

## ABSTRACT

Dissertation work for the degree of Doctor of Philosophy (PhD) in the specialty 6D075100 – "Computer science, computer technology and management"

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“Development of information system for monitoring granaries based on contactless 3D measurements”

President – Leader of the Nation Nursultan Nazarbayev noted the importance of transferring the agro-industrial complex to innovative rails in his Message to the People of Kazakhstan "Kazakhstan's Way-2050: Common Goal, Common Interests, Common Future." The president, in particular, said: “Competition in global agro-production will increase. First of all, those who introduce new technologies and continuously increase productivity must work on the ground, working on the basis of the best world standards”. The implemented intellectual solutions and technologies in many industries have significantly improved productivity, product quality, resource efficiency and optimized process control. In this regard, work is underway on the introduction of new equipment and technologies in the agro-industrial complex of the Republic of Kazakhstan. However, most of the developments are the computerization and automation of accounting.

Foreign companies in the issue of implementing intelligent solutions in the agro-industrial complex have advanced further. For example, in China, modern grain storages are being produced, which provide for monitoring the upper and lower levels of grain loading, as well as thermal hangers for continuous monitoring of the temperature of the grain mass and the ventilation control system for cooling the grain. The Italian company TECNOIMPIANTI offers sectional grain storages that are not sufficiently automated, as they include only automated control systems for loading, distribution, unloading, ventilation, temperature and humidity control. There are companies in the CIS that are engaged in the design and supply of components for the automation of granaries, but their technical solutions are limited to a narrow range of tasks and do not exclude human involvement in the management process, so they can be considered insufficiently effective.

It is necessary to introduce intellectual technologies into automation processes and increase the efficiency of storing agricultural products to ensure food security and stable economic development of the country, especially given the conditions for increasing competition from foreign grain producers.

**The relevance of the topic of the dissertation research.** One of the leading directions of modern development of information systems is the automation of management and control of technological processes. Solving such problems allows reducing the influence of the so-called human factor and, accordingly, improving the quality of products and optimizing operations in the storage of raw materials.

Studies on the automation of technological processes are also conducted in the field of agriculture. The North Kazakhstan region is one of the leading agrarian regions of the country (it provides a third part of the total production of grain and

oilseeds in Kazakhstan), therefore, research in the field of automation of agro-industrial tasks and, in particular, monitoring processes of granaries in order to ensure the grains are relevant. Usually, quantitative and qualitative preservation of grain is carried out in the form of a visual inspection of grain storage sites. However, the results of the practice showed that the prevailing traditional forms of granary work reveal such global problems as the theft of grain and the preservation of the quality of grain.

In the laboratory of M.Kozybayev North-Kazakhstan State University, an experimental model of an innovative type granary was developed using horizontal silos, described in the innovation patent of the Republic of Kazakhstan No. 25280 dated December 8, 2011. Using horizontal silo technology will help reduce the cost of building and renovating grain storage elevators while improving quality, increasing shelf life and reducing current storage costs. This will help reduce the cost of Kazakh grain and increase its competitiveness.

In connection with the foregoing, the development of an effective information system for monitoring a granary with horizontal silos is relevant. The developed system will carry out quantitative control of the loading, storage and unloading of the granary, monitor the quality of the safety of the grain according to the results of measurements of temperature, humidity, carbon dioxide level and, if necessary, issue notifications about the violation of the process. In the presented scientific research it is supposed to develop an information system allowing automation of the technological process of grain storage.

The **purpose of the research** is to develop methods, tools and algorithms for the operation of the information system for monitoring a granary with horizontal silos based on temperature, humidity, carbon dioxide levels and non-contact 3D measurements of the grain surface. The peculiarity of the system is to automate the transitions between the operations of the technological process of a granary with horizontal silos and active monitoring, that is, control and management of the operations themselves.

In accordance with the chosen method of achieving the goal, the following **research objectives** are formulated:

- analysis of the current state of theoretical and applied research in the field of automation of technological processes of granaries;
- analysis of the possibility of using existing solutions for automated measurement of the amount of grain mass in the granary;
- development of a method for automatic registration of 3D measurements to obtain quantitative characteristics of the embankment formed during the operation of loading, mixing and unloading into the granary;
- development of algorithms for processing information about the spatial coordinates of surface points and calculating the quantitative characteristics of the embankment on their basis;
- study of the technological process of storage of grain in the granary of the innovative type;
- design of the information system that automates the quantitative and qualitative monitoring of a grain silo with horizontal silos and generating control

signals to the executive equipment;

- development of algorithms that carry out information and mathematical support of the operating modes of the control object;
- development of the automated information system for monitoring a grain silo with horizontal silos based on the parameters of temperature, humidity, carbon dioxide level and non-contact 3D measurements of the grain surface.

The **object of the research** is the technological process of an innovative type granary with horizontal silos, covering work operations from the acceptance of grain to its unloading from the silo. A prototype of the granary was created in the framework of scientific research team of scientists in M.Kozybayev NKGU and implemented in the production process of LLP "Firma Dikanshy".

The **subject of the research** is models, methods and algorithms for the implementation of active monitoring of parameters that influence the process of a grain silo with horizontal silos.

**Research methods:** analytical studies, analysis and synthesis, computer modeling and design, the use of methods for calculating and designing intelligent systems. In the process of implementation of the dissertation research, methods of processing and displaying digital information, automation equipment based on wireless information transfer systems, and testing during the operation of an experimental portable granary will be applied.

