

Development of a generator of practical tasks in higher mathematics using the Microsoft Office suite and LaTeX digital typesetting system

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Abstract – Successful teaching of mathematics to students is impossible without their independent fulfillment of practical assignments. The preparation of a set of individual assignments in traditional ways requires a large amount of time and effort from the teacher. At the moment, there are various assignment generators, mainly representing ready-made software products. In this article, we propose a different approach, that does not require the teacher to know special programming languages. To create our simple generator of test and practical assignments in mathematics for distance learning systems, such as Moodle, and electronic educational resources, in general, knowledge of the widespread Microsoft Office office suite is enough. It is known, that the preparation of individual sets of assignments (variants of a typical calculation or CGW) in mathematics is associated with the need to set a large number of formulas, which is quite laborious. This problem can be solved by using the TeX (or LaTeX) digital typesetting system, as well as office suite features such as random number generation, branching using the "IF" function of Excel and a tool for a set of output documents (individual calculation options) using the merge tool in Word

Keywords — *independent work, higher education, educational technologies, assignment generator, Moodle, distance education*

I. INTRODUCTION

In modern higher education, a significant amount of hours is devoted to students' independent work, which is understood, first of all, as students' autonomous activity, characterizing their independence and cognitive interest.

Individualization, differentiation and personalization of modern higher education became one of the key paradigms of it. One of the tools, that allow you to use these teaching principles without fundamental changes in the existing education system, in our opinion, could be the use of distance learning systems in the educational process, including with regular full-time learning, according to the Blended Learning concept. E.S. Polat and V. A. Smirnov write, that distance learning systems allow to "organize personality-oriented learning based on a combination of traditional pedagogical

and information technologies, which is associated with the creation of a single interactive educational and information space". [1]

Distance learning is usually understood as a combination of technologies, that ensure the presentation of the studied material by means of information technologies, and that provide interaction in the student-student and student-teacher systems. An obvious feature of the organization of the educational process, using Blended Learning technologies, is the reduction in the teaching load and the replacement of passive listening to lectures by increasing the share of students' independent work.

Today, in educational institutions, distance learning is carried out using various software systems, primarily web-oriented. One of the most effective and widespread in Russia is the LMS Moodle system — a course management system, known as a learning management system or virtual learning environment. It is a web application, that provides the opportunity to create courses for online learning and containing a rich set of tools for organizing educational interaction and monitoring the process of mastering material. When preparing learning courses in mathematics, it is also useful, that LMS Moodle has a built-in TeX marking language support module, which provides rich opportunities for using mathematical formulas in educational materials.

In addition, this system has broad capabilities for organizing students' independent work and monitoring its fulfillment. To do this, it is possible to use its various tools, for example, a tool such as "Assignment" course element, which allows students to receive an assignment, and then, after completing, unload it in the system, for example, in the form of a scan or photos, for verification by the teacher. The assignment involves a creative answer from the student. The student can publish the answer immediately on the site, or upload as a file, or several files. If necessary, the teacher has the opportunity to set some restrictions on the assignments, for

example, by the deadline, by the number of possible retakes, blocking the answer from the expiration of the deadline.

Another opportunity to create a list of individual assignments is to prepare a PDF document and place it with a distance learning system or on a university website.

In any case, for the effective organization of the SIW there is a need for a large and constantly updated database of options of control or calculation-graphic work. Having a regular text editor, for example Microsoft Word, it is possible to create the current version of work. However, when there is a need for change the set of tasks, it will take almost the same time to develop a new version of this work.

Thus, it can be stated, that the development of a large number of assignments in mathematics causes certain difficulties, primarily related to the difficulty of typing formulas in text editors.

II. RESEARCH METHODOLOGY

One of the solutions of this problem is to use the TeX digital typesetting system, developed by the American computer science professor Donald Knuth. TeX is often considered to be the best way to set complex mathematical formulas. In relation to our task, it is essential, that the initial file is a regular ASCII file, containing information about the formatting of the text or the output of images, including mathematical formulas, that are presented in the form of specially designed text.

The problem of generating assignments is regularly raised in pedagogical science [2–5]. In this case, various methods of presenting mathematical assignments are used. The most convenient way to prepare the text of the work and its subsequent presentation using mathematical formulas is to use a TeX or LaTeX digital typesetting system (and the syntax for marking up text and formulas). Various assignment generators are also built on the capabilities of this system. [6–8]. Works of M. Gandur et al. are devoted to the development of various assignment generators for testing systems, which also use TeX syntax for marking formulas, but initially oriented to web technologies, using MoodleTeX in LMS MOODLE or jsmath, mimeTeX in other testing systems. [9–14]

Previously, we designed the assignment generator, using programming systems [15], however, not all mathematics teachers are able to write the required computer program for generating assignments on their own.

