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THE APPLICATION OF IOT SOLUTIONS IN GREENHOUSES WITH THE AIM OF REDUCING ELECTRICAL ENERGY CONSUMPTION
PRIMENA IOT REŠENJA U PLASTENICIMA SA CILJEM SMANJENJA POTROŠNJE ELEKTRIČNE ENERGIJE

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ABSTRACT

In this paper, we will show a prototype of a system designed based on Internet of Things solutions with the aim of optimizing electrical energy consumption in order to achieve desired conditions for the growth and development of plants located in the greenhouse. The physical parameters that this system monitors are temperature, relative humidity, soil humidity and luminescence levels. In this prototype, we have three measurement nodes with the task of collecting parameter data, processing them and sending resulting data, via wireless communication, to a receiver. The receiver forwards data to the application on PC. The application processes the data and displays it to the end user who can choose to automatically or manually control the devices that are inside of the greenhouse. Systems placed inside the greenhouse are heating, irrigation, lighting and ventilation systems.
Keywords: *prototype, greenhouse, control, application, Python*

REZIME

U ovom radu je prikazan razvijeni prototip sistema, projektovanog na bazi Internet of Things rešenja, koji ima za cilj smanjenje potrošnje električne energije pri postizanju željenih uslova za rast i razvoj biljaka koje se nalaze u plasteniku. Fizičke veličine nad kojima se vrši monitoring jesu temperatura, relativna vlažnost vazduha, nivo osvetljenja i vlažnost zemljišta. U prototipu su realizovana tri merna noda koja su raspoređena u plasteniku i sakupljaju podatke o merenim veličinama, obrađuju ih i, putem bežične komunikacije, šalju do prijemnika. Prijemnik, po pristizanju podataka, dalje podatke prosleđuje aplikaciji koja se nalazi na računaru. Aplikacija, napisana u Python programskom jeziku, obrađuje pristigle podatke i prikazuje ih krajnjem korisniku, koji može da izabere automatsko ili ručno upravljanje uređajima. Pored prikazivanja podataka i upravljanja uređajima aplikacija omogućava krajnjem korisniku postavljanje alarma za svaku merenu veličinu, prikaz istorije merenja kao i logovanje podataka za dalju obradu. Sistemi kojima se upravlja unutar plastenika su sistemi za grejanje, navodnjavanje, osvetljenje, ventilaciju. Uređaji su povezani na relejni modul koji je dalje povezan na prijemnik. Kada je potrebno promeniti stanja uređaja aplikacija šalje naredbu prijemniku koji postavlja releje u zadata stanja. Upotrebom ovakvog sistema krajnji korisnik može da obezbedi željene uslove u plasteniku sa minimalnom potrošnjom električne energije.
Ključne reči: *prototip, plastenik, regulacija, aplikacija, Python*

INTRODUCTION

Implementation of IoT solutions in agriculture is taking momentum in recent years. The solutions that make their application in greenhouses and allow the user to monitor the desired parameters within the facility are particularly significant. With the ability to perform acquisition in many differing ways (Nikolić et al., 2016), it was decided that this prototype should collect data wirelessly by using multiple measuring nodes. By adding device management capabilities within the facility, it is easier for the user to work with the equipment and achieve optimal conditions for plant growth and development. Using this type of system improves the quality and quantity of the final product. Achieving optimal conditions can be ensured through establishing manual control, but there are major drawbacks in areas of maintenance and greater cost from the point of view of electricity consumption. It is possible to calculate energy losses due to heating (Kamenko et al., 2016). With automatic regulation, it's easier to maintain optimal conditions (Dimitrijević et al. 2015; Dimitrijević et al., 2016; Karadžić, 2005; Karadžić, Babić 2005), with minimal electricity consumption.

MATERIAL AND METHOD

The realized prototype consists of three measuring nodes, a receiver and a PC. The prototype block scheme is shown in Fig. 1. Each measuring node consists of an Arduino Nano board, which is the central part of the measuring node, SHT3X, a sensor for measuring temperature and relative humidity of the air, TEMT6000, a sensor for measuring luminescence levels, capacitive soil moisture sensor and NRF24L01 wireless communication module. Each node is powered by a 9 V battery. In the algorithm implemented on the microcontroller, readings are done every 30 s. This time interval is selected given that all physical processes take place relatively slowly and that no rapid and sudden changes in the values that are measured are expected. On the other hand, the time interval cannot be too long because device management and regulation Algorithm are being performed based on the last set of measurements. Taking into consideration previously mentioned conditions, the time interval that was selected as optimal value is 30 s. If needed, this time interval can be longer, depending on actual needs in implementation. However, a longer time interval gives longer battery life. After successfully reading the value with the sensors, processing it and sending the data, the microcontroller and wireless module enter the deep sleep mode in which they draw minimal power from the battery. To further save battery power, the sensors are connected to the microcontroller's digital outputs. Before reading the sensor, power is provided through digital output, and that enables the sensor to be powered down after acquisition, which saves power until the next cycle of data

