Data protection in the automated agribusiness management system

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Abstract
The paper discusses the development of components of the agribusiness management system, in particular: a system for collecting and analyzing data from sensors, task management for foremen, integration of data on the phases of crop development, and decision-making tools. A thorough analysis and selection of development technologies that most effectively solve the tasks of agribusiness was carried out. Attention was paid to the integration of different level components of the system and ensuring their harmonious operation in real conditions. A data transmission network is selected and configured to ensure stable and fast communication between system components. Data protection is provided through the use of SSL certificates. The obtained results can be useful in the automation of similar or similar agricultural enterprises.

Keywords
agribusiness, management system, data analysis, sensor integration, data protection, encryption, optimization

1. Introduction

In our world, agribusiness is one of the key industries that ensures food security and economic stability in most countries, including Ukraine. However, global challenges such as climate change, geopolitical instability, and regional conflicts are making adjustments to traditional approaches to agricultural production. This became especially relevant for Ukraine, where the long devastating war against Russia caused significant losses of water resources due to the destruction of infrastructure, in particular, the terrorist attack on the Kakhovskaya HPP. This has led to a critical shortage of water, which is necessary for the cultivation of crops, especially in regions dependent on irrigation.

The relevance of the topic is enhanced by the need to optimize the use of available resources, reduce costs, and increase the efficiency of agricultural production. The integration of advanced information technologies into these processes opens the world to new opportunities for solving the above-mentioned problems. In particular, automation allows us to implement advanced methods of monitoring the condition of crops and optimizing the use of water and fertilizers, which is especially important in the context of limited resources and the need to adapt to changing climatic conditions [1].

This study proposes the development of an information system that will use a variety of sensors to collect data on growing conditions, providing quality monitoring of soil moisture, temperature, and chemical composition [2]. Based on the received data, the system will be able to automatically regulate watering and fertilization, adapting to the current needs of plants and environmental conditions. This will not only contribute to a more rational use of natural resources but will also increase the yield and quality of agricultural products.

Given the steady growth in demand for food products and the need to adapt to rapidly changing conditions, such a system becomes relevant, offering a solution that helps Ukrainian farmers not only survive but also successfully compete in the world market.

The purpose of this work is to develop an automated system for managing production processes in agribusiness to increase the efficiency of resource use and the productivity of agricultural production.

The practical significance of the obtained results lies in the possibility of implementing the developed automated management system in agribusiness, which will significantly increase the efficiency of resource use, reduce costs, and increase the yield of crops.

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To fulfill the set goals, it was necessary to solve the following tasks: develop the system project, determine the components, subsystems, and methods of their interaction; analyze existing solutions to justify the expediency and uniqueness of the development; create information blocks for notifications and decision-making; to develop data processing and analysis algorithms [3]; ensure data protection through authentication and authorization [4]; conduct system testing to identify and eliminate errors, check reliability of data transmission [5–7], software stability and usability [8].

2. Description of the subject area

2.1. Description of the process of agribusiness activity

Agribusiness involves complex and varied activities oriented around seasonal cycles that determine the dates of sowing, tending, harvesting, and processing. These cycles vary depending on geographical location, type of crops, and climatic conditions. For example, spring is usually sowing, summer requires intensive care and watering, autumn—is harvesting, and winter—planning for the next season, and maintenance of equipment.

The management structure in agribusiness includes several levels: the highest is focused on strategic planning; the middle level is responsible for coordination between departments, and the lower level ensures the implementation of operational tasks in the fields and factories [9]. Agribusiness faces many challenges, such as climate change that introduces unpredictability to production cycles, pests and diseases that can spread quickly, fluctuating market prices that require flexibility in financial planning, various political conflicts, wars, and other irresistible forces. All these factors require effective management and implementation of the latest technologies to ensure sustainable development and reduce costs [10].

The implementation of automated systems can help to optimize production processes, reduce resource losses, and increase the overall productivity of agriculture. Such systems allow collecting and analyzing data on the condition of the fields, weather conditions, and the level of moisture and nutrients in the soil. This helps to make more informed decisions about crop care, irrigation, and fertilization, which ultimately increases yield and product quality [11, 12].

