ANNOTATION

dissertation work of **Umarov Amantur Amangeldyevich**
on the topic “Developing a situational intellectual system control
mini greenhouses based on IoT devices ”,
granted for the degree of Doctor of Philosophy (PhD)
in the specialty 6D070200 - Automation and control

Analysis of the vegetable market of the Republic of Kazakhstan over the past decades has shown that a domestic producer can fully meet domestic demand by only 20%.

The main reasons for this situation are:

- - insecurity of domestic demand with products of own production;

- sharply continental climatic conditions and lack of water, which do not allow for year-round cultivation of vegetable products;

- a limited amount of irrigated land in the south of Kazakhstan allocated for the cultivation of vegetable products;

- not modern systems for growing vegetable crops;

- lack of developed infrastructure for processing vegetable crops.

Digitalization of agribusiness is a priority and relevant direction for the development of the agricultural sector of our economy and ensures the country's food security. The rapid decline in the share of the rural population and its aging pose problems for the state to consolidate and decent employment of rural youth by instilling skills and abilities of high-tech agro-industrial production.

The most important component of such transformation is the intensification of production, import substitution of supplies of early vegetables with a constant decrease in the difference in the comfort of life in the city and rural areas.

The emergence of budget microcontroller elements of micro and small automation allow expanding the areas of digitalization of the country's farms. This is facilitated by the active study of the basics of robotics and the Internet of Things based on AVR, ESP32 series microcontrollers in secondary schools and rural colleges. All this creates a fruitful ground for the technological integration of the domestic agricultural sector into the digital society.

The complexity of the development of smart greenhouses lies, firstly, in the difficulty of continuous monitoring of technological processes of the greenhouse and, secondly, in the complexity of modeling and describing the dynamic processes of the greenhouse.

Firstly, the control object under consideration is a plant, which is a biological system, which is a living organism that requires continuous self–care. In this regard, the monitoring and management process cannot be suspended and restarted, as in the production of machinery and equipment – it may die. A greenhouse as an object of management is an agroecological system of a closed type in which energy processes are not deterministic and do not have certain boundary conditions and allow growing crops taking into account changes in environmental parameters.

Secondly, the complexity of mathematical modeling of agroecosystem processes lies in the interaction of physical, chemical and biological parameters of the control object.

The dissertation discusses models and methods for developing a situational intelligent control system for a greenhouse based on IoT devices, as well as algorithms for decision support for managing technological modes of a greenhouse based on an expert system.

The relevance of the study lies in:

- development of domestic smart greenhouses that allow year-round production of agricultural products and are accessible to the general population;

- development of decision support algorithms depending on the current situation at the management facility (greenhouse);

- development of new measuring instruments and technological equipment for monitoring and control of technological processes based on IoT devices.

The object of the study is the processes of plant growth and development, the state of the environment (microclimate) inside the greenhouse during the growing season.

The subject of the study is the monitoring of plant growth and development processes, and the management of greenhouse technological modes based on modern intelligent technologies and IoT devices.

The purpose of the work is to develop a situational intelligent greenhouse process control system based on modern intelligent technologies and IoT devices and accessible to the public.

To achieve this goal, it is necessary to solve the **following tasks**:

- review and analysis of modern precision farming technologies, vegetable import market and consideration of Kazakhstan's climatic conditions, analysis of existing mathematical methods and models of smart greenhouse management;
- construction of a mathematical model of the "Plant-Environment-Situation-Management" system, which allows the formalization of the tasks of smart management of greenhouses in the form of an expert system;
- development of a technological scheme that allows performing technological modes;
- - development of the functional scheme of the iOS device, with the help of which the functional requirements for the system are fulfilled;
- development of a prototype of a smart greenhouse in the form of an IoT device that meets the Price-Quality criterion;
- comparative analysis of the model for different climatic conditions.

Research methods. Experimental methods of biology, methods of situational management and decision-making theory, fuzzy logic and neural networks were used to solve the scientific tasks set in the work.

The scientific novelty of the work includes five scientific provisions:

1) for the first time, a mathematical model of the ecosystem "Plant-Environment-Management" was constructed;

2) on the basis of the constructed model, the structure of a general expert system for situational management of a greenhouse is proposed;

3) on the basis of the constructed model, an algorithm/algorithms of intellectual decision support are proposed;

4) a technological scheme has been developed, which is implemented in the form of a semi-industrial prototype of a smart greenhouse;

5) the functional scheme of the IoT device has been developed, which allows fulfilling the set functional requirements for the system.

The practical significance lies in the application of a new technological scheme of an iOS device that provides functions for monitoring and fuzzy control of technological processes for controlling the growth and development of a plant in a greenhouse based on intelligent technology and IoT devices. The equipment includes: tank, irrigation valve, main pipeline, droppers, soil sensor, fan, temperature sensor, spotlight, light sensor, control unit, irrigation valve relay, fan relay, spotlight relay. The main element of the system is the Control unit (Control unit, control unit).