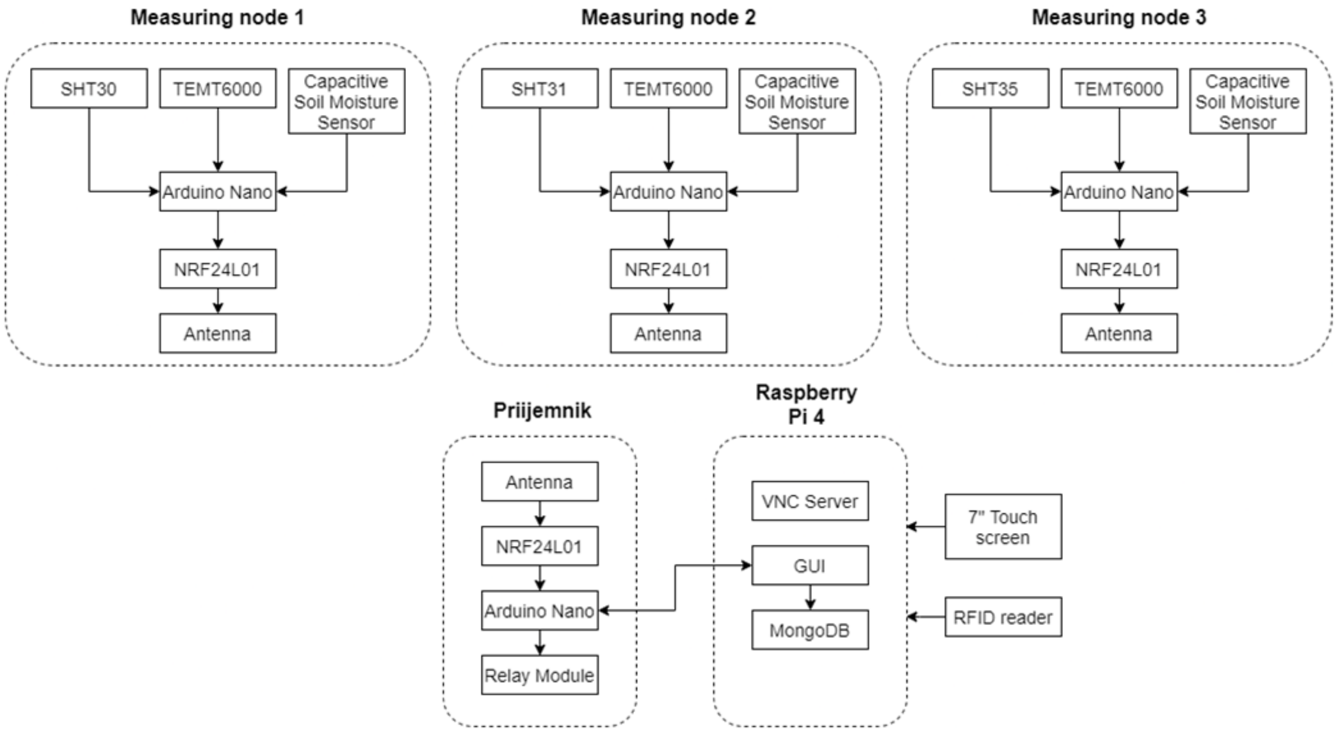

Fig. 1. Prototype block scheme

acquisition. This type of connectivity is enabled by the increase in the current capabilities of GPIO pins of the microcontroller itself and the small current requirements of the sensors themselves.

The receiver consists of an Arduino Nano board to which NRF24L01 and relay module are connected. The receiver is connected to the computer, which in this instance is a Raspberry Pi 4. Raspberry Pi 4 has a GUI (Graphical User Interface) application that communicates with the receiver. The decision to select the previously mentioned PC has been made after the need for a reduction in electrical energy consumption was taken into consideration. To interact with a PC, we have used a 7'' touchscreen.

The application is created in Python programming language and its tasks include: receiving data from the receiver, processing, displaying and storing data, managing devices, and managing all of the user commands. The application layout is shown in Fig. 2. In order for the application to successfully perform all tasks, a multithreading method of execution is used.

