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Results of Analysis of the State of Development of the Intelligent Microclimate Management System of the Smart Greenhouse

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Abstract: Nowadays, the importance of performing research through an IoT project is increasing for their practical implementation in agriculture: both on an industrial scale and for individual use. The article discusses the possibilities and advantages of the IoT project for growing plants, which arouses high interest among extremely busy residents of city apartments who grow seedlings for their garden or just ornamental plants for beauty and comfort in the house. The research results were obtained by performing a master's work on the theoretical implementation and practical operation of IoT elements. The interest of the presented results lies in the novelty of integrating the process of caring for their crops into the user's daily life: now the results of their work can be shared on social networks (in the form of video materials on monitoring the harvest). This approach makes this ICT and IoT project very attractive to a young audience, working in agriculture.

Keywords: Internet of Things, device, shield, sketch, Arduino IDE, sensor, actuator, air analyzer.

It is well known that in order to make a management decision, for example, from the dynamic behavior of a technological process or a change in cost to the opening of a new point of sale for products, even from the creation of a new business or the introduction of an innovative business process, relevant information is required. However, decisions have to be made constantly and analyzed information is required to make a decision on conducting marketing research. It takes a long time to accumulate such information. At the same time, almost all the necessary information is usually at the disposal of any enterprise, but it is not systematized, not analyzed and not ready for use.

In our age, the business process of creating a web-based system for monitoring the dynamic and informational properties of objects can be carried out using the example of a digital object with the ability to connect to it via the Internet.

Regarding this article, for example, the tasks of creating an intelligent control system for a “smart greenhouse” in the technology environment will allow organizing the monitoring of information processes of such a farm and managing its sensors and actuators. This idea would find its modern and relevant development, since the agricultural direction in our country is promising. The relevance and practical significance of the idea of "smart greenhouse" as an independent unit of the agricultural economy is confirmed in the general context of the country's agricultural development for the accelerated solution of agricultural issues and problems. "Smart farming" is in high demand today, when farmers can try the possibilities of the Internet of Things (IoT) technology from the screens of their gadgets. The elements and links of IoT in isolation do not look like a single well-coordinated intelligent system of operation of all our measuring instruments and actuators, but the need in the agricultural sector has already matured. Now among the population of our country there is an acute unsatisfied need, figuratively speaking, for an “autonomous home assistant” to care for both their crops, both in country greenhouses and in apartment flower beds or plants. At the same time, the management of such a system should be understandable to an ordinary user on ICT, be compatible in the modern information space (social networks, e-mails, online services, online stores). And, most importantly, the IoT system should be inexpensive to acquire.

Therefore, the importance of conducting research in IoT projects is increasing for their practical implementation in agriculture: both on an industrial scale and for individual use. The project proposed to the reader, according to the authors of the article, will arouse high interest among extremely busy residents of city apartments who grow seedlings for their garden or simply ornamental plants for beauty and comfort in the house.

The proposed research results are obtained in the development and implementation of a master's work on the theoretical implementation and practical operation of IoT elements. Therefore, the authors think that the results will be of interest to readers of this article. Moreover, the special interest of the work performed lies in the novelty of incorporating the process of caring for one's crop into the user's daily life: now the results of one's work can be shared on social networks (in the form of video materials on monitoring the harvest). This approach makes this ICT and IoT project very attractive to a young audience, workers in agriculture

With the development of the Internet in a digital format over 4G, the user has the opportunity to monitor the growth of his plants in real time and remotely, monitor the indicators of the greenhouse operating modes that are responsible for the health of the crop and, if necessary, remotely interfere intellectually in the autonomous operation of the greenhouse, carrying out additional watering or, for example, increasing the lighting in the greenhouse.

The authors of the article believe that the expected results of the project may be the creation of a commercial business plan for assembling a smart greenhouse, with which it will be possible to automate and remotely control the cultivation of various crops. Such a project integrates with any existing greenhouse or home flower garden. The management of an intelligent greenhouse will be quite understandable even for older people who do not know how to work with digital technology devices. Since here you can create the most intuitively simple web-based monitoring system for objects (devices) and for ongoing events and processes.

In this formulation, the project can solve the following tasks:

- the study of the physical foundations of the growth of plants and domestic crops;
- comparison of their grown products with the performance of competitors;
– collection, adjustment and operation of a set of sensors and actuators with common measuring and virtual instruments;
– further testing, operation and improvement of the project for growing crops in visual and program ways.

