

Neural networks as a promising direction in the agricultural industry

*Besarion Meskhi*¹, *Dmitry Rudoy*^{1,2*}, *Anastasiya Olshevskaya*¹, *Mary Odabashyan*¹, *Anna Vershinina*¹, *Sergey Marchenko*¹, and *Egor Alentsov*¹

¹ Don State Technical University, Gagarin Sq., 1, 344010 Rostov-on-Don, Russia

² Agricultural Research Centre “Donskoy”, Lenin Str., 14, Zernograd, 347740 Rostov Region, Russia

Abstract. The agro-industrial complex (AIC) is considered one of the most conservative in terms of innovation. The global agro-industrial complex is developing today according to the concept of electronic agriculture, one of the basic elements of which is information and communication technologies. Big data, robotics, M2M systems, the Internet of Things, artificial intelligence, blockchain and cloud computing are effectively used by the world's leading agricultural producers. Russia is following the same path: large and medium-sized agricultural producers are trying and implementing various modern technologies, and advanced developers are offering new solutions to the market. Among the many different types of neural network schemes, the so-called recurrent neural networks occupy a special place. Their architecture allows efficient processing of data representing a directed sequence: for example, text, speech and time series. The purpose of this study is to identify growth points and problem areas in the field of robotics and informatization of the agro-industrial complex based on a comparison of the experience of various organizations and different countries in the use of artificial intelligence technologies in agriculture.

1 Introduction

The global agro-industrial complex is developing today according to the concept of electronic agriculture, one of the basic elements of which is information and communication technologies. Big data, robotics, M2M systems, the Internet of Things, artificial intelligence, blockchain and cloud computing are effectively used by the world's leading agricultural producers. Russia is following the same path: large and medium-sized agricultural producers are trying and implementing various modern technologies, and advanced developers are offering new solutions to the market. Actively implemented neural networks are nothing more than mathematical models, parts of software and hardware structural implementations aimed at analysis, action in accordance with the most appropriate algorithm and scenarios. In the agro-industrial complex, it is especially convenient to track any changes by building a network by analogy with a biological system.

In order to meet the growing demand for milk, it is necessary to increase its production by an average of 2% per year, the Food and Agriculture Organization of the United Nations

* Corresponding author: rudoy.d@gs.donstu.ru

(FAO) estimated last year. However, due to the COVID-19 pandemic and the resulting changes in the operation of markets, as well as due to drought in key global agricultural regions, milk production will grow by only 0.8%. Forecasts of the development of the situation on the meat market are even less optimistic: FAO experts say that the volume of its production will decrease by 1.7%. The way out of the crisis will be difficult, and this will be facilitated not only by the specific features of the dairy and meat livestock industry, but also by an elementary shortage of workers. According to FAO forecasts, the number of people employed in agriculture will decrease by more than a third in the near future.

The agro-industrial complex (AIC) is considered one of the most conservative in terms of innovation. According to the results of the Index of readiness of priority sectors of the Russian economy for the introduction of AI in this industry, about 12% of companies use AI technologies, another 37% only plan to do so in the near future. In order to stimulate agricultural producers, the authorities are working on the issue of mandatory use of AI technologies within the framework of receiving state subsidies.

Currently, Russian agricultural organizations are making the transition to digital technologies. The widespread introduction of precision farming technologies has led to the need for not only technical, but also intellectual modernization. Thus, the introduction of artificial intelligence, training neural networks to solve problems and problems of the agro-industrial complex, as well as the prospect of possible results led to a new ambition aimed at improving performance using neural networks and monitoring in general. According to the forecasts of experts from the research company Json and Partners Consulting, the total economic effect of the transition of Russian agriculture to these technologies may amount to more than 4.8 trillion rubles annually, which is 5.6% of GDP growth (relative to 2016) (1, p. 103). According to experts, the implementation of the roadmap of the Ministry of Agriculture of Russia will allow by 2024 to increase the share of agricultural organizations using the so-called technologies of the Internet of Things, precision agriculture, digital herd and smart greenhouses to 60%.

The purpose of this study is to identify growth points and problem areas in the field of robotics and informatization of the agro-industrial complex based on a comparison of the experience of various organizations and different countries in the use of artificial intelligence technologies in agriculture.