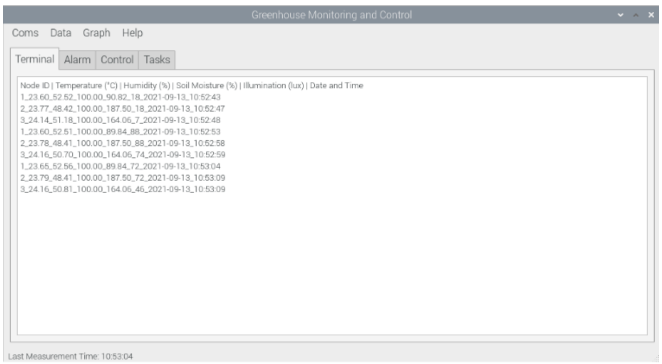

Fig 2. Application layout

Additionally, an RFID (Radio Frequency Identification) reader is used to increase security and restrict access to unauthorized personnel. Each user is given an RFID card with a unique code, the reading of which confirms the user's identity and unlocks the application for further interaction.

RESULTS AND DISCUSSION

In order to further reduce the load on the battery, it is suggested to use the power control from Fig. 3.

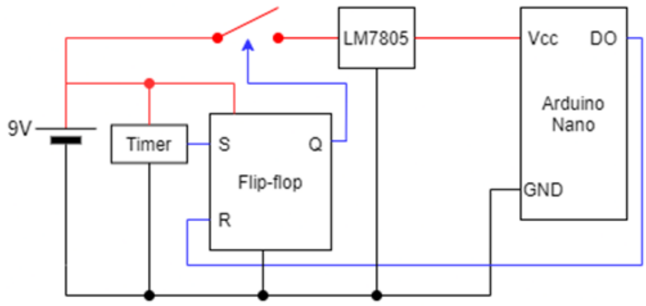

Fig. 3. Power control proposal

A 9 V battery is the source of electrical energy, but the energy is not consumed constantly. Using the proposed scheme, only a part of the hardware made in CMOS technology is constantly powered by the battery. This block has exceptionally low current consumption, which is at the level of self-discharge of the used battery. The role of the CMOS block is to generate a time interval when the electronic switch should be turned on to provide the rest of the circuit with the supply voltage. A Set Reset Flip Flop (SR FF) set by CMOS hardware is used for this purpose. The SR FF output turns on an electronic switch and supplies power to the microcontroller and the rest of the circuit. Upon completion of required tasks, the Arduino gives the command to reset the SR FF, which is why a logical zero is set at its output, causing the electronic switch to turn off, and thus the power supply to be interrupted. It is also recommended to use a higher capacity battery, such as power bank solutions, which can be charged via solar panels. In addition to battery power, the possibility of mains power (AC power) connected to sensor nodes in larger greenhouses was also considered, where applicable. In the realized prototype a battery power supply was used in order to conduct the system operation test. Battery power provides an additional degree of flexibility in the process of measuring and the parameters that correspond to the appropriate physical values of interest in the greenhouse. During the trial period, it is possible to place several sensor nodes in various locations within the greenhouse. Based on the collected data, it is possible to decide on the nominal number of sensor nodes required for optimal operation and continue to work with that number without powering an unnecessarily large number of additional nodes. During the test, the usage of battery power supply enabled no further need to provide mains voltage to the place where we want to perform a test acquisition to gain a better understanding of the behavior of the physical parameters of interest.

There are several ways to manage devices in the greenhouse within the application. The first way is by setting the limits of the measured quantities. Setting the limits and enabling control of an algorithm that will perform hysteresis control of the device, where the limits of hysteresis are set by the user, as shown in Fig. 4.

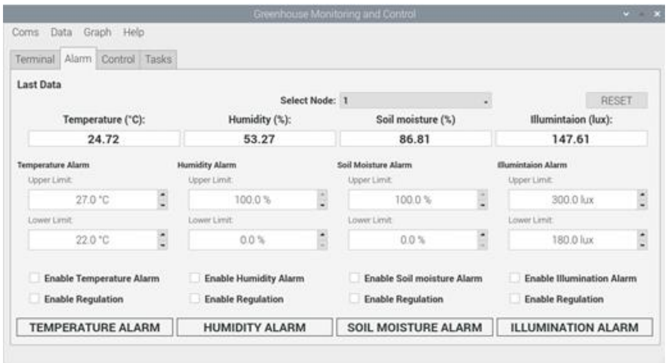

Fig. 4. Alarm tab

Fig. 4 shows the Alarm tab of the application in which it is possible to set the limits of hysteresis. In addition to setting the hysteresis control, it is possible to see the last read values for each measured physical parameter. There is also a possibility to choose the measurement node whose data is being displayed. In addition to the listed options, the user can also monitor the status of alarms that have been set. Each alarm can further be monitored graphically, with the state of the field at the bottom of the window as a visual indicator. If the field is green, the monitored value is within the specified limits. If the field is red, the monitored value is outside the specified limits. The field which is colored white represents inactive alarm.

