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APPLICATION OF THE INTERNET OF THINGS IN AGRICULTURE

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Abstract

The development of information technologies expands the possibilities for economic growth and the development of the digital economy. A new direction in the agricultural sector such as smart (precision) agriculture with technologies such as the Internet of Things, computer vision and artificial intelligence can improve agricultural efficiency, transparency, profitability and equity for farmers in low- and middle-income countries. This paper presents an overview of the main challenges in agriculture at the current stage of development, an analysis of the perspectives of using the Internet of Things in the agro-industrial complex, an examination of the main technologies and drivers of development, as well as an analysis of the barriers that hinder the spread of digital technologies in agriculture. In other words, the aim of the paper is to analyze the current development of digital technologies in agriculture in general, and especially in the development of the Internet of Things – IoT.

Key words: Smart (precision) agriculture, digital technology, information technology, internet of things.

Introduction

The industrial revolution took place in stages, and the first industrial revolution used water and steam power to mechanize production. The second was based on the use of electricity for mass production. The third stage is the use of electronics and information technology to automate production.

Today, the Fourth Industrial Revolution is built on the Third, the digital revolution that has emerged since the middle of the last century. It is characterized by the merging of technologies, which leads to the blurring of the boundaries between the physical, digital and biological spheres.

The concept of Industry 4.0 is based, above all, on the use of the Internet and information (IT) and communication technologies. In this regard, with the combination of modern information technology and traditional agriculture, the era

of agriculture 4.0 began, which takes the form of smart or precise agriculture. This concept transforms traditional agriculture into a modern one, based on innovation and high technologies, such as artificial intelligence, robotics, machine learning. These are intelligent systems that enable the prediction of requirements from the environment, which are often complex and unknown (Karadžić & Babić, 2005).

For developed countries, the agriculture and industrial sectors continue to face challenges such as the demands for increased productivity and food production, as well as the development of employment opportunities for people from poor and rural areas. The agricultural sector is affected by economic trends, as well as rapid changes. Various studies have shown that there is a strong demand for IT used to solve problems as well as to improve and increase agricultural productivity and marketing. But the interest of IT for agriculture has not been fully exploited. The introduction of information technology in the rural and agricultural sector is quite slow compared to other economic sectors where modern information technology is being incorporated at a faster rate.

The development of information technologies has had a significant impact on the agriculture of highly industrialized countries. Over the past few years, a number of new technologies and industry-specific applications have emerged, including the increasing agricultural application of mobile communication devices and technologies. Providing Internet access for every individual, especially for those living in rural areas (e-Rural), is among the first priorities of the European Union's research and development program for information society technologies (Szilágyi, 2012). According to research development and application trends, as well as predictions and expectations, these technologies and services will become widely applied tools to enhance business innovation and support business management.

The Food and Agriculture Organization of the United Nations (FAO) reports that, compared to 2010 levels, global food production needs to increase by 70% before 2050 to feed the growing world population, which is expected to reach between 9.4 and 10.2 billion (FAO, 2009). We need to achieve this goal despite the fact that the amount of arable land is not increasing, diets are changing, demand for water is increasing, the climate is changing, and both the environment and soil health are under pressure. It should also be noted that the majority of the population is rural, and more than 70% of farmers are small producers (Lowder et al., 2016).

The challenge of growing agriculture in any country is great, not only to meet the increased demand for food, but also to reduce hunger and malnutrition. The issues are therefore complicated because the growth of the agricultural industry, taking into account the preservation of the environment, should take place in a sustainable manner. In the current situation, farmers face smaller profit margins, the costs of many inputs such as fertilizers and fuels have risen, while the prices of products have been fairly stable, or fallen. Lowder et al., (2016) states that of the total number of farms (570 million) in the world, 72% belong to farmers who cultivate land on less than 1 ha of land, whose products are for their own needs. The fact that agriculture is a significant driver of economic growth and is key to

the total gross domestic product (Mellor, 2017), farmers must invest in their business, produce and market.

Therefore, the introduction of high technologies for the processing of big data, the use of unmanned vehicles, self-driving vehicles, the use of sensors can modify agricultural farms into smart farms. Therefore, the aim of the paper is to point out the importance of introducing new technologies in the agricultural sector.

What is the Internet of Things - IoT?

The Internet of Things is a new and currently the fastest developing area of information technology. Many authors state that IoT is a technological revolution, which represents the future of computing and communication. The development of IoT depends on technical innovations in numerous areas, from wireless to nano-technology.

