Use of popular electronic resources to improve the visibility of the course solving tasks in preparing students for USE in computer science

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Abstract. Currently, the main way to check the quality of education in schools in the Russian Federation is the state final certification, conducted in the format of a unified state exam. The unified state exam in computer science includes 27 tasks of various levels of complexity. Analysis of statistics on the success of various tasks shows that students experience the greatest difficulties when solving task number 23. To increase the visibility of the process of solving this task, you can use the well-known electronic resource MS Excel, which is part of the Microsoft MSOffice package. This electronic resource has a built-in programming language Visual Basic for Application, with which you can significantly expand the functionality of MS Excel. Written in Visual Basic for Application, the macro allows the student not only to get the correct answer, but also to view the problem solution tree, compare it with their own solution, and identify errors in their solution if there is a discrepancy. This article is devoted to the methodology of using this electronic resource in the process of preparing students for the unified state exam in computer science.

1. Introduction
The unified state exam (USE) in computer science [1] consists of two parts: 23 tasks with a short answer and 4 tasks with a detailed answer. For school leavers, the most difficult part with a short answer was always task number 23. This task presents a system of logical equations that could contain a certain number of logical variables (usually from 8 to 14). In the task, you need to determine the number of different sets of logical variables for which each equation is true. The following is an example of a task:

How many different solutions does a system of logical equations have:

\[( x_1 \equiv y_1 ) \rightarrow ( x_2 \equiv y_2 ) \land ( x_1 \lor y_1 ) = 1 \]
\[( x_2 \equiv y_2 ) \rightarrow ( x_3 \equiv y_3 ) \land ( x_2 \lor y_2 ) = 1 \]
\[\ldots\]
\[( x_6 \equiv y_6 ) \rightarrow ( x_7 \equiv y_7 ) \land ( x_6 \lor y_6 ) = 1 \]

where \(x_1, x_2, \ldots, x_6\) and \(y_1, y_2, \ldots, y_6\) – logical variables.

The response does not need to list all the different sets of variable values for which this equality holds. As a response, specify the number of such sets.
The solution of this task is usually reduced to finding the recurrent dependence of the values of logical variables located in neighboring equations. This method is called the mapping method, which is based on the dynamic programming method. Let’s consider the solution of this system of equations. First of all, you should convert logical expressions to get rid of the implication operation. As a result, we get:

\[
((x_1 \neq y_1) \lor (x_2 \equiv y_2)) \land (x_1 \lor y_1) = 1 \\
((x_2 \neq y_2) \lor (x_3 \equiv y_3)) \land (x_2 \lor y_2) = 1 \\
\ldots \\
((x_6 \neq y_6) \lor (x_7 \equiv y_7)) \land (x_6 \lor y_6) = 1
\]

Let’s make a decision tree for the first equation from the system. Because, in the first equation, there are only 4 variables \((x_1, y_1, x_2, y_2)\), then the number of different sets will be 16. The solution tree of the equation is shown on the left in figure 1. Variables value \(x_1, y_1, x_2, y_2\), satisfying the equations, are marked in black, do not meet white. Figure 1 shows that the first equation becomes true for 10 different sets of variables. It is easy to notice the regularity of the location of variables in neighboring equations. Variables \(x_1\) and \(y_1\) from the first equation correspond to variables \(x_2\) and \(y_2\) from the second equation, \(x_3\) and \(y_3\) from the third equation, and so on.

Using the decision tree, you can get the variable mapping scheme shown on the right in figure 1. This diagram shows how the values of variables \(x_1\) and \(y_1\) displayed in the variable values \(x_2\) and \(y_2\):

\[
01 \Rightarrow 00, 01, 10, 11 \\
10 \Rightarrow 00, 01, 10, 11 \\
11 \Rightarrow 00, 11
\]

Using these patterns, you can get table 1, which shows the number of sets of variables depending on the number of equations in the system.

| x1 y1 | x2 y2 | x3 y3 | x4 y4 | x5 y5 | x6 y6 | x7 y7 |
|-------|-------|-------|-------|-------|-------|-------|
| 00    | 1     | 1+1+1 | 2+2+3 | 4+4+7 | 8+8+15 | 16+16+31 | 32+32+63 |
| 01    | 1     | 1+1   | 2+2   | 4+4   | 8+8   | 16+16   | 32+32   |
| 10    | 1     | 1+1   | 2+2   | 4+4   | 8+8   | 16+16   | 32+32   |
| 11    | 1     | 1+1+1 | 2+2+3 | 4+4+7 | 8+8+15 | 16+16+31 | 32+32+63 |

Table 1 shows that the number of sets for the first equation is 10, for the system from the first and second 22, for the system from the first second and third equation 46, and so on. The number of sets for all six equations is 382, as can be seen in the last column of the table.
This method of solution is quite time-consuming, in addition, when it is used, the probability of an error associated with loss of concentration at some stage of its implementation is quite high. This is why the highest percentage of erroneous decisions was observed in this task from year to year.

