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DEVELOPMENT OF A PROTOTYPE OF A SOFTWARE AND HARDWARE COMPLEX FOR STUDYING THE IMPACT OF THE DYNAMICS OF THE GREENHOUSE EFFECT ON THE GROWTH AND DEVELOPMENT OF AGRICULTURAL CROPS

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Abstract. The article discusses the development of a prototype of a specialized scientific hardware and software complex that can be used to study the impact of the greenhouse effect on the growth and development of agricultural plants. This complex supports automated cultivation with the ability to reproduce the required growth parameters, such as meteorological, soil, and climatic conditions. The proposed software enables automated accumulation of environmental parameters, as well as image collection for digital phenotyping and analysis of morphological, physiological, and biochemical characteristics of plants. The generated databases are intended for training and retraining convolutional neural networks, which ensures high-precision visualization of crop growth and development under current and forecasted cultivation conditions. The results of the study can be applied to the formation of scientifically grounded agrotechnical plans, optimization of cultivation regimes, yield forecasting, and modeling of adaptation scenarios considering climatic changes and anthropogenic impacts. The practical significance of the complex lies in ensuring the sustainable functioning of agricultural systems, reducing climate-related risks, increasing ecological resilience, strengthening long-term food security, improving economic efficiency, and implementing innovative digital solutions in modern crop production.

Keywords: software and hardware complex; prototype; climate impact; greenhouse effect; yield.

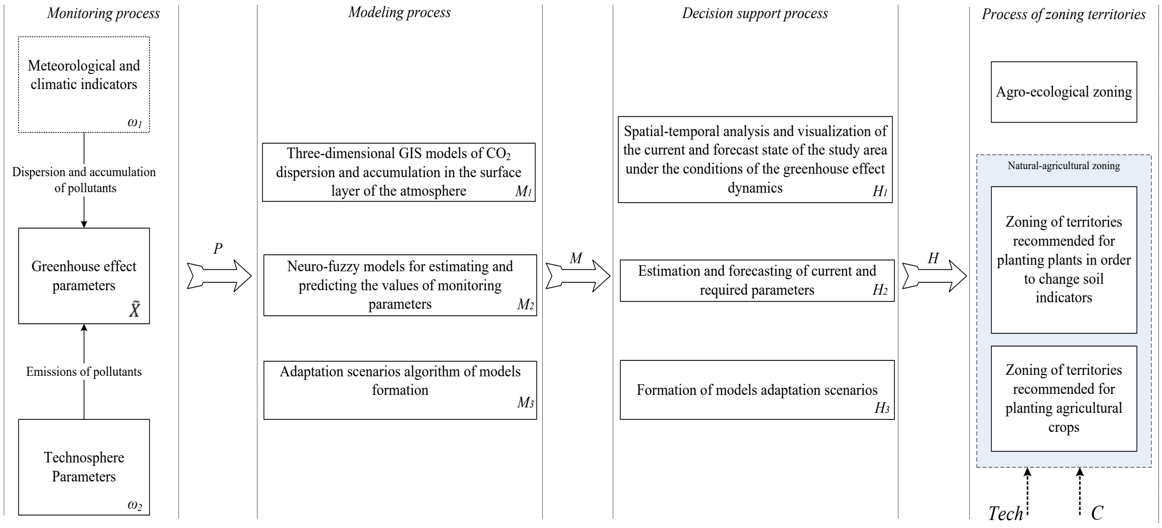
Relevance of the study:

The development and growth of agricultural plants depend on the process of photosynthesis: leaves absorb carbon dioxide from the lower layers of the atmosphere and, in combination with water, convert it into organic substances necessary for growth. Thus, the lack of CO_2 is one of the key factors limiting plant growth, development, and yield. This problem can be effectively addressed by identifying areas with the required levels of CO_2 concentration for different agricultural crops, taking into account the dynamics of the greenhouse effect (GE). It is important to note that in this context, opportunities also arise for managing the humus layer of the soil, which plays a significant role in its fertility and productivity.

The creation of adaptation scenarios and the scientific justification for zoning agricultural lands, considering the dynamics of the GE, requires the collection and processing of large volumes of diverse data. This includes simultaneous attention to controlled parameters that are widely distributed across extensive territories and are of a random nature, as well as the participation of living organisms in production processes [1]. All this emphasizes the necessity of applying digital technologies, which are actively developing within the framework of Industry 4.0.