In this article, we want to introduce a simpler and more available way to generate assignments for distance learning systems and electronic educational resources.

Our development was based on the possibility of generating random numbers in Excel and, accordingly, choosing a particular mathematical function in LaTeX notation (i.e. as normal text) depending on the value of this random number using the standard "IF" function of Excel. In other words, if the specific value of the number in the cell was 1, then the conditional function 1 was selected in the target cell, with the value 2 - function 2 was selected, etc.

Considering that, for example, when generating assignments with integrals, there is a clear dependence between the functions, that should eventually form an integrand, we built chains of dependent cells with attachments (again implemented using the "IF" function of Excel). For example, to prepare an assignment for a variable replacement method, when the generator selects the sine with the argument $g(x)$ as the initial function, which can also be generated according to certain rules, in order to implement the variable replacement method, this function should be multiplied by the derivative of $g(x)$, i.e. we should get an integrand function of the form: $\sin(g(x))g'(x)$.

As a result, we got cell dependencies, and, in some cases, we tried to hide the explicit form of the derivative function $g(x)$ from the user, using other factors and other methods in it.

We combined the final data from the Excel worksheet with the text of the control work using the document marking syntax and LaTeX mathematical formulas, typed in a Word text editor. To combine, we used the merge method, implemented in the Microsoft Office Suite, and which allows to prepare a set of output documents (individual options of calculations) by combining the main document with a certain database. Usually, this method is used to prepare and print standard letters, that use data from an Excel worksheet, such as a list of names, addresses, phone numbers and personal information of other categories. We used it to combine the main document, containing the basic design of the option of working with the changing data of specific assignments, prepared by us according to special rules in Excel. As a result, instead of letters, we got the opportunity to prepare a large number of control work options.

III. RESULTS

Let give an example of a concrete implementation of the considered above concept.

We used a program for working with TeX format documents (we used the TeXnicCenter editor (<http://www.texniccenter.org/>) as an editor for working with MiKTeX) for work.

For the actual generation of assignments, we suggest using the Microsoft Office suite. Let describe our work on the design of the generator. Let analyze an example of the generation of control work options.

Initially, we prepared one of the control work options in the TeXnicCenter editor. It is worth noting, that, if you started working in the TeX editor recently, and it is difficult for you to type formulas, then there are services on the Internet for typing formulas, using the WYSIWYG principles, for example, Online LaTeX Equation Editor (<http://www.codecogs.com/eqneditor>).

After checking the correctness of the display of the work text and all formulas, the main text (body) of the TeX document was copied into the Word text processor.

In the Excel book, using the CASEBETWEEN function, we generated a set of variables, some values of which were used by us to select functions, and others to determine factors.

Then, on a separate sheet, using the IF function, we made a selection of functions:

```
=IF(Sheet1!A306=1;"sin";IF(Sheet1!A306=2;"cos";IF(Sheet1!A306=3;"e^";IF(Sheet1!A306=4;"5^";IF(Sheet1!A306=5;"3^";IF(Sheet1!A306=6;"2^";IF(Sheet1!A306=7;"sin";IF(Sheet1!A306=8;"arctg"))))))))
```

As can be seen from the above function, here, depending on the value of the cell Sheet1!A306, one or another function is selected, which will then be substituted as an example. Depending on the type of function (the values in the cell Sheet1!A306), the values of dependent cells should obviously be formed. For example, in the case of integration, the numerator must be correctly generated when solving the integral by changing the variable. We also implemented this moment using the IF function.

A few more columns are filled the same way:

```
=IF(Sheet1!J306=1;LINK("\sin^";TEXT(H307;"#");"{";TEXT(R307;"#");"x}\cdot");IF(Sheet1!J306=2;LINK("\frac{\tg^";TEXT(E307;"#");"{";TEXT(R307;"#");"x}"}");IF(Sheet1!J306=3;LINK("\frac{\arctg^";TEXT(F307;"#");"{";TEXT(R307;"#");"x}"}");IF(Sheet1!J306=4;LINK("\frac{\arcsin^";TEXT(J307;"#");"{";TEXT(R307;"#");"x}"}"))
```

As it can be seen from the last function, tags for formatting formulas in TeX format are already used here.

After preparing the source data, we distributed the formulas to obtain the required number of assignments, and then we used the "Merge" tool to generate text files.

