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# COMPUTER SCIENCE

## МАТЕМАТИЧНІ МЕТОДИ ТА МОДЕЛІ УПРАВЛІННЯ ВИРОБНИЧОЮ ДІЯЛЬНІСТЮ ПІДПРИЄМСТВА

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## MATHEMATICAL METHODS AND MANAGEMENT MODELS OF PRODUCTION ACTIVITIES OF THE ENTERPRISE

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### **Анотація**

Сучасне функціонування підприємств аграрного сектору економіки дає право стверджувати, що оптимальне управління аграрним підприємством є ключовим чинником розвитку будь-якого сільськогосподарського підприємства. Під час управління підприємством доцільно застосовувати методи оптимізації, які є універсальним методом наукового пізнання та визначення факторів економічного зростання аграрних підприємств, які неможливі без застосування економіко-математичних моделей. Саме використання сучасних методів оптимізації діяльності підприємств у аграрному секторі економіки неможливе без застосування економіко-математичних моделей.

### **Abstract**

The modern functioning of enterprises in the agricultural sector of the economy gives the right to assert that optimal management of an agricultural enterprise is a key factor in the development of any agricultural enterprise. During enterprise management it is expedient to apply optimization methods, which are a universal method of scientific knowledge and determination of factors of economic growth of agricultural enterprises, which are impossible without the use of economic and mathematical models. It is the use of modern methods of optimizing the activities of enterprises in the agricultural sector of the economy is impossible without the use of economic and mathematical models.

**Ключові слова:** оптимізація, математична модель, аграрний сектор, сільськогосподарське підприємство, методи.

**Keywords:** optimization, mathematical model, agricultural sector, agricultural enterprise, methods.

Modern socio-economic transformations in agriculture and market orientation of the agricultural sector objectively require the use of new methods of enterprise management, which are aimed at optimizing the use and rational use of available resources, which improves the economic efficiency of economic activity.

Finding optimal management involves building models of management objects in different areas of the agricultural sector.

Recently, there has been an increased interest in economic and mathematical modeling of domestic scientists, among them - M.M. Ilchuk, O.Ya. Lotish, A.T. Moskovchuk, MI Sinenko, OV Cherneckaya, NA Potapova SV Kolyadenko, LA Volunteer and others.

However, the implementation of methods of economic and mathematical modeling to optimize the activities and management of enterprises in the agricultural sector of the economy remains insufficiently studied. Identifying possible problems in the management of agricultural enterprises requires in-depth analysis, so further research, development and implementation of models, methods, programs for optimal management of

agricultural enterprises are modern urgent tasks.

The principles of market management, the emergence of commercial relations in the activities of agricultural enterprises require qualitatively new approaches to the formation of principles of optimal management of the agricultural sector.

The pace and direction of development of the agricultural sector of the economy largely depend on the optimal management of agricultural production in each production cycle. For the analysis and synthesis of control systems of socio-economic systems, especially agricultural, uses a variety of economic and mathematical methods and models. The main motive of any enterprise is to maximize profits. Costs are the main limiter of profit and at the same time the main factor influencing the volume of production, so the process of minimizing production costs should be considered taking into account the issue of profit maximization. When optimizing production costs, scientists choose different criteria of optimality, namely the maximum profit from sales, maximum profit or maximum income from sales.

Improving economic efficiency and providing the

necessary amount of material and technical resources is the primary task of every agricultural enterprise. As it is impossible to achieve high results in agriculture without observance of all technological terms of tillage, introduction of the established norms of mineral and organic fertilizers and means of protection of plants. To do this, each manager must take measures to upgrade fixed assets involved in production activities and provide the company with the necessary amount of material and technical resources. The use of methods of mathematical modeling of economic processes allows to use resources efficiently and provides improvement of planning methods, which is very important in a market economy.

Modern management at the enterprise should be aimed at ensuring the rational management of it in terms of scarcity of resources, achieving the end result with minimal costs, rapid adaptation of the enterprise to market conditions. The management system must be flexible and efficient, which is impossible without paying special attention to the organization of production processes, assessment of the production potential of the enterprise, the formation of effective production structures. In this regard, the consideration of production management is quite relevant [1, 2].

Management systems, which were developed in Soviet times, did not take into account the influence of the external environment and provided for the stability of its behavior. Today, this factor has the greatest impact on the activities of the enterprise and provides for its mandatory consideration in the management of the enterprise.

