Creating a "Logical intelligent plant care system" in digital agriculture based on Mivar approach

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Abstract. This work is devoted to developing an automated information processing and management system based on logical artificial intelligence. The proposed system has been designed to support the process of growing agricultural and house plants. This research is one of the global trends of intelligent tools and services application in the agricultural industry for improving human environmental and food safety. This work is a practical demonstration on mivar expert systems operation in the control loop with cyclic and calendar planning of processes. The results obtained in this work can be used as an information basis for implementing automated farms in urban environments. This implementation is based on mivar knowledge base platform which allows considering individual characteristics of crop growth, making decisions in conditions of heterogeneous sensor data, and timely adjusting the process of plants growing.

1. Introduction
The number of the "connected" Internet of things (IoT) devices is growing inexorably all over the world. The scope of their applications is quite extensive: energy, industry, housing, transport, healthcare, etc. Particular attention is drawn to agriculture which uses IoT technologies to implement "smart" agriculture, particularly in urban conditions [1]. Development of smart city concepts has been supported by both the state and business and has an impact on all areas of citizens’ life from security control in public places to food production.

One of the most difficult questions facing the food and agriculture industry is how to double food production by 2050 with the amount of available land decreasing every year. In addition, according to the United Nations (UN), the world's population may reach 9.7 billion by 2050 [2], two-thirds of which will be urban residents [3]. These realities represent a huge challenge for the agricultural sector and entails serious difficulties in meeting the needs of the growing urban population including
environmental and food security insurance. One of the possible solutions may be the intellectualization and automatization of agricultural activities [4, 5].

The concept of "smart" agriculture is based on the utilization of various innovative solutions by farmers. These solutions allow them to automate agricultural activities as much as possible, increase productivity, and improve financial indicators [6]. Applying detectors and sensors in agricultural activities is an important step towards creating an intelligent farm [7, 8].

Therefore; relevance and necessity of research in the field of intellectualization and automation of agriculture doesn't disappear over time. In particular, cities which are going to form most of the world's population, according to the UN prediction, will be concentrated and will have a direct interest in meeting food needs of residents.

Methods based on neural networks and deep learning applications are well demonstrated in the tasks of processing and analyzing satellite images, plants photos from automated greenhouses, and crop planning [9, 10]. However; there is a shortage in rule-based information platforms using knowledge bases. Such systems are required in the tasks of planning programs for agricultural activities, determining parameters for managing plant growth cycles, correcting growth maintenance processes, and making recommendations according to the current state of production. Currently, there are several technologies that are ready to implement these tasks. These technologies include mivar technologies of logical artificial intelligence. This work allows demonstrating the conceptual possibility of using mivar information processing tools in digital agriculture with greenhouse management system as an example. To achieve this goal, a logical intelligent system for providing plant care (AGRO LIS) has been developed. This intelligent system is based on mivar approach.

AGRO LIS is a virtual demonstration stand which allows setting the parameters of the greenhouse microclimate, the current time and phase of plant growth. In the output, it gets information about the necessary control effect in the current conditions according to the compiled technological map of plant growth. Three agricultural crops have been selected to demonstrate the AGRO LIS work: peas, tomatoes, cucumbers. Knowledge bases founded on the formalism of mivar networks and presented in the form of mivar knowledge models have been prepared for them.

2. Description of the approach used

The proposed system based on logical artificial intelligence is founded using mivar approach. Mivar approach is a combination of computer science and discrete mathematics. Mivar approach is based on the "Thing-Property-Relation" model of knowledge processing. This model allows describing and structuring the available information about the subject area. Moreover; it allows solving complex logical problems using logical-computational processing with linear computational complexity on mivar networks. Mivar networks are a bipartite directed graph where one of the vertices sets represents input objects – "If" conditions, and the other – logical conclusions "Then". Thus; mivar networks allow using cause-and-effect "If – Then" dependencies and developing a logical conclusion for the task on their base. With this structure, mivar networks have the scalability property. This allows adding any available type of knowledge to the mivar network structure at any time without changing the methods of processing them. The decision-making (thinking) model based on mivar approach makes it possible to make decisions under constantly changing rules and conditions.

