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Remote Access Greenhouse Automation Application Based on LabVIEW

Uzaktan Erişimli LabVIEW Tabanlı Sera Otomasyonu Uygulaması

[1]Behçet KOCAMAN, **[2]Mehmet Fatih GÜLER**

[1]Bitlis Eren Üniversitesi, Mühendislik-Mimarlık Fakültesi, Bitlis, Türkiye
[2]T.C. Milli Savunma Bakanlığı, Ankara, Türkiye

[1]bkocaman@beu.edu.tr, [2]guler.mfatih@gmail.com

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ABSTRACT

Various automatic control systems have been established in order to increase the yield of the products to be obtained from the plants grown in the greenhouses. These control systems come into prominence in ensuring the automatic solution of the determined problems by being activated quickly, controlling the temperature and moisture values in the greenhouse and in the stable operation of the system. In this study, remote access greenhouse automation application with NI MyRIO control card was carried out on the prototype. System datas were monitored and controlled in real time with the LabVIEW (Laboratory Virtual Instrument Engineering Workbench) graphical program. The values of the plants to be grown in the greenhouse such as water, temperature, moisture and appropriate photosynthesis light ratio are measured and determined by the sensors used in the system and shown to the user with the LabVIEW interface program with the NI MyRIO control card.

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ÖZET

Seralarda yetiştirilen bitkilerden elde edilecek ürünlerin verimini artırmak için çeşitli otomatik kontrol sistemleri kurulmuştur. Bu kontrol sistemleri, hızlı devreye girerek belirlenen problemlerin otomatik çözümünün sağlanmasında, sera içindeki sıcaklık ve nem değerlerinin kontrol edilmesinde ve sistemin stabil çalışmasında ön plana çıkmaktadır. Bu çalışmada, NI MyRIO kontrol kartı ile uzaktan erişimli sera otomasyonu uygulaması, prototip üzerinde gerçekleştirilmiştir. Sistem verileri, LabVIEW (Laboratory Virtual Instrument Engineering Workbench) grafik programı ile gerçek zamanlı olarak izlenip kontrol edilmiştir. Serada yetiştirilecek bitkilerin su, sıcaklık, nem ve uygun fotosentez ışık oranı gibi değerleri sistemde kullanılan sensörler tarafından ölçülerek belirlenir ve NI MyRIO kontrol kartı ile LabVIEW arayüz programı ile kullanıcıya gösterilmektedir.

ORCID ID: [1]0000-0002-1432-0959
[2]0000-0003-3291-407X

1. INTRODUCTION

Nowadays, the need for agricultural products has increased with the increase of the world population and it has become very difficult to meet the desired product at the desired time. In order to prevent this situation, greenhouses where fruit and vegetables are grown have been established. It is important in terms of applying developing technologies to the agricultural sector in developing countries and bringing the market share of the agricultural economy to the desired level. In this respect, to integrate technology into agriculture; together with the agricultural industry, it enables it to connect with many sectors and to development many sectors. One of the applications of technology in agriculture is greenhouse automation. Thanks to this automation, the control of the temperature, moisture, light and irrigation amount needed by the plant during the production phase is provided.

It is not possible to grow plants in all seasons of the year in traditional farming systems. In addition, plant productivity is not optimum in these systems. There should be suitable conditions for growing plants in all seasons of the year. These environments can be provided with a greenhouse. Because greenhouses protect plants from too much heat or cold and dust storms. In this study, a greenhouse automation system has been designed to provide a suitable environment for plants, providing temperature, ventilation, light and irrigation.