At the already implemented stages of the scientific research, the team presented a scheme for forming adaptation scenarios for zoning territories to increase the yield of agricultural crops under external natural-climatic and technogenic influences. This scheme includes: stages of modeling, intelligent decision support; determination of optimal parameters of natural-agricultural and agroecological zoning of the studied territories, their qualitative and quantitative structure [2]. The necessary methods and intelligent models have been developed [3], and algorithms have been implemented for creating software and automated formation of adaptation scenarios for zoning agricultural lands (Figure 1) [4].

At present, there is an increasing interest in the situational approach, which is applied in various fields of human activity, accompanied by the establishment of situational centers [4, 5].



Tech – technology of planting agricultural crops;
C – type of culture.

Figure 1 – Scheme of automated formation of adaptation scenarios for zoning territories under external natural-climatic and technogenic impacts

In this study, the results of developing the main aspects and situational models for creating a prototype of a regional situational center are presented. The primary function of this center is the development of scientifically grounded scenarios for zoning agricultural territories under the dynamics of the greenhouse effect (GE), which should lead to a gradual increase in crop yields and territorial productivity.

Decision-making in the field of agricultural crop production faces serious challenges caused by a lack of information, conflicts of interests and objectives, as well as rapid and multiple changes in the environment and the technogenic impact of the production sector [6]. Under such conditions, the requirements for flexibility in the agricultural sector and the speed of managerial decision-making increase significantly, which in turn necessitates the introduction of intelligent and information technologies into management processes.

The adoption of scientifically grounded decisions on zoning becomes possible through the use of artificial neural networks, the functioning of which requires prior training on large datasets [7]. The accumulation of such information is possible during laboratory research and the reproduction of various cultivation conditions. The cultivation of agricultural crops in a closed environment is a technically labor-intensive process that cannot be implemented without specialized technical equipment [8]. Errors made in controlling growth parameters can lead to uneven germination, pale plant coloration, and low resistance to pests [9].

To address these problems, a grow box (PROBOX ECOPRO) was used — a closed structure designed to create an optimal microclimate for the growth and development of agricultural crops. The external view of the developed laboratory equipment is shown in Figure 3.

The technical equipment of the laboratory complex consists of the following components:

- LED lighting with brightness control;
- Microclimate system (heat fan, supply and exhaust ventilation system, recuperative cooling unit, carbon dioxide supply system);
- Soil moisture control system;
- Photosynthetic activity monitoring system;

- Automated control system for the parameters of the laboratory complex.

Figure 3 – External view of the laboratory equipment for controlled cultivation of agricultural crops

To control the elements of the laboratory complex, a control system was proposed, the structural diagram of which is shown in Figure 4 [10].