Now we will continue the description of the project with an analysis of the state of existing problems and the formation of requirements for natural processes observed in the growth of crops and plants.

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Drip irrigation. Let's start with the drip irrigation system, as a low-volume technology for vegetable, flower and seedling complexes, taking into account their irrigation with a return solution. To date, not a single new greenhouse complex can do without a drip irrigation system. This is the basis of the basics, which allows you to apply a strictly metered amount of fertilizer and water to the plants at the right time in the right proportion.

Modern drip irrigation involves the installation of a whole range of engineering systems and networks that automatically provide plants with the required top dressing. All technological equipment operates under the control of a specially written program that allows you to control irrigation processes in real time, as well as view the accumulated and make adjustments.

The drip irrigation system consists of several components:

– preparation of water (filtration, heating, stabilization of bicarbonates);

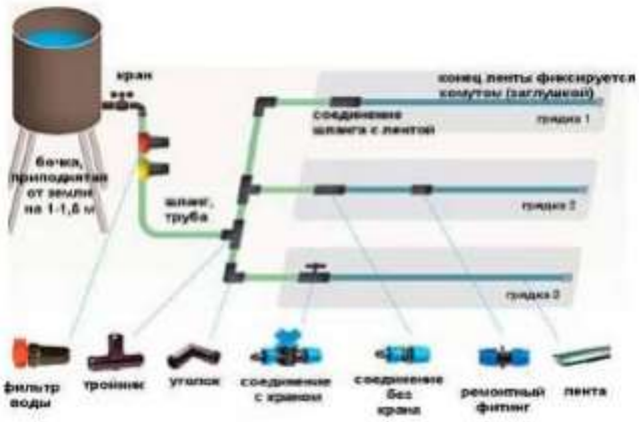
- solution preparation (solution unit - the brain and heart of the drip irrigation system);

– main pipeline and drip network (distribution of nutrient solution to plants);

- a drainage reuse system (feeding the used solution back to irrigation);

– preparation of mother solutions (dissolution of dry fertilizers in water).

Figure 1 shows a diagram of a functional simple drip irrigation system.



Picture 1 - Drip irrigation system

Modern technology provides for high requirements for the quality of irrigation water. It must contain a certain amount of micro and macro elements, and there are also requirements for the pH level and water purity. An additional factor is that the water must be supplied to the plant at a sustained temperature.

Irrigation water filtration. Multi-stage units, consisting of sand-gravel and disc filters, purify water from mechanical particles up to 130 microns. Filters help to get rid of organic compounds that often enter the water from open reservoirs. The unit is equipped with electronics, which, as the filter becomes dirty, automatically flushes it.

Water filtration in drip irrigation systems is very widespread. It is necessary when preparing water for irrigation, to prevent clogging of droppers, as well as to ensure uninterrupted and long-term operation of engineering equipment.

Filtration is also used in systems with drainage solution recirculation. As you know, the drainage must be disinfected before reuse, but any disinfectant installation, regardless of type, requires preliminary filtration from the suspensions contained in the drainage.

For example, sand and gravel filters (of any capacity) purify water from impurities and suspensions that mesh or plate filters cannot handle. The device is made on a stainless frame as an independent module and can be easily integrated into existing systems. For ease of use, the filter can be washed automatically.

Additional water purification is provided by a fine filter (130 microns). Reliable and practical plate filters provide mechanical purification of solutions from fractions larger than 130 microns. The filter elements are easy to clean and have an almost unlimited service life. The device can be supplied with a pump that performs the function of supplying water from the storage tank to the solution unit.

Microclimate monitoring. Obtaining high results when growing vegetables, flowers, seedlings, lettuce in greenhouses directly depends on the quality of providing plants with optimal conditions for growth and development. One of the most important indicators is a well-balanced microclimate.

Until recently, microclimate control could be carried out manually by an employee of a greenhouse or summer cottage, but with the advent of a large number of engineering systems in a greenhouse, as well as with increased requirements for the quality of microclimate maintenance, today, not a single industrial greenhouse can do without an automatic control system.

Therefore, a modern greenhouse includes many actuating devices (actuators) that allow you to control the microclimate of the greenhouse.

Heating system. The main task of the heating system is to maintain the temperature set by the greenhouse worker. Heating a greenhouse consists of several separate stages. The air temperature is controlled by changing the water temperature in the circuits, which is carried out using a mixing valve that mixes the water from the heat source (direct heat carrier) in the required proportion with the water returned from the greenhouse (return heat carrier).