2 Materials and methods

Some issues related to the introduction and use of AI technologies in agriculture were considered by Russian scientists A.V. Akimov, M. I. Gorbachev, A. A. Grishin, L. P. Kormanovsky, Yu. F. Lachuga, N. M. Morozov, P. A. Surovtsev, E. A. Tyapugin, V. K. Uglin, R. R. Hisamov, Yu. A. Tsoi, S. V. Shanygin, E. I. Yurevich and others. However, the theoretical and methodological development related to the implementation and utilization of AI technologies in agriculture remains inadequate. Insufficient progress has been made in establishing a conceptual framework and comprehensively studying the consequences of utilizing artificial intelligence technologies. This lack of development has influenced the choice of the research topic, as well as the object, subject, purpose, and objectives of the study.

To gather information for further analysis, the bibliometric method was employed during the research; to evaluate the potential applications of AI technologies in agriculture, SWOT analysis tools were utilized.

Additionally, economic and statistical analyses, along with other scientific research methods, were employed in accordance with the specific research objectives outlined in order to provide a comprehensive investigation.

3 Results and discussion

Artificial intelligence has a wide range of applications both in general and in individual branches of the agro-industrial complex. It is widely used in the field of forecasting and analysis of crop yields, taking into account a variety of climatic, weather and anthropogenic factors.

A good example is the experience of Australian scientists using a neural network method to predict coffee yields. The applied technology allows them to obtain a clear forecast in accordance with environmental, climatic and soil conditions (2, p. 57). Their research uses AI technologies based on extreme machine learning (ELM) to analyze soil properties and fertility. The use of ELM in comparison with similar models makes it possible to significantly increase the efficiency of crop yield forecasting in farms, to choose soils with the most optimal properties.

Machine learning (ML) methods make it possible to process a large amount of input data on plant development and, on this basis, to carry out a very accurate prediction of crop yields (3, p. 90). Machine learning, using algorithms and computer vision, can be effectively applied in the agro-industrial complex to solve various tasks. This includes yield forecasting, detection and treatment of plant pests and diseases, optimization of resource use, forecasting of market prices and automation of processes. By analyzing huge amounts of data and training models based on this data, machine learning allows farmers to make more informed decisions, increase production efficiency and improve the quality of agricultural products. In addition, machine learning has the potential to improve the accuracy and speed of data analysis, which helps to reduce the reaction time to changes in the environment and take prompt action. For example, with the help of machine learning, it is possible to create soil monitoring systems that will automatically determine the optimal conditions for sowing various crops. The use of machine learning also contributes to the collection and analysis of large amounts of data on climatic conditions, vegetation and the level of environmental pollution. This helps to anticipate possible environmental risks and take measures to prevent them. One of the advantages of machine learning is its ability to continuously learn and adapt. Machine learning systems can constantly collect new data and improve their models, which allows them to improve results and achieve greater accuracy and reliability over time. In general, the use of machine learning in the agro-industrial complex opens up new opportunities for increasing efficiency, sustainability and improving the quality of agricultural production. This helps to reduce costs, optimize the use of resources and improve the standard of living for all participants in this industry.

Among the many different types of neural network schemes, the so-called recurrent neural networks occupy a special place. Their architecture allows efficient processing of data representing a directed sequence: for example, text, speech and time series. It is the time series that well describes the dynamics of plant growth over time.

Information about the state of the soil is also very important, allowing you to make effective management decisions. A group of researchers applied AI technologies to monitor and predict soil moisture, which is very necessary for understanding the dynamics of soil processes and subsequent decision-making (4, p. 200). Their research used hybrid models of intelligent data and extreme machine learning. Other scientists have applied various machine learning models to estimate soil temperature (5, p. 9).

A significant amount of research on the use of AI technologies is devoted to the detection of diseases of plants and animals. Thus, a system has been developed for detecting nitrogen stress and yellow rust, infected and healthy winter wheat plants, based on a hierarchical self-organizing classifier and hyperspectral data. The study was aimed at accurately identifying these categories for more efficient use of fungicides and fertilizers (6, p.21). AI technologies are used in weather forecasting. Thus, the use of machine learning (ELM) technologies has

made it possible to obtain more accurate forecasts of potential drought risks in eastern Australia (7, p. 8; 9, p. 130).