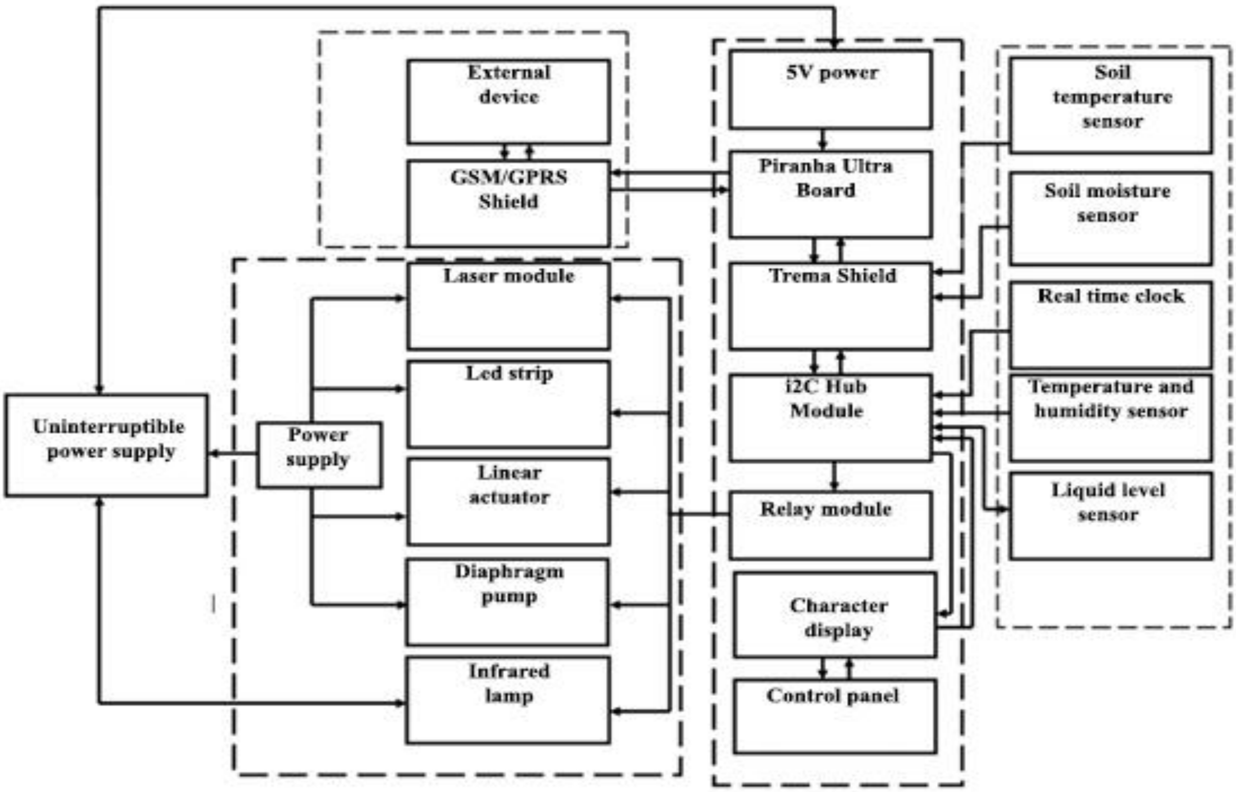


Figure 4 – Structural diagram of the technical components of the laboratory complex

To describe the principles of connecting various electrical and electronic components into a single system, the following specification was developed, corresponding to the structural diagram (see Figure 5). The connection diagram includes the following elements:

1. Piranha Ultra R3 control board;
2. Trema Shield connection device;
3. GSM/GPRS Shield for integration with a mobile device;
4. Control buttons;
5. Laser module;
6. Non-contact liquid level sensor XKC-Y25-V;
7. Set of resistors;
8. Linear actuator XDHA12-50;
9. Power supply 12V (2A);
10. Infrared lamp;
11. Membrane pump 385;
12. 12V fans;
13. 5V power supply;
14. Dual-channel relay module FLASH-I2C;
15. i2C Hub for connecting peripheral devices;
16. Real-time clock (RTC);
17. Temperature and humidity sensor FLASH-I2C;
18. Character display LCD1602 IIC/I2C;
19. Capacitive soil moisture sensor;
20. LED lamp PHOTON PROM;
21. UPS Cyberpower UTC650E.