Greenhouse technology and controlled environment agriculture (CEA) some of the latest developments in CEA have been highlighted. For this, various aspects of a high-tech CEA system, such as the framework and coating materials, environmental perception and data sharing, and advanced microclimate control and energy optimization models, are discussed. It also described urban agriculture and its derivatives, including vertical farming, rooftop greenhouses and plant factories [1]. It has been proposed to develop a cost-effective automated system for greenhouse environmental control. It has been analyzed in terms of architectural and functional features. The proposed embedded platform provides remote monitoring and control of the greenhouse environment. It is also implemented as a distributed detection and control network integrating wired and wireless nodes [2]. The development of a greenhouse area network system and intelligent wireless sensor and field performance to monitor, control and access sera microenvironments has been proposed [3, 4]. It has been proposed to the design and implementation of the electrical and mechanical requirements of a smart greenhouse system. Measurement and control systems have been developed to autonomously manage the greenhouse and the interconnection between hardware components such as sensors, actuators and controllers. The system is based on a wirelessly connected microcontroller [5]. The software application created for smartphones with Android operating system provides remote user access to the database over the Internet for remote control and analysis of climate indicators in the greenhouse. The lighting control system suggested in the greenhouse improves the greenhouse lighting control system and increases efficiency. Thus, it contributes to the development of agriculture [6]. An automatic pest count and environmental status monitoring system using integrated camera modules and an embedded system as sensor nodes in the wireless sensor network has been built. Information on pest concentrations has been further analyzed temporally and spatially, together with environmental factors [7]. It is aimed to examine the progress of microcomputers in smart remote monitoring and control applications for the control and management of different systems using wireless / wired techniques [8]. A general scheme of an intelligent greenhouse control system based on the Internet of Things (IoT) and Zig Bee wireless sensor network technology is designed. Greenhouse control strategy has been investigated using IoT technology and fuzzy adaptive PID control algorithm [9,10]. The design system applied using LabVIEW, allowing the user to monitor the data obtained from the greenhouse, a real-time remote light intensity, temperature and humidity monitoring system was designed and applied for the greenhouse based on Raspberry Pi3 platforms [11]. Current strategies for energy efficient control operation and state of the art energy simulation for greenhouses are explained [12]. The environmental factors affecting all indoor temperatures for the greenhouse were collected as data on outdoor air temperature, wind speed and external solar radiation. In this research, 13 different training algorithms were used for Artificial Neural Networks models. Based on K-fold cross validation and Randomized Complete Block methodology, the best model was chosen [13]. A new phenotyping greenhouse facility has been designed. It is built with an automatic, highly efficient imaging system and a belt-based plant conveyor. Plants were transported to the greenhouse during the experiment with the conveyor system controlled by computer algorithm [14]. It is aimed to increase the quality and efficiency of greenhouses by saving time, energy, light and water consumption by measuring and controlling the climate parameters that are effective in the formation of climate factors in greenhouses. For this, it has been controlled with the fuzzy logic-based control strategy proposed as an intelligent and remotely accessible Android based interface [15]. A decentralized smart irrigation approach has been proposed for strawberry greenhouses. It performed significantly better than the traditional approach in terms of both soil moisture change and soil moisture [16, 17]. A wireless sensor network prototype of MicaZ nodes used to measure the temperature, light, pressure and humidity of greenhouses is presented. With this system, farmers can control their greenhouses from the moisture on their mobile phones or computers with internet connection [18]. A greenhouse sensor smart management system based on the Internet of Things has been designed. The performance of the system has been tested in the laboratory. The results showed that the system is reasonable, the structure is compact, the network layer is reliable, and the performance is stable [19]. Based on the current state of development of greenhouse remote monitoring systems, a greenhouse remote monitoring system based on WinCE has been designed and developed. The remote control of the greenhouse is realized by monitoring. Computer and mobile phone tests have shown that the system is reliable and easy to use, and that the expected goals are achieved in every respect [20]. Using a combination of Arduino, different digital sensors, bluetooth module and mobile device, a system of monitoring natural ambient light in a greenhouse with a sensitivity similar to other electronic devices has been made. It is stated that the system can provide assistance to small entrepreneurs in the vegetable and horticultural sector [21]. Enclose-Loop wireless power supply technology has been proposed to take into account the distribution of the sensors in smart greenhouses and for the energy consumption of the sensor nodes. The proposed wireless transmission technology has been stated that the sensor node can effectively resolve the energy consumption and charging [22].

In this study, differently from the studies, remote access greenhouse automation was designed using the MyRIO control card and LabVIEW interface program. The rest of the paper has structured as follows. In Section III, material and method have explained. In other words, hardware and software features of the device prototype have described. Results and discussion have investigated in Section IV. Conclusion has been evaluated in Section V.

2. MATERIAL AND METHOD

In this study, a greenhouse prototype was created in order to create the necessary climatic conditions for the plants to be grown in greenhouses and to allow the plants to act as if they were outdoors. A control system has been designed for this. In the control system, the fans for cooling, heating, ventilation, lighting and irrigation rate are automatically managed by a specific program with the MyRIO control card and the LabVIEW interface program. The proposed system consists of experimental and software. Experimental mainly includes analog/digital input and digital output circuits, MyRIO control card, test cables, LM35 temperature sensor, infrared heater and relay, rain sensor, Light Dependent Resistors (LDR), Light Emitting Diode (LED) lighting and relay, soil moisture sensor, water pump, relay, servo motor, fan and computer. LED luminaries were preferred for lighting. Because it is one of the best solutions in the field of sustainable lighting for light quality and energy efficiency and is small in size compared to traditional luminaries [23-27]. The block scheme of the experimental setup is shown in Figure 1.

