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## OVERVIEW OF SOFTWARE FOR SOLVING OPTIMIZATION PROBLEMS

*A review of software products for solving optimization problems, an analysis of the capabilities of computer mathematics systems and spreadsheets has been carried out, a list of classes of optimization problems and optimization methods for their implementation has been indicated, the expediency of using computer mathematics systems in the educational process of the university has been investigated.*

***The purpose of the work** is to review the existing modern software systems working with optimization problems, to specify the classes of problems and the optimization methods that are implemented.*

***Methodology.** To obtain the results presented in the article, an analysis of modern software that implements optimization methods has been made.*

***Scientific novelty.** The paper reviews the software that implements optimization methods, in particular, computer mathematics systems, which allow us to talk about its application for solving optimization problems of different classes and the feasibility of using it in the educational process.*

***Conclusions.** Thanks to the review, the types of optimization problems have been identified, for the solution of which it is advisable to use existing software products, namely computer mathematics systems, for everyone interested in this topic.*

***Key words:** optimization problems, computer mathematics systems, optimization methods.*

## ОГЛЯД ПРОГРАМНОГО ЗАБЕЗПЕЧЕННЯ ДЛЯ РОЗВ'ЯЗАННЯ ЗАДАЧ ОПТИМІЗАЦІЇ

*Проведено огляд програмних продуктів для розв'язання задач оптимізації, здійснено аналіз можливостей систем комп'ютерної математики та електронних таблиць, зазначено перелік класів оптимізаційних задач та оптимізаційних методів, які їх реалізують, досліджено доцільність використання систем комп'ютерної математики в навчальному процесу ВНЗ.*

***Мета роботи** – провести огляд існуючих сучасних програмних систем, які працюють з оптимізаційними задачам, зазначити класи задач та оптимізаційні методи, які реалізуються.*

***Методологія.** Для отримання результатів наведених у статті було зроблено аналіз сучасного програмного забезпечення, яке реалізує методи оптимізації.*

***Наукова новизна**. У роботі проведено огляд програмного забезпечення, яке реалізує методи оптимізації, зокрема, систем комп'ютерної математики, що дозволяє вести мову про його застосування для розв'язання оптимізаційних задач різних класів та доцільність використання в навчальному процесі.*

***Висновки.** Завдяки проведеному огляду визначені типи задач оптимізації, для розв'язування яких доцільно використовувати існуючі програмні продукти, а саме, систем комп'ютерної математики, для всіх зацікавлених цією тематикою*

***Ключові слова:** задачі оптимізації, системи комп'ютерної математики, оптимізаційні методи.*

**Statement of the problem in general terms and its connection with important scientific or practical problems.** The search for software tools for solving optimization problems has always been one of the main stages of the modeling process, while the latter has been and remains dynamic.

New realities provide the emergence of new problems that require the involvement of the modeling process to solve. This leads to the development of the mathematical apparatus, in particular, the emergence of new classes of mathematical models and requires the expansion of software tools for their implementation. Creating your own software for each new problem, or at least writing a software implementation of the algorithm that implements it, is a rather voluminous and difficult process for specialists, so it is more expedient to consider using existing software products.

Most of them make it possible to successfully complete the modeling process by obtaining solutions, but they must meet certain criteria and adequately characterize the process or phenomenon under study in the form of obtained solutions. It is important to review the existing software for solving optimization problems, and determine the feasibility of its use in the educational process of the university.

**Analysis of recent research and publications.** The modern process of mathematical modeling is difficult to imagine and implement without computers. The rapid development of the IT sphere has created excellent conditions for the development of software of this level, available for use not only by experienced professionals, but also by the average user.

A large number of publications devoted to the use of existing software products, in particular, computer mathematics packages, for solving various problems that arise in various areas of application packages [2, 4-6, 24-25]

The widespread use of optimization models indicates the need to develop appropriate software and analyze the capabilities of existing software packages that implement known methods for solving optimization problems [1, 3, 9-10, 14, 15, 18-22, 28].

**Setting objectives.** Make an overview of modern software systems working on optimization problems, in particular, computer mathematics systems and data processing systems, analyze their capabilities for solving such problems.

**Presentation of the main research material.** In the modern world, all spheres of human activity, in one way or another, are associated with modeling processes, among which optimization models occupy a special place. As you know, modeling is the most effective way to study complex systems for various purposes – technical, economic, environmental, social, informational – both at the stage of their design and during operation, the latest methods and technologies for modeling are constantly emerging. Creating a model is a long, multi-stage and creative process that requires the researcher not only to have deep theoretical knowledge of various mathematical and technical disciplines, but also a creative approach to solving problems, the ability to generate certain heuristics that correspond to the deep essence of the object under study. Working not with the object itself (phenomenon, process), but with its model makes it possible to relatively quickly and painlessly investigate its basic properties and behavior in various possible situations. At the same time, computational (computer, simulation, simulation) experiments with object models make it possible to carefully and deeply study an object, which is not available in purely theoretical studies.