**Scientific novelty:**

- the innovative method has been developed to automatically register 3D measurements of the grain surface in the storage, which can be used to recognize the surfaces of other bulk objects;
- the method has been developed for creating a 3D-meter for automated receipt of a set of surface points;
- algorithms have been developed for processing information on the spatial coordinates of surface points formed in a granary as a result of loading, unloading or mixing operations;
- algorithms have been developed for calculating the maximum height of the embankment and the volume of grain on the basis of contactless 3D measurements in an innovative type granary;
- model of the information system for monitoring and process control of a granary with horizontal silos based on the parameters of temperature, humidity, carbon dioxide level and 3D measurements of the grain surface has been developed;
- methods and algorithms have been developed that carry out mathematical and information support for the operation modes of a grain silo with horizontal silos, including using the theory of identification measurements.

**Practical significance:**

1. The system has been developed for 3D measurements of spatial coordinates of surface points of a grain mass formed as a result of filling a granary. The application of the method of obtaining the coordinates of surface points allows continuous monitoring of the quantitative preservation of grain.

2. The automated information system for monitoring a grain silo with horizontal silos was developed based on the parameters of temperature, humidity, carbon dioxide level and 3D measurements of the grain surface. This information system will allow you to process the measurement results, to give the results of the analysis in the form of control signals to the transport equipment and notifications on the operation of the granary.

3. The models developed in the course of the dissertation research, methods and algorithms can be used in the development of information systems for monitoring and managing other objects that make up the agro-industrial complex.

**Approbation of the results.** Materials of the thesis were reported to :

- III International Scientific Conference "Mathematical and Computer Modeling", Omsk, Russian Federation, 2015;
- International scientific conference "Remote sensing of the Earth and photogrammetry, environmental monitoring, geo-ecology", Novosibirsk, Russian Federation, 2016;
- XII International scientific-practical conference "Science without borders", Sheffield, England, 2016;
- XIII International Scientific Congress "Machines. Technologies. Materials. 2016", Varna, Bulgaria, 2016;
- International scientific-practical conference "Ualihanov readings-20", Kokshetau, Republic of Kazakhstan, 2016;
- International scientific and technical conference "Dynamics of systems, mechanisms and machines", Omsk, Russian Federation, 2016;
- IV International Scientific Conference "Mathematical and computer modeling", Omsk, Russian Federation, 2016;
- V International Scientific Conference dedicated to the memory of R.L. Dolganov "Mathematical and computer modeling", Omsk, Russian Federation, 2017;
- Seminars of the department "Information Systems" of M. Kazybaev North Kazakhstan State University.

Scientific studies presented in the dissertation were conducted within the framework of grant financing of the Ministry of Education and Science of the Republic of Kazakhstan on the subject "Development of the intelligent system for remote monitoring and management of the technological process of storing grain in the innovative type granary".

Developed in the framework of the thesis, the 3D measurement system based on the use of stationary cameras and lasers, as well as algorithms, methods for determining the volume of the grain mass and process control obtained positive results in the production environment of Firma Dikanshy LLP.

**The main scientific provisions that are put in defense of the thesis.**

The method for automatically registering 3D measurements of surface points formed in a granary as a result of technological operations. Algorithms for recognition of three-dimensional coordinates of points on the surface of the grain. Method and algorithms for calculating the quantitative characteristics of a grain mound in the storage: height of the embankment and volume.

Mathematical and informational support of the information system for monitoring and managing a grain silo with horizontal silos. Algorithms support the functioning of the technological process of storing grain.

**Personal contribution of the author.** The results of the research presented in the dissertation were obtained by the author independently.

**Publications on the topic of dissertation research.**

On the topic of the thesis 21 scientific works were published. Of these, in the journals included in the Scopus and Web of Science databases – 2, in Kazakhstan editions recommended by the Committee on Control and Science of the Ministry of Education and Science of the Republic of Kazakhstan – 3, in the Russian edition with impact factor RINTS – 1, monograph – 1, in the Russian edition of the Global Impact Factor – 1, in the publications of foreign countries – 2, in the materials of international conferences in the Republic of Kazakhstan – 2, in the materials of foreign international conferences – 9 (of which 1 in the Scopus and Web of Science databases).

**The structure and scope of the dissertational work.** The thesis work is presented on page 141, consists of an introduction, four chapters, conclusion, a bibliography (143 titles), 5 applications.

The introduction justifies the relevance of research carried out in the framework of this dissertation work, formulates the goal, problem statement, scientific novelty and practical significance of the work.

In the first chapter, an analysis of the current state of theoretical and applied research in the field of automation of technological processes of granaries was carried out, the problem was formulated with the definition of the information system in the technological process of the granary, the characteristics of the automation object, a grain silo with horizontal silos, were considered, and the possibilities of using existing solutions were considered for automated measurement of the surface of the grain in the granary.

The second chapter is devoted to organizing and automating the registration process of 3D measurements using an innovative 3D meter device, for which a method of creating and methods for obtaining measurements of grain surface points was developed, as well as methods and algorithms for obtaining quantitative characteristics of embankments based on them.

In the third chapter, the technological process of granary of innovation type with horizontal silos was studied; functional research and design of an information monitoring and control system based on temperature, humidity, carbon dioxide levels and 3D measurements of the grain surface were performed on the results of the study.

The fourth chapter presents the results of the development of an information system for monitoring and managing a grain silo with horizontal silos in the form of a data flow model, algorithms that support the operation of the technological process, the physical structure of the data warehouse and the user interface, and also presents the test results of the experimental implementation of the 3D measurement system in production during the operation of the granary of Firma Dikanshy LLP.