2.2. Setting the problem

2.2.1. Purpose of the system

Automated agribusiness management systems are aimed at solving many serious problems that have traditionally complicated agricultural production. The main goal of the system is to improve production management processes, such as improving the facilitation of communication between employees of different levels, reducing costs, and more efficiently distributing resources.

The system is being developed as a tool that allows you to significantly simplify and optimize processes due to automation and detailed control of key indicators. This includes the use of sensors to collect data on the state of plants, the ability to react in real-time to changes in growing conditions, and to provide timely adjustments to crop care.

One of the main advantages of automated systems is the ability to centrally manage all aspects of production, including monitoring soil conditions and controlling moisture levels, temperature, and nutrient levels such as potassium and nitrogen. Thanks to this, agronomists can quickly make the necessary changes in agrotechnical measures, increasing the efficiency of resource use [13].

The system must be user-friendly, reliable, and functionally complete to ensure easy implementation and use in the field.

2.2.2. Development goals and objectives

The main objectives are to develop a data acquisition subsystem, which is the source of input information, and a control system, which allows users to control important parameters of the production process, such as irrigation and fertilization. Agribusiness is a complex system that depends on many factors such as seasonal cycles, climatic conditions, and market fluctuations. Effective management of these factors is critical to ensure sustainable development and increase productivity.

The formulation of the task and the determination of the purpose of the system showed the need for the introduction of automated systems to optimize production processes, reduce costs, and increase the efficiency of resource use. The main goal is to create a tool that will allow you to centrally manage all aspects of production, providing monitoring of soil conditions, and control of humidity, temperature, and nutrients. This will allow agronomists to make the necessary adjustments on time, which will increase the yield and quality of products.

Defining the goals and objectives of the development emphasized the importance of creating a data collection subsystem and control system, developing data processing algorithms, and creating an adaptive user interface. Completion of these tasks will ensure effective implementation of the system in agribusiness, which will allow farmers to make informed decisions based on up-to-date data and increase their competitiveness in the market.

Analysis of ready-made solutions on the market showed that there are several advanced agribusiness management systems, such as AgroTop [14] and AgriChain [15], which provide a wide range of functionality for large agribusinesses. AgroTop focuses on task automation, performance monitoring, and data visualization, while AgriChain offers an end-to-end solution that includes land bank management, agro-production, warehouse logistics, and crop monitoring.

AGRIUNO has certain differences and advantages, including its focus on smaller farms. It offers the separation of functionality into separate roles, which ensures ease of use without overloading users with unnecessary information. In addition, our system allows agronomists to manage the phases of crop development, set threshold values for sensors, and monitor average sensor values through graphs. An important advantage is also the automation of data collection and analysis, which allows farmers to make informed decisions based on up-to-date data.

Table 1
Comparison with existing solutions

Functionality	AgroTop	Agri Chain	AGRIUNO
Planning and analysis of crop rotation	Yes	Yes	No
Automation of setting tasks and control of execution	Yes	Yes	Yes
Visualization and monitoring	Yes	Yes	Yes
Performance analysis	Yes	Yes	Yes
Separation of functionality	No	No	Yes
Field management	No	Yes	Yes
Tasks and execution control	No	Yes	Yes
Monitoring and notifications	No	Yes	Yes
Data collection	No	Yes	Yes

Thanks to this, our system provides effective management of production processes, facilitates decision-making, and increases the productivity of farms. It is affordable, easy to use, and requires no additional training, making it attractive to smaller agribusinesses seeking to implement modern management technologies without incurring significant costs.

3. Formation of system requirements

3.1. Requirements for the system as a whole

The AGRIUNO system consists of several main subsystems, each of which performs specific functions necessary for effective agribusiness management. The authentication subsystem provides secure user access to the system, supporting the roles of agronomist, foreman, and manager.

The field management subsystem allows agronomists to manage information about fields and crops, and store data about fields, crops, and their development phases. It also supports setting limit values for sensors and monitoring field status through graphs and alerts.

The task management subsystem provides the ability to create and edit tasks for foremen, monitor the status of task execution, assign tasks to foremen, and control their execution.

The monitoring and data collection subsystem provides data collection from humidity and temperature sensors, as well as manual data entry for potassium and nitrogen sensors. It includes notifying users about indicators exceeding the set limit values.

The administrative subsystem coordinates and manages production processes, providing monitoring of tasks and the status of fields, review, and analysis of used resources, as well as management of users and their roles.