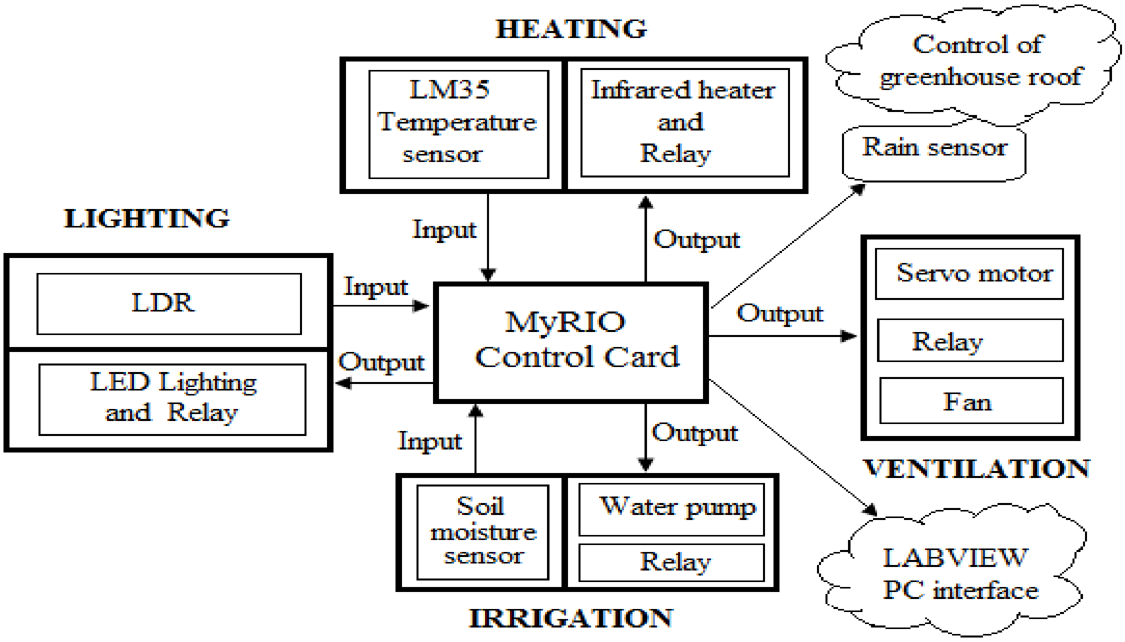

Figure 1. Block scheme of the experimental setup.

In the designed system, the control of the greenhouse is done in terms of ventilation, heating, irrigation and lighting systems. These systems are managed by the program prepared automatically with the MyRIO control card. First of all, parameters such as moisture, temperature, light are recorded for automatic or manual monitoring and control of the greenhouse. The recorded data is presented to the user with the designed LabVIEW interface program. Flowchart of the proposed system is given in Figure 2.

As can be seen in the flowchart in Figure 2, the primary MyRIO control card is introduced to the system and all operations are performed in connection with the MyRIO control card. It compares the values obtained from the MyRIO card, LM35 temperature sensor, Light Dependent Resistors (LDR) lighting sensor, rain sensor and soil-moisture sensor with the values determined by the user in the LabVIEW graphical program. Later, the values read by the MyRIO control card are decided in the decision cycle and the system runs continuously. The photograph of the experimental setup of the designed system is given in Figure 3.

