The feature of the graph is that each vertex has at most one outgoing edge. Queries revolve around deleting a given edge and finding the length of the shortest path between two vertices. There are several approaches on how to solve this problem. The main thing is to note that the graph will consist of one or more components containing one cycle along with trees suspended to this cycle.

We can do some pre-processing and for each vertex check whether it is in the cycle and, if it is, calculate the cycle number and the vertex position in it. Otherwise, we calculate the vertex level in the tree. After this we will process queries in the reverse order (avoiding edge deletion by adding edges instead). When an edge is added, the vertices need to be marked as connected, which is done using a disjoint sets structure. So, when we have a query on the shortest path, we need to check whether vertices are connected using disjoint sets and, if they are, calculate the shortest path using information about level, cycle number, and position in the cycle. As you see it's not easy to solve this problem for full constraints where the number of vertices and number of queries can be up to

10^5, but this problem has an easy subtask for 50 points where the number of vertices is not greater than $2 * 10^3$ and number of queries is not greater than $2 * 10^4$, which can be solved relatively easy.

6. Commentary

Joined ICPC and IOI activity along with the ongoing work of the educational and scientific organizations in Kazakhstan has lead us to fast and positive results: in 2007 our students reached the World finals of ICPC and the gold medal level of the IOI. One important factor of our success is the participation of Kazakhstan students in various International competitions and camps, among them we would like to emphasize the Summer school of computing for secondary school students (Summer School of Computing), Petrozavodsk training camps for high school students (Petrozavodsk Training Camps), and E. Pankratiev Open Team Programming Collegiate Cup (E. Pankratiev Open Team Programming Collegiate Cup), all these events in Russia.

Inspired by the successful development of programming contests in Kazakhstan, Informatics was introduced since 2009 into the International Zhautykov Olympiad and All-Russian Team Olympiad in Programming for schoolboys hosted in Kazakhstan as Eurasian Olympiad in Informatics.

Herewith we present statistics of IOI medals for the participants of International Zhautykov Olympiad:

IOI 2009: 1 Gold (Dzmitry Bahdanau, Belarus), 2 Silver, 3 Bronze;

IOI 2010: 2 Gold (Rumen Hristov, Vladislav Haralampiev, Bulgaria), 4 Silver, 10 Bronze;

IOI 2011: 1 Gold (Baris Kaya, Turkey), 2 Silver, 6 Bronze;

IOI 2012: 2 Gold (Maxim Akhmedov, Oleg Ivanov, Russia), 3 Silver, 3 Bronze.

7. Conclusions

In this paper we covered some aspects of conducting an international on-site contest from the position of technical and scientific committee. To sum up, holding an International contest is a big responsibility and has large number of difficult and not-so-difficult challenges, all of which are about compromise. We described only a few of them: preparing workplaces, testing system, preparing problemset. Having experienced team, all these challenges can be easily solved in ideal environment, but the reality introduces many limits, so we always need to find balancing point between ideal and possible solution, which experienced team always find! In 2015, the International Olympiad in Informatics and Asian-Pacific Informatics Olympiads will be hosted by the Republic of Kazakhstan. We will be happy to present our country in these events at the best level of International contests organization!

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References

All-Russian Team Olympiad in Programming for Schoolboys. http://neerc.ifmo.ru/school/russia-team/index.html
Ejudge CMS Home Page. http://ejudge.ru/
International Zhautykov Olympiad. http://izho.kz/eng/
Ministry of Education and Science of the Republic of Kazakhstan. http://www.edu.gov.kz/en/
NRU ITMO PCMS2 CMS. http://neerc.ifmo.ru/trains/information/software.html
E. Pankratiev Open Team Programming Collegiate Cup. http://www.opencup.ru/
Petrozavodsk Training Camps. http://acm.petrsu.ru/site/?lang=eng
Republican Scientific Practical Centre "Daryn". http://daryn.kz/?lang=en
Summer School of Computing. http://olympiads.ru/sis/
Testlib. http://code.google.com/p/testlib/
O. Zhautykov Republican Specialized Physics-Mathematics Secondary Boarding School. http://fizmat.kz/
Windows Sysinternals. http://www.sysinternals.com

A. Iglikov, participated at IOI from 2012 as Kazakhstan team leader. Graduated from K. Satpayev Kazakh National Technical University, currently PhD student of Kazakh-British Technical University. Successfully participated in ACM ICPC 2005–2009, advanced to the ACM ICPC 2007 World final. In top 200 of TopCoder rating.

Z. Gamezardashvili, participated at IOI from 2002 as Georgia team deputy leader. Graduated from Tbilisi State University, Georgia, in 1988. Research interests include algorithms design, software engineering, compiling techniques, digital systems and operating systems. Jury member of the Zhautykov International Olympiad from 2009.

B. Matkarimov, participated at IOI from 2005 as Kazakhstan team leader, IOI IC member from 2012. Graduated from Novosibirsk State University, Russia, in 1989. Initiator and Jury chairman of Kazakhstan quarterfinal of ACM ICPC. Secretary in informatics of Zhautykov International Olympiad and Eurasian Olympiad in Informatics.