Matrix Thinking in the Fractal Digitalization of Education

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Abstract This article is devoted to improving the motivation of students to study and, in general, the quality of education in the context of global digitalization. Along with numerous existing methods, the internal component of thinking and perception as an integral part of it plays a significant role. Research has shown that the mathematical logic used in the creation of most algorithms is not identical to the logic of thinking. The combined fuzzy and genetic logic that guides the student only partially includes clear logical structures. Moreover, this inclusion is manifested in different students with different degrees of belonging. If the teacher understands and uses the degree of such inclusion, then students will be able to show results of education that seem to exceed their own capabilities. Examples of the implementation of matrix thinking with students of military accounting, technical and creative specialties, as one of the ways to digitalize knowledge, are given. An example of the implementation of digitalization of training with students of applied programmers is considered on the example of creating software based on the material passed in a related IT discipline.

Keywords Digitalization · Data processing · Matrixes · Data fields · Training · Quality of education · Teaching methods · Innovative approaches · Non-standard pedagogy · Increasing student interest · Learning theory · Innovative pedagogy · Interest in knowledge · Matrix thinking

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A. Beskopylny and M. Shamtsyan (eds.), *XIV International Scientific Conference “INTERAGROMASH 2021”*, Lecture Notes in Networks and Systems 247,
https://doi.org/10.1007/978-3-030-80946-1_49

1 Introduction

Information consists of various classes of nondeterministic sources. Therefore, the nondeterministic logic that a person uses when making decisions and obtaining information often contradicts the mathematical logic of numbers, formulas and schemes. A person needs a digit with an image, and objects need a digital prototype. Mechanical and electronic devices are controlled by algorithms of clear mathematical logic. And the human brain controls actions, guided by a combination of fuzzy and genetic logic. As a result, a multi-component field of knowledge, thoughts and opportunities (including learning) is formed. Such fields have only some properties of mathematical fields, namely commutativity and multiplicativity. The results of the activity of aggregate logic can be written in matrices, over which addition and multiplication operations can be performed, but not multiplication by a number. Various matrix multiplications: maximin, minimax, maximultiplicate, minimultiplicate, midimultiplicate, as well as products with block and variable multiplicativity are processed by the human brain [1–4].

This is probably why the topic of "Matrices and actions on them" so often evokes positive emotions during training. Arrays of data written on the board in the form of matrices are primitive analogues of the aggregate fields of information in the head. How can you not get lost in the numbers while learning? How do I keep my interest in abstract digital prototypes alive?

2 Materials and Methods

This article presents the results of an analytical study of the possibility of using system-based educational blocks in the technology of teaching in higher education. The essence of the method is to conduct disciplines at the intersection of numbers and creativity, numbers and the history of the Fatherland, numbers and physical culture, numbers and patriotic education of a citizen of society, numbers and narrow-profile technical specialization, and so on. The quintessence of such a conglomeration should be a digit with a software implementation [5–9].

3 Main Part

Matrix thinking can be implemented in different ways in different groups of students.

1. Military accounting specialties

With students studying in military accounting specialties, in the field of matrices, you can study material with a military-historical and patriotic orientation.

Let's consider an example of studying military-historical dates in the process of studying matrices:

$$\begin{pmatrix} 1\,2\,4\,0 \\ 1\,2\,4\,2 \\ 1\,7\,7\,0 \\ 1\,8\,1\,2 \end{pmatrix}.$$

The first line of this matrix contains the year of the Battle of the Neva, the second line-the year of the Ice Battle, the third line—the Battle of Chesma, and the fourth line-the Battle of Borodino.

Thus, it is possible to create a system-educational block of historical-military-mathematical orientation. This type of training is aimed at increasing the level of attention, efficiency and evokes positive emotions in students.

2. Technical specialties

Let's consider a system-educational block that implements and consolidates knowledge in the aggregate in the disciplines "Algebra", "History of the Fatherland", "Organization of operation of means of mechanization and automation of lifting and transport, construction and road works".

