Developing an IoT system for an agricultural enterprise on a single-board computer platform

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***Abstract*–The article discusses the main trends in the development of agriculture and the agro-industrial complex. Currently, for this industry, the priority tasks are the improvement, development and implementation of projects of intelligent agriculture, which includes the principles of automation and production robotization. The issues of developing a system for automated management of business processes for an agricultural enterprise are considered. The main stages of creating the hardware of the system, using microcontrollers, sensors and modules are defined. The organization of the server part of the developed system, as well as the connection of sensors and modules to the microcontroller, are investigated. The development of modules for monitoring and managing electricity, light, temperature and humidity using the C ++ programming language is presented. The analysis of test modules under the control of the microcontroller. Further development of this scientific direction can be directed to the development and creation of automated control systems based on single-bit processors.**

Keywords— IoT system, monitoring and control system, automated control systems, intelligent automation, system development, agriculture, agricultural enterprise.

I. Introduction

The capacity of factories and farms should increase by 70-100% to meet the needs of mankind due to the increase in the population of the planet. For this reason, companies are actively implementing Industry 4.0 projects in order to prepare for the growth of load. About every tenth agrarian economy or large holding in Russia uses digital technologies to increase its efficiency.

First of all, the industry is now launching projects of intellectual agriculture, which includes the principles of automation and robotization of production.

Agricultural smart systems should use external resources (fuel, chemicals) as little as possible to reduce the burden on the environment. At the same time, “green technologies” are increasingly used in agriculture: renewable energy sources, biofuels, organic fertilizers, etc.

About 80% of the industry manufacturers who work in the European Union, as of 2018, have introduced elements of the Internet of Things, in the USA about 60% of such companies [4].

In Spain, innovative products account for 12.7% of the total volume of goods and works shipped in the agro-industrial complex, in Denmark - 11.6%, in the Netherlands - 9.2% [3].

In Russia, approximately every tenth farm, farm or holding introduces precision farming technologies. These are the results of a survey conducted by Agroinvestor magazine among 200 market participants [1].

By the term Precision Farming, experts mean an integrated agricultural production system. In its contour, employees use IT-technologies, tools for automatic control of equipment, sensor technology, and so on.

Innovative products in the domestic agricultural sector account for only 1.4% of the total volume of sectoral products and work, 0.05–5% of manufacturers of the Russian Federation use IoT capabilities [2].

These technologies are only being introduced in Russia, while other countries have been engaged in this for a long time and therefore are far advanced. But the agricultural potential in Russia is very large, so from the point of view of the future, these technologies will be in demand.

The industry has great potential to reduce costs. For example, the production of grain crops can save about 30% if you implement the tools of the digital economy. Now the cost of 1 ton of grain is 6.58 thousand rubles, the figure actually reduced to 5.07 thousand rubles [4].

At the end of 2018, 189 farms in the Krasnodar Territory, 182 and 144 farms in the Voronezh and Nizhny Novgorod regions, respectively, were actively introducing elements of precision farming. In domestic agriculture, several digital solutions are popular today.

The most popular are the so-called parallel driving systems based on GPS: using satellite navigation, farmers can remotely control straight and curved driving of cars, while minimizing overlap and under-income of cars between pins.

Another IT solution that interests market participants is yield mapping. Due to special sensors, on-board computers and GPS receivers, it is possible to create special maps of grain yield and moisture. Companies get accurate predictions about what the results of the collection will be at the end of the season [5, 8].

In addition, decisions on differentiated fertilization are beginning to appear in Russia, this system helps to distribute the top dressings most effectively.

Thus, the development of IT control systems for this area of management is a priority for the development of the state economy, which needs the development of modern tools for managing its subsystems.

The current level of development of agriculture and the agro-industrial sector imposes very high demands on the organization of all its processes, ranging from the selection of land to the provision of security and control of auxiliary equipment. Requirements for the reliability of complex farm management systems are increasing.

The engineering equipment of enterprises as a result is steadily becoming more complicated, and the number of devices participating in the formation of this environment is growing.

The purpose of this study is the improvement and development of an automated control system for an agricultural enterprise to implement the functions of monitoring and managing its business processes.

Achieving this goal requires the following tasks:

- to determine the basic principles of the functioning of the developed system of automatic control of equipment for monitoring and managing business processes of an enterprise;

- identify microcontrollers as the main tool for the implementation of monitoring hardware;

- explore the use of sensors, modules and expansion cards that are compatible with microcontrollers;

- consider the possibility of using a computing server that will process the data transmitted from the microcontroller;

- identify the main electronic and electrical processes;

- identify the shortcomings of the chosen ways of implementation and propose alternative ways to solve them.