The Internet of things (IoT) is defined in many ways. The shortest definition is IoT represents a network that connects smart things. That is, it forms a platform that connects devices, objects, and people via wired and wireless networks, and with the obtained data, analyzes can be performed with or without human activity.

Radić et al., (2022) define IoT as a set of technologies in which physical objects interact with the digital world. This enables the connection of a large number of users, devices, services and applications to the Internet, which implies the exchange of data directly or indirectly. Also, according to the same authors, IoT devices include: sensors, actuators, modules, microcontrollers and microcomputers. The basis of starting IoT is computer components and web and/or mobile applications, with the help of which data from the physical world is collected directly from sensors or communication devices to the software platform, for further use and use of the obtained data.

In general, the goal of IoT is the integration of the virtual world with the physical world, using the Internet as a communication medium. The Internet of Things is practically feasible with several existing technologies, such as wireless sensor networks, radio frequency identification, cloud computing, and end-user applications (Figure 1).

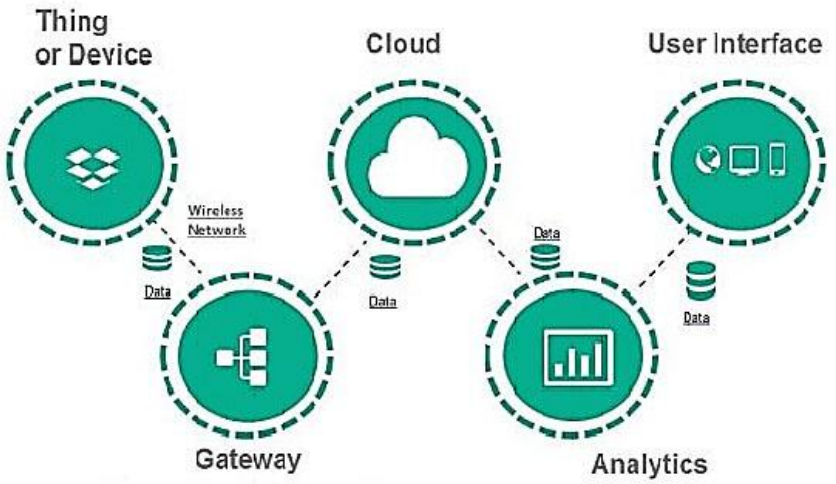

Figure 1. Major components of IoT (https://www.rfpage.com/what-are-the-major-components-of-internet-of-things/ - accessed on 06/28/2023)

Digital technologies and IoT in agriculture

The creation and development of digital technology based on the Internet of Things (IoT) has changed almost every industry, including agriculture (Bonneau and Copigneaux, 2017). The use of data in agriculture leads to the development of a new direction in agriculture, which is called smart or precision agriculture. According to the available literature, the definition of smart agriculture refers to a management concept focused on providing infrastructure to the agricultural industry to use advanced technology – including big data, cloud and Internet of Things – to monitor, observe, automate and analyze operations, as well as software and sensors. Smart agriculture is gaining importance due to the combination of a growing global population, increasing demand for higher crop yields, the need for efficient use of natural resources, monitoring of climate conditions and the increasing use of modern information and communication technologies.

Agricultural farms have historically not used high technologies, but by 2025 they are planned to significantly increase their use to millions of gadgets. The reason for this is the increasing urbanization of the world population, where it is predicted that by 2050, 70% of the population will be urban compared to the current situation, which is 49% (UN, 2018). This implies an increase in the demand for food, and food production should double by 2050 (UN, 2009).

The Internet of Things (IoT) is a key technology in smart agriculture as it enables networking and data exchange between sensors and other devices, which adds value to information obtained through automated processing, analysis and access, enabling faster and more cost-effective farm management (Rechkin et al., 2019).

The use of precision agriculture technologies based on the Internet of Things is the consequence of increasing yields on a large scale. For the first time in history,

it became possible to obtain information about any agricultural object, create an accurate mathematical algorithm of actions and make a forecast of the results. The main innovative solutions that characterize the concept of intelligent agriculture are: precise agricultural production; unmanned land vehicles; autonomous wireless sensors; simulation of digital management; cloud technologies.

According to Radić and Radić (2021), the basic digital technologies in agriculture are the so-called sensor technologies, such as temperature, humidity and soil scanners, field weather stations, yield mapping, satellite, drone or aircraft imagery, and the Internet of Things.