The system must be available to users 24/7 without interruption, with the ability to easily expand to support a growing number of users and data. It should provide a high level of user data protection, provide the possibility of registration and login to their accounts, support the submission, editing, and monitoring of tasks, as well as ensure the storage and updating of data in the database in real-time.

Prospects for development include expanding the functionality, adding new functions, such as tracking the condition of the equipment, and integrating with mobile applications for fieldwork. It is also possible to use the system in other countries, adapting to local conditions and requirements, as well as constantly improving the interface to ensure greater convenience and accessibility for users.

3.2. Requirements for functional characteristics

List of functions, tasks, or sets of tasks to be automated:

- Automation of the process of user login to the system (agronomists, foremen, managers) with identity verification.
- Ensuring authentication of users when entering the system, and supporting roles.
- Storage of data on fields, cultures, and phases of their development.
- Setting limit values for sensors according to the phases of crop development.
- Monitoring the average values of the sensors through graphs [16].
- Notification of the deviation of sensor data from the set limit values [17].
- Creation and editing of tasks for foremen. Monitoring the status of tasks, assigning tasks to foremen monitoring their execution, and receiving notifications about urgent tasks and important messages.
- Data collection from humidity and temperature sensors. Manual data entry for potassium and nitrogen sensors. Analysis and visualization of collected data.
- The system should ensure fast execution of requests and data processing. Any operation should not take more than a few seconds.
- The system must be fault-tolerant and provide data backup. It should be possible to quickly restore data in the event of a crash.
- The user interface should be easy to use and understandable even for inexperienced users. All functions should be easily accessible and understandable.

These requirements ensure that the AGRIUNO system will efficiently perform all the necessary functions, ensuring the accuracy, reliability, and speed of data processing, which are critical for agribusiness management.

3.3. Requirements for types of security

3.3.1. Information support

Information support includes data structures, methods of storage, processing, and management.

- Database tables to store data on users, fields, cultures, development phases, tasks, sensors, and resources.
- Using a relational database (MongoDB) to ensure data integrity and consistency [18].
- Storing data in the form of JSON documents ensures flexibility of the data structure and ease of scaling [19].
- Data filtering and sorting methods for efficient search and processing of information about fields, crops, and tasks [20].
- Using MongoDB queries to interact with the database, provide fast access, and process large volumes of data [21].

3.3.2. Software

Software includes software components that ensure the functioning of the system.

- Web server for processing user requests and providing access to the database [22].
- Web application based on Vue.js for the interaction of users with the system, including agronomists, foremen, and managers [23].
- Interfaces for field monitoring, task management, and resource utilization analysis.
- Admin panel to monitor and manage tasks, fields, and users.
- Tools for viewing and analyzing data.
- Software tools for authentication and authorization of users, ensuring confidentiality and protection of information [24].
- Use of encryption protocols to protect data during transmission between the client and the server [25].

3.3.3. Technical support

Technical support includes the hardware and infrastructure necessary for the functioning of the system.

- Servers to ensure high performance and reliability of system operation [26].
- Data storage systems for storing large amounts of information and providing quick access to it [27].
- High-speed network connections ensure fast access to the system and the processing of requests in real-time [28].
- Backup communication channels to ensure uninterrupted operation of the system in case of failure of the main channel [29].
- Computers, laptops, and mobile devices for user access to the system ensure ease of use at any stage of the production process [30].

Thus, the AGRIUNO system will be equipped with all the necessary software and technical support, which will allow it to effectively perform all the necessary functions for agribusiness management, ensuring high productivity, reliability, and data security.

4. Development of an information system

4.1. System structure

The AGRIUNO system consists of several main components, each of which performs specific functions to ensure effective agribusiness management. The main components of the system include a client part, a server part, an administrative interface, management devices, end devices, and security modules.

The client part includes a web interface designed for user interaction with the system through a web browser. The web interface is implemented based on the Vue.js framework [31], which ensures a dynamic and interactive user experience. It provides access to system functionality for agronomists, foremen, and managers. The server part consists of a web server that processes requests from the client part and interacts with the database. The web server is implemented based on the Express.js framework [32], which runs on the Node.js platform [33] and includes an API for data exchange between the client part and the server, providing task processing logic, field status monitoring, user management, and other functions. The database uses MongoDB [34] to store data in the form of JSON documents [35], which provides flexibility in data structure and ease of scaling. The administrative interface is represented by the manager panel, which is designed to monitor and manage all aspects of the system. It is integrated with a web server and database to provide access to up-to-date information and provides tools for viewing and analyzing data, monitoring tasks and field status, and managing users and their roles.