Ventilation system. To ventilate the air inside the greenhouse, vents are provided in the roof, the area of which is up to 30% of the total glazing area. The opening and closing of the vents is carried out using motorized gearboxes (we also refer to the class of actuators).

Curtain system. Almost all new greenhouse projects are equipped with a screening system, because. it allows you to save up to 30% of heat resources, as well as protect plants from sunburn. The principle of its operation is that a special polymeric material folds and unfolds over the plants, thereby cutting off the roof. Collapsing and unfolding is done using special actuators called gearmotors.

CO_2 feeding system. The most important parameter of the microclimate, along with temperature and humidity, is the concentration of carbon dioxide in the air. This is due to the fact that carbon is the main building material for a plant and the process of photosynthesis (production of dry matter) is impossible without CO_2.

The most cost-effective solution is to use the off-gases from the boiler room for top dressing, and this is the case in most greenhouses. But in some cases it is necessary to resort to the use of liquid carbon dioxide for feeding, which is a more expensive solution.

Illumination system. The modern intensive technology of growing vegetables provides for the installation of an assimilation lighting system. For growing flowers, an additional lighting system is generally a necessary condition. The main task of the system is to provide a certain level of illumination for cultivation in those moments when natural light is not enough.

Air recirculation system. To ensure air exchange in the greenhouse, fans are installed in its upper part. When turned on, they provide air movement, equalization of the thermal field and accelerate convective heat transfer.

Automation of the microclimate regime. It is designed to link all of the above systems into a single whole, i.e. into a single process with centralized control of the microclimate support process.

All of the above natural and technological processes: heating and ventilation systems, shading and lighting, CO2 and recycling can be observed, controlled and managed using the digital technology of the Internet of things. The technology takes over the intelligent control of processes, for example, so that the microclimate in the greenhouse exactly matches the specified requirements of the owner of the greenhouse. Figure 2 shows a typical microclimate control system.

Figure 2 - Microclimate control systems

And, finally, at the end of the article, we present the results of the authors' research on the selection and use of a heating system for a greenhouse economy (boiler equipment). The considered overview of the types of boilers for greenhouses meets the most advanced requirements, they include heat storage tanks that allow the production of carbon dioxide necessary for plants during the daytime. As is known [3-4], most of the cost of products produced in greenhouses is energy costs. Therefore, the quality of the used power equipment comes to the fore.

Such global brands as "Crone", "Viessmann", "HKB" are used as boiler equipment, which allow obtaining high combustion efficiency with at the same time low emission of nitrogen oxide gases, as well as a high percentage of CO2 output. The latter fact makes it possible to successfully use flue gases from these boilers to feed plants with carbon dioxide.

Modern boilers are equipped with a number of special subsystems that guarantee long-term uninterrupted operation:

– each boiler must be equipped with a shunt pump, which ensures the circulation of water inside the boiler, making the process of water heating more uniform;

– the boiler must also contain a damper pump, which is activated at low return water temperatures and prevents the formation of condensate in the boiler.

It is recommended to use products of well-known companies as burners: Zantingh, Thermeta or Weishaupt. A distinctive feature of their burners is a wide range of adjustable power from 10% to 100%. Comparing the new burners with the previous ones, it is necessary to note the presence of frequency converters on the air supply fans, which allows significant savings on electricity.

To increase the efficiency of combustion, as well as to enable CO_2 extraction, some or all of the boilers are equipped with flue gas condensers. The effect of increasing the efficiency is that in the condenser the exhaust gases are cooled from 180 g to 60 g, while heating the coolant, and the cooled gases, after measuring the level of

CO_2, can be freely supplied to the greenhouse. The use of CO_2 for plant nutrition gives up to 15% yield increase. The entire operation of the boiler house can be entrusted to an industrial computer, which, upon request from the greenhouses, automatically increases or decreases the power of the boiler house and supplies CO_2.

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To provide plants with CO_2 during the day, a modern boiler house is equipped with an accumulator tank. Its principle of operation is that during the day the boiler room turns on to produce CO_2, and pushing cold water out of the tank, replaces it with hot water. At night, on the contrary, hot water from the tank enters the greenhouses, and cooled water from the greenhouses returns to the tank.

Thus, plants are supplied with the necessary amount of carbon dioxide without heat consumption. All battery management is carried out in a fully automatic mode.