Thanks to the development of IoT, with the help of digital technologies, it enables the monitoring and collection of a large number of data (parameters) in real time on large areas, in all climate and weather conditions, 24 hours a day, such as the appearance of weeds, pests, diseases, monitoring of dangerous weather conditions or soil conditions. Such progress leads to the reduction and adequate use of resources, including fertilizers or protective equipment. Radić et al., (2022) state that the data obtained with the help of precision agriculture and robotics enable optimal sowing, fertilizing and crop protection, precise irrigation, precise weed control and automated harvesting, statistical processing and data analysis, which allows correct decisions to be made based on data from sensors and with the help of other technologies (big data, cloud computing, blockchain and artificial intelligence).

In developed countries, the collection and processing of data, including the practical use of high-tech innovations, is carried out using telecommunication and satellite navigation systems. Among the adopted solutions, we can mention pest control systems, planting and replacement of heavy tractors, soil compaction, precise fertilization systems, irrigation. Using IoT to monitor water use for optimal plant growth and determine soil moisture and nutrient content is the most common application for IoT (Kurdyumov and Korolev, 2020). According to Rechkin et al., (2019) monitoring the physical health of plants and soil is one application, but it can lead to a large return on investment for industrial farmers through the use of sensor technology.

Processing and analysis of the obtained main parameters allows solving the problem of working time in the field, including the yield of arable land. This allows farmers to obtain parameters, such as the amount of fertilizer, food, water in the soil and planted seeds, the temperature of stored products, the status of agricultural machinery and equipment in use and much more (Gorbunova et al., 2019).

Thanks to the use of the Internet of Things, the agricultural economy becomes manageable, that is, decisions are made in real time, reducing uncertainty and inefficiency, and therefore the negative impact on the environment. The emergence of "smart" devices allows control of crop productivity, taking into account changes in the growing environment. The introduction of IoT in plant production automates the control of climate parameters, soil characteristics,

minimizes human participation in the technological operations of product production (Gorbunova et al., 2019).

Informacioni sistemi i neuronske mreže analiziraju više događaja i poboljšavaju poslovnu efikasnost. Generalno, farmeri se suočavaju sa dva glavna zadatka: da maksimiziraju prihod i smanje troškove, uz održavanje visokog kvaliteta proizvoda i zaštite životne sredine. U poljoprivrednom preduzeću se kreira informacioni oblak za razmenu podataka analitičkih i administrativnih struktura u non-stop režimu IT sistema, a takav oblak je neophodan za razvoj IoT (Gázquez et al., 2016).

The basic groups of technologies and supporting equipment for the proper functioning of smart agriculture, according to many studies, are:

1. Information systems

With the help of information systems and additional equipment, such as various devices, sensors, drones, etc., data is collected, processed, stored and distributed.

2. Precision agriculture

Precision agriculture involves looking at spatial and temporal parameters in order to form the most efficient agricultural production strategy while reducing inputs and reducing environmental pollution. In order for the aforementioned to work, it is necessary to implement and use technologies such as GPS (Global Positioning System), GNSS (Global Navigation Satellite System), analysis of digital and hyperspectral images and terrain recordings with the help of cameras mounted on unmanned aircraft - drones and satellites, creation of terrain maps showing all relevant factors that can be measured (for example: crop yield, terrain characteristics, soil moisture, chemical elements).

3. Agricultural automation and robotics

It is about the process of applying robotics, automated control and artificial intelligence at all levels of agricultural production. These processes significantly increase productivity, precision in work, as well as the economy of agricultural production.

GPS (Global Positioning System)

The implementation of precision agriculture or location-specific agriculture becomes possible through the use of GPS ("Global Positioning System") technology. As IT engineers explain, GPS technology combined with the GPS-server.net tracking system enables real-time data collection with accurate position information, which leads to efficient manipulation and analysis of the collected data. GPS - server.net service can be used for precision farming, field planning, yield mapping and tractor guidance. GPS works in any weather conditions, anywhere in the world, 24 hours a day, with no subscription or setup fees.

The accuracy and benefits of using GPS allow farmers to create farm maps with precise acreage, road locations and distances between points of interest, collect soil samples or monitor crop conditions. GPS receivers collect location

information to map field boundaries, roads, irrigation systems, and crop problem areas such as weeds or disease. Special devices equipped with GPS devices are able to precisely distribute the swaths on the field, applying chemicals only where it is needed, minimizing the chemical ratio, reducing the number of required chemicals, thereby contributing to the environment and more precise use of materials.