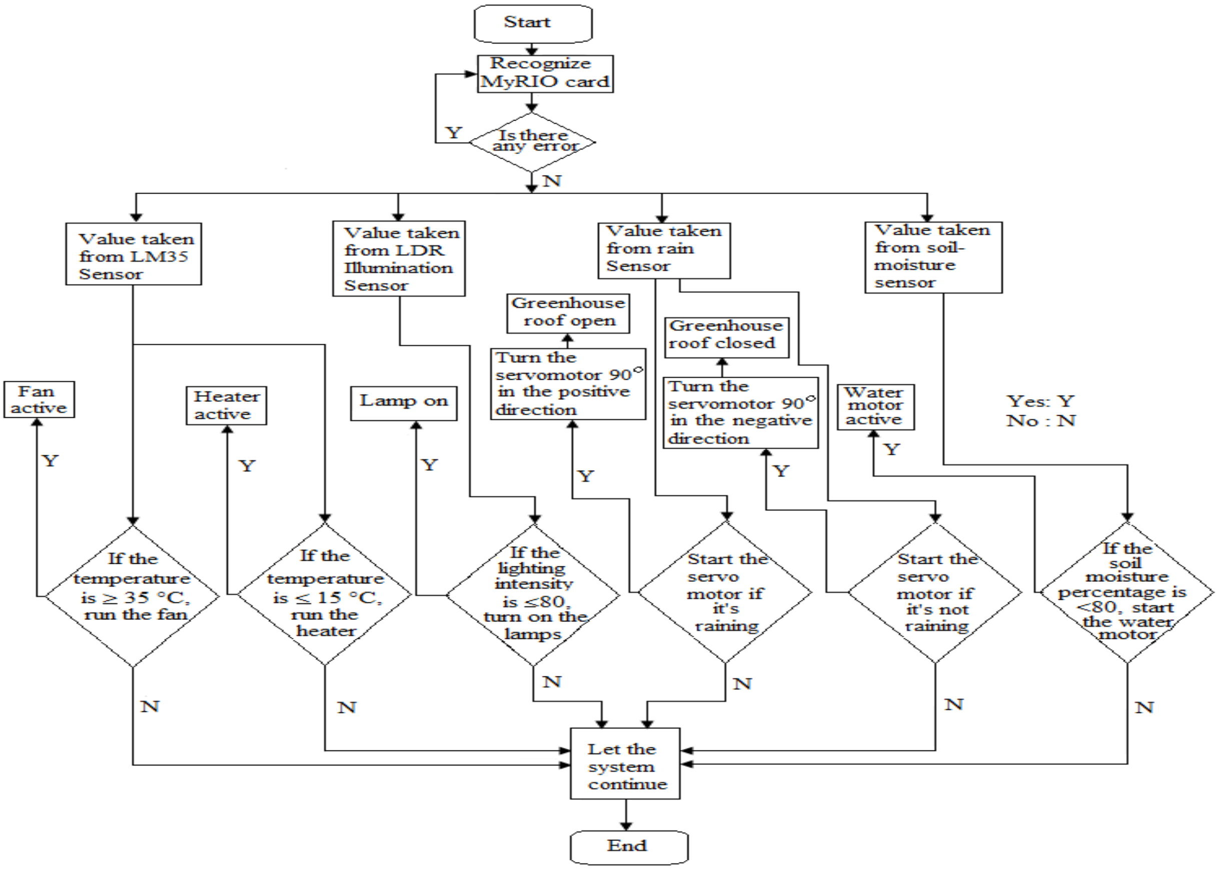

Figure 2. Flowchart of the proposed system.

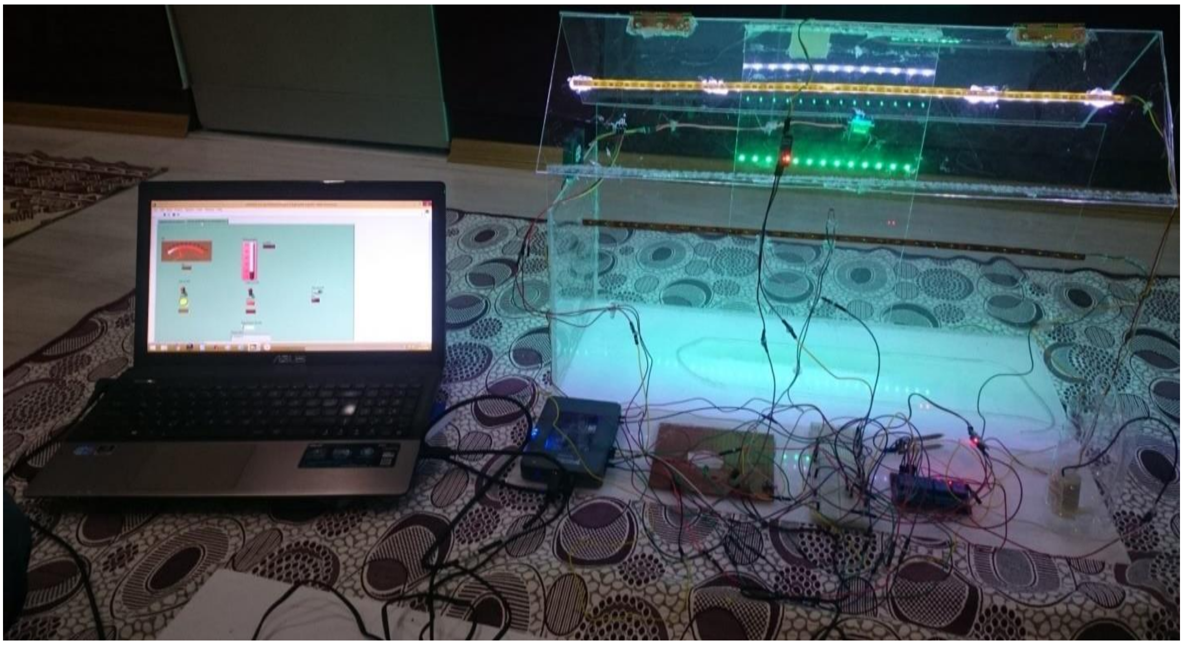

Figure 3. Photograph of the experimental setup.

In this study, block diagrams in accordance with the working logic of the sensors in the LabVIEW visual program for the automatic control of the greenhouse in the designed greenhouse prototype and front panels for the user to see the values taken from the sensors were created. For these, greenhouse roof control software, soil-moisture control software for irrigation, lighting control software, temperature control software for heating, ventilation control software, reporting software of moisture and temperature values in the air conditioning system, data communication software was made in LabVIEW program. Graphical programming block diagram is given in Figure 4.