Control devices include pumps, dispensers, and valves used for automated irrigation and fertilizer management. These devices are controlled through a gateway that receives commands from the backend [36]. End devices include sensors that collect data on moisture, temperature, nitrogen, and potassium in the soil, as well as a device for collecting and processing information that transmits the collected data to the server part via the Internet.

Security and data protection modules ensure confidentiality and protection of information with the help of software tools for authentication and authorization of users, using encryption protocols to protect data during transmission between the client and the server [37, 38].

The encryption process is based on the use of SSL certificates. These are electronic documents that certify that the website owner is a valid organization. When installing an SSL certificate, the owner's identity is verified by a trusted third party—the Certificate Authority (CA). This process ensures that the data you send to the website will be securely protected from unwanted intrusions or other digital threats.

Data encryption process. Stages:

1. Connection initialization: the website URL is entered, and the browser initiates a connection to the web server.
2. Sending the public key: The web server sends the public key from its SSL certificate to your browser.

3. Certificate Verification: The browser checks the web server's SSL certificate to ensure that it is valid and appears to be a trusted third party.
4. Generation of a shared secret key: The browser generates a shared secret key that will be used for further data encryption.
5. Symmetric Cipher Encryption: Using the web server's public key, the browser encrypts the shared secret key that it sends back to the server.
6. Decrypting the secret key: The web server uses its private key to decrypt the shared secret key that was sent by the browser.
7. Secure data transmission: Now that the browser and web server share a secret key, all data transmitted between them is encrypted with a symmetric cipher using that key.

Encryption with SSL has many advantages. Among them:

- Confidentiality. The data you transmit over the Internet remains confidential and unintelligible to unwanted persons.
- Data integrity. SSL protection ensures that data during transmission will not be changed by attackers.
- Web server authentication. You can be sure that you are interacting with exactly the website you intended to visit.

The system architecture provides scalability that allows the system to be easily expanded to support a growing number of users and data, reliability that includes high performance and system stability with the ability to backup and quickly restore data in the event of a crash, and ease of use thanks to an intuitive interface that makes it easier for both beginners and experienced users.

4.2. Functional model of the system

To ensure effective agribusiness management, the AGRIUNO system includes different user roles, each of which has its functional responsibilities. These roles or actors interact with the system to perform specific tasks, manage processes, and monitor the status of fields. Below are the functional responsibilities and functions of each actor.

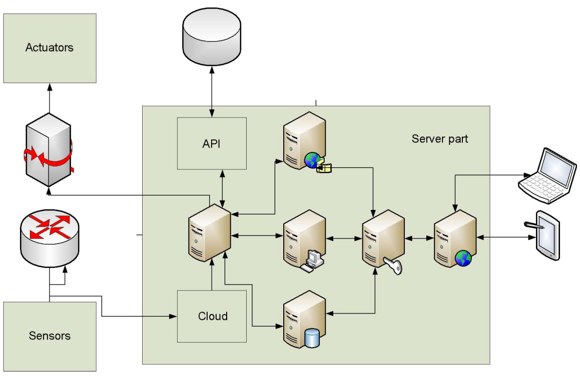

Figure 1: Detailed structural diagram of the system

Actors and functions

Manager:

- Authorization: login to the system.
- Ability to add and remove fields.
- View information about the status of the fields.
- View comments from an agronomist.
- View information about tasks and their status.

Agronomist:

- Authorization: login to the system.
- Management of crop development: Planning and control of crop development phases.
- Sensor settings: Setting limit values for sensors according to the phases of crop development.
- Monitoring indicators: Viewing the average values of the sensors with the help of graphs.
- Field Status Review: Assessment of current crop status and development phases in each field.
- Assignment of tasks: Distribution of tasks between foremen.
- Commenting: Adding comments on the status of fields and providing recommendations.
- Receiving notifications: Notifications about the deviation of sensor indicators from the established norms.
- View information about tasks and their status.