GIS (Geographic Information System)

Geographic Information System is a system for collecting, memorizing, checking, handling, analyzing and displaying data that are spatially related to the Earth. It is a technology that combines hardware, software and data. Data can represent almost anything imaginable as long as it has a geographic component. Satellites, drones and manned aircraft are used for remote sensing, which is the collection of information about the earth's surface by scanning from high altitudes. Landsat 8, is an observation satellite (a joint effort of the United States Government Science USGS and NASA) that orbits the Earth every 16 days. It includes 9 bands of the visible light spectrum that can be used to calculate factors such as plant diseases, nutrient deficiencies, insects or crop moisture excess and deficiency. It also captures thermal infrared radiation (TIR) that is beyond the range of human vision. Depending on the surface temperature, the intensity of the wavelengths emitted by different types of vegetation varies, managing the consumption of irrigation water, detecting plant diseases or evaluating the ripeness of fruits.

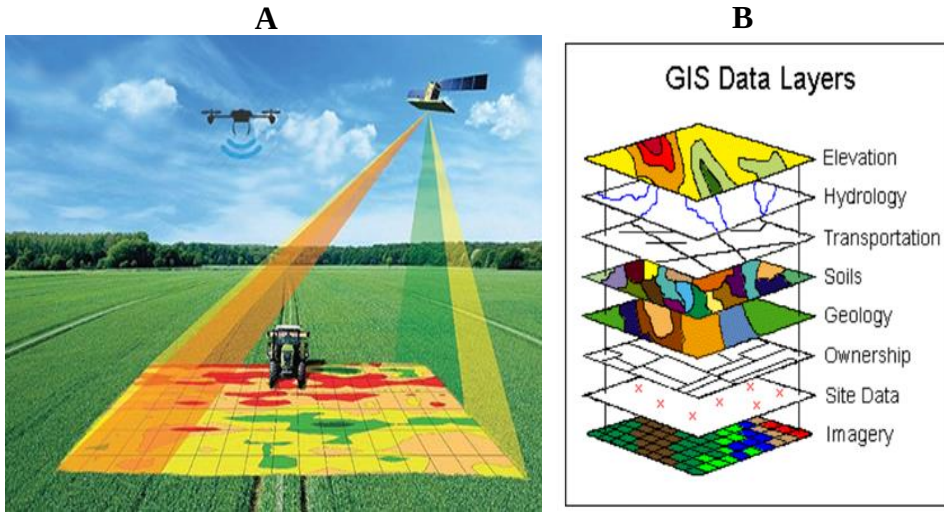

Figure 2. The success of precision agriculture is based on the accuracy of the collected data, in two ways (Hassan, 2018)

A. it involves the use of multifunctional imaginary devices equipped with remote sensing platforms, such as satellites, agricultural planes, balloons and drones,

B. it involves different types of sensors – the collected data is identified with precise location information using GPS and GIS devices, so that treatment specific to that location can subsequently be provided.

Sensors

Modern sensors are widely used in various applications such as robotics, navigation, automation, remote sensing, underwater imaging, etc., and in recent years, sensors with advanced techniques such as artificial intelligence (AI) are playing a significant role in the field of remote sensing and smart agriculture. AI-enabled sensors work as smart sensors, and additionally, the emergence of the Internet of Things has resulted in very useful tools in the field of agriculture by making available various types of sensor-based equipment and devices (Plotnikov, 2019).

Sensors are most commonly used in numerous applications ranging from measuring body parameters to automated driving. Furthermore, sensors play a key role in performing detection and vision-related tasks in all modern science, engineering and technology applications where computer vision dominates (Hassan et al., 2020). An interesting emerging domain using smart sensors is the Internet of Things (IoT) which deals with wireless networks and distributed sensors to hear data in real time and produce specific results of interest through appropriate processing (Shafi et al., 2019). In IoT-based devices, sensors and artificial intelligence (AI) are the most important elements that make these devices sensible and intelligent. In fact, due to the role of artificial intelligence, sensors act as smart sensors and find effective use for various applications, such as general environmental monitoring (Sishodia et al., 2020); monitoring of a certain number of environmental factors; weather forecast (Di Napoli et al., 2020); satellite imaging (Zhu et al., 2018) and its use; applications based on remote sensing (Addabbo et al., 2016); monitoring hazardous events such as landslide detection (Di Napoli et al., 2020); self-driving cars; healthcare and so on.