Consider the features of optimization modeling as one of the areas of applied mathematics, the subject of which is the problem of finding the extremum of a certain function under certain given conditions. A typical problem statement is as follows: a certain process can develop according to different options, each of which has

its own advantages and disadvantages, and, as a rule, there can be many such options. It is necessary to choose the best one from all possible options (directions)" [1, p. 11-13].

"In general terms, the problem of optimization modeling is formulated as follows: to find such values of variables at which the objective function acquires an extreme optimal value, i.e., the structure of the model must contain an optimized objective function and a set of constraints that determine the behavior of the process or the phenomenon being modeled. In the process of applying optimization modeling in economics, a clear statement of the problem and its formalization is the most difficult stage of the research, which requires thorough knowledge, first of all, of the essence of the phenomena or processes being modeled, and a successfully created optimization model can be further used to solve other unrelated problems to the initially simulated situation, for example, as in [30]. At the moment, a certain set of classical problem statements has been formed in optimization modeling, in particular, economic and mathematical models of which are widely used in practical studies of various problems [24, pp. 4-22].

After completing the modeling process, there is a search for methods and means of solving the use of modern information technologies. When a completely new problem is being investigated, for which the corresponding problem-oriented software has not yet been created, the traditional technology of solving practical problems using a computer is justified, for example, as in [16]. To solve more typical problems, it is more expedient to consider the use of existing software products, including computer mathematics packages [17, pp. 7-8].

Given the basic general requirements for software products that work with complex mathematical projects, it is necessary to take into account the features of solving optimization problems, taking into account the possibility of their application in the educational process of the university. Among these requirements, the following can be distinguished: the functionality of the software product (a list of classes of models of optimization problems that can be worked out); clear and accessible development interface, providing the ability to be applied by users with different levels of training; realizable diverse set of standard and special mathematical operations and functions; ensuring the adequacy of the solutions obtained (the ability to set the accuracy of calculations, the number of iterations, the possibility of deriving a step-by-step solution); the presence of powerful graphic tools; the ability to integrate into other environments; the ability to create reports in a convenient form); affordable cost or generally free application and so on.

Among the software tools that can be used to solve fairly wide classes of optimization problems, and which are the most accessible, the following can be distinguished: specialized optimization packages; computer mathematics systems; and spreadsheet editors. The first ones were developed by research institutes, and the created complexes and software systems worked with a very wide range of optimization problems.

In recent years, the use of computer equipment and information technologies for solving optimization problems has intensified due to the appearance of modern mathematical packages such as Marle, Matlab, Mathematika, Mathcad, etc. These systems meet the requirements listed above, while each of them has its own specific features.

Mathematical systems allow the user to work with a wide range of tasks, namely: conducting mathematical research that requires analytical transformations and numerical calculations; analysis and processing of experimental data; mathematical modeling and computer experiment; development of algorithms that implement numerous methods for solving problems, their analysis and use; visualization of research results, scientific and engineering graphics, creation of graphic and numerical reporting materials, etc.

Developers of mathematical packages in recent years have paid great attention to their integration and sharing. This significantly expands the class of problems that can be solved using each of the systems and allows you to choose the best and most adequate tools. Solving complex mathematical problems with the help of several software products significantly increases the likelihood of obtaining correct results, especially when the initial problem is incorrectly formulated [6].

Let us consider in more detail the capabilities of each of the modern mathematical software packages that have found their use from the average user, university students, in particular, to well-known research laboratories and institutes.

The most accessible to use is the Excel spreadsheet, which has a powerful "Search for Solutions" add-on, the ability to solve various linear programming problems using the simplex method with full output of simplex tables, as well as non-linear smooth programming problems using the generalized gradient method, and non-smooth programming problems using the evolutionary method. In addition, it is possible to set the accuracy of the obtained solutions, the number of iterations, the output of the results at each iteration. Each of these methods has its own specific settings, using which the user gets the optimal solution, taking into account the specifics of the real problem (solid solutions, error, etc.). In addition, for each obtained result, it is possible to create a report in three modes, as well as to save the scenario of the process of finding a solution.

