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MODELING THE INFORMATION SYSTEM "SMART FARM" USING AUGMENTED REALITY FOR AGRICULTURE

MODELOWANIE SYSTEMU INFORMATYCZNEGO „INTELIGENTNE GOSPODARSTWO" Z WYKORZYSTANIEM ROZSZERZONEJ RZECZYWISTOŚCI DLA ROLNICTWA

***Summary**: Year after year, agriculture increasingly utilizes smart technologies to solve production tasks. These technologies are often used in specific agricultural sectors or technological processes. Climate change and rising prices for plant protection products, fertilizers, fuels, and lubricants are driving the need for comprehensive implementation of smart technologies in farm operations, which will enable agricultural management at a new, higher level of quality. Smart farm technologies enable rapid data collection, increasing the level of monitoring and control over all areas of operation. Smart technologies are actively used in various types of farms, but the potential use of augmented reality as a potential element of this process has not yet been sufficiently explored. Augmented reality can help farmers combat pests. Augmented reality has potential in precision agriculture. Some elements of augmented reality are present in the functionality of modern agricultural machinery. Although agriculture has historically been characterized by a slower pace of technological innovation, the decline in their costs has accelerated the implementation of smart technologies, including augmented reality, in agriculture. The research substantiates the structure of the "Smart Farm" IT system using augmented reality and presents its description. The new feature of the article is the proposed directions for the transformation of the "Smart Farm" IT system, taking into account the potential challenges and opportunities of digital transformation of technological processes in agriculture.*

***Keywords**: Information systems, modelling, smart farm, augmented reality, agricultural enterprise*

Streszczenie: Rolnictwo z roku na rok coraz częściej wykorzystuje inteligentne technologie do rozwiązywania zadań produkcyjnych. Technologie te są często stosowane w określonych sektorach rolnictwa lub procesach technologicznych. Zmiany klimatyczne i rosnące ceny środków ochrony roślin, nawozów, paliw i środków smarnych wymuszają potrzebę kompleksowego wdrożenia inteligentnych technologii w działalności rolniczej, co umożliwi zarządzanie rolnictwem na nowym, wyższym poziomie jakości. Inteligentne technologie rolnicze umożliwiają szybkie gromadzenie danych, zwiększając poziom monitorowania i kontroli nad wszystkimi obszarami działalności. Inteligentne technologie są aktywnie wykorzystywane w różnych typach gospodarstw rolnych, ale potencjalne wykorzystanie rzeczywistości rozszerzonej jako elementu tego procesu nie zostało jeszcze wystarczająco zbadane. Rzeczywistość rozszerzona może pomóc rolnikom w walce ze szkodnikami. Rzeczywistość rozszerzona ma potencjał w rolnictwie precyzyjnym. Niektóre elementy rzeczywistości rozszerzonej są obecne w funkcjonalności nowoczesnych maszyn rolniczych. Chociaż rolnictwo historycznie charakteryzowało się wolniejszym tempem innowacji technologicznych, spadek ich kosztów przyspieszył wdrażanie inteligentnych technologii, w tym rzeczywistości rozszerzonej, w rolnictwie. W artykule uzasadniono strukturę systemu informatycznego „Inteligentne Gospodarstwo" wykorzystującego rzeczywistość rozszerzoną oraz przedstawiono jego opis. Nowością w artykule są proponowane kierunki transformacji systemu informatycznego „Inteligentne Gospodarstwo", uwzględniające potencjalne wyzwania i możliwości cyfrowej transformacji procesów technologicznych w rolnictwie.

Słowa kluczowe: Systemy informatyczne, modelowanie, inteligentne gospodarstwo, rzeczywistość rozszerzona, przedsiębiorstwo rolne

Introduction

Farmers and large agricultural companies around the world are increasingly using smart technologies to solve production tasks. The use of smart technologies occurs under the influence of processes related to climate change and rising prices for plant protection products, fertilizers, fuel and lubricants, gas, etc. Farmers, using smart technologies comprehensively or partially, have the opportunity to effectively manage agriculture, reducing costs and losses in economic activity.