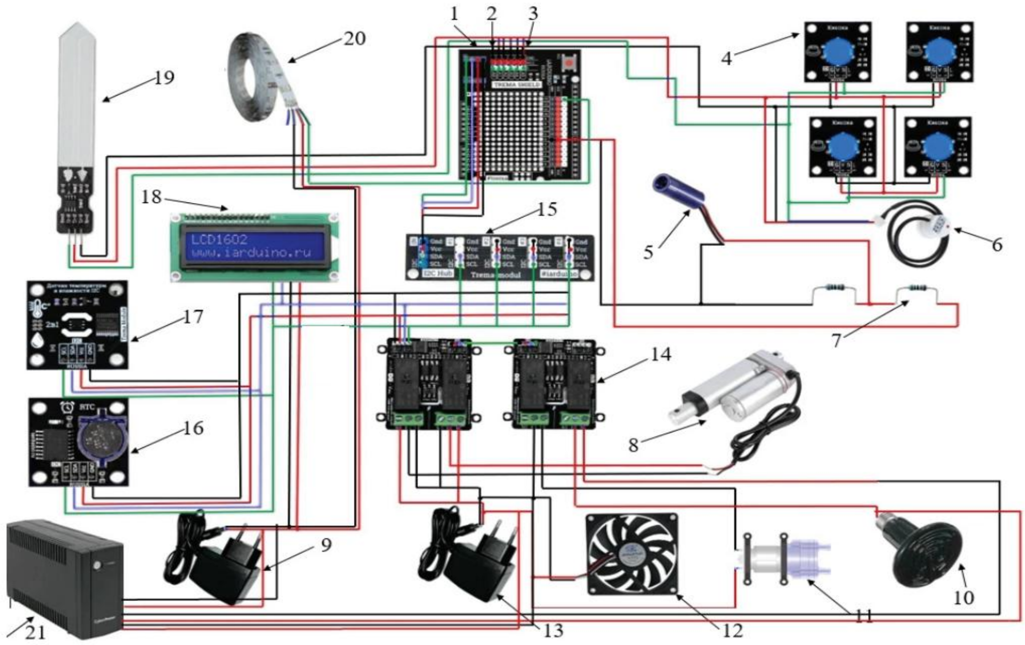


Figure 5 – Connection diagram of the laboratory complex components

Specialized software is used to record the growth parameters and visual condition of the crops [11, 12].

Conclusion. As a result of the study, a prototype of a hardware and software complex for use in scientific research was presented. The authors obtained data and photographs of agricultural crops at different stages and under various cultivation conditions. The collected data made it possible to train a convolutional neural network for digital phenotyping of plants and visualization of their growth and development.

REFERENCE

1. Konstantinov I. S., Ivashchuk O. A. Automated environmental safety management system for the industrial and transport complex // Bulletin of Computer and Information Technologies. – 2009. – No. 8. – P. 44-49.
2. O.A. Ivashchuk, V.I. Fedorov, D.V. Goncharov. "Approaches to the Development of an Automated Control System for the Adaptation of Agricultural Areas under the Changing Greenhouse Effect" // Mathematical Statistician and Engineering Applications, vol. 71, No. 3s2, p. 948, 2022.
3. Goncharov D. V., Ivashchuk O. A., Fedorov V. I. Modeling of an automated yield management system for agricultural crops under the dynamics of the greenhouse effect // Information Technologies in Science, Education and Production (ITNOP-2023): Proceedings of the IX International Scientific and Technical Conference, Belgorod, May 31 – June 2, 2023. – Belgorod: Belgorod State National Research University, 2023. – P. 147-152.
4. Ivashchuk O. A., Konstantinov I. S. Supporting ecological safety adaptive management in industrial and transport complex // Upravlenie Bol'shimi Sistemami. – 2009. – Vol. 25. – P. 96-115.
5. Fedorov V. I., Ivashchuk O. A., Uzharynsky A. Yu. Development of a model for assessing and forecasting the state of soils in rural-urban areas based on an artificial neural network // Scientific Result. Information Technologies. – 2017. – Vol. 2, No. 4. – P. 3-9.
6. Ivashchuk O. A., Kuzichkin O. R., Goncharov D. V., Dunaeva V. A. Digital technologies for assessing and forecasting the influence of spatio-temporal distribution of greenhouse gases on the photosynthetic activity of agricultural crops // Proceedings of the Southwest State University. – 2023. – Vol. 27, No. 1. – P. 38-56.
7. Pryadkina G. A. Pigments, photosynthesis efficiency and wheat productivity // Plant Varieties Studying and Protection. – 2018. – Vol. 14, No. 1. – P. 97-108.
8. Albegov R. B., Gagieva S. S. Climate change in the North Caucasus: possible threats and countermeasures // Bulletin of MANEB. – 2010. – Vol. 15, No. 4. – P. 162-167.
9. Ashabokov B. A., Bischokov R. M., Bischokova L. B. On one approach and some results of forecasting changes in the air temperature regime in the surface atmospheric layer in the steppe and foothill zones of the central part of the North Caucasus // Proceedings of AMAN. – No. 1, 2008.
10. Polushkina T. M. Sustainable development of rural areas through the establishment of organic agriculture // National Interests: Priorities and Security. – 2016. – No. 6 (339). – P. 22-32.
11. Klimkina E. V., Morozova T. V. Implementation of the strategy for achieving carbon neutrality under sustainable growth of the agricultural production economy // Management of Innovative Development of Agri-Food Systems at the National and Regional Levels. – 2021. – P. 287-293.
12. Shvetsova A. A., Zvyagintseva A. V. Information and analytical decision support system for strategic planning of the development of regions and cities // Soft Measurements and Computing. – 2020. – Vol. 36, No. 11. – P. 55-66.

