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THE METHODOLOGY FOR PREPARING UNDERGRADUATE STUDENTS FOR OLYMPIADS IN INFORMATICS IN EXTENDED FORMAT

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Abstract. This article examines didactic features for preparing university students for contests in informatics. Some methodical approaches are analyzed regarding the necessity of extending the formats of the contests.

Key words: algorithmic thinking, Olympiads in informatics, mathematical modeling.

METODOLOGIA DE PREGĂTIRE A STUDENȚILOR DE LA CICLUL I, LICENȚĂ, PENTRU OLIMPIADELE DE INFORMACĂ ÎN FORMAT EXTINS

Abstract. În acest articol se examinează aspectele didactice de pregătire a studenților de la ciclul I - licență pentru concursurile de informatică. Sunt analizate unele abordări metodice cu privire la necesitatea extin-derii formatelor concursurilor.

Cuvinte cheie: gândire algoritmică, olimpiade de informatică, modelare matematică.

1. Specific features of computer science contests

Contests in informatics represent both a method of testing knowledge and a method for classifying competitors according to their programming and algorithmic thinking skills. But at the same time, Olympiads in informatics must become a forum for algorithmic thinking that calls and urges absolutely all those who are fascinated and passionate about computer science to get involved in the process of running these competitions and to discover (rediscover) their own abilities and skills, to rebuild confidence in their own intellectual powers and to develop the “appetite” for progressing in at least some departments of computer science. The reasons for student’s participation in contests in informatics are:

a) Cultivating algorithmic thinking;
b) More complex understanding of the programming skills;
c) Cultivating the ability to quickly focus and react in a short period of time;
d) Accumulating the necessary experience for the future IT programmers;
e) Elaborating an attractive CV which mentions participation in the regarding contests. These aspects are quite often making a differences in CV-s and are more taking into account in the process of employing people in IT companies;
f) Identifying weak and strong points regarding the student’s theoretical and practical skills.

„Elite” computer science contests, and not only, are for „strong” students with deep knowledge, good and very good training in algorithmic, who think logically and have a speed of thinking higher than the average level. In these kind of contests, qualities determined by the reaction of thoughts, speed in relation to the decision-making process vis-à-vis the methods and approaches to be implemented, intuition and other time-dependent factors make the difference most of the time. But what do we do with those students who do not fall into that category? Thus, the experience gained over several years in the process of organizing and conducting several Olympiads in informatics highlights the following aspects:

1. There are students that are equally well trained in the field of computer science but are slower and have a slower speed in the process of logical analysis and thinking. The negative experiences, accumulated in various competitions cut them off from the desire to participate in other competitions, no longer wanting to get involved and losing confidence in their own powers.
2. Another category of students, due to objective and subjective considerations, have a lower training in the field of computer science, but the quite advanced intellectual capacities and the desire to perform would allow them to grow professionally in this field.

Taking into account the listed aspects, a special emphasis is placed on the process of preparing students of the above mentioned categories, also placed on the accomplishment of the following stages:

Stage 1. Appealing to the predetermined criteria, the preparation level of the students is determined.

1. The level of the algorithmic thinking of the students is identified.
2. The level of preparation from the theoretical point of view of the students is identified, including programming skills.
3. The quality regarding the speed of operational thinking is determined.
4. The level of preparation regarding working with the computer is determined.

The realization of points 1 to 4 implies organizing and conducting the tests for the students based on the mention criteria. Thus, the strengths and the weaknesses of the students will be highlighted from their results.

Stage 2. Elaboration and monitoring of the individual training program for students with emphasis on studying methods and techniques for solving problems.

1. An individual training route is elaborated with the realization of specific performance indicators.
2. The implementation of the elaborated program shall be monitored and evaluated.
3. Recommendations and suggestions may intervene in the training program originally developed.

Knowledge and successful application of solving strategies is the key to success for preparing students for Olympiads in informatics. Below we will examine some of the specifics.

2. Teaching aspects regarding the solution of problems in the process of preparing undergraduate students for contests in informatics

In our opinion, both in the process of preparing the students for the respective competitions and in the subjects proposed for conducting the competitions themselves, there must be problems which involve the elaboration of mathematical models from the perspective of the inter / transdisciplinarity of the exact sciences. In this way, emphasis will also be placed on the understanding of the interdisciplinarity of the methods, which have as common denominator principles and methods of investigation in various exact sciences and of the interdisciplinarity based on common concepts, fundamental for several disciplines.