Modern agriculture using advanced technologies such as artificial intelligence and smart sensors can produce increased yields with appropriate crop quality assessment (Doshi et al., 2019), crop classification and soil moisture measurement (Lu et al., 2020). Zhang and Wei (2020) state that smart sensors are being used in the agricultural sector by incorporating modern sensors, advanced AI techniques, in soil health monitoring systems, sensor applications in animal husbandry and crop yield analysis. The role of smart sensors is extremely important in agriculture and pharmaceuticals where not only productivity is increased, but sustainable growth is also achieved. Smart sensors and the Internet of Things are changing conventional farming practices into smart agriculture that is helping to empower farmers around the world.

Today, there are a large number of sensors that measure various parameters very accurately using certain methods:

1. Location sensors - determine latitude, longitude and altitude with the help of GPS satellites.
2. Optical sensors - use light to measure soil properties. They are placed on satellites, drones or robots to determine the content of clay, organic matter and moisture in the soil.

3. Electrochemical sensors - sensors help collect soil chemical data by detecting specific ions in the soil. They provide information in the form of soil pH and nutrient levels.
4. Mechanical sensors - These sensors are used to measure soil compaction or mechanical resistance.
5. Dielectric Soil Moisture Sensors - These sensors measure moisture levels by measuring the dielectric constant of the soil
6. Air flow sensors - These sensors are used to measure air permeability. They are used in fixed position or in mobile mode.
7. Sensors for monitoring animal health and activity
8. Temperature sensors
9. Sensors for morphological conditions and analyzes of plants, etc

Agriculture drones

The use of drones in the agricultural sector has led to the improvement of many agricultural practices. When it comes to precision agricultural production, the use of drones has become a basic measure of production, which takes place by recording and collecting data on real and current crop conditions. Based on this data, producers can plan and organize their sowing/planting, as well as the treatments needed in order to obtain high stable yields.

From data collected by drones, farmers can derive insights related to plant health indices, plant counts and yield predictions, plant height measurements, canopy cover mapping, stock measurements, chlorophyll measurements, wheat nitrogen content, drainage mapping, weed pressure mapping, and so on.

According to the available literature, there are two types of drones – aerial drones and ground-based drones used in agriculture for crop health assessment, crop monitoring, pesticide spraying, irrigation, planting and field analysis.

All large investments in agriculture require intensive production and large areas in order to make the investment pay off. This is also the case with drones, which in order to be profitable, must be constantly in use and perform as many operations as possible during the season.

Operations that can be performed with the help of drones are:

1. Monitoring the health status of plants
2. Monitoring of conditions on the ground
3. Sowing and planting
4. Application in plant protection
5. Use for security purposes
6. Pollination

7. Irrigation

In addition to the many advantages offered by the use of drones, it is very important to understand their limitations and functions, since drones, like other precision farming equipment, are extremely expensive.

The introduction of big data technology, the use of unmanned vehicles, self-driving vehicles, the use of sensors can modify agricultural farms into smart farms.

However, Radić et al., (2022) explains that there are certain obstacles in the implementation of technologies in smart agriculture: fragmented market, coverage and connection (connection), large investments, fear of new technologies, untrained personnel and undeveloped standards.

The key advantages and main reasons for using IoT in agriculture are:

1. The ability to collect, analyze and create conditions for continuous planning of agricultural production
2. Monitoring, development and improvement of agricultural production
3. Digitized parcels and monitoring of execution of operations
4. Centralization of documentation.
5. More effective management of development and ongoing agricultural policy, etc.

Conclusion

Agriculture 4.0 creates dynamic communication systems that increase productivity, save resources and materials, and optimize costs, through the automation and digitization of a large number of processes in agriculture.

The agricultural sector must overcome challenges such as climate change, environmental pollution and the production of healthy food. In order to increase productivity, it is necessary to use innovative technology and the Internet of Things.

IoT-related technologies have a major impact on precision or smart agriculture, as well as the global economy. The integration of products, knowledge and services through IoT maximizes the scope of productivity, product quality, business profits and time savings.

The application of new information technologies enables the timely performance of work in agriculture, as well as the prevention of problems. It is also significant that, thanks to precise data, accurate and precise measures and methods can be calculated, which results in significant savings, and enables the increase and preservation of yields.

The current use of information technologies in agriculture in our area is modest and is explained by economic arguments. Precision technology and smart solutions in agriculture contribute to the improvement and increase of yields, but

the main contribution of digitization in agro sectors is the management of natural resources in a sustainable way.

Digital agriculture has an enviable potential to increase economic contribution through expanding market opportunities, agricultural productivity and cost efficiency. There are also environmental benefits through optimized resource use and adaptation to climate change, as well as social and cultural benefits through increased communication and inclusiveness.

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