Example 1 Buses PAZ 320435-04 Vector NEXT are delivered in RTC 1, RTC 2, RTC 3, RTC 4 in the amount of 21, 09, 13, 80 units, respectively, where the numbers written in this sequence are the date of victory in the Battle of Kulikovo of the Russian troops under the command of Prince D. Donskoy over the Mongol-Tatar regiments.

LiAZ 529265 buses are delivered to RTC 1-4 in the amount of 24, 12, 17, 90 units, respectively, where the numbers written in this sequence are the date of the capture of the Turkish fortress of Izmail by the Russian troops under the command of A. V. Suvorov.

NEFAZ 5299-30-52 buses are delivered to RTC 1-4 in the amount of 02, 02, 19, 43 units, respectively, where the numbers written in this sequence are the date of the victory of the Soviet troops in the Battle of Stalingrad.

If we remove the names of the rows and columns from the table, and enclose the numeric values in round or square brackets, we get an example of what is called a matrix in mathematics:

$$\mathrm{A} = \begin{pmatrix} 21 & 09 & 13 & 80 \\ 24 & 12 & 17 & 90 \\ 02 & 02 & 19 & 43 \end{pmatrix}.$$

For example, as a result of insufficient funding, the equipment of the new equipment of RTC 1 and RTC 2 is postponed to the next year, and the provision of ground vehicles for RTC 3 and RTC 4 remains unchanged.

This will cause the first and second columns to disappear. We will get another example of the matrix, where the above days of military glory will be associated with the years of these events:

Table 1 Control of the distribution of vehicle supplies

Name of the vehicle	Distribution by road transport companies (units)			
	RTC 1	RTC 2	RTC 3	RTC 4
PAZ 320435-04 Vector NEXT	21	09	13	80
LiAZ 529265	24	12	17	90
NEFAZ 5299-30-52	02	02	19	43

$$B = \begin{pmatrix} 13\ 80 \\ 17\ 90 \\ 19\ 43 \end{pmatrix}.$$

Example 2 Let Table 1 reflect the distribution of new special equipment at municipal enterprises this year:

$$\mathrm{A} = \begin{pmatrix} 21 & 09 & 13 & 80 \\ 24 & 12 & 17 & 90 \\ 02 & 02 & 19 & 43 \end{pmatrix}.$$

The rows of this matrix also display the days of military glory of Russia.

Let the distribution of the same types of new vehicles for the same utilities in accordance with the plan, next year is given by the matrix:

$$\mathrm{B} = \begin{pmatrix} 21 & 09 & 13 & 80 \\ 09 & 05 & 19 & 45 \\ 07 & 07 & 17 & 70 \end{pmatrix}.$$

In order to prepare documents for the purchase of new vehicles, it is necessary to determine the total number of new equipment by position, in this and next years:

$$\mathrm{A} + B = \begin{pmatrix} 21 & 09 & 13 & 80 \\ 24 & 12 & 17 & 90 \\ 02 & 02 & 19 & 43 \end{pmatrix} + \begin{pmatrix} 21 & 09 & 13 & 80 \\ 09 & 05 & 19 & 45 \\ 07 & 07 & 17 & 70 \end{pmatrix} = \begin{pmatrix} 30\ 17\ 30\ 94 \\ 11\ 07\ 38\ 88 \\ 08\ 19\ 35\ 123 \end{pmatrix}.$$

Example 3 Let $A = \begin{pmatrix} 05 & 12 & 19\ 41 \end{pmatrix}$-vector—a string that defines the number of FD 18 forklifts purchased at four wholesale-retail bases. The elements of the matrix-row display the day of the beginning of the Soviet counteroffensive in the battle of Moscow.

Let $B = \begin{pmatrix} 0.3 \\ 1 \\ 1.5 \\ 3 \end{pmatrix}$-vector—a column that determines the cost of special equipment, million rubles. It is required to determine the total cost of special equipment.