Among the many problems that most Ukrainian enterprises have, it is also necessary to single out those, which are associated with the planning and implementation of long-term goals that increase the efficiency of the enterprise. In order to bring the company revenue, not only in the current period, but in the future, need to develop a strategic vision of production.

But the strategic planning system is still underdeveloped. This suggests that managers make short-term, current plans, and the mechanism of long-term planning is either absent or underdeveloped and has a somewhat unsystematic nature.

A major obstacle to management is the lack of qualified specialists in the management system. The fact is that positions are held by people who do not have the appropriate higher education, or those who performed other functions, but with the advent of new units had to take on new positions with completely new tasks and responsibilities [3]. In addition, new requirements are set for management staff. Among the factors that contribute to the growth of efficiency, we should also single out the innate or acquired in the process of special training art of management, which is unique to certain individuals [4].

Because of the identified problems businesses faced with the fact that the existing organizational structure does not reflect management innovation processes, which causes chaos in the duties of performers and the responsibility of managers for performance. Many agricultural enterprises of Ukraine use standard organizational management structures (linear, linear-

functional, etc.), although modern conditions require enterprises to build more progressive, strategic organizational structures of a new type with the ability to integrate structurally reflected innovation processes. The problem of their absence is a chronic lack of funds, time, ability to build them and the understanding of managers of their need [3].

In modern conditions of development of society and the state, to ensure sustainable development of Ukraine, new requirements are set for the protection and rational use of land and their structure. Intensification of exploitation of natural resources often leads to a negative impact on the potential of territories, which is the national pride and national wealth of Ukraine [20].

The problem of analyzing approaches to evaluating the effectiveness of management deserves special attention, as there is still no single method of evaluating this category, and some of them do not even have their own name, so they were classified according to the names of authors who developed them [5].

Each economic object as a subject of economic activity, which is a rather complex technical and economic system that reflects its individuality and specificity.

The enterprise is a system of economic relations, first of all relations of economic property, which are formed both within it and between other entities in connection with the production, exchange, distribution and consumption of various objects of property, as well as property management for the purpose of profit appropriation.

The Ukrainian economy, at the same time as the world economy, is going through difficult times, which causes the existence of actual crises in all sectors of Ukraine's economy. This is due to negative global trends, political and economic crises, the military conflict in the east.

Also, one of the important problems in the current crisis is the shortage of funds, which is becoming increasingly significant against the background of unfavorable investment climate, unstable economic and political situation in the country. As a result, companies do not have the opportunity to implement strategic measures in the production management system, because they require significant cash infusions and require time to achieve a positive effect. Thus, enterprises, given the current state of affairs, do not risk investing money in the production system of the enterprise.

In today's rather difficult economic conditions, according to the analysis, the general direction of improving the efficiency of production management of enterprises can be defined as the need to create, develop and implement appropriate tools to improve the adaptive characteristics of the enterprise. Such tools include various economic and management concepts and techniques, models, simulators, decision support systems, as well as appropriate hardware and software for information processing.

Despite all the negative phenomena in the economy of Ukraine, which affect the efficient functioning of agricultural enterprises, statistics show that even in such difficult conditions of doing business you can

make a profit. First of all, the successful operation of such enterprises is based on the use of modern tools and information technology in management, improve efficiency and quality of management decisions, as well as - competent management in the production sphere, with the effective use of appropriate tools.

One of the main stages of modeling an agricultural enterprise is the choice of the criterion of optimality and the need to optimize its structure and economic activity, which corresponds to the main purpose of economic activity. The purpose of the study is to identify areas, mechanisms for improving the management of production activities of the enterprise, building an economic and mathematical model of enterprises and developing organizational and economic principles and constructive proposals for the formation of a system of effective management of agricultural enterprises.

Machine learning algorithms can be described as learning the objective function  $f$ , which best correlates the input variables  $X$  and the output variable  $Y$ :  $Y = f(X)$ .

We do not know what the function  $f$  is. Because if they knew, they would use it directly, rather than trying to teach using different algorithms.

The most common task in machine learning is to predict  $Y$  values for new  $X$  values. This is called predictive modeling, and our goal is to make the most accurate prediction possible.

Overview of algorithms used in machine learning.

Linear regression is probably one of the most well-known and understandable algorithms in statistics and machine learning.

Prognostic modeling is primarily concerned with minimizing errors model or, in other words, how can a more accurate prediction. We will borrow algorithms from various fields, including statistics, and use them for these purposes.