II. Methodology

The basic principles of the system will be considered on the example of an agrofirm that uses the technology of growing crops on the basis of a greenhouse system.

In each modern farm, to a varying degree, a large amount of equipment functions, providing and creating a full-fledged working environment. The convenience of managing these systems, their integration with each other, the ability to work together harmoniously, thereby increasing the functionality of each of them individually - makes it possible to call such an economy smart or intelligent. The IoT system (Internet of Things) optimally maintains a constant microclimate, thus maintaining the desired temperature, humidity and light.

Automated control system based on IoT technologies continuously monitors all engineering systems and prevents emergencies. Management also consists in obtaining information about the state of the system as a whole, as well as its transmission over any distance. This type of control system is an intelligent automation system for managing engineering systems of a modern economy.

The system provides a mechanism for centralized control and intellectual control in office, industrial, auxiliary and utility rooms of the farm, workshops, warehouses, oil depot, auto garage and other rooms. The use of the system allows the farm to set the parameters of the individual environment, manage all subsystems, and access information on the status of all systems.

The system interface is based on the interaction with the touch video panels, which display the plan of any room or the surrounding area and display images from video cameras.

When the system operates according to the chosen scenario, the farm worker quickly changes the device parameters. When installing certain modes, the system will turn off or place unused rooms in the economy mode (climatic warm chambers, air conditioners, etc.), and turn on the perimeter security mode. This ensures an economical and safe operation of the equipment. The system will notify about emergency situations through the built-in speaker systems or, if instructed, call the special services - the Ministry of Emergency Situations, the police, the fire station, etc.

III. Results

A huge number of functions are assigned to microcontrollers. They are programmed on the board using a development environment and a C / C ++ based programming language.

Sensors in the system measure different physical quantities or react to physical phenomena and send this information as an electrical signal.

Based on the action of the photoresistor, a circuit was created that transmits the data on the level of illumination as an analog signal to the control electronics. To do this, an elementary voltage divider is implemented, where one of the resistors is a photoresistor, and the second is a 100 kilo-ohm resistor.

Pyroelectric sensor captures the movement of warm objects. The output information from the sensor is a binary digital signal - if there is no movement, the signal contact is set to a logical zero. When motion is recorded, the signal contact is established in a logical unit for a certain period of time.

Infrared and ultrasonic range finders are connected to the system [6]. The first is used to bypass obstacles and orienteering. The second is to determine the distance to objects by generating sound pulses propagated by the sound wave to the object and back.

The system also has functional modules that carry a specific mechanism. Consider some of them.

The text display uses the LCD display MT-16S2H.

Module of the reed switch, inside which are flexible metal ferromagnetic contacts. Contacts overlap in length, but are located at a short distance from each other. There are several of them, for different inclusions. When the magnet is brought up to the reed switch, the contacts close / open. If you install it as a position control sensor, then when you raise an object, a siren will work.

Another system module is designed to manage the load. The maximum switching voltage is 250 volts or 30 volts. The rated switched current 10 Ampere. The contact group of the relay consists of three contacts, which makes it possible to control not only to close the circuit, but also to break it.

The LED indicator is available to control the operation of the module, it is connected to the system without additional strapping. It is galvanically isolated and, therefore, reliably protected from high voltage sources.

The system also includes data transmission modules that are used to organize wired and wireless communication between microcontrollers. Consider some of them.

Wireless communication modules nRF24L01 +, which are transceivers, organize a wireless survey of sensors, as well as sending commands to the actuators of the system. Based on them, a radio control system was built for system devices and other modules. Due to the high speed of information transmission, digitized sound and images are quickly transmitted through radio transmitters.

The transceiver is based on the nRF24L01 + microcircuit. The module supports sufficiently high speed and can operate on 126 independent channels, so several devices can interact with each other at once, without interfering with each other.

The nRF24L01 model is more suitable for point-to-point connections, in which the data channels are not protected at all. It connects to the control electronics via the SPI protocol with additional control contacts.

The system uses an Ethernet Shield expansion card, which acts as a network device for accessing other devices. It is based on the Wiznet W5100 chip, which supports both TCP and UDP protocols.

The web server is organized for remote monitoring and control of the system microcontrollers with connected sensors and modules, which is responsible for receiving and processing requests from clients to the site.

The most common web servers are Apache, IIS and iPlanet server. They support a large number of modules, utilities and add-ons.

The best option for a small agricultural enterprise intranet is Internet Information Server (IIS). It has an uncomplicated deployment and configuration process, integration with access control tools, performance monitoring system parameter monitoring tools, etc. IIS can be noted for a fairly high speed. Its components support the HTTP, HTTPS, FTP, NNTP, SMTP, POP3 protocols.

The next step in creating the system is to connect sensors and modules to the microcontroller.