The technical result of the work consists in the application of a new technological scheme of an Ios device that provides functions for monitoring and fuzzy control of technological processes for controlling the growth and development of a plant in a greenhouse.

The researcher's personal contribution consists in analyzing the problems of greenhouse development in the conditions of the Republic of Kazakhstan (Articles 1, 2, 3, 4 and 5), researching methods and schemes for designing smart greenhouses based on PLC (Articles 6, 7, 8, 9 and 10), obtaining and processing data through the developed mobile application "Akyldy Zhylyzhay" (copyright certificate 11) and (patent 12); planning and execution of a biological experiment (articles 13, 14); development of a situational management model and decision support algorithms and writing software based on them (15, 16).

Implementation of the research results. The system model was implemented in greenhouses of Al-Farabi Kazakh National University (Almaty), Yasavi Moscow State Technical University

(Turkestan) and Ecoproduct (Aktobe). Based on the results of the implementation, proposals were formulated to the farmer in the form of recommendations for growing SHK depending on environmental conditions. The results of biological experiments are of great practical importance in the field of biology and agrotechnology.

As a result of the study, optimal conditions for growing cucumber hybrid “Asylym” were determined for all three regions. It was also concluded that under optimal environmental conditions, a process of normal, balanced growth and development of the plant is observed, and under non-optimal conditions, an uneven process of growth and development of the plant is observed. This conclusion fully reflects the basic law of biology and ecology – the Law of Optimum.

Publications. The topic of the dissertation is devoted to 16 scientific papers, including 3 in scientific publications of the KN of the Ministry of Education of the Republic of Kazakhstan, 1 in scientific publications of the KN of the Ministry of Education of the Russian Federation, 7 in the materials of international conferences, 2 in scientific journals included in the Scopus database, 1 - copyright certificate and 1 patent of the Republic of Kazakhstan.

Structure and scope of work. The dissertation consists of an introduction, five chapters, general conclusions, a list of references and an appendix. It is presented on 168 pages, including 85 figures, 40 tables and a list of references from 108 titles.

The first chapter is devoted to an overview of modern technologies in the greenhouse economy and the problem of importing vegetables in Kazakhstan. A review of mathematical models of the possibility of using intelligent technologies in greenhouses is carried out. An overview of the world's It technology manufacturers is briefly described. The chapter also discusses the main technological processes in modern greenhouses. The analysis of progressive technologies and the possibility of their application from the point of view of the price - quality criterion is given.

The second chapter describes the formulation of the research task and the principles of smart greenhouse management. Mainly, the influence of environmental conditions on the growth and development of plants is described and the optimum law is given – the most important law of biology, which plays a key role in this study. The formal description of the model of the system “Plant-Environment-Management", the formulation of the problem of technological management based on an expert system is given. To solve the control problem, the model is reduced to the tasks of fuzzy identification and classification of the Mamdani and Sugeno types. This chapter discusses the features of using the Plant-Environment-Situation-Management system model to identify the current situation on a daily time scale (task 1), identify an integral situation on a biological time scale (task 2), determine the moments of transition of phenophases (task 3) and situational management of agrotechnical measures (task 5) and algorithms for their solution are given.

The third chapter examines the methods and tools for researching the object of management. The goals and objectives of a biological experiment for studying the growth and development of plants in a greenhouse are determined. The experiment is carried out in the research greenhouse of the KazNU named after al-Farabi. The chapter describes the solution to the problem of regulator synthesis based on a fuzzy logic controller (NLC) for the “Plant-Environment-Situation-Control” system.

The goals and objectives of management are determined, the system configurations and functional requirements for the development of the NLC are selected, the NLC model is built (task 4), and also the functional diagram, the diagram of technological equipment and data collection and cloud storage for a smart greenhouse are selected.

The fourth chapter is devoted to a discussion of the results and optimization of control parameters. The description of experiments is given: a) on monitoring and control in real time using wireless and IoT technologies in a home greenhouse; b) on monitoring and control in real time using wireless and IoT technologies in the research greenhouse of KazNU named after al-Farabi.

The scheme of introduction of the "Agyldy zhylyzhai" installation into the research greenhouse of the KazNU named after al-Farabi, as well as a comparative analysis of the yield for the three greenhouses above. The evaluation of the performance of the developed system is determined.

The fifth chapter describes the principles of operation and operating instructions for the IoT device and the mobile application “Akyldy Zhylyzhay”, for which a patent and copyright certificate were obtained. The developed IoT device is a prototype of a smart greenhouse and meets the Price-Quality criterion. Conclusions and recommendations on the cultivation of agricultural crops are also formulated, depending on environmental conditions.