Solution

$$A \cdot B = \begin{pmatrix} 5 & 12 & 19 & 41 \end{pmatrix} \cdot \begin{pmatrix} 0.3 \\ 1 \\ 1.5 \\ 3 \end{pmatrix} = (5 \cdot 0.3 + 12 \cdot 1 + 19 \cdot 1.5 + 41 \cdot 3) = (165).$$

4 Research Results

The results of the implementation of this method are given on the examples of specialties of creative orientation and software-applied orientation.

1. Creative specialties

With students who have a creative orientation, you can use matrices to study the dates of the lives of great people of art, consider various statistics on the life of interesting people, and study the main milestones and results of their work.

During the implementation of project activities at the Don State Technical University, the following results were obtained. The works of the poets of the Silver Age were taken for consideration and their work on rhyming and theme was analyzed. The works of young writers of the twenty-first century were also considered.

The results of the analysis of works of poets of different time periods are presented according to the creativity of each in the form of diagrams and then in the aggregate in the form of a matrix.

For the study, 50 poems of the authoritative literary figure of the first third of the nineteenth century, A. S. Pushkin, whose genius has not yet been surpassed, were taken. As a result, it was concluded that A. S. Pushkin used a cross rhyme in 56% of cases, a ring rhyme in 24% of cases, and a pair rhyme in 20% of cases.

The results of the analysis of 50 poetic works by A. S. Pushkin are presented in Fig. 1.

Next, 35 works of the authoritative poet and playwright of the Silver Age, Yu. M. Lermontov, were taken for consideration. As a result, it was found that M. Yu. Lermontov mainly used a cross rhyme—60%, a pair rhyme—34%, a ring rhyme—6%.

The results are shown in the diagram (see Fig. 2):

Further, 31 works of the young Russian poet of the early twenty-first century, D. V. Impersky, were considered, as a result it was found that the poet places the greatest emphasis on cross-rhyme—90%. He uses the ring rhyme in 7% of cases, the pair rhyme—3%. The results of the research are shown in the diagram (see Fig. 3).

40 works of the young Russian poet of the beginning of the twenty-first century O. I. Boronenko were also considered. As a result, the following conclusions were obtained: cross-rhyme is involved in 75% of cases, pair-in 15%, ring-in 10%. The results of the research shown in the diagram (see Fig. 4).