The next powerful system is the Matlab package, one of the most popular mathematical packages, which has 50 sets of tools for numerical calculations, modeling and data analysis. Versions of the Matlab system (the last one was released in 2022) can function under most modern operating systems including Windows, Linux, UNIX, MacOS. A rich library of functions, divided into sections, each of which has a name that reflects its purpose. The Matlab system contains a significant set of extension packages (Toolbox) that enhance the mathematical capabilities of the system, increase the speed, efficiency and accuracy of calculations. Optimization Toolbox is an interesting optimization package – a library of functions that expand the capabilities of the Matlab system for numerical calculations and is intended for solving optimization problems and systems of nonlinear equations. It supports basic methods of optimization of functions of a number of variables: unconditional optimization of nonlinear functions; method of least squares; solution of nonlinear equations; linear programming; quadratic programming; conditional minimization of nonlinear functions; minimax methods; multicriteria optimization, in addition, Matlab also has powerful graphical capabilities for visualizing results and the ability to import and export data in ASCII, Binary, Lotus 1-2-3, Excel, Word, PowerPoint and built-in programming languages.

Mathematical package Maple is a representative of a new generation of software tools and is designed for engineering and mathematical calculations. The Maple package from the Canadian University of Waterloo is a computer mathematics system designed for the serious user. The system is able to perform quickly and efficiently not only symbolic, but also numerous calculations, and combining this with excellent means of graphic visualization and preparation of electronic documents, it has a powerful set of tools for solving optimization problems: the Simplex extension package for solving linear programming problems by the Simplex method and the Optimization package, which allows solving not only problems of linear, but also quadratic and nonlinear programming with an increased degree of visualization and preparation of electronic documents.

The MathCAD package is a mathematical editor that allows you to perform various scientific and engineering calculations, starting from elementary arithmetic and ending with complex implementations of numerical methods, performing symbolic calculations, and also has an excellent apparatus for calculating results, graphics of various types, powerful tools for preparing printed documents and Web – pages, the user interface being intuitive and similar to other Windows applications. This is the only system of computer mathematics in which the description of the algorithm for solving problems is carried out in a language similar to the usual mathematical language for describing mathematical problems, it is enough to simply enter mathematical expressions using the built-in formula editor, and immediately get the results. Basic user skills are enough to work effectively with the MathCAD editor. On the other hand, professional programmers can get much more out of MathCAD by creating their own software solutions, significantly expanded capabilities directly embedded in the system.

The MathCAD package has in its arsenal powerful tools for solving problems of linear and nonlinear optimization. The advantage is that the same functions Minimize, Maximize are used to solve different types of optimization problems, and the condition of the extremal problem is written in a form similar to the conventional notation in mathematics, while the user is given the opportunity to use both the keyboard and toolbars.

The Mathematica system. The new version of the system (2022) can run a wide range of operating systems. Among the wide range of possibilities of using the Mathmetica system is the solution of conditional and unconditional optimization problems (in particular linear discrete and nonlinear programming problems), and the use of the Fuzzy Logic extension ensures the creation, modification and visualization of fuzzy sets, which are also used in optimization.

Sometimes, solving the problem in different mathematical systems, the results obtained do not coincide. This indicates that when solving real optimization problems, one should use various computer mathematics systems and carefully analyze the results obtained, especially for nonlinear programming problems. Let us briefly analyze the main capabilities of the computer mathematics systems Marle, Matlab, Mathematika, Mathcad for solving optimization problems, which are equipped with sufficiently powerful tools, either built into the core of these systems, or included in their composition in the form of additional modules (extension packages) and implement the most popular methods optimizations, in particular the golden section method and parabolas for one-dimensional optimization; simplex Nelder-Mild method, conjugate gradient method, quasi-Newtonian methods for multidimensional nonlinear optimization problems; interior point method (Karmarkar method) for solving high-dimensional linear programming problems, etc. Note that in these systems, as a rule, when solving specific problems, several optimization methods are implemented, which are applied depending on the dimension of the problem, the properties of the objective function, or the features that are present in the given constraints [6, p. 265].

**Conclusions from the study and prospects for further research in this direction.** Wide analytical, computational and graphical capabilities of modern mathematical systems make them one of the main tools in the professional activity of specialists in various fields. The conducted review proved that the areas of use of these packages largely overlap, therefore, to solve optimization problems, and not only, it is better to simultaneously

use parts of computer mathematics packages, taking into account spreadsheets. Perhaps it is better to start studying and using these systems with Mathcad, in which the condition of the problem is written simply and uses only two standard functions to find solutions to optimization problems.

This will ensure the adequacy of the obtained solutions, and, if necessary, the improvement of the model itself. Therefore, the use of modern computer mathematics packages in the curriculum is advisable, which will determine the high level of professional training of students, the level of their mathematical and information culture, and make future specialists competitive in the international labor market.

As promising areas of research, one can analyze a deeper comparative analysis of the capabilities of these systems by solving a certain list of various optimization problems.

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