Linear regression can be represented as an equation that describes a direct, most accurate never relationship between the input variables  $X$  and the output variables  $Y$ . To compile this equation you need to find certain coefficients  $B$  for the input variables.

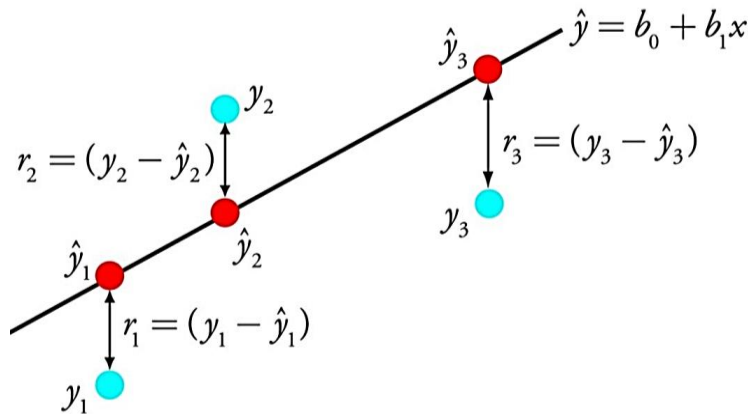


Fig. 1. The method of linear regression

For example:  $Y = B_0 + B_1 * X$  knowing  $X$ , we must find  $Y$ , and the purpose of linear regression is to find the values of the coefficients  $B_0$  and  $B_1$ .

Various methods such as linear algebra or the least squares method are used to estimate the regression model.

Logistic regression is another algorithm that came into machine learning directly from statistics. It is good to use it for binary classification problems (these are problems in which we get one of two classes at the output).

Logistic regression is similar to linear in that it also needs to find the values of the coefficients for the input variables. The difference is that the original value is converted using a nonlinear or logistic function.

A logistic function looks like a capital letter S and converts any value to a number ranging from 0 to 1. This is very useful because we can apply a rule to the output of a logistic function to bind to 0 and 1 (for example, if the result of the function is less than 0.5, then the output is 0) and the prediction of the class.

Due to how the model learns, logistic regression prediction can be used to display the probability that a sample belongs to class 0 or 1.

As with linear regression, logistic regression performs its task better if you remove redundant and similar variables. The logistic regression model learns

quickly and is well suited for binary classification problems.

Linear discriminant analysis (LDA)

Logistic regression is used when you want to assign a sample to one of two classes. If there are more than two classes, it is better to use the algorithm LDA (Linear discriminant analysis).

Presentation of the LDA is quite simple. It consists of statistical data properties calculated for each class. For each input variable this includes:

- Average value for each class;
- Dispersion calculated for all classes.

Predictions are created by calculating the discriminant value for each class and selecting the class with the highest value. It is assumed that the data has a normal distribution, so it is recommended to remove abnormal values from the data before starting work. This is a simple and efficient algorithm for classification problems.

Decision trees

The decision tree can be represented as a life tree, familiar to many by algorithms and data structures. Each node is an input variable and a dividing point for this variable (provided that the variable is a number).

Leaf nodes are the output variable used for prediction. Forecasts are created by passing a tree to a leaf node and deriving a class value on that node.

Trees quickly learn and make forecasts. In addition, they are accurate for a wide range of tasks and do not require special data preparation.

Naive Bayesian classifier

Naive Bayes is a simple but surprisingly effective algorithm.

The model consists of two types of probabilities, which are calculated using training data:

- Probability of each class.
- Conditional probability for each class for each value of  $x$ .

After calculating the probabilistic model, it can be used to predict with new data using Bayes' theorem. If you have material data, then, assuming a normal distribution, to calculate these probabilities is not particularly difficult.