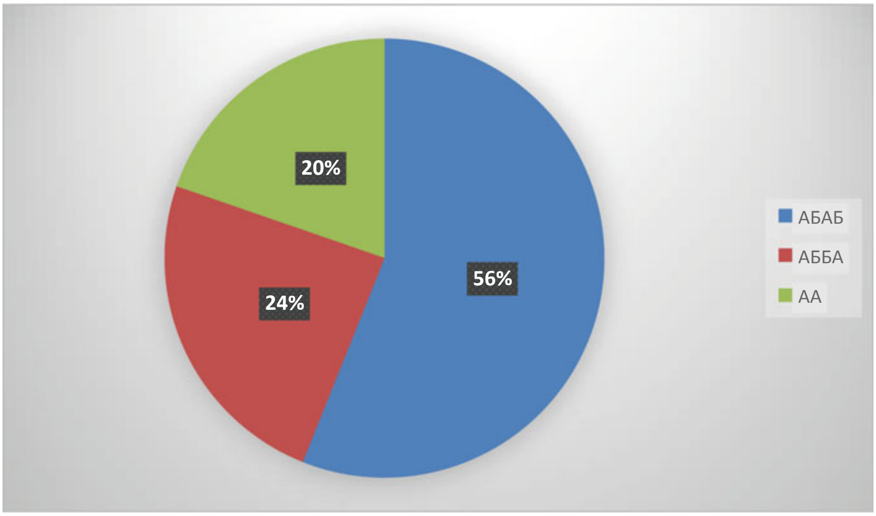


Fig. 1 Percent ratio of rhyming types in A. S. Pushkin's poems

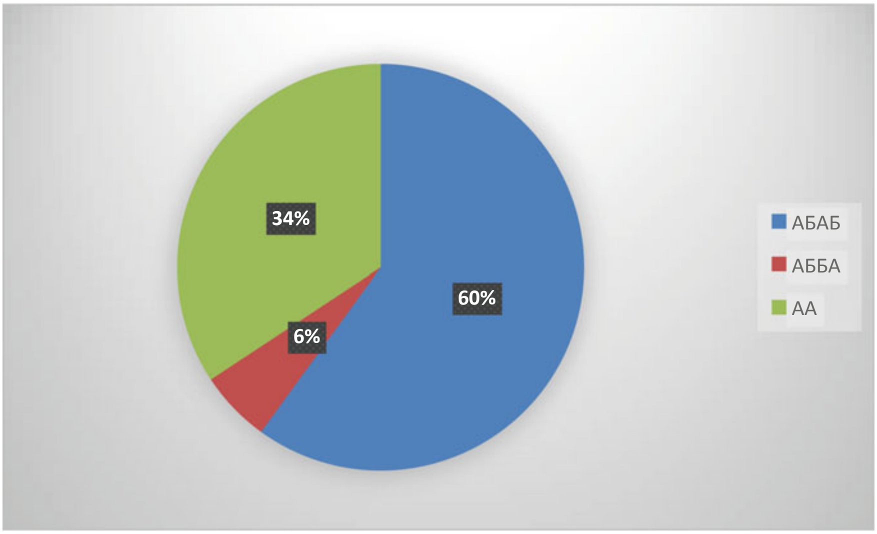


Fig. 2 Percentage ratio of rhyming types in the poems of Yu. M. Lermontov

It is convenient to write all the conclusions for further analysis in the form of a matrix:

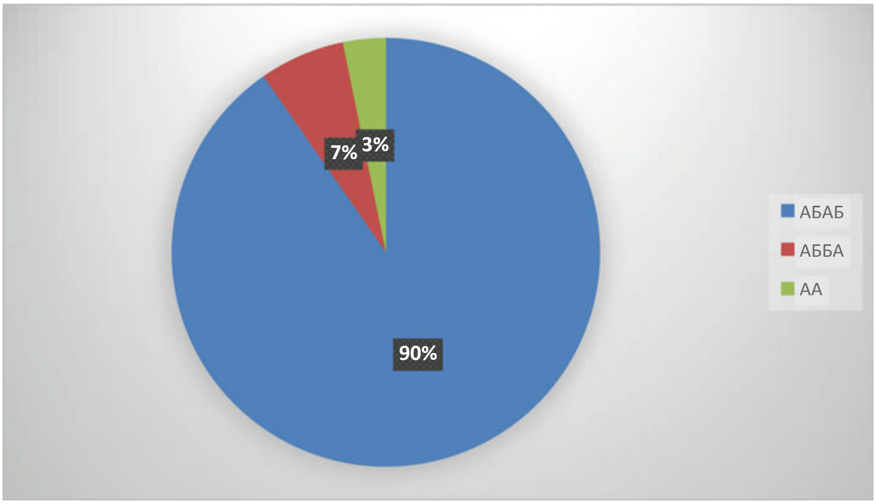


Fig. 3 Percentage ratio of rhyming types in D. V. Impersky's poems

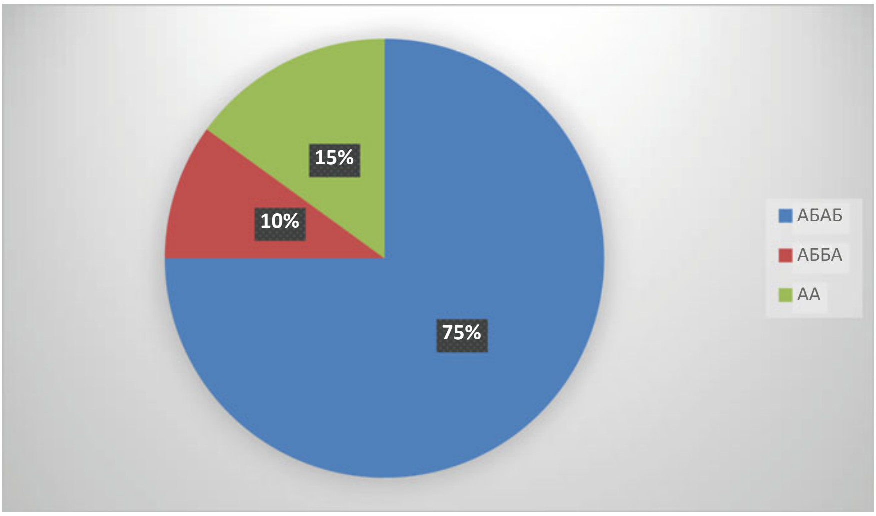


Fig. 4 Percentage ratio of rhyming types in O. I. Boronenko's poems

$$A = \begin{pmatrix} 56 & 60 & 90 & 75 \\ 20 & 34 & 3 & 15 \\ 24 & 6 & 7 & 10 \end{pmatrix},$$

where the rows display the types of rhyming: cross, pair, ring, respectively; the columns correspond to the names of great poets: A. S. Pushkin, Yu. M. Lermontov, D. V. Impersky, O. I. Boronenko.

2. Domain-specific programming

You can directly digitize knowledge matrices and capabilities with students of applied programmers. The set-theoretic operations studied in the course of the course can be visualized, gamified, giving the study of the topic a certain intrigue and understatement, and then provide an opportunity to encode the studied algorithms. Students of applied programming were asked to come up with various tasks for the geometric representation of sets. As a result, the students developed a training manual on set-theoretic operations. Here are some examples from this collection.

Example 1 A puzzle problem. After performing operations on sets, you need to answer the question: "Where does our programmer live?"

$$
\begin{aligned}
A &= \{(x, y)| -8 \le x \le 8, \quad 0 \le y \le 8\}, \\
B &= \{(x, y)|y \ge 8\}, \\
C &= \{(x, y)|y \le -|0.8 * x| + 16\}, \\
D &= \left\{(x, y)|x^2 + (y - 12)^2 \le 3\right\}, \\
E &= \{(x, y)| -2 \le x \le 2, \quad 3 \le y \le 7\}, \\
F &= \{(x, y)| -6 \le x \le -4, \quad 8 \le y \le 14\}, \\
G &= \{(x, y)|4 \le x \le 7, \quad 0 \le y \le 5\}, \\
H &= \{(x, y)|0 \le y \le 14, \quad -0.3 \le x \le 0.3\}, \\
I &= \{(x, y)| -2 \le x \le 2, \quad 4.7 \le y \le 5.3\}, \\
J &= \{(x, y)| -2 \le x \le 2, \quad 11.7 \le y \le 12.3\}, \\
K &= \{(x, y)|4.1 \le x \le 6.9, \quad 0 \le y \le 4.9\}, \\
Q &= (A \backslash E)\mathrm{G} \cup B \cup C \backslash D \cup F \cup H \cup I \cup J \cup K.
\end{aligned}
$$

Example 2 The task—a joke.

After performing operations on the sets, you need to finish the phrase: "Nothing so invigorates a cybersecurity specialist in the morning as…"

$$
\begin{aligned}
&\mathrm{A} = \left\{(x, y, z)|\frac{x^2}{4} + \frac{y^2}{4} = 2z\right\}, \\
&B = \{(x, y, z)|0.5 \le z \le 3\}, \\
&C = \left\{(x, y, z)|x^2 + (y - 3)^2 + (z - 1.25)^2 + 1 - 0.75^2 - 4\left(z^2 + (y - 3)^2\right) = 0\right\}, \\
&Q = (A \cap B) \cup (C \backslash A).
\end{aligned}
$$

When students created methodological guidelines on set theory, difficulties arose in displaying the drawings given by the formulas of analytical geometry. As a result, a software tool was developed that displays the shaded areas as a set of mappings of various inequalities of analytical geometry by applying Boolean operations on logical expressions to them.