Precision farming systems can reduce the use of harmful chemicals and carbon emissions. Effective application of the smart farming system will help the owners of agricultural land to adapt to climate change while maintaining the appropriate level of productivity in production.

In general, there are a number of problems in the development of information systems and applications for agriculture related to the integration of smart technology with other modules of the information system used by the agricultural enterprise.

There are some differences in the application of smart technologies by farmers, depending on the products they produce. The use of smart technologies in agriculture also depends on the technological development and digital culture of the countries where the farm is located. One of the obstacles to the effective implementation of smart farming in rural areas is the poor quality of connectivity (digital divide) [1].

In the countries with a high level of development and application of information technologies, it is possible to observe a wider application of smart technologies in agriculture. An example of this is augmented reality technology, which can help solve a number of production tasks in a farmer's activity.

Problems related to the development, implementation, and use of smart technologies in information systems and activities of agricultural enterprises have been studied in scientific articles by many scientists around the world [1-6]. However, not all tasks related to using innovative information technologies such as "Smart farm" for agriculture, have been considered and displayed in scientific publications. Scientists prove that smart technologies do not suffice on their own. They need to be intelligently combined to provide meaningful information to the farmer in near real time.

A review of scientific works on this issue showed that a lot of research is devoted to the problems of the practical application of the smart farming system for agriculture, data collection, and processing in agriculture [7-9, 25-26, 31]. Scientists use a variety of methods and models related to the implementation of smart farming in agriculture. The issue of real-time data processing, and the use of an artificial intelligence system when working with data coming from the fields, during harvesting, or animal care is being investigated.

Many scientific studies are devoted to the issue of using augmented reality in agriculture and creating useful knowledge based on it for solving operational tasks [10-11, 13-24, 30]. Scientists raise the issue of innovative technologies of data collection and processing, which focuses on two interrelated processes: management of operations in agriculture and decision-making.

At the same time, it is difficult to answer to what extent smart farming systems are resistant to new tasks related to the increase in the use of smart technologies (including augmented reality technologies), and their integration into existing information systems.

Agricultural producers at any stage of the company's activity can decide to apply the comprehensive information system "Smart Farm" based on precision farming systems, or partially implement smart technologies in production. Smart technologies are actively used in various types of farms, however, the prospects of using augmented reality as a potential component of the information system have not been sufficiently studied before.

A promising direction for the use of smart technologies by farmers is the improvement of the decision-making process, decision-making based on data obtained almost in real time. In previous studies [12], it was taken into account that the use of modern technological solutions by an agricultural producer requires making changes in the planning module, based on possible scenarios of the development of an agricultural enterprise. At the same time, there is a need to improve the existing model of the "Smart Farm" generalized information system, which would be resistant to changes, and foresee the prospects of applying new innovative technologies in agriculture using the example of augmented reality technology.

This led to the expediency of substantiating the approach and model of the "Smart Farm" information system with augmented reality, taking into account production processes in agriculture and possible technological solutions to the tasks.

The purpose and objectives of the study

The goal of the study is to model and substantiate the structure of the "Smart Farm" information system using smart technologies, including augmented reality, which will take into account potential challenges and opportunities of digital transformation of technological processes in agriculture. To achieve this goal it is necessary to solve the following tasks:

– to substantiate the structure of the information system “Smart Farm”, based on the characteristics of the subject area and planning in terms of changes in information data flows;
– to improve the process of modeling the architecture of the information system “Smart Farm” using augmented reality for agriculture, taking into the potential challenges and opportunities of digital transformation of technological processes in agriculture.