This tool is used when there is a need to create a set of documents, for example, stickers with addresses or letters on forms, that are sent to a large number of customers. At the same time, each letter contains both general, unchanging information, and individual, such as, for example, address or surname. Individual information for each letter is taken from a data source, which can be databases, electronic table sheets, or tables in text documents. In our case, these are separate control work options, or rather, individual elements of specific assignments: factors, functions, mathematical expressions. In these documents, the part of the text is the same - the title, the wordings of the assignments, and only certain sections of each document are differentiated and individually configured - the formulas in the assignments, generated in Excel.

The merge process consists of several general steps:

1. Initially, the main document, containing the necessary design, graphics, text, which will be permanent for all documents, is created. In our case, the heading, text wordings of assignments, signatures were such a text.
2. In the second step, you must connect the document to the data source. The data source in our case was a file, containing factor values, functions, written using the TeX syntax.
3. In the next step, the so-called text placeholders (merge fields) must be inserted into specific places in the text

document. When merging, merge fields are filled with data from the data file.

4. In the next step, which is called a preview, you can see the specific result of the merger. At this step, specific values are substituted instead of field names from the data source.
5. At the last stage, there is, in fact, the formation of a large list of letters (control work options).

After inserting the appropriate merge fields, we got the following letter in Word (the names of the column headers from Excel are in quotation marks):

```
\begin{center}
The Moscow Polytechnic University
Discipline: "higher mathematics"
Control work 4
Option 1
\end{center}
Find integrals
1. $ \int \left( \langle c1 \rangle \langle f1 \rangle \langle c2 \rangle x + \langle k4kv \rangle \langle f2 \rangle \langle k1 \rangle x - \langle k7 \rangle x^{\langle k5 \rangle} + \frac{\langle k8 \rangle}{x} - \frac{\langle c2 \rangle}{\{x^2 + \langle k4kv \rangle\}} \right) dx $
```

2. $\int \langle fp1 \rangle \langle pfp1 \rangle dx$ \$
3. $\int \sin^{\langle c1 \rangle} \langle k6 \rangle x \cdot \cos^{\langle c2 \rangle} \langle k6 \rangle x dx$ \$

After switching to the letter view mode, specific data was substituted instead of the column headers' names.

```
Here is a fragment of what we got:
\begin{center}
The Moscow Polytechnic University
Discipline: "higher mathematics"
Control work 4
Option 1
\end{center}
Find integrals
1. $ \int \left( 4 \sin \{4x\} + 49 \arctg \{4x\} - 8x^{\{3\}} + \frac{7}{x} - \frac{4}{\{x^2 + 49\}} \right) dx $
2. $ \int \frac{\arctg^4 \{5x\}}{\{1 + 25x^2\}} dx $
3. $ \int \sin^4 3x \cdot \cos^6 3x dx $
```

The letters, generated this way, were copied by us into TeXnicCenter and, after converting the TeX-document to PDF, we received a control work:

Контрольная работа 4
Вариант 1

1. $\int \left(4^{6x} + 16 \cos 4x - 8x^4 + \frac{4}{x} - \frac{6}{x^2 + 16} \right) dx$
2. $\int \sin^7 3x \cdot \cos 3x dx$
3. $\int \sin^4 3x \cdot \cos^6 3x dx.$
4. $\int \frac{xdx}{\sqrt{16 - x^2}}$

Fig. 1. Control work option

As a result, we were able to easily generate more than 100 individual control work options.

IV. DISCUSSION

Our proposed method has flexible options for the individual configuration of the assignment generator. In our example, we considered the most difficult case of generation - the preparation of assignments in integral calculus. Meanwhile, in many other areas of mathematics, for example, such as matrices, systems of linear equations, and many others, it was enough for us to simply generate arrays of numbers and substitute them as elements or factors to generate assignments.

We used this technology to create PDF documents. However, this technology can be used not only for preparing files of this format or for printing collections of control works. Modern distance learning systems, such as Moodle, have built-in support of the TeX language (when activated by the system administrator). Thus, there is no need even to use TeX editors (such as TeXnicCenter), because using the MathJax library gives a visual presentation of formulas when inserting them in TeX (LaTeX) language in the page text.

When creating electronic educational resources, the presentation of material in HTML format is often used. At the same time, it is possible to connect the same MathJax library for visualizing mathematical formulas and not requiring connection to outside servers.

V. CONCLUSIONS

The article proposes a method for preparing individual options of control and practical works in mathematics, that does not require programming skills from the teacher. This method is based on the capabilities of the Microsoft Office

office suite for document merging and on the capabilities of the TeX marking language for presenting mathematical formulas.

The proposed method for generating a large number of individual assignments in mathematics can be used in the design of courses in distance learning systems, local electronic educational resources (with the MathJax library turned on or others capable of working with MathML), as well as when using TeX editors to prepare assignments in PDF files.

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