An important direction in the development and use of artificial intelligence is the use of neural networks in mapping fields. One of the main applications of neural networks in field mapping is the analysis of multidimensional data, such as data on soil properties, humidity, topography and vegetation. Neural networks can process large amounts of data, analyze complex dependencies and identify the main characteristics that affect the quality and yield of the field. The basic tasks for the development of a mapping and monitoring system usually include such items as the development of a descriptor, the development of a mathematical model, and, in fact, the mapping system itself, which uses the imposition of masks of sown and unseeded areas. An image segmentation algorithm can be used to provide an accurate and reliable monitoring system for acreage. The use of a texture descriptor can provide an informative description of the image features.

Machine learning algorithms based on neural networks can predict the optimal time and volume of fertilization, irrigation and other agrotechnical measures. This allows you to reduce resource costs and improve the quality of agricultural products. In addition, the neural network mapping method is used to identify areas with an increased risk of diseases or pests on the field. Data analysis, including information about weather, climate and crop history, can help predict the likelihood of a series of problems and offer recommendations for their prevention. Several types of neural networks are commonly used in mapping applications:

1. Convolutional Neural Networks (CNNs): These networks excel at processing and analyzing image data, making them well-suited for tasks such as satellite or aerial image analysis and classification in mapping.
2. Recurrent Neural Networks (RNNs): RNNs are designed for processing sequential data and find applications in mapping for tasks like climate change prediction or boundary line movement analysis.
3. Deep Learning Networks: Combining multiple layers of neural networks, deep learning networks are used for handling diverse and complex geographic data, including text information, images, sound, and more.
4. Generative Adversarial Networks (GANs): GANs are employed in mapping to generate realistic and high-quality maps or images, which can be useful for various mapping purposes.
5. Autoencoders: Autoencoders are used to extract hidden or compact representations of geographic data, aiding in visualization and analysis of intricate maps.

These are just a few examples of neural networks used in mapping. Other types or combinations of neural networks may be used depending on specific tasks and data types.

Neural networks can analyze the sounds emitted by animals and determine their emotional state, needs or diseases. They can also analyze video recordings and determine movement patterns, which can be useful for detecting diseases or stressful situations. One of the areas where the use of neural networks in animal husbandry is becoming increasingly popular is the improvement of animal welfare conditions. For example, neural networks can analyze the behavior of animals and determine their preferences in relation to weather, food, noise level and other factors. This information can be used to create optimal conditions for keeping and caring for animals, which as a result will lead to an improvement in their well-being and productivity.

Moreover, the use of neural networks in animal husbandry can help in anticipating various events and problems related to animal behavior. For example, neural networks can help in determining the likelihood of aggressive behavior among animals or diseases, detect warning signals and suggest measures to prevent them. This greatly simplifies the work of farmers and helps them make more informed decisions to ensure the health and welfare of animals.(10, p. 58).

The Ecorobotix solution in the form of a table on wheels with GPS navigation moves across fields and destroys weeds with high accuracy. At the same time, solar panels provide power. The declared efficiency reaches 95%. At the same time, Energid and Universal Robots equipped with cameras and special flexible manipulators help to collect citrus fruits, such as oranges and grapefruits. (Figure 1)