2. Description of the electronic resource

To improve the effectiveness of teaching students to solve 23 tasks USE [2], an electronic resource (ER) has been developed that allows students to compare their solution step by step with the solution performed by a computer. Figure 2 shows the interface of an ER implemented on the basis of MS Excel [3] using Visual Basic for Application (VBA) [4]. As you can see from the figure, in column "A" of the spreadsheet, you can enter logical equations (no more than 16), including logical variables (no more than 20) and signs of logical operations. The list of available logical operations is shown in column "C". For reference, the "D" column indicates the priority of each logical operation. In column "B", the function value (0 or 1) is set for each equation).

![Figure 2. ER interface.](image)

The "Autocomplete" button is used to facilitate the process of entering a system of equations. Just type the first equation, then in column "B" mark with zeros or ones the rows where the other equations of the system should be and click the button – the program will automatically generate the remaining equations, taking into account changes in the variable numbers. You can see the appearance of the program before and after clicking the button by comparing figures 2 and 3.

The "START" button starts the program for calculating the system of equations. To do this, the program analyzes equations, selects variables, logical operations, and parentheses in them, and then converts the equation entry to the reverse Polish entry. Representation of equations in reverse Polish (Postfix) notation allows you to calculate the values of these equations depending on all possible sets of variables included in the equations. The program performs a full search of variable values and counts the number of variants in which each equation of the system corresponds to a given value. After that, the result of the program is displayed on the screen. In figure 4 the number of different sets of logical variables is 382.

In itself, getting the result of the task does not have much methodological value in the learning process. But in some cases, this result can serve as a confirmation of the correctness of the answer printed in the USE task book [5]. Unfortunately, today the presence of errors in the educational literature is not uncommon. In addition, this program allows the student to do without a problem book at all,
coming up with their own systems of equations, solve them and compare the answer with the result of the program.

But the main advantage of this electronic resource from the point of view of teaching methods is the ability to demonstrate the solution tree of a given system of equations. Let's consider a situation when a student made a mistake when solving a system of equations at the first stage: he incorrectly built a decision tree. Of course, in this case, his answer will not match the answer in the problem book. In this case, it can set only one equation in the ER and check the number of sets for it. As can be seen from table 1, for one equation, the number of sets of variables must be equal to 10. If the student has built a decision tree that has a result other than 10, the ER allows you to enable the display mode for all decisions. To do this, run the program by first setting the "Show all options" flag. After starting the program, the correct decision tree will be displayed on the screen. It is shown in figure 5.
Figure 5. Solution tree for the first equation from the system.

The decision tree is located in columns "E"-"I" of the Excel table [6, 7, 8]. It is easy to see not only the final result (10 sets), but also how the final result is formed. This decision tree is exactly the same as the tree shown in figure 1.

After making sure that the solution tree for the first equation is correct, the student can check that table 1 is filled in correctly. At the stage of filling out this table, students usually make two types of errors:

- 1 - the next column in the table is filled in incorrectly;
- 2 - arithmetic errors are allowed when adding numbers in a column.

Both of these errors can be tracked by running the program in turn, first for only one equation (the result should be 10), then for the first two equations of the system (result 22), then for the first three equations (result 46), and so on, until the correct final result is obtained.

It is possible to view the complete solution tree for all the equations of the system, but this function is due more to the versatility of the interface than to the need to monitor errors in the student's solution. The fact is that even for a system of six equations (as in our example), the number of logical variables is 14. Therefore, the complete tree for the system will take up 15 columns and 8192 rows. You can only view such a large tree on the monitor screen in scrolling mode. And it is almost impossible to find errors in it. Therefore, the process of detecting errors in the student's solution should be performed step by step, starting with the first equation.
3. Conclusion
Using an electronic resource developed on the basis of the popular MS Excel application [9] in the process of preparing students for USE [10] in computer science will increase the effectiveness of training by visualizing each stage of the solution and forming a clear and consistent picture of the solution for the student.

References
[1] Yakushkin P A and Krylov S S 2011 USE-2012: Informatics (Moscow: Astrel) p 251
[2] Zaslavskaya O Yu and Levchenko I V 2009 Informatics: the whole course: for preparation for USE (Moscow: Eksmo) p 206
[3] Bondarenko S and Bondarenko M 2017 Excel 2003 Popular self-help guide (Moscow, Saint Petersburg: Piter) p 320
[4] Kimmel P T 2005 Excel 2003 and VBA Programmer's guide (Wiley) 1176
[5] Malyasova S V 2018 Informatics and ICT: Manual for preparing for USE (Moscow: Academia) p 637
[6] Garnaev A 2005 Using MS Excel and VBA in Economics and Finance (Moscow: BHV-Petersburg) p 816
[7] Walkenbach J 2005 Excel 2003 Bible (Wiley) p 938
[8] Walkenbach J 2014 Excel 2013 Professional programming in VBA ((Wiley) p 960
[9] Moore J H, Weatherford L R and Weatherford L R 2001 Decision Modeling with Microsoft Excel (Prentice Hall) p 693
[10] Roitberg M A 2017 Informatics and ICT. Preparing for USE in 2017 Diagnostic work (Moscow: MTSNMO) p 176