Brigadier:

- Authorization: login to the system.
- Data entry: Daily data entry from sensors.
- View information about tasks and their status.
- Execution of tasks: Implementation of tasks set by the agronomist.
- Notifications: Receive urgent tasks and important messages.

4.3. Database model

The database model of the AGRIUNO system defines the structure of the data and the relationships between the various data elements in the system. Below are the main tables (collections) and their attributes that provide system functionality.

The following is a description of the collections in the database:

Users collection:
_id (ObjectId) is a unique user identifier
UserID—numeric user ID
Name—user name
Role—user role (agronomist, foreman, manager)
login—login to enter the system
password—password for logging into the system
Fields collection:
_id (ObjectId) is a unique field identifier
FieldID—numeric identifier of the field
Name—field name
ForemanID—identifier of the foreman responsible for the field

PhaseID is the identifier of the current phase of culture development

Table 2
Description of database tables

Collection	Appointment
users	This collection stores information about system users. It includes data for managing access to the system, authentication, and authorization.
fields	This collection stores information about fields, including their names, foreman IDs, and current crop development phases.
phases	This collection stores information on the development phases of crops, including their descriptions and threshold values for various parameters.
tasks	This collection stores information about tasks, including their descriptions, statuses, and creation dates.
sensors	This collection stores information about sensors installed in fields, including their types and locations.
measures	This collection stores information about measurements, including the value, time, and date of the measurement.

Phases collection:

_id (ObjectId)—unique identifier of the phase

PhaseID—numeric identifier of the phase

Name—the name of the development phase

Description—phase description

HumidityMin—the minimum level of humidity

HumidityMax—the maximum level of humidity

TemperatureMin—the minimum temperature

TemperatureMax is the maximum temperature

PotassiumMin—the minimum level of potassium

PotassiumMax—the maximum level of potassium

NitrogenMin—the minimum level of nitrogen

NitrogenMax—the maximum level of nitrogen

Tasks collection:

_id (ObjectId) is the unique identifier of the task

TaskID—numeric identifier of the task

Description—task description

FieldID—identifier of the field to which the task belongs

Status—task status (new, in progress, completed)

CreationDate—date and time of task creation

Sensors collection:

_id (ObjectId) is the unique identifier of the sensor

SensorID—numerical identifier of the sensor

Type—sensor type (temperature, humidity, potassium, nitrogen)

FieldID—identifier of the field where the sensor is installed

Measures collection:

_id (ObjectId)—unique identifier of the dimension

MeasureID—numeric identifier of the measurement

SensorID—the identifier of the sensor to which the measurement is linked

Value—value of measurement

MeasureDate—date and time of measurement

Relationships between tables:

users and fields: A one-to-one relationship where one user (foreman) can be responsible for one field.

fields and tasks: A one-to-many relationship where one field can have many tasks.

fields and sensors: A one-to-many relationship where one field can have many sensors.

fields and phases: A one-to-one relationship where one field can have one current phase.

sensors and measures: A one-to-many relationship where one sensor can have many measurements.

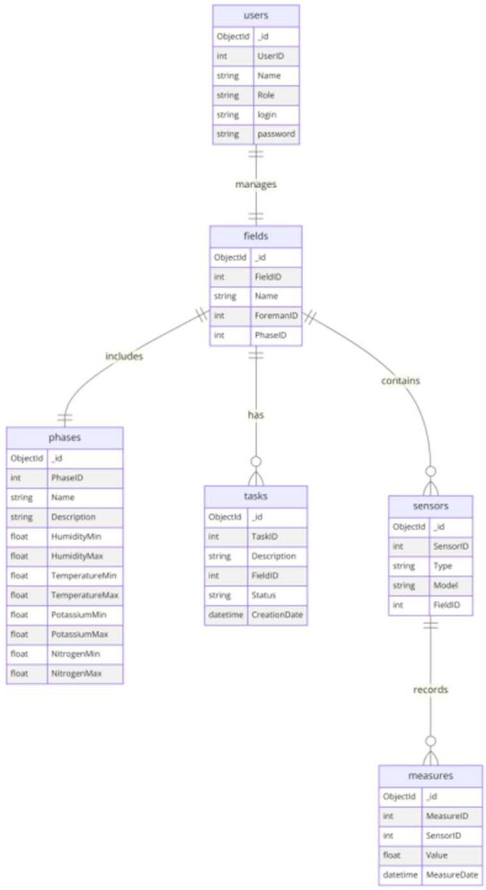

Figure 2: ER diagram of the database

This database model provides efficient storage, management, and processing of data necessary for the operation of the AGRIUNO system, allowing monitoring, analysis, and management of production processes in agribusiness.

