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Conducting Off-Line Informatics Olympiads with Individual Tasks

Jyldyz R. JANALIEVA
International University of Kyrgyzstan
e-mail: noledi@yandex.ru

Abstract. Conducting off-line olympiads is convenient and demands less resources than on-line olympiads. To prevent using results of other participants by a participant, we use individual generativity of tasks involving personal data. Also, uniqueness (all participants taking the test will obtain different versions of tasks) is provided. Winners obtain certificates related to their personal data only (not prizes), hence participants are not motivated to solve for others. On the base of experience of conducting such olympiads (including team olympiads with inverse tasks) in Kyrgyzstan since 2006, methods to develop tasks and pairs of inverse tasks, examples of tasks and instructions for organizing such competitions are proposed.

Key words: internet olympiads, off-line olympiads, individual tasks, team competitions.

1. Introduction

Undoubtedly, using the Internet to organize competitions for pupils yields large advantages and possibilities including involving participants of different countries, and in fact of the entire world. However, on-line competitions demand vast and complex equipment and use more resources. Hence, we propose to conduct some competitions off-line. Also, the main defect of Internet competitions is the opportunity to obtain "help" from other persons. To diminish this defect we propose to use individually generated tasks. Also, using the Internet for team competitions yields the possibility of forming commands of distantly separated members, as it was proposed (Pankov, 2006) in the form of necessarily-collective ones: each teammate works at a separate computer; they can communicate only by means of a computer network across a central computer-server; a goal of the competition can be achieved if and only if each teammate fulfils their own task.

To ensure these terms we also propose to use individually generated inverse tasks.

Section 2 contains definitions of extended tasks and individually generated tasks.

Section 3 contains definitions of inverse and semi-inverse tasks for team competitions, with examples.

Section 4 describes off-line individual competitions.

Section 5 reports about such competitions on applied mathematics (new genre) in Kyrgyzstan.

Section 6 stresses peculiarities of conducting necessarily-collective competitions.

2. Definitions of Extended and Individually Generated Tasks

In our observation, almost all young persons who could master programming begin to write testing programs performing the following standard "method of multiple choice": the student is shown a question and some (three-five) preliminary written answers and is to choose a right answer. This method is easy for programming but instigates the student not to solve the task but to "guess" the right answer. Also, implementation of this method does not give opportunity to evince programming skills and knowledge of subjects previously studied. Attempts of diversification of this method are reduced to a random choice in data base with ready tasks and to a random permutation of answers.

We, with our students, implemented some principles which gave the opportunity to develop software involving various peculiarities of the subjects studied, and examining various abilities of persons tested.

For brevity, we shall use the term "test" to mean any kind of control of quality of education, in a more general sense than a common one.

Other than common demands of tests (Validity, Objectivity and Reliability), to improve efficiency of testing, we offer the following ones:

Generativity: a complete text (content) of a task must not exist before testing, and must be generated randomly just before it.

Uniqueness: all students taking the test must obtain different versions of tasks (of the same level of difficulty or of different levels, according to the teacher's will).

DEFINITION 1. An extended task is an algorithm generating different logically correct and methodically proper tasks (of same level of difficulty) and corresponding right answers from initial data, (randomly) chosen from finite but sufficiently large sets (ranges).

This general definition was offered by Pankov, Janalieva (1995).

Remark. Extended tasks do not conform to a well-known class of "problems with parameters". Each participant receives a concrete task.

Remark. Random (occasional) tasks were used in various kinds of testing. For example, occasional commands are being given at military manoeuvres. We proposed to use this technique for all subjects and to implement it by means of computer.

DEFINITION 2. The number of ranges being used for generating the task in sufficiently different ways is said to be the dimension of the extended task.

DEFINITION 3. An algorithm permitting one (a teacher) to choose subsets of sets of initial data and generating different logically correct and methodically proper tasks by initial data, (randomly) chosen from these subsets is said to be an adjustable extended task.

EXAMPLE 1 of a mathematical task (well-known type of algebraic tasks).

1) Randomly choose $V \in 10 \dots 20$ (boat's velocity), $W \in 2 \dots 9$ (current velocity), $D \in 5 \dots 10$ (time of boat's steaming downstream) and $U \in 5 \dots 10$ (time of boat's steaming upstream).
2) Calculate $R := D(V + W) - U(V - W)$.
3) If $R = 0$ then go to 1.
4) Randomly choose $L \in 1 \dots 4$.
5) Form the text of task using three of four values V, W, D, U. If $L = 1, 2, 3, 4$ then the unknown (right answer) A is V, W, D, U correspondingly, as follows:
   «Boat steamed from the pier ... hours downstream and ... hours upstream and stopped at $|R|$ km below/upstream (by the sign of R) the pier. Boat's velocity is ... and/or current velocity is ...». «Find ...».
   So, this extended task is five-dimensional.
   Version for current testing by computer:
6) Output the text «Input answer».
7) Input $A1$.
8) If $A1 = A$ then output the text: Congratulation: you have solved the task."
   else output the text: "Unfortunately, you are wrong".