General purpose resistors are used to change the resistance of the electric current. Their resistance varies within 10%, which depends on the temperature coefficient of resistance.

Another element of the system is a capacitor as a means of accumulating electricity in electrical circuits. Capacitors are used here as separating elements - where it is necessary to limit the passage of direct current, but skip the alternating one.

The next element is the transistor. To obtain increased power, use a series circuit of several transistors.

Consider an Arduino microcontroller as the most affordable means on the basis of which an automation and robotics system can be created for an agricultural enterprise.

There are several reasons for choosing this microcontroller. Arduino has long outgrown the stage of "toys" and shows itself as a serious development tool. In small farms it does not make sense to develop special systems (for example, Cropio - an automatic satellite monitoring system for agricultural land [7]) in view of their complexity and high cost. A large number of free libraries have been created for this microcontroller, with which you can program the functions necessary for monitoring and control. In addition, many types of sensors and other electronics are available for it, covering possible needs and demands of customers.

The microcontroller development environment contains two blocks: void setup () {} and void loop () {}. The setup block is executed only once at startup. The loop block defines the execution in a loop.

Required card and port parameters must be set before downloading the program.

The bootloader is used when loading a program that loads the program code without using additional hardware. When the platform is rebooted and when any program is loaded into the microcontroller, the Bootloader is active for a few seconds. His work is recognized by LED signals (13 pin).

The microcontroller uses serial bus monitoring, which displays the data sent to the platform. This indicates the transfer rate corresponding to the value of Serial.begin in the program.

We define in general terms the requirements for the device being developed.

First, there is a remote collection of the kilowatt consumption, which is shown by the electricity meter, as well as information about the load on the electrical circuit at the moment.

The electricity meter generates pulses in accordance with the amount of electricity consumed. Pulses are indicated by an LED indicator.

Then you can start creating a device that reads the meter readings, and allows you to remotely find out at any time the number of kilowatts spent and the load at the moment.

In order to connect the photoresistor to the microcontroller, it is necessary to take into account that the output of the photoresistor circuit will have a voltage in the range from 0 to 5 Volts, which must be converted to a specific number for the microcontroller to work.

The result is a voltage divider, the upper arm of which will vary depending on the level of light falling on the photoresistor. The voltage read from the lower arm is fed to an analog input, which converts it to a number from 0 to 1024.

When creating a program code, it is necessary to take into account the complexity level of the processor, its ability to work correctly with floating point numbers and the likelihood of complex calculations on the server.

With a large load of flashing of the counter pulses, they are rather short and frequent, the microcontroller must read the photoresistor readings very quickly and very quickly, therefore it is undesirable to load it with numerous calculations.

A variable is created that indicates to which input the photoresistor is connected. In the loop block, the readings of the photoresistor are constantly read and written to this variable.

The number of flashes is recorded, depending on whether the signal was on or off. As soon as they reach the gear ratio of the meter, the amount of electricity consumption becomes equal to 1 kilowatt, the pulse counter is reset. The resulting value of electricity is transmitted to the server for processing and storing statistical information (Fig. 1).

```
sketch_jun04a §
if ((val>500) and (impuls==false)){
     impuls = true;
}
  if((val<500)and(impuls==true)){
    imp++; //количество импульсов
}
if (imp==schetchik){
        imp=0; //по достижению А, обнулить импульсы
        kilovat++;  //количество киловат
      }
impuls=false;
```

Fig. 1. Calculation of electricity consumption

The computing power of the microcontroller is enough to process these values in the normal mode. However, in order to implement load monitoring, it is better not to overload the microcontroller with additional operations, since in order to calculate the load, it is necessary to record very precisely the flashing time of the indicator, which may flash several times per second. The more accurate the flashing time, the smaller the error in the calculations.

It is necessary to know the load at the moment, in addition to determining the number of kilowatts. To do this, use the millis () command, which starts the stopwatch. If you remember the time when the counter turned on and when it turned off, then considering the difference between these values, the duration of one pulse is determined.

The power consumption of each appliance with their alternate inclusion in the network with a minimum load of the network is recorded separately for each room. Based on this data, it is determined which devices can be switched on at the moment.

If for some reason the worker forgot to turn off the appliance, then going to the web server, he will be able to see which appliances are now turned on, which will reduce electricity consumption.

In addition to monitoring the readings of electricity, the system should be able to determine and record the ambient temperature both indoors and outdoors.

The DHT11 temperature and relative humidity sensor is used to measure the indoor temperature. The readings recorded by this sensor are displayed on the LCD 1602 display, and are also sent to the server for collecting and displaying statistical information (Fig. 2).