As a result, we note that today there are many different systems that help a person manage a greenhouse, but unfortunately, all these systems are scattered in relation to each other.

Therefore, the implementation of a project that will combine all the necessary functions for remote control of a greenhouse into a single ecosystem is quite in demand at the moment. Therefore, in the project under consideration, the Arduino platform was chosen. Its advantage is the absence of a high-performance computer in the platform. Everything in Arduino is designed so that even a novice user does not write programs that are complex in meaning and structure. The compiled simple code could be downloaded to any user-accessible controller via a USB port. In Arduino, this advantage is achieved not by some programmer already built in advance, but by a special firmware - a “bootloader”. Firmware is special software that runs immediately after connection and listens for any commands, whether the processor needs to control the issuance of commands, if there are Arduino projects, etc.

When using such firmware, attractive advantages are revealed:

- the use of one communication channel, which does not require additional costs;
- Arduino projects will not require the use of many wires to connect sensors and actuators. So the occurrence of confusion in the wires is eliminated;
- one USB port is enough for successful operation;
- the controller does not need to be specially flashed, which simplifies its operation.

The user can independently program the bootloader into a pure microcontroller. To do this, the IDE has integrated programmer support based on the AVRDude project. Several types of popular and cheap programmers are supported

Thus, the Arduino platform or Arduino-compatible boards are made in such a way that they can be expanded if necessary by adding new components (sensors and actuators) to the device. These expansion boards connect to the Arduino via the pin headers installed on them. There are a number of boards with a unified design that allows structurally rigid connection of the processor board and expansion boards in a stack through pin strips. In addition, boards of reduced dimensions (for example, Nano or Lilypad) and special designs for unified solution tasks are produced.

Microcontrollers for Arduino are distinguished by the presence of a bootloader pre-flashed into them. With this bootloader, the user downloads their program to the controller without the need for traditional separate hardware programmers. The bootloader is connected to the computer via a USB interface or using a separate UART-USB adapter. Bootloader support is built into the Arduino IDE and is done with a single click.

In case of overwriting the bootloader or buying a controller without a bootloader, the developers provide the opportunity to flash the bootloader into the controller on their own. To do this, the Arduino IDE has built-in support for several popular programmers, and most Arduino boards have a pin header for in-circuit programming.

The next advantage of the platform is the presence of the Arduino IDE, based on the site "arduino.cc". Here you will always find a way or an opportunity to create your own software and hardware platforms

Let's note the simplest types of Arduino controllers:

– AVR. In the line of Arduino devices, Atmel AVR controllers are mainly used: ATmega328, ATmega168, ATmega2560, ATmega32U4, ATTiny85 with a clock frequency of 16 or 8 MHz. There are also boards based on the ARM Cortex M processor;

– ESP8266. Third-party developers have ported support for the popular ESP8266 Wi-Fi microcontroller to Arduino. Now you can compile and upload firmware for ESP8266 with your sketches and Wi-Fi support directly from the Arduino IDE, getting a single-board circuit with Wi-Fi support;

– Intel x86. As part of a collaboration with third parties, support for some Intelx86 hardware has been included in the Arduino IDE. Intel Galileo (Intel Quark X1000 400 MHz processor), Intel Edison and Arduino 101, i.e. Arduino-compatible boards on Intelx86 architecture. The boards are mechanically and electrically compatible with Arduino peripheral boards and run on their own Linux OS, on top of which runs an application that allows you to upload and execute Arduino sketches.

The input-output ports of the controllers are designed in the form of pin bars. There is no buffering, protection, level conversion. Microcontrollers are powered by 5V or 3.3V, depending on the board model. Accordingly, the ports have the same range of permissible input and output voltages. The user has access to some special features of the I / O ports of the controllers, for example, PWM, ADC, UART, SPI, I2C interfaces. The number and capabilities of I / O ports are determined by the specific version of the microprocessor board.

Third-party manufacturers produce a wide range of sensors and actuators (actuators) connected to the Arduino. For example, gyroscopes, compasses, pressure gauges, hygrometers, thermometers, relay modules, indicators, keyboards. Such a set of devices turns the Arduino into a universal controller core that can be configured in a wide variety of ways.

Thus, summarizing the results of their research, the authors of the article conclude that the microcontrollers or netbooks with processors that exist to achieve the goal of the project are either very expensive or do not perform the necessary functionality to solve the tasks of the project to create a "smart greenhouse"

The best option is to create a project based on the Arduino platform for its worthy characteristics and ease of creating devices.

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