Version for off-line competition:

6) choose random numbers B, C and calculate any complex expression $N = F(A, B, C)$ such that M can be found from this equation uniquely, for instance $F(A, B, C) = B \cdot M^3 + C \cdot M - A^2$;
   – output the text «Write your answer and numbers 'B', 'C', 'N' into the file of your answers».
   – stop.

Before the deadline of the competition the participant sends the file with answers to the jury. The deciphering program calculates the value of A by means of the values of B, C, N for the jury.

EXAMPLE 2 to create a "black box" type program for interactive solving.

1) Output the text:
   «There is a cubic polynomial $P(X) = AX^3 + BX^2 + CX + D$ with integer coefficients. Requesting non-zero integer values of X and analyzing the corresponding values of $P(X)$ detect the polynomial. The fewer queries you make, the higher right answer will be estimated».
2) Randomly choose
   $A \in \{-3, -2, 2, 3\}$, $B \in -9 \dots -1 \cup 1 \dots 9$,
   $C \in -9 \dots -1 \cup 1 \dots 9$, $D \in -9 \dots -1 \cup 1 \dots 9$.
3) Let $M := 0$.
4) Output the text:
   «Input non-zero integer value of X in the range $-100 \dots 100$ or 0 for output»

5) Input X.
6) If $X \neq 0$ then let $M := M + 1$, calculate and output $P(X)$ and go to 4.
   Version for current testing:
7) If $X = 0$ then output the text «Input A, B, C and D».
8) Input $A1, B1, C1, D1$.
9) If $A1 = A$ and $B1 = B$ and $C1 = C$ and $D1 = D$ then output the text:
   "Congratulation: you have solved the task in 'M' queries."
   else output the text: "Unfortunately, you are wrong".

Version for off-line competition:

7) If $X = 0$ then
   - calculate any complex expression $N = F(M, A, B, C, D)$ such that M can be found from this equation uniquely, for instance $F(M, A, B, C, D) = B \cdot M^3 + C \cdot M + D - A^2$;
   - output the text «Write found values A, B, C, D and the number 'N' into the file of your answers».
   - stop.

Before the deadline of the competition the participant sends the file with answers to the jury. The deciphering program calculates the value of M by means of the values of A, B, C, D, N for the jury.

This class of tasks is four-dimensional.

DEFINITION 4. An individually generated task consists of two algorithms. The first algorithm composes different, logically and methodically correct tasks using personal information about a contestant. The second algorithm generates corresponding right answers using the same information.

Correspondingly, the contestant is to write their personal data and found answers into the file of answers and the second algorithm generates right answers for checking using the same data.

The same data are printed into the certificate.

3. Definitions of Inverse and Semi-Inverse Tasks

A task T in general can be presented as follows:

"Given $G(T)$ (with some explanations); find $A(T)$" (if the answer is single-valued) and

"Given $G(T)$ (with some explanations); find any element of the set $A(T)''$ (if the answer is multiple-valued).

If it is an examination or a competition then "... in appropriate time" is to be added.

DEFINITION 5. A task T_2 is said to be inverse to the task T_1, if $G(T_2) = A(T_1)$ and $A(T_2) = G(T_1)$.

The first teammate solves the task T_1, the jury transfers their solution $A'(T_1)$ to the second teammate, the second teammate solves the task T_2' with the initial data $G(T_2') = A'(T_1)$ and the jury compares their solution with $G(T_1)$.

But the teammates can find opportunity to communicate $G(T_1)$ too (for instance, by mobile telephone). Hence, we propose also

DEFINITION 6. A task T_2 is said to be semi-inverse to the task T_1, if there is a (simple) algorithm M such that $G(T_2) = M(A(T_1))$ and $G(T_1) = M^{-1}(A(T_2))$.

The first teammate solves the task T_1, the jury calculates $M(A'(T_1))$ for their solution $A'(T_1)$ and transfers it to the second teammate, the second teammate solves the task T_2' with the initial data $M(A'(T_1))$: $A(T_2')$ and the jury calculates $M^{-1}(A(T_2'))$ and compares it with $G(T_1)$.

Example of an inverse task with single-valued answer:

EXAMPLE 3. *Task* T_1. Given three segments cut by the plane on the coordinate axes X, Y, Z. Find coordinates of the point on this plane being closest to the origin of coordinates.

Task T_2. Given the point on the plane being closest to the origin of coordinates. Find three segments cut by this plane on the coordinate axes X, Y, Z.

Example of an inverse task with multiple-valued answer:

EXAMPLE 4. *Task* T_1. Given three segments cut by the plane on the coordinate axes X, Y, Z. Find coordinates of three non-collinear points lying on this plane but not on coordinate axes.