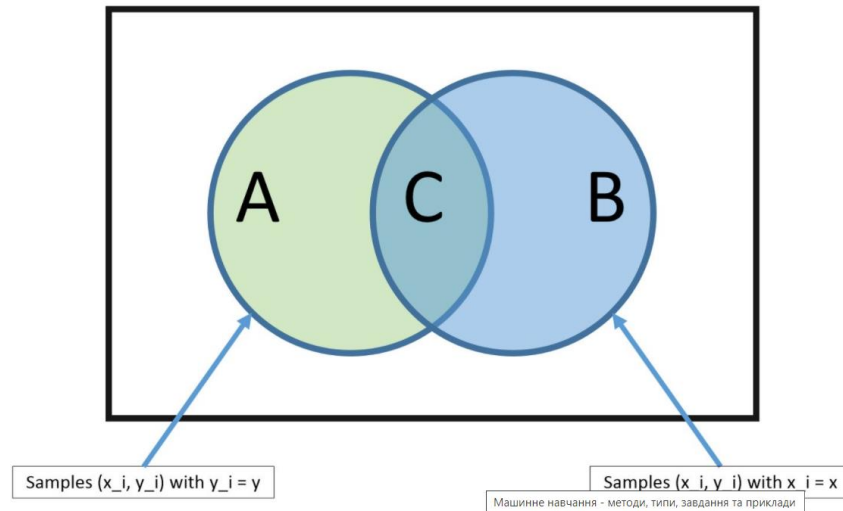


Fig. 2 Bayesian model

Naive Bayes is called naive because the algorithm assumes that each input variable is independent. This is a strong assumption that does not correspond to real data. However, this algorithm is very effective for a number of complex tasks such as spam classification or handwriting recognition.

K-nearest neighbors - a very simple and very efficient algorithm. The KNN (K-nearest neighbors) model is represented by the entire training data set.

Prediction for a new point is made by finding K nearest neighbors in the data set and summing the original variable for these K instances.

The only question is how to determine the similarity between data instances. If all the features have the same scale (for example, centimeters), then the easiest way is to use the Euclidean distance - a number that can be calculated based on the differences from each input variable.

Machine Learning is the training of a mathematical model on historical data in order to predict an event or phenomenon on new data. That is, an attempt to force program algorithms to take action based on previous experience, not just based on available data.

Machine learning includes a set of methods and algorithms that can predict a result from the input data.

Machine learning algorithms are many: some are effective for solving one type of problem, the other - for another.

Python was chosen to implement the software product. This language is quite new, but in recent years is rapidly gaining popularity. This year it is among the top three most popular. All this is because it is quite easy to learn and has an intuitive syntax. Python has also developed a large number of libraries, which greatly simplifies the work of developers. There are many implemented algorithms that are actively used for

machine learning and working with large data sets. That is why this language is the most popular among modern data scientists. Python is unpretentious to the platform and can run most operating systems, including the most popular Windows 10, Mac OS X, Android, IOS and others.

When working with Python, it should be borne in mind that Python is not only used as a language in which final projects are written: this language is often used to automate various tasks, say, system administration (Ansible - one of the examples written in Python, which is used during administration). Therefore, python is often already present in installed operating systems.

Python is especially likely to be installed on a system when it comes to the Linux family of operating systems - namely, one of the versions of Linux will most likely be installed on the machine on which you want to run the server of your web-application or multiplayer game. And it will not be possible to replace it, because the replacement can lead to the failure of the entire OS. There are popular machine learning libraries and frameworks for Python. The two largest are scikit-learn and TensorFlow. Some well-known machine learning algorithms discussed above are built into scikit-learn.

TensorFlow - a lower-level library that allows you to build custom algorithms. Developers who need to use statistics or data analysis techniques in their work often choose Python as their language. It is also used by data science scientists to integrate their tasks with web applications or production environments. But in the field of machine learning Python is just a "star". The combination of consistent syntax, shorter development time and flexibility makes this language suitable for developing intricate models and predictive engines that can be directly implemented in production systems.

One of the biggest benefits of Python is the wide range of libraries. Libraries are sets of routines and functions written in this language. A good set of libraries can make complex tasks easier without having to write many lines of code. Machine learning is largely based on mathematics. In particular, on mathematical optimization, statistics and probability theory. Python libraries help researchers / mathematicians to "do machine learning" without even having much knowledge in development. Scikit-learn is one of the most popular machine learning libraries. It supports many controlled and uncontrolled learning algorithms. For example, linear and logistic regressions, decision trees, clustering, k-means, etc. It is based on the two main Python libraries - NumPy and SciPy. Scikit-learn adds a set of algorithms for common machine learning and data mining tasks, including clustering, regression, and classification. Even tasks such as data conversion and function selection can be implemented with just a few lines.

Regarding Tensorflow, it is interesting that when writing a program in Python, you can compile and run the program on both CPU and GPU. This way, you don't have to write in C++ or CUDA to run on the GPU. The library uses a system of multilevel nodes that allows you to quickly configure, train and deploy artificial neural networks with large data sets. This allows Google to identify objects in photos and understand spoken words in speech recognition applications.