One of the characteristics of the university Olympiads in informatics, organized within the Tiraspol State University, is about solving the problems that, as mentioned above, involve the development of mathematical models. In such situations, students develop their ability to develop mathematical models, and subsequently these models are solved through the studied algorithms. In order to develop mathematical models, students must be versed in different disciplines related to the exact sciences (mathematical analysis, geometry, physics, graph theory, number theory, abstract algebra, etc.) and their application, in many cases, including the concept STEM, [1-8].

The intellectual activity carried out by the student is focused on problem solving divided into the following types of problems:

A) *Standard type problems*

The algorithm for solving these problems is known. The student only has to apply the respective algorithm or simple combinations of algorithms to solve the examined problem. This type of problem corresponds to abilities and programming skills that are determined by the content of the studied subject.

Example 1. *We have the product of 5 factors. To each of the first three factors of the respective product add the factor itself multiplied to one and the same number x. From each of the following two factors, of the product, the factor itself is multiplied by the one and the same number x. Determine the number x, if it is known that the product of these factors, after modification, remains unchanged.*

Solution. Suppose that *a, b, c, d, e* –are the product's factors, *x* – part of each factor. According to the condition of the problem we write the relation:

$$(a+ax)(b+bx)(c+cx)(d-dx)(e-ex)=a\ b\ c\ d\ e;$$
$$a(1+x)b(1+x)c(1+x)d(1-x)e(1-x)= a\ b\ c\ d\ e;$$

$$a\,b\,c\,d\,e\,(1+x)^3(1-x)^2 = a\,b\,c\,d\,e;$$
$$(1+x)^3(1-x)^2=1;$$
$$(1+3x+3x^2+x^3)(1-2x+x^2)=1;$$
$$x^5+x^4-2x^3-2x^2+x=0;$$
$$x\,(x^4+x^3-2x^2-2x+1)=0$$

The mathematical model represents the following relation

$$x^4+x^3-2x^2-2x+1=0.$$

The student, by applying some methods of solving algebraic equations (Bisection method, Method of chords, Newton's method) and root localization, elaborates the program in a known programming language and determines two segments with positive roots [0, 1] and [1, 3] for the problem examined. For example, for the segment [0,1], the root by the Newton's method is 0.38939068, the root by the Method of chords is 0.38939080. And for the segment [1,3], the root obtained through the tangent method is 1.28879519, and respectively, the root by the Method of chords is 1.28912073 [4-8].

B) ***Problems that involve selecting suitable algorithms, methods or procedures for solving the problem***

In order to be solved, this type of problem requires the development of a not too complicated research process on the part of the student. In these situations, the research process involves selecting from the variety of known methods some methods and procedures or combinations of methods and timely procedures (which may require minor modifications) that would lead to solving the problem examined. In such cases, the student must have the necessary skills and abilities to choose from the set of known algorithms those that would perfectly fit the examined situation.

Example 2. *A hemispherical vessel is filled with water (Fig.1). At what angle α should the vessel be tilted so that one third of the water remains in the vessel? The result to be obtained with the error eps = 0.001.*

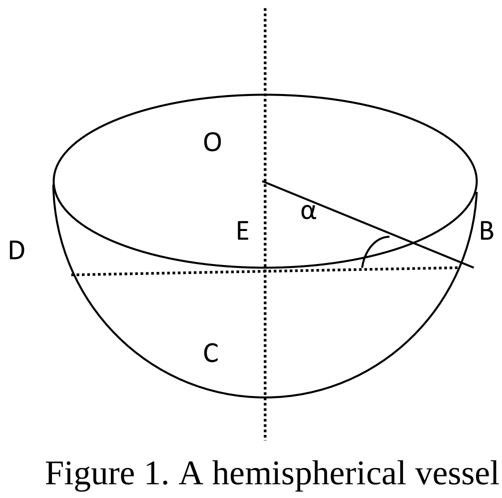

Figure 1. A hemispherical vessel

Solution. The volume of water in the hemisphere is calculated according to the formula:

$$V = 2\pi r3 / 3, (1)$$

and according to the condition of the problem we have that

$$1/3\ V = 2 / 9\pi r3\ (2)$$

Supposing that one third of the volume of the water will be situated in the hemispherical segment DBC , expressed by radius r. Therefore we will obtain:

$$V_{DBC}=\pi h^2(r-h/3)\ (3)$$

where $h=|OC|-|OE| = r - r \sin\alpha = r(1-\sin\alpha)$

$$V_{DBC}= \pi r^2(1- \sin\alpha)^2(r-r(1-\sin\alpha)/3)=$$
$$= \pi r^2(1- \sin\alpha)^2(3r-r+r\sin\alpha)/3)=$$
$$= \pi r^3/3(1- \sin\alpha)^2(2+\sin\alpha)=$$
$$= \pi r^3/3(1- 2\sin\alpha+\sin^2\alpha)(2+\sin\alpha)=$$
$$= \pi r^3/3(2- 3\sin\alpha+\sin^3\alpha)=$$
$$= \pi r^3/3(\sin^3\alpha- 3\sin\alpha+2);$$

We obtained: $V= \pi r^3/3(\sin^3\alpha-3\sin\alpha+2);$ (4)

As the left sides of equations (2) and (4) are equal, so are the right parts:

$$2\pi r^3/9= (\pi r^3/3)(\sin^3\alpha-3\sin\alpha+2);$$

Bringing the above relation to the form *f(x)=0*, we obtain

$$\sin^3\alpha-3\sin\alpha+4/3=0.$$

We substitute $\mathbf{x = \sin\alpha}$ and obtain the equation:

$$\mathbf{x^3- 3x + 4/3=0}.$$

To solve this equation, the student can apply either the Bisection method or the Method of chords, or the Newton’s method. For example, by developing the unified program for localization and the Method of chords, it is determined that positive roots are only in the segment [0; 1]. Taking into account the accuracy of eps = 0.001, we obtain that the root is 0.482403. Thus, **sin α** = 0.482403 and the angle under which the vessel must be tilted so that exactly one third of the water remains is $\alpha=28^0 48'$.

C) ***Problems for which the process of solving is not known***

In such situations, the student does not know the process of solving the problem. The respective type of problems involves the invention, independent discovery of the algorithm, method or procedures suitable for solving the problem.

For this purpose, the student is oriented to do the following:

- Recalling relevant information and recognizing part of the problem that can be solved by already known algorithms.
- Replacing some conditions of the problem with equivalent conditions in which the solving algorithm is known or represents a combination of known algorithms.
- In case the solution is not seen it is necessary to examine some particular cases of the problem. Particular cases may suggest the general solution of the problem.

- The intermediate results obtained, through various approaches, could suggest the correct algorithm, or at least part of the algorithm, which would subsequently lead to the general solution of the problem examined.

Example 3. *A cone-shaped vessel is given, directly circular with the vertical axis; its location and size are shown in Fig. 2. The vessel is filled with water and then the water is drained (drained) through a small circular hole, located at the bottom of the vessel (which is at tip B). Determine the water drainage time in the vessel.*

Solution. Supposing that the time *t*, for which the water level in the vessel will discharge at height *x*, is an arbitrary function *t (x),* we determine its differential *dt* for the changes of *x* at height *dx*.

Suppose the drop of water in the vessel to a small height *dx* is determined by the increase of time Δt. Then, assuming that, during this small period of time, the water flows out of the vessel at a constant speed equal to $0.6\sqrt{2g(H-x)}$.

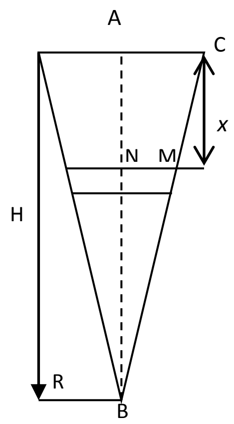

Figure 2. A cone-shaped vessel

We determine the volume of water that flowed during Δt through the hole in the bottom with the area, according to the formula $\Delta v = 0.6\pi r^2\sqrt{2g(H-x)\Delta t}$.

At the same time Δt the volume of water in the vessel will decrease with the height which must be equal to the volume of water that has flowed Δv.

From the equality $\Delta v = \Delta v1$, we obtain

$$\Delta t \approx \frac{y^2 dx}{0.6r^2\sqrt{2g(H-x)}} = dt$$

The time *T* of the total water drainage from the vessel is obtained by integrating *dt* after *x*, from *x = 0 to x = H:*

$$T = \frac{1}{0.6r^2\sqrt{2g}}\int_0^H \frac{y^2 dx}{\sqrt{H-x}}$$

Therefore, the mathematical model of the problem is constructed.