The second way of management is one where the user can directly and instantly change the status of all devices in the greenhouse, as shown in Fig 5.

Fig. 5 shows the Control tab of the application. In this part of the application, the user can manually operate the devices in the greenhouse. Each device is represented by a single button and clicking on it changes the status of the device. If the button is red the device is not active, if it is green the device is active. The algorithm that sets the state of the device requires the user to first set the devices to the desired states, and then to select the SET STATES button. Clicking on this button sets the devices to the desired states. In addition, this option allows the technicians to quickly check the correctness of each device. In addition to these options, there is a TOTAL STOP button that puts all devices in an inactive state. Additionally, the last measured values, from each node, are displayed on the screen.

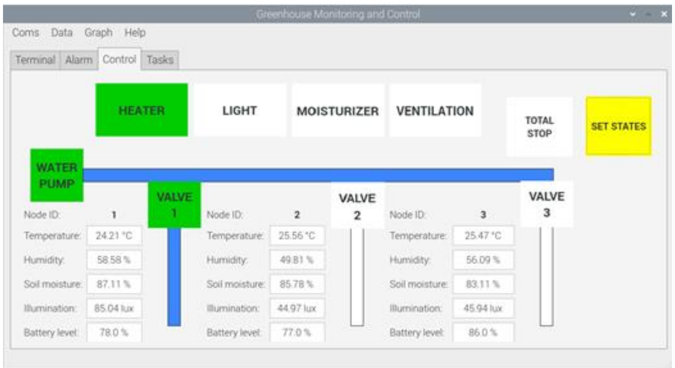

Fig. 5. Control tab

The third way to control the device is by setting tasks. The application allows the user to set tasks that need to be performed in a specific time period. To create a single task, the user must enter the start and end time, the state of all devices during the task, and a brief description of the task being performed, as can be seen in Fig 6.

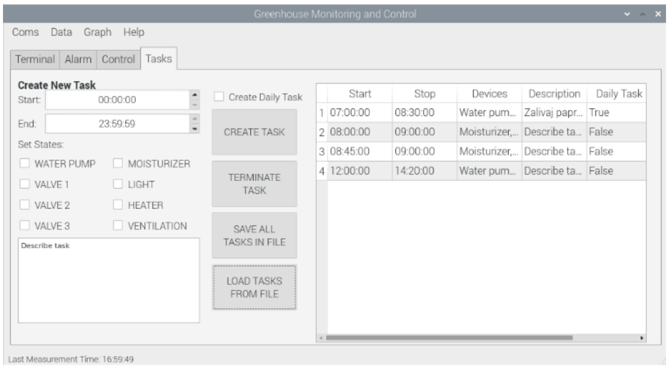

Fig. 6. Tasks tab

Fig. 6 shows the Tasks tab of the application in which the user can monitor the status of all tasks that are set. All tasks are listed in a table. When the task is activated, the corresponding field in the table will be green. When the task is completed, it will be automatically removed from the table, unless the user has specifically indicated that the task is to be performed repeatedly every day by selecting the Create Daily Task option. If this is the case the task will remain in the table. Additionally, the user is allowed to save the set tasks for later usage and to load previously set tasks from the external file.

It is easy to conclude that the biggest losses in the greenhouse occur with the use of electric heating. The prototype of the proposed system assumes that this method of heating is implemented in the greenhouse. Alternative ways of heating greenhouses can be based on the usage of hot water or heating lamps. If the plants are located on the floor of the greenhouse, in pots, it is recommended to provide heating with hot water in the form of pipes that are placed in the floor, through which hot water flows. Again, the question that arises is, in which way to heat the water? Alternative ways of heating and cooling the greenhouses are based on biothermal energy where water is heated and cooled using energy from renewable sources. Using this energy can save money when the long-term investment is taken into consideration, but more investment is needed when setting up the system itself.

CONCLUSION

The choice of using greenhouses in the production of plants is a big step for every manufacturer. Due to its energy inefficiency, it is necessary to pay attention to the choice of shape, foil thickness and insulation that is being used. The application of control systems for devices located in the greenhouse leads to an increase in energy efficiency, and in achieving optimal conditions of physical parameters such as temperature, relative air humidity, light level and soil moisture. The system proposed and presented in this paper has been successfully implemented and shows that it is possible to use widely available components to implement a complex system that meets the needs of optimization of electricity consumption, and achieving optimal conditions for growth and development of plants within greenhouses.

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