The recorded data is sent to the server. Also, the temperature can be displayed on the display, so that each time you do not go to the site. To do this, use the LiquidCrystal.h library. It is connected with the #include command, then the LCD is initialized with indication of the control contacts by the LiquidCrystal.lcd () command. In the setup block, the display dimension is set with the lcd.begin (x, y) command.

Functions are also added: displaying the current temperature value; output the minimum and maximum values; moisture output.

That all this information was located on the display, function of change of the screen once every three seconds is added. This feature works by cleaning the screen and displaying the characters again.

The current temperature is displayed on the first screen, on the second - the minimum and maximum values of temperature, and on the third - humidity.

```
sketch_jun04a §
#include "DHT.h"
#define DHTPIN 3
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);

void setup()
  {
  }
void loop()
  {
    int h = dht.readHumidity();
    int t = dht.readTemperature();
  }
```

Fig. 2. Readings from the temperature sensor

These functions are implemented with the millis () command, which starts the counter and counts 3 seconds, then changes the screen to the next, depending on which one was turned on. In this case, the screen order is set using boolean variables d1, d2, d3, meaning respectively the temperature, the minimum and maximum temperature values, as well as humidity.

The initial values for d1, d2 and d3 are set to true, false and false, respectively. This means that when the program starts, the display will show information about the current temperature.

When displaying text on the display, time t1 is fixed, equal to the current time of the counter. As soon as the time difference between the counter and the fixed value of t1 becomes more than three seconds, the information from the display is deleted. In this case, t1 again changes to the current time value of the counter and d1, d2, d3 become equal to false, true, false. This means that the screen that displays the minimum and maximum temperature values will be active at the moment.

The screen displaying humidity is implemented in a similar way. Thus, it turns out a cyclic change of display of information on the screen every three seconds. This allows you to monitor the temperature and relative humidity readings in the room without having to go to the web interface where the information will be stored.

The system also developed a module that performs automatic notification of illegal entry into the farm. Informing occurs on any known communication channel (loudspeaker, telephone, electronic message).

The reed switch module is used to fix the opening or closing of doors. In order not to waste the free resources of the microcontrollers, the reed switch is connected to the microcontroller, which fixes the temperature and humidity, and displays the readings on the display through a free digital output.

Connecting libraries in this case is not necessary. To receive data from the reed switch module, a digital output is set on the microcontroller. This information is then read in the loop block. The result is transmitted to the server, which informs about the opening and closing of the door through the communication channel. The opening or closing state of the entrance door is displayed on an already used display, since it has a lower line of 16 characters.

Thus, you can be completely sure that no one entered the premises during the absence of workers in it. You can also find out how many times and at what time the front door opened and closed, and determine how long it was open.

Motion sensors are also installed to save energy. They give the command to automatically turn on the light when workers appear.

When using an infrared motion sensor, moving inanimate objects does not affect the automatic switching on of the light. It reads thermal radiation from the object and, based on the change in the position of the thermal radiation, sends 0 or 1 to the microcontroller. If there was no movement, the signal is zero, otherwise - 1.

We present the results of the analysis of the test modules of the microcontroller.

The microcontroller is multifunctional, but has several limitations. The first is a small amount of memory. 32 and 64 kilobytes of memory is enough to write compact programs. With a significant scale of operations, it is necessary to use an external memory module.

Another limitation is low computational characteristics. As the analysis of the microcontroller's operation as an automatic reading of the electricity meter indicator showed, this microcontroller does not work correctly with real numbers. When working with them, he may lose some remainder of the fractional part or nullify the variables when they are divided.

Sometimes it is necessary to send data for processing to an external server to avoid this, as well as to use additional processing devices such as, for example, the Raspberry Pi 2 Model B. It has a processor, RAM, HDMI, USB, Ethernet connectors, analog audio and video outputs. It also has 40 general-purpose I / O pins. Peripherals can be connected to them for interaction with actuators such as a contact relay, servomotors and any sensors.

Microcontrollers operating in the system have 512 bytes of EEPROM, a non-volatile memory that stores data available after a power outage. This allows you to fix the failures of the program and prevent overloading the microcontroller.

IV. Conclusions

The Internet of Things in the agricultural sector is one of the most promising niches in the development of agricultural technologies. The introduction of artificial intelligence technologies in agriculture has benefits for the business of Russia.

In this paper, we consider such an element of digitization of the agrarian complex of the country as smart farming. The development of an IoT solution for an agricultural enterprise that performs the functions of monitoring and managing electricity, temperature and humidity in the premises used is presented. It is used to automatically control various devices on a single-board computer platform. Analyzed the limitations and possible failures in the system, suggested ways to solve them.

The use of the developed software for intelligent systems in agriculture will allow the company to develop steadily, economically and steadily, which is a priority task of any economic entity in the modern conditions of the development of society.

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