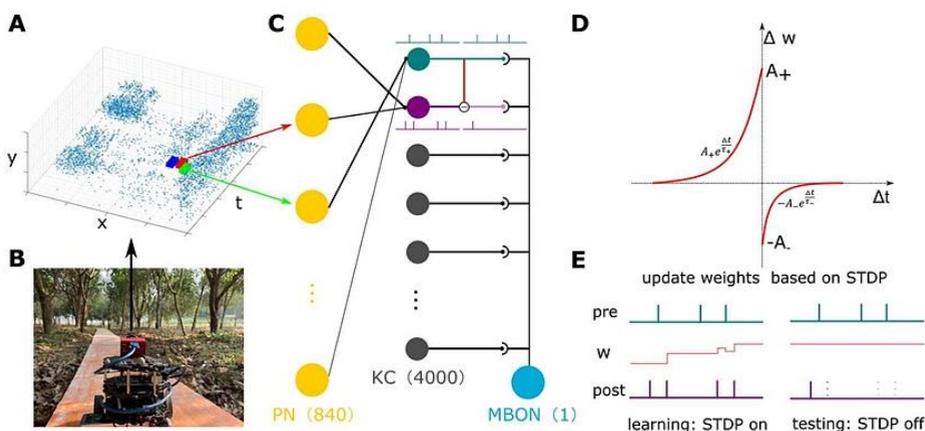


Fig. 1. Development of an algorithm simulating the behavior of ants for visual navigation in dense vegetation. Source: <https://www.tadviser.ru/>

The River LettuceBot system scans crops and effectively thins overgrown areas, distinguishing between weeds and useful plants. The complex ensures optimal growth with minimal use of pesticides. The PrecisionHawk platform, in turn, helps to perform all types of robotic agricultural operations using remote sensing and drone-based analytics.

Specialists from the University of Edinburgh in Scotland and the University of Sheffield in Britain are solving the problem of visual navigation in dense vegetation by developing algorithms that mimic the behavior of ants. They have created a special neural network like the insect brain, which helps robots navigate in space, guiding them in difficult field conditions. One of the problems in such environments is the recognition of previously visited places or routes traveled. New algorithms make it possible to circumvent existing restrictions. The researchers tested their neural model on difficult routes on uneven, dirty, densely overgrown fields and achieved positive results.

The data obtained from drones and satellites can be processed using AI to analyze plant growth, identify areas with the greatest care needs or detect possible problems in the fields. (Figure 2).

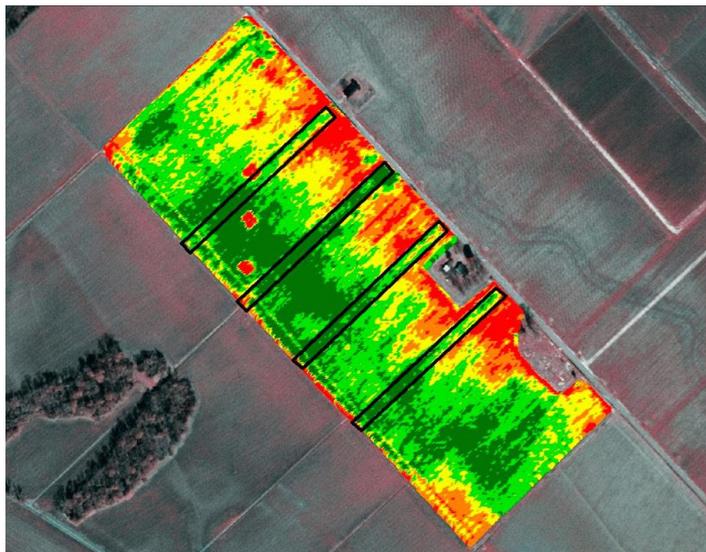


Fig. 2. Aerial and space images of fields. *Source: <https://vc.ru/>*

Several companies offer autonomous robots for weed control in agriculture. Nao Technologies has created the OZ WEEDING ROBOT, while Bilberry Company develops tracking systems for weed removal on agricultural machinery. Precision Hawk is working on autonomous aircraft equipped with weed identification systems. Blue River Technology provides updates on neural network applications in agriculture on its website. Ecorobotix has introduced the WEEDING ROBOT, and Carre has developed the Robot ANATIS. However, these companies have not provided comprehensive documentation or experimental data on the performance of their technologies, often only sharing fragmented video demonstrations of their devices.

4 Conclusion

Summarizing the results of the study, we note the presence of a number of problems in digital agriculture due to the great complexity and dynamism of the functioning of the agricultural sector. In the context of the digital transformation of the industry, the use of intelligent technologies is relevant to increase the competitiveness and efficiency of the agro-industrial complex. Neural networks will teach specialists to save resources, improve the quality and safety of crop and livestock products, and simplify business processes. The use of neural networks will reduce risks in the agro-industrial complex, increase the profitability of the industry. (11, p. 69)

Acknowledgements

The study was supported by a grant within the framework of the “Nauka-2030”.

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