Remark. In this task, the jury is to check the condition "not on the coordinate axes" before transferring.

Task T_2. Given three points lying on the plane. Find three segments cut by the plane on the coordinate axes X, Y, Z.

Example of an semi-inverse task with single-valued answer:

EXAMPLE 5. *Task* T_1. Given three segments cut by the plane on the coordinate axes X, Y, Z. Find three coordinates of the point on this plane being closest to the origin of coordinates.

Algorithm M. Multiply three coordinates by a non-zero number m.

Task T_2. Given three coordinates of a point on the plane being closest to the origin of coordinates. Find three segments cut by this plane on the coordinate axes X, Y, Z.

Algorithm M^{-1}. Divide three obtained numbers by the number m.

Combinations of above definitions yield also "extended inverse tasks", "individually generated inverse tasks", etc.

4. Organization of Off-Line Competitions

4.1. Some days before forthcoming competition, applications are collected.
4.2. 20–30 minutes before the beginning of the competition the executable file with individually generated tasks is sent to all participants and confirmations when obtained and successfully run are collected.
4.3. When the competition starts, the password for the opening the executable file is sent to all participants.
Comment. Sending of the executable file and communication of the password are separated because communication of the password requires less time and has less chance of any difficulties.
4.4. Participants solve the tasks and fill in files with answers.
4.5. Before the deadline participants send files with their personal data and answers.
Remark. Earlier submitting of these files is encouraged with additional points (it is announced in advance).
4.6. Jury inputs all participants' information and some complementary information into the deciphering and estimating second program (Algorithm 2 for all the tasks).
4.7. Jury sends total table with winners' list, notes about right way of 'tasks' solutions, best works, some mistakes and winners' certificates to all participants.

There is no reason to do other's work, because winners get certificates only.

5. Olympiads on Applied Mathematics

Using the methods discussed, since 2006 the Applied Mathematics and Informatics chair jointly with the Information and Computing Technologies chair of the Kyrgyz–Russian Slavic University has conducted open competitions in applied mathematics both for KRSU students and for students of other universities.

Here are some tasks. Letters denote individually generated positive integer numbers in appropriately selected ranges.

Task 1. Find the length of the arc of the parabola $y = Ax^2$ $(B \leqslant x \leqslant C)$ with accuracy 0.1.

Remark. This easy task gave the paradoxical, although predictable result. All students who knew the integral formula for arc length made mistakes in the calculations and the results were meaningless but most of the students, who did not know this formula, solved the task correctly.

Task 2. *KRSU_1.exe* program is given. It calculates one of the towns in Kyrgyzstan using personal data. Further the contestant inputs arbitrary shifts along the earth surface (receiving corresponding feedback), but not far from Kyrgyzstan until s/he reaches the capital Bishkek with the KRSU. «Guess where you were first, and write the answer either in the form: a) to the east (west) . . . km and to the north (south) . . . km from the KRSU (less points), or b) by the name of the town (more points)».

Task 3. A right-angled triangle with legs A and B rotates around a line passing through the apex of the right angle, and lying in the plane of the triangle. Find the greatest possible volume of the resulting solid of revolution with accuracy 1%.

Task 4. There is a mixture of two radioactive isotopes with different half-lives. For a given a) $0 \leqslant t < 50$ or b) $1 \leqslant t < 50$ the program (exe-file) gives the mass of the mixture at time t after the start. Find the mass of each isotope in the initial time with an accuracy of 1%.

Task 5. With a piece of plasticine of volume A cm^3 and a ruler, measure an approximate value of π by as many as possible sufficiently different ways. For each method, write the idea, giving results of measurements and calculations, and presenting one or two photos.

6. Organization of Off-Line Team Competitions

There are two types of such competition for pairs.

1) participants are of same educational institution;
2) participants are of different towns or countries.

In the first case, participants form teams by their own will.

All first teammates sit in the first computer class, all second teammates sit in another one.

Individually generated semi-inverse tasks are used.

Tasks are more difficult, only one tour (2–3 hours) is conducted.

In the second case, teams are formed randomly, no pairs from a same town. Participants do not know who their teammates are before the end of the competition.

Individually generated inverse tasks are used.

Tasks are easier; some tours (20–40 minutes each) are conducted. For each tour, new pairs are formed. Thus, the sum of points of every participant in some pairs shows their average level.

7. Conclusion

We hope that the organization of the competition by the proposed technique will expand the range of distance competitions in general, simplify their organization, make them more diverse, and evaluation of the results more objective. We are grateful to the KRSU administration for the support of olympiads in applied mathematics as a new genre of competitions.

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J.R. Janalieva (1969), doctor of pedagogical sciences, conducts various competitions on mathematics, informatics and languages including collective ones for students of Bishkek and Internet ones for students of Kyrgyzstan. Graduated from the Kyrgyz State University in 1991, she works as a docent of the International University of Kyrgyzstan.