Theano is another good Python library for a numerical calculation algorithm similar to NumPy. It allows you to efficiently define, optimize and compute mathematical expressions containing multidimensional arrays. Highlights this library using the benefits of a computer GPU. This allows it to do calculations with large amounts of data a hundred times faster than when running only on the CPU.

Theano speed is especially valuable for deep learning and other complex computational tasks. The last release of Theano Library was released in 2017. This is version 1.0.0 with many new features, interface changes and other improvements. Pandas is a very popular library that provides high-level data structures that are easy to use and intuitive. It has many built-in methods for grouping, combining, and filtering data, as well as time series analysis. Pandas can easily extract data from various sources, such as SQL databases, CSV files, Excel, JSON, and manipulate this data to perform operations with them. Matplotlib is a standard Python library used by all data science people to create graphs. It is quite low-level, which means it requires more commands to generate good-looking graphs and shapes than more advanced libraries.

On the other hand, it is flexible. By operating a sufficient number of commands, you can create almost any schedule. You can build a variety of charts, from histograms and scatter plots to graphs with non-Cartesian coordinates. This library supports GUI-backend in all operating systems, and can also export graphics in common formats (PDF, SVG, JPG, PNG, BMP, GIF). Seaborn is a popular visualization library that builds graphics based on Matplotlib. This is a top-level library, which makes it easier to generate certain types of

charts, including heat charts, time series, and violin charts.

Based on the task, the following Python libraries were used: - pandas - used for easy operation of data arrays in the form of date frames; - numpy - fast calculations, operations with matrices, etc. ; - tkinter - building a user interface, adding text fields, keys and graphics; - sclearn - various methods of data mining, including calculations based on Bayes' theorem; - networkx, matplotlib - construction of various graphs and graphs of the Bayesian network.

The NumPy library provides the ability to work with multidimensional arrays using high-level mathematical functions. Pandas allows you to use these indexed data in the form of tables and implements many useful functions for working with them, including downloading data from files. SciPy is a library for performing scientific and engineering calculations (its statistical functions are most often used in data analysis). Matplotlib is used to visualize data (Only 2D graphics are supported).

The Scikit-Learn library implements many methods of data mining for visualization, classification, clustering, etc., as well as auxiliary classes such as finding hyperparameters of the model, assessing the quality of models by different methods, calculating metric values, etc.

Quite popular today is the neural network approach to data analysis tasks. In particular, it has been proved that a multilayer perceptron is a universal approximator and is able to approximate any continuous real function of many variables by addition, multiplication, number, function superpositions, linear functions and one arbitrary nonlinear continuous function of one variable [16]. Classification using a perceptron with one hidden layer is carried out according to formula (8):

$$a(x) = \arg \arg \max_{y \in Y} F \left( \sum_{d=1}^D a_d * F((x, w_d)) \right) \quad (3.8)$$

where  $F$  is the activation function of neurons,  $w_d$  is the weight vector  $d$  of the synaptic connection between the input and hidden layer,  $ad$  is the weight vector of the synaptic connection between the hidden and output layer.

Multilayer perceptron training is performed by an error backpropagation algorithm, which is a modified version of the gradient descent.

In the implementation of Scikit-Learn it is not possible to assess the significance of the features using this method, so for this purpose the paper uses the significance of the features, estimated by logistic regression.

Hyperparameters of the multilayer perceptron:

- hidden\_layer\_sizes - the number of hidden layers and neurons in them.
- activation - the function of activation of neurons of the hidden layer.
- alpha - regularization coefficient. Gives more value to the stronger
- regularization.

The advantages of the multilayer perceptron include high flexibility due to the possibility of learning nonlinear models, online learning, with which you can

control this process, as well as low requirements for the original data.

Instability with respect to the initial approximation is one of the main disadvantages, as the loss function of the multilayer perceptron has many local minima. Also, the method is able to relearn, but is poorly interpreted and has a high algorithmic complexity, depending on the number of examples, features, hidden layers, neurons in each of them and the number of iterations. This method requires pre-processing of data (standardization, normalization, etc.).

The above methods have their own characteristics, which allows them to be applied to various tasks, in particular in agronomy. To improve their quality and reduce computational costs, as well as memory costs, you can use methods to select the most informative features and fill in the missing values in terms of the task.

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