Mivar technologies allow creating algorithms based on an active learning evolutionary network controlled by the input data flow. This aspect makes it possible to present the accumulated knowledge [11] in the form of sets of modules, services and procedures. Thanks to mivar approach, it is possible to implement a system of plant care taking into account the individual characteristics of crop growth, making decisions in conditions of heterogeneous data from sensors, and timely correcting the process of plants growing.

Mivar approach proved its viability and practically demonstrated the possibility of building a system with fundamentally new mechanisms for situational robots control and decision-making for robotic systems. Also, the application of mivar technologies in medicine can be distinguished from applied research areas.
3. System description
Figure 1 shows the interaction concept of AGRO LIS with external systems and modules in industrial operation. The system diagram shows the process of organizing plant care. The object of the system control is a plant. Various sensors are responsible for monitoring the environment and the plants. Growth support tools act as controls (Figure 2). The AGRO LIS input receives information from sensors installed in the greenhouse and the current state of the plant, recognized by computer vision, corresponds to the current growth phase. The received data is already prepared according to the format of mivar models. Generated control solutions from the AGRO LIS are delivered to the auxiliary systems of the greenhouse where the control action is performed according to the technological programs.

Logical inference is performed in AGRO LIS using "Razumator” which is the computational core of logical inference based on mivar model. Users can monitor the state and manage the system through a web application. This web application is a client-server application in which the client interacts with the web server using a web browser.

4. Mivar knowledge base development
Three agricultural crops have been selected to demonstrate the work of AGRO LIS: peas, tomatoes, and cucumbers. General mivar models structure has been prepared while working on the knowledge of the selected plants as shown in Figure 3. Formalization of knowledge models has been produced in the development environment of mivar expert systems designer (Wi!Mi).

In total, there are three models with a common structure consisting of 55 parameters and 15 rules. A specific implementation of one of the rules in mivar model can be considered. Irrigation is carried out if the current soil moisture is less than 37.5% and the difference between the last date of irrigation activation and the current date is greater than the required frequency of irrigation or irrigation has not been performed before. Moreover, irrigation is performed only in the first two hours after the beginning of daylight. The following code expresses a description of the above mentioned rule. The computing core "Razumator” uses JavaScript for rules description.

![Figure 1. Concept of interaction between AGRO LIS and external environment.](image-url)
// Rule: activate irrigation
var moisture, last_activation, frequency, y, ris, cur_h;
if (moisture < 37.5 &&
    (last_activation >= frequency || last_activation==-1 )) {
    if(cur_h>=ris && cur_h< ris +2) {
        // Code to activate irrigation goes here
    }
}
5. Conclusions
The results obtained in this work suggest that mivar approach can and should be applied for implementing automated farms in urban environments. Mivar knowledge bases in the project have performed well in terms of flexibility and scalability. These aspects contribute to the creation [20] of greenhouse management systems [21] that consider individual characteristics of crop growth [22]. They also contribute to decision making in the conditions of heterogeneous sensor data, and promptly adjusting plants growing process.

The project presented in this work can be used as a hybrid expert system. Advantages of this system include high speed solution development with linear computational complexity, availability of requirements for computing equipment, the ability to enter information into the knowledge base directly to the expert agronomist [16], and the ability to solve and visualize complex logical problems on ultra-large data sets [17]. Thanks to the algorithms based on active trainable evolutionary mivar network, it is possible to implement a plant care system that considers individual characteristics of crop growth, make decisions in conditions of heterogeneous sensor data (data collection), and timely adjust the process of plants growing.

The experience and knowledge gained in this work can be used in further research on applying mivar systems in digital agriculture.

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