4.4. Data transmission and processing

The agribusiness management system provides storage, processing, and presentation of various data necessary for the optimization of production processes and decision-making. Below is a list of input data required for the system to function:

- Sensor data: Sensors are placed in fields to monitor various parameters such as soil moisture, temperature, nitrogen, and other nutrients. This data is critical for assessing the current condition of the fields and making decisions about irrigation, fertilization, and other agrotechnical measures.

- Field Information: Includes details about each field, such as location, name, foreman's name, and other characteristics. This information makes it possible to better plan work in the fields and monitor their condition during the season.
- Phase information: Data on the different phases of plant growth, including sowing time, periods of active growth, flowering, ripening, and harvest. The data includes limit values for sensors. This allows you to coordinate agrotechnical measures at the optimal time to achieve the maximum yield.
- Information for authorization: Data for registration, authentication, and authorization of system users. Include user logins, passwords, and roles, providing access control and data security.
- Information about users: Includes personal data about users, their contact information, and roles. This allows you to manage users and ensure the appropriate level of access to various system functions.
- Tasks to foremen: Data about tasks assigned to foremen, including task descriptions, deadlines, and other necessary details. This helps to organize work in the fields and ensures timely implementation of agrotechnical measures.

The output of the system includes the results of sensor data analysis, which are presented in the form of reports and graphs, allowing agronomists to assess the condition of the fields in real-time. The system also provides task management tools to foremen, including creating, assigning, and monitoring task completion.

5. Mathematical support

5.1. Meaningful formulation of the problem

The agribusiness management information system is aimed at optimizing the use of resources, monitoring the condition of fields, managing the phases of crop development, and providing recommendations for crop care. The goal of the system is to increase production efficiency, reduce costs, and improve crop quality.

5.2. Mathematical formulation of the problem

The mathematical model of the agribusiness management system may include the following components [39]:

Set of fields: $\mathrm{P} = \{\mathrm{P}_1, \mathrm{P}_2, \ldots, \mathrm{P}_n\}$, where P_i is a separate field.

Set of sensors: $\mathrm{D} = \{\mathrm{D}_1, \mathrm{D}_2, \ldots, \mathrm{D}_n\}$, where D_i is the separate sensor.

A set of measured parameters: $\mathrm{X} = \{\mathrm{T}, \mathrm{H}, \mathrm{K}, \mathrm{N}\}$, where T is temperature, H is humidity, K is potassium, N is nitrogen.

Data requests M_{ij} are the measurements from the sensor D_j on the field P_i at a moment in time t.

5.3. Justification of the solution method

To solve the task of monitoring and analyzing the condition of the fields, it is necessary to develop a method of calculating the average values of the indicators and forming graphs based on the collected data, taking into account the irregularity of the data. The main solution methods can be:

- Interpolation: Used to fill gaps between irregular data.
- Calculation of average values: To evaluate the current state of the fields.
- Graphing: To visualize changes in indicators over time and make decisions about crop care.

5.4. Description of the solution method

5.4.1. Processing irregular data

To process irregular data from sensors, the interpolation method can be used to fill the gaps between the received data and ensure the continuity of the analysis [40].

Interpolation:

- For each sensor and parameter, we determine time intervals where there is no data.
- We use linear interpolation to fill these gaps.

$$M_{ij}(t) = M_{ij}(t_1) + \left(\frac{M_{ij}(t_2) - M_{ij}(t_1)}{t_2 - t_1}\right) \times (t - t_1)$$

where t_1 and t_2 are the times between which the interpolation is carried out, $M_{ij}(t_1)$ and $M_{ij}(t_2)$ are the value of the sensor at these moments [41].

5.4.2. Calculation of average values of indicators

After interpolation of the data, it is possible to calculate the average values of indicators for a certain period [42]. Input data: $M_{ij}(t)$ is the measurement value from the sensor D_j on the field P_i at a moment in time t. T is the period over which the average value is calculated (for example, a week).