Materials and methods

The use of smart technologies in agriculture is one of those advantages that allow agricultural companies to be competitive in the market. Digital transformations in society have a positive effect on the fact that agricultural companies willingly invest their funds in technologically advanced tools. Smart technologies such as precision agriculture, smart agriculture, artificial intelligence, the Internet of Things (IoT), and big data analytics are popular in agriculture. Augmented reality technology is just beginning to be actively used in rural enterprises. Analytical studies show that global augmented reality in the agriculture market was valued at $0.84 million in 2021 and is projected to reach $4.89 million by 2027 [17]. The adoption of augmented reality can reduce large extra costs and facilitate many processes by providing farmers [24].

The main feature of augmented reality technology is that it superimposes a computer-generated image on the user's real world, thus providing a relevant image for the user. Augmented reality can help farmers fight pests, and has prospects in precision agriculture [13]. Some elements of augmented reality are present in the functionality of modern agricultural machinery.

Fig. 1. Augmented reality in agriculture: challenges and opportunities [own study]

The use of augmented reality in agriculture will grow every year, but there are a number of factors that can affect this (Fig. 1).

The augmented reality and other intelligent technologies are progressing in the world and have already been implemented in many industries, including agriculture.

Agricultural entrepreneurs are still afraid to invest in technology because they simply do not know the full range of possibilities of augmented reality. Despite the fact that agriculture used to be characterized by a slower rate of introduction of innovative technologies, the decrease in their cost has accelerated the process of applying smart technologies, including real augmented ones, in agriculture.

A new employee can practice certain scenarios in game mode and train their skills, using virtual and augmented reality. Virtual reality helps in recreating a 3D work environment [27]. Virtual training recreates a real working environment. An employee can carry out pre-planting field processing or harvesting in augmented reality.

Farmers can conduct a survey of the field using virtual reality. There is often a need to obtain reliable information about temperature, soil moisture, plant condition, fertilizer requirements, and fruit maturity. An agronomist can get all the necessary data by pointing to a smartphone or other device with augmented reality software. Augmented reality in agriculture helps improve pest/insect inspection and detection [28].

Augmented reality (AR) and virtual reality (VR) are leading segments in the extended reality market [29]. These technologies are based on the concepts of spatial computing. Agricultural enterprises use different types of augmented reality (Fig. 2).

Some elements of augmented reality are present in the functionality of modern agricultural machinery. Farmers through Augmented Reality in agriculture are able to receive instructions for repairing this machinery. Livestock monitoring applications are the most promising segment of augmented reality for agriculture.

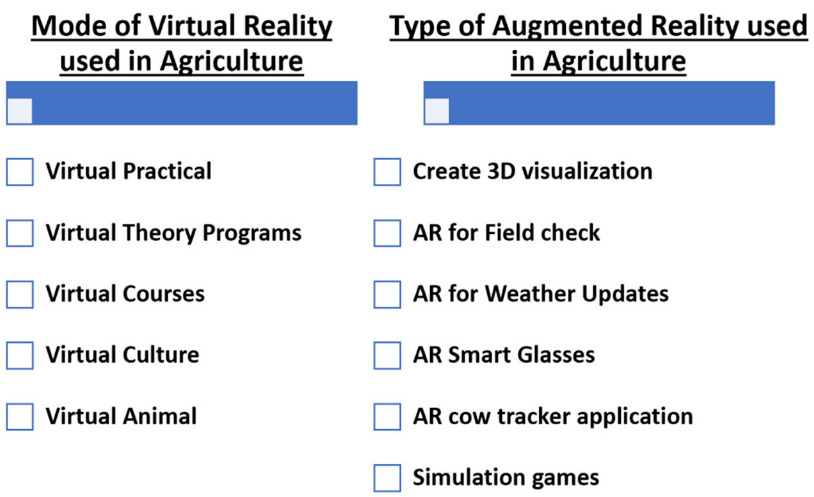

Fig. 2. Virtual and Augmented Reality for Agriculture [own study]

Results and discussion

Smart farming combines these components: sensors, IoT (Internet of Things) devices, data analytics, autonomous robots and drones, and software applications. Augmented Reality technology as an effective component can be integrated into the information "Smart Farm" (Fig. 3).