ПАРНИКТІК ЭФФЕКТ ДИНАМИКАСЫНЫҢ АУЫЛ ШАРУАШЫЛЫҒЫ ДАҚЫЛДАРЫНЫҢ ӨСУІ МЕН ДАМУЫНА ӘСЕРІН ЗЕРТТЕУГЕ АРНАЛҒАН БАҒДАРЛАМАЛЫҚ-АППАРАТТЫҚ КЕШЕННІҢ ПРОТОТИПІН ЖАСАУ

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Аңдатпа. Мақалада парниктік әсердің ауылшаруашылық өсімдіктерінің өсуі мен дамуына әсерін зерттеу үшін қолдануға болатын мамандандырылған ғылыми аппараттық-бағдарламалық кешеннің прототипін жасау қарастырылады. Бұл кешен метеорологиялық, топырақ және климаттық жағдайлар сияқты өсудің қажетті параметрлерін көбейту мүмкіндігімен автоматтандырылған өсіруді қолдайды. Ұсынылған бағдарламалық қамтамасыз ету қоршаған орта параметрлерін автоматтандырылған жинақтауға, сондай-ақ цифрлық фенотиптеу және өсімдіктердің морфологиялық, физиологиялық және биохимиялық сипаттамаларын талдау үшін кескіндерді жинауға мүмкіндік береді. Құрылған мәліметтер базасы қазіргі және болжамды өсіру жағдайларында дақылдардың өсуі мен дамуын жоғары дәлдікпен визуализациялауды қамтамасыз ететін конволюциялық нейрондық желілерді оқытуға және қайта даярлауға арналған. Зерттеу нәтижелерін ғылыми негізделген агротехникалық жоспарларды қалыптастыруға, өсіру режимдерін оңтайландыруға, өнімділікті болжауға, климаттық өзгерістер мен антропогендік әсерлерді ескере отырып бейімделу сценарийлерін модельдеуге қолдануға болады. Кешеннің практикалық маңыздылығы ауылшаруашылық жүйелерінің тұрақты жұмыс істеуін қамтамасыз ету, климатқа байланысты тәуекелдерді азайту, экологиялық тұрақтылықты арттыру, ұзақ мерзімді азық-түлік қауіпсіздігін нығайту, экономикалық тиімділікті арттыру, заманауи өсімдік шаруашылығында инновациялық цифрлық шешімдерді енгізу болып табылады.

Түйін сөздер: бағдарламалық-аппараттық кешен; прототип; климаттың әсері; парниктік эффект; кірістілік.

РАЗРАБОТКА ПРОТОТИПА ПРОГРАММНО-АППАРАТНОГО КОМПЛЕКСА ДЛЯ ИЗУЧЕНИЯ ВЛИЯНИЯ ДИНАМИКИ ПАРНИКОВОГО ЭФФЕКТА НА РОСТ И РАЗВИТИЕ СЕЛЬСКОХОЗЯЙСТВЕННЫХ КУЛЬТУР

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Аннотация. В статье рассматривается разработка прототипа специализированного научного аппаратно-программного комплекса, который может быть использован для изучения влияния парникового эффекта на рост и развитие сельскохозяйственных растений. Этот комплекс поддерживает автоматизированное выращивание с возможностью воспроизведения требуемых параметров роста, таких как метеорологические, почвенные и климатические условия. Предлагаемое программное обеспечение позволяет автоматически накапливать параметры окружающей среды, а также собирать изображения для цифрового фенотипирования и анализа морфологических, физиологических и биохимических характеристик растений. Сформированные базы данных предназначены для обучения и переподготовки сверточных нейронных сетей, что обеспечивает высокоточную визуализацию роста и развития сельскохозяйственных культур в текущих и прогнозируемых условиях возделывания. Результаты исследования могут быть применены для формирования научно обоснованных агротехнических планов, оптимизации режимов возделывания, прогнозирования урожайности и моделирования адаптационных сценариев с учетом климатических изменений и антропогенных воздействий. Практическая значимость комплекса заключается в обеспечении устойчивого функционирования сельскохозяйственных систем, снижении связанных с климатом рисков, повышении экологической устойчивости, укреплении долгосрочной продовольственной безопасности, повышении экономической эффективности и внедрении инновационных цифровых решений в современное растениеводство.

Ключевые слова: программно-аппаратный комплекс; прототип; воздействие на климат; парниковый эффект; урожайность.