In the conclusion, the main results and conclusions of the dissertation are presented.

Confidence level and results of approbation. The validity and reliability of the study correspond to the justified responsibilities of the task, the analysis of the criteria and the state of research in this area, a large number of experiments carried out and their successful implementation in practice. The methods used in the study were aimed at solving the formulated goals and objectives of the study.

The main provisions and results of the work were reported at: XI International Conference "Mathematical, Physical Sciences and Engineering Applications", May 9-12, 2018, Davao, Philippines; XIX International Scientific and Technical Conference "Problems of Engineering and Telecommunication Technologies", May 16-18, 2018, Uralsk, Kazakhstan (2 reports); IV International Conference of Young Scientists "Prospects for the Development of Science and Education", December 10, 2018, New York, USA; IV International Conference "New Trends in Engineering, Science and Technology" (ICETEST-2020), February 26-27, 2020, Bangkok, Thailand; International scientific conference in the field of Information technologies dedicated to the 75th anniversary of professor U. Tukeyev, October 8, 2021, Almaty, Kazakhstan; scientific seminar of the Faculty of Automation and Computer Engineering, Novosibirsk State Technical University, March 13, 2020, Novosibirsk, Russia.

16 scientific papers have been published on the topic of the dissertation:

1. Ауылдың рухани жаңғыруы: шағын жылыжайлар // “Қазақ үні” Республикалық қоғамдық саяси газеті – ұлттық портал. 2018/07/17. https://qazaquni.kz/2018/07/17/87636.html.

2. Исследование температурного режима минитеплицы для условий Казахстана // Вестник Национальной инженерной академии наук Республики Казахстан. - Алматы. 2018. – № 2(68).

3. Systems for monitoring and controlling the parameters of the microclimate of greenhouses: a review of the current state and analysis of the directions of development // Abstracts of the International Conference "The 11th Dynamical systems, Mathematical, Physical Sciences and It's Engineering Applications", March 28-30, 2018, Bali, Indonesia,

4. A review of the current state and analysis of the directions of development // Abstracts of the International Conference "The 11th Dynamical systems, Mathematical, Physical Sciences and It's Engineering Applications", March 28-30, 2018, Bali, Indonesia.

5. Жылыжайдағы микроклимат параметрлерін бақылау және басқару жүйелерінің модельдері: қазіргі күйіне шолу және даму бағыттарын талдау // Материалы XIX Международной научно-технической конференции «Проблемы техники и технологий телекоммуникаций» (Республика Казахстан, г. Уральск: КазИИТУ, 16-18 мая 2018 года). — Уральск: КазИИТУ, 2018 — 384- 397 с.

6. Микроклимат жүйелерін жобалау ерекшеліктері. Материалы XIX Международной научно-технической конференции «Проблемы техники и технологий телекоммуникаций» (Республика Казахстан, г. Уральск: КазИИТУ, 16-18 мая 2018 года). — Уральск: КазИИТУ, 2018, 397- 405 с.

7. Exergy Calculation Analysis Of Differing Solar Collector Systems In Various Climate Conditions Of Kazakhstan //Journal of Engineering and Applied Sciences 14 (20): 7709-7713, 2019.

8. Relay Law of Management by a Mini-Hothouse // The 4th International youth conference “Perspectives of science and education”, New York: Premier Publishing, USA (2018). 41-47.

9. БЛК негізінде жасалған ЕИМ контроллерінің моделі // ҚР Ұлттық инженерлік ғылым академиясының хабаршысы. Алматы. 2019. – № 2(72), 35-42 с.

10. “Microclimate Monitoring System for a Home Greenhouse as Part of ESP32” 4th International Conference on Emerging Trends in Engineering, Science and Technologies (ICETEST-2020), Bangkok, Thailand 26th – 27th February’ 2020.

11. Авторское свидетельство “Ақылды жылыжай” // Программа для ЭВМ № 7578 от 17.01.2020.

12. Патент на полезную модель «Домашняя смарт-теплица» Рег. №2019/1162.2 от 30.12.2019.

13. Проектирование смарт теплицы, удовлетворяющей критерию цена – качество // Вестник КазНУ. Серия математика, механика, информатика, N.1(105), 2020.

14. Разработка «умной теплицы» на основе модели «Растение–Среда–Ситуация–Управление» Сборник научных трудов НГТУ. – 2020. – № 3 (98). – 49–64.

15. “Smart greenhouse and plant growth control” // Periodicals of Engineering and Natural Sciences. Vol. 9, No. 3, July 2021, pp. 474-493.

16. Ситуационная экспертная система “Ақылды жылыжай” // Материалы Международной научной конференции в области информационных технологий, посвященной 75-летию профессора У.А. Тукеева. Алматы, 8 октября 2021 г.: – Алматы: Қазақ университеті, 2021. – 109-115 с.