The formula for calculating the average value [43]:

$$\overline{X_k}(P_i) = \frac{1}{|T|}\sum_{t\in T} M_{ij}(t)$$

where $\overline{X_k}(P_i)$ is the average value of the indicator X_k on the field P_i,$|T|$ is the number of measurements per period T.

An example of calculating the average humidity value. Suppose there is a field P_1 with three humidity sensors D_1, D_2, D_3, and we have the measurements for the last week. The input may look like this:

$$M_{1,1}(t) = 70\%$$
$$M_{1,2}(t) = 75\%$$
$$M_{1,3}(t) = 72\%$$

The average value of humidity in the field P_1 for the last week:

$$\overline{H}(P_1) = \frac{1}{3}(M_{1,1}(t) + M_{1.2}(t) + M_{1.3}(t)) = \frac{1}{3}(70 + 75 + 72) = 72.33\%$$

5.4.3. Formation of graphs

Graphs of indicators are created based on the collected data to visualize changes in indicators over time.

Input data: A set of measurements $M_{ij}(t)$ for each sensor D_j on the field P_i for a certain period.

The process of building a schedule:

- Collected data are grouped by time.

- For each point in time, the average values of indicators for each field are calculated.
- Data is plotted on a graph where the x-axis represents time and the y-axis represents metric values.

An example of graph construction:

Suppose we have a temperature measurement in the P_i field in a week:

To construct a graph, the data is entered as points on the graph and connected by a line to show the trend of temperature changes for a week (Fig. 3).

Table 3
Example data

Time	Temperature (°C)
01.06.2024	25
02.06.2024	26
03.06.2024	27
04.06.2024	24
05.06.2024	26
06.06.2024	25
07.06.2024	27

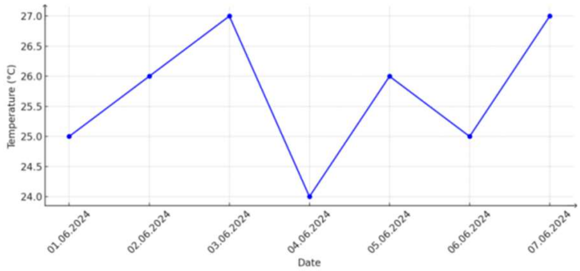

Figure 3: An example of a schedule

The graph will help agronomists quickly assess the dynamics of temperature changes in the field and make appropriate decisions about crop care.

6. Conclusions

The development of an automated agribusiness management system is a complex and multifaceted task that requires deep knowledge in the fields of information technology, agronomy, and data management. The main goal of the project was to create an integrated system that provides effective management of fields, monitoring of soil, plant, and resource conditions, as well as optimization of production processes.

The developed agribusiness management system makes it possible to significantly increase the efficiency of production processes, ensuring accurate monitoring of the state of the fields and optimal use of resources. The system provides users with the opportunity to respond to changes in conditions on time and make informed decisions regarding the care of crops. It also provides a convenient interface for interacting with the system, which facilitates its use and increases user satisfaction.

Key aspects of irregular data processing are considered, including the use of interpolation methods to fill gaps between measurements and calculate average values of indicators. These methods allow for continuous data analysis, which helps to accurately monitor the condition of the fields.

The process of constructing graphs for visualization of changes in indicators over time is described, which allows agronomists to quickly assess the dynamics of changes in temperature, humidity, and levels of potassium and nitrogen in the fields. Data visualization on graphs is an important tool for making informed decisions about crop care.

The proposed methods and approaches to data processing allow the system to effectively perform the functions of monitoring and managing agrarian processes. This helps to optimize the use of resources, and increase productivity and product quality, which ultimately ensures the sustainable development of agribusiness.

Special attention was paid to the development of algorithms for analyzing sensor data and making decisions about crop care. The most effective methods of analysis were selected and implemented, which ensure high accuracy of forecasting and optimization of agronomic processes. This included the use of modern technologies for data collection, processing of large volumes of information, and machine learning.

Further research and development can be aimed at expanding the functionality of the system, including support for additional types of sensors, integration with other control systems, and the use of the latest technologies for data analysis. This will further increase the efficiency of agribusiness and ensure the sustainable development of this important industry.

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