The main application window is divided into two zones, in the first one the user can enter analytical inequalities describing the areas bounded by second-order curves. The program displays sets defined by inequalities. Inequalities can be displayed as a list and then the intersection, union, and difference operations can be applied to them. Since each operation on sets corresponds to a certain logical connection, then applying Boolean algebra, we get the corresponding mapping. By combining different functions, you can create absolutely any drawing (see Fig. 5).

The data processing system allows you to define display zones. The algorithm remembers the inequalities and creates a separate set in memory for further combinations (see Fig. 6).

The function outputs an array of points on the plane. The created algorithm finds points that are repeated in several objects and, depending on the specified logical operations, performs actions on these formulas (see Fig. 7).

The program is designed in such a way that the user has the opportunity to save the lists of functions entered by him with the possibility of further copying and editing them. In the input field, you can adjust the size of the drawing. The image display field contains a grid with a Cartesian coordinate system, the OX and OY axes which

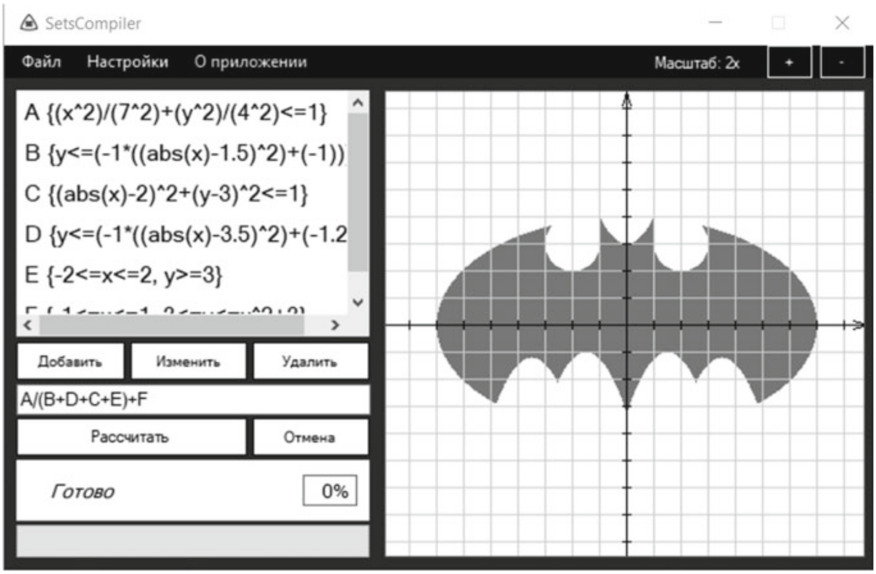


Fig. 5 Input and output windows

Fig. 6 Buffer of sets

A {-4<=x<=4, -4<=y}

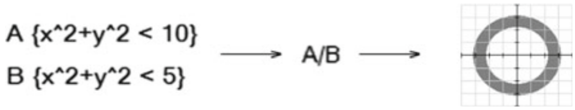


Fig. 7 Visualization of actions on formulas

is convenient for determining the coordinates of points and selecting the coefficients of inequalities. This system allows you to program drawings in any operating system. In the settings, there is a function for controlling the image quality of the drawing, which allows you to study the result in detail for the changes of interest (see Fig. 8).

The program allows you to save the drawing in various modes. The user can control the display of the axes and the grid (Fig. 9). The image can be saved in jpg format with further translation to other formats (see Fig. 9).