To calculate the integral we will express variable *y* through variable *x*. From the resemblance of the triangles ABC and NBM, we have for the vessel the following formulas:

$$\frac{H}{R}=\frac{H-x}{y}, \quad y=\frac{R}{H}(H-x); \qquad (5)$$

Substituting (5) in *T* we obtain:

$$T=\frac{1}{0.6r^2\sqrt{2g}}\int_0^H \frac{(\frac{R}{H}(H-x))^2 dx}{\sqrt{H-x}} \qquad (6)$$

The student then selects one of the known methods (for example: the Trapezoidal rule, Simpson's rule, Milne rule) to compose the program and solve the integral of the formula (6). For example, for the values of *r = 0.5, R = 3, H = 10, g = 9.8*, applying the trapeze method to solving the integral of (6) gives the result:

$$T=\frac{1}{0.6\cdot 0.5^2\sqrt{2\cdot 9{,}8}}\cdot 11{,}3979013=17{,}165237$$

Note: The student must take into account the upper limit of integration. In case of relation (6), for obvious reasons, the upper limit is recommended to be H = 9,999. These aspects show the competences of using numerical methods to solve complex problems.

3. The stages of solving a problem in computer science

Thus, summarizing the above we can point the following steps to solve a informatics problems:

***Stage* 1. *Careful analysis of the conditions of the problem*.** At this stage, students are drawn to examine very carefully the conditions of the problem, including the dates of entry, the results to be obtained, the execution time, etc. Going through the statement of the problem several times is very important. Some aspects of the conditions of the problem can be noticed after careful analysis of all the conditions as a whole.

Stage* 2. *Development of the mathematical model. The mathematical description of the main links between the detected essential components requires the knowledge of the theoretical foundations of the various exact disciplines. Applying the appropriate mathematical apparatus to describe the processes examined in a strict and precise form remains the most difficult problem for students. The mathematics of the examined processes, in this regard, remains one of the most important problems in the process of preparing the students.

***Stage* 3. *Selecting the solution methods*.** After the mathematical model has been developed, it is necessary to decide on the solution methods. For example, if the mathematical model represents a system of linear equations, then one of the many existing methods for numerical solving can be selected. If no suitable method is found, in order to achieve the proposed objectives, it is necessary to modify one of the existing methods, or to develop a new method.

***Stage* 4. *Development of algorithms*.** Before using the computer, the selected method must be displayed in the form of algorithms, using a programming language. It is known that different programming languages are oriented to solving problems of different types. In this case, the most suitable programming language is chosen for writing the respective program. In the context of those examined, this stage was discussed in more detail in section 2.

***Stage* 5. *Verifying the correctness of the proposed algorithms*.** The test data sets should be carefully designed so as to cover, as far as possible, all the variants of the algorithm execution, including exceptional situations, and to verify that each subproblem of the given problem is solved correctly (if possible, each program module will be tested separately). Testing may reveal omissions or errors in the design of the algorithms, but does not guarantee the correctness of the algorithm. For this, the algorithm should be tested on all possible sets of input data, which is practically impossible.

***Stage* 6. *Analysis of the complexity of the algorithm*.** In general, there are several algorithms for solving a given problem. In order to choose the best algorithm, these algorithms must be analyzed in order to determine their efficiency and, as far as possible, their optimality. Students are reminded that the efficiency of an algorithm is evaluated from two points of view:

1) from the point of view of the memory space needed to memorize the values of the variables involved in the algorithm;

2) from the point of view of the execution time. The complexity is analyzed above all when the algorithm is transposed into a programming language.

Conclusions

The interuniversity Olympiads in informatics organized within the Tiraspol State University, during 10 editions, are held for students from year I separately and students from years of studies II-IV separately. One of the central reasons, for which it is organized separately by years of study, relates to the level of student preparation and the subject matter studied in the various specialized disciplines. In this context students are proposed no less than 8 - 10 problems with different levels of complexity, so that the student can select the subjects on their own taste, from different compartments of the computer sciences, according to their own knowledge and skills, which could lead to solving the problem. In this way, the students involved in the development of contests in informatics - organized according to this format- gain confidence in their own strengths and subsequently tend to progress not only in the study of computer science but also in exact sciences [2-8].

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