The implementation of an integrated approach to the development and modeling of the information system, the use of intelligent technologies and augmented reality in agriculture as a source of new data in the agricultural industry can lead to the emergence of new components of Smart Farm Management Software.

These modules can be related to data processing in crop and livestock production: land accounting, visual analysis of field location, satellite image processing, field research using mobile applications, GPS equipment monitoring results, GIS technologies and cartograms, meteorological observations, technological maps, livestock management and monitoring (Fig. 4).

Software using augmented reality can be included and integrated into the "Smart Farm" information system. The development of an effective and high-quality information system with an augmented reality "Smart Farm" taking into account all possible directions of digital transformation of farming will allow effective agricultural plan development to be made in the future.

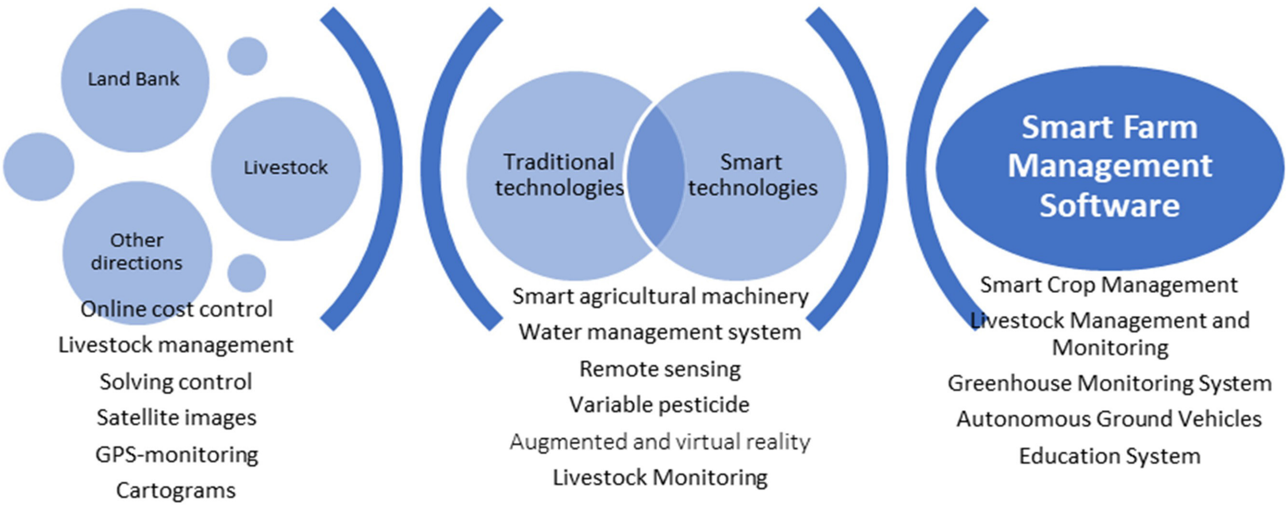

Fig. 3. Augmented Reality as a component of Smart Farm Management Software [own study]