Computational operations are performed asynchronously with the main program, which allows the user to collapse the application or see the calculation process with a significant number of operations on sets (see Fig. 10).

The program developed by students to teach other students is universal, practical and visual. This software application can be used in the course of training in the course of set theory, as well as used in solving various problems of visualization of operations on sets.

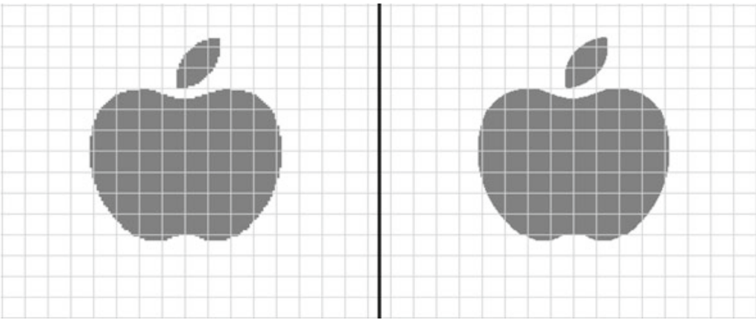


Fig. 8 Setting the image quality

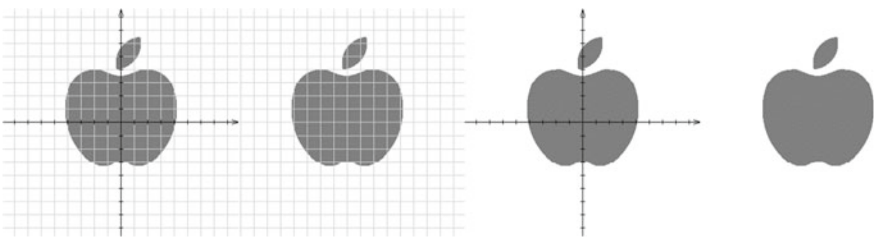
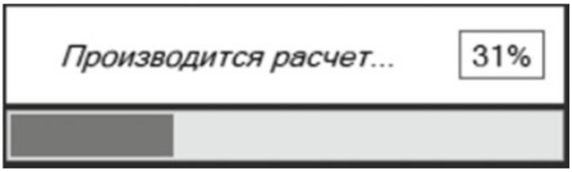


Fig. 9 Image modes

Fig. 10 Calculation field



5 Conclusions

Education in the era of digitalization should be of a multi-component research nature, integrating several disciplines at the same time. A versatile approach to the study of matrix algebra makes it possible for students to understand that matrices are used not only in the development and use of databases, but also are an integral part of the perception of data, as well as software. Almost all information in the computer is processed and stored in matrix form. Human thinking also uses matrix algebra as an element of aggregate logic [10]. The block-based nature of learning, combined with matrix thinking and an analytical approach, provides the basis for building mathematical models and writing program codes. And clear logical schemes, intertwined with the soul and creativity, with an interest in the specialty, can increase the effectiveness of training and digital literacy, as its integral fractal component.

6 Discussion

The matrix as an object of data visualization makes it possible not only to briefly and uniformly present them, but also, having a well-developed theory, allows you to work with large amounts of information rolled up in it. It implements the basic principles of visualization as a quality tool—clarity of data, reduction of visual noise, the use of different sign systems, the possibility of instant pre-reading. This is how it is possible to ensure the fulfillment of the key requirement of modern students to the educational process—reducing the time of perception and working with new data in disciplines representing different areas of knowledge. The quality of modern education is reflected in two aspects—as a process and as a result. The use of the matrix as an abstract visualization tool in the educational process will provide both an increase in its quality in the perception of new information, and an increase in the quality of the result—the acquisition of competencies in the three levels of "know-know-own" [11–16].

The matrix as an object that visualizes structured information on several objects at once at a minimum of space and has the ability to perform operations with it and the like, is one of the preferred forms of knowledge transfer in the educational process, providing an increase in the quality of education as a whole.

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