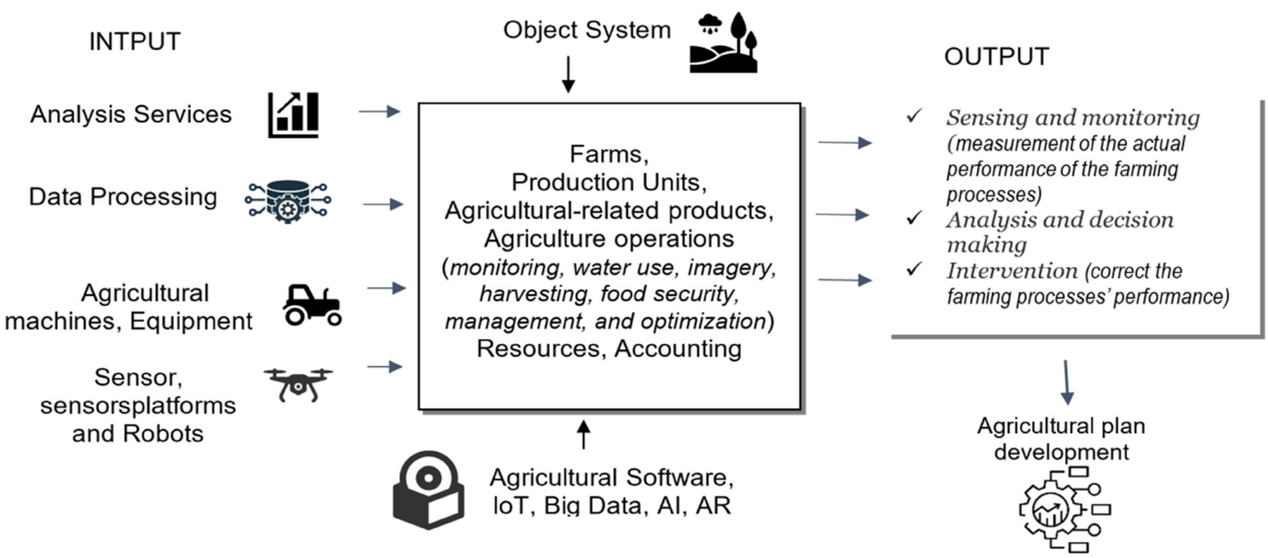

Fig. 4. Software components of an information system "Smart Farm" [own study]

The main result of the information system "Smart Farm" will be a measurement of the actual performance of the farming processes, analysis, comparison objectives, and correct farming processes' performance.

Integration and improvement of information systems for smart farming can contribute to the development of agriculture. After studying agricultural patterns with augmented reality, farmers can learn more about crops and their protection methods and reduce crop losses.

Modeling the information system "Smart Farm" on the basis of scenarios of society and enterprise digital transformation, changes in the modules, devices, and data collection will involve the following steps:

1. Description of requirements, business processes, and goals of digital transformation of an agricultural enterprise.
2. Assessment of the current state of application of smart technologies and determination of the stages of digital transformation of agricultural processes in the short- and medium-term perspective.
3. Defining the information model of the software used by the agricultural enterprise at the moment. Assessing the benefits and limitations of smart farming equipment.
4. Selection of optimal methods and technological solutions to ensure data security and stable operation of the information system.
5. Assessing the compliance of the software architecture in accordance with possible scenarios, and the ability to make changes so that the script can be executed.
6. Identifying the necessary changes in the model of the information system "Smart Farm".
7. Assessing the modeled information system "Smart Farm".

The development of an effective and high-quality information system for smart farming with augmented reality will involve the use of tracking technology, human-computer interaction technology, data storage, and access technology. The development and application of mobile augmented reality can accelerate the digital transformation of agricultural enterprises.

Conclusions

Information systems currently used in agriculture are increasingly using various smart technologies. Smart technologies make it possible to increase the efficiency of agriculture, reduce costs, and increase the yield of crops.

Augmented reality and other smart technologies are progressing in the world and already find implemented in many industries including agriculture.

1. Our rationale for the "Smart farm" information system model includes components related to the types of smart technologies currently popular in agriculture and trends in digital transformations of agrarian enterprises. Information systems, modeled taking into account the possible directions of digital transformation of farming, will allow effective management decisions and a development plan to be made.
2. Farming entrepreneurs are still fearful of investing in technologies as they do not simply know the full spectrum of augmented reality possibilities. Despite the fact that agriculture used to be characterized by a slower rate of introduction of innovative technologies, the decrease in their cost has accelerated the process of applying smart technologies, including augmented reality in agriculture.

The results of this study will be useful to the scientific community to understand the use of augmented reality as a component of the information system of smart farming. The process of modeling the information system has been improved, taking into account the positive and negative factors of the digital transformation of agricultural enterprises and a comprehensive approach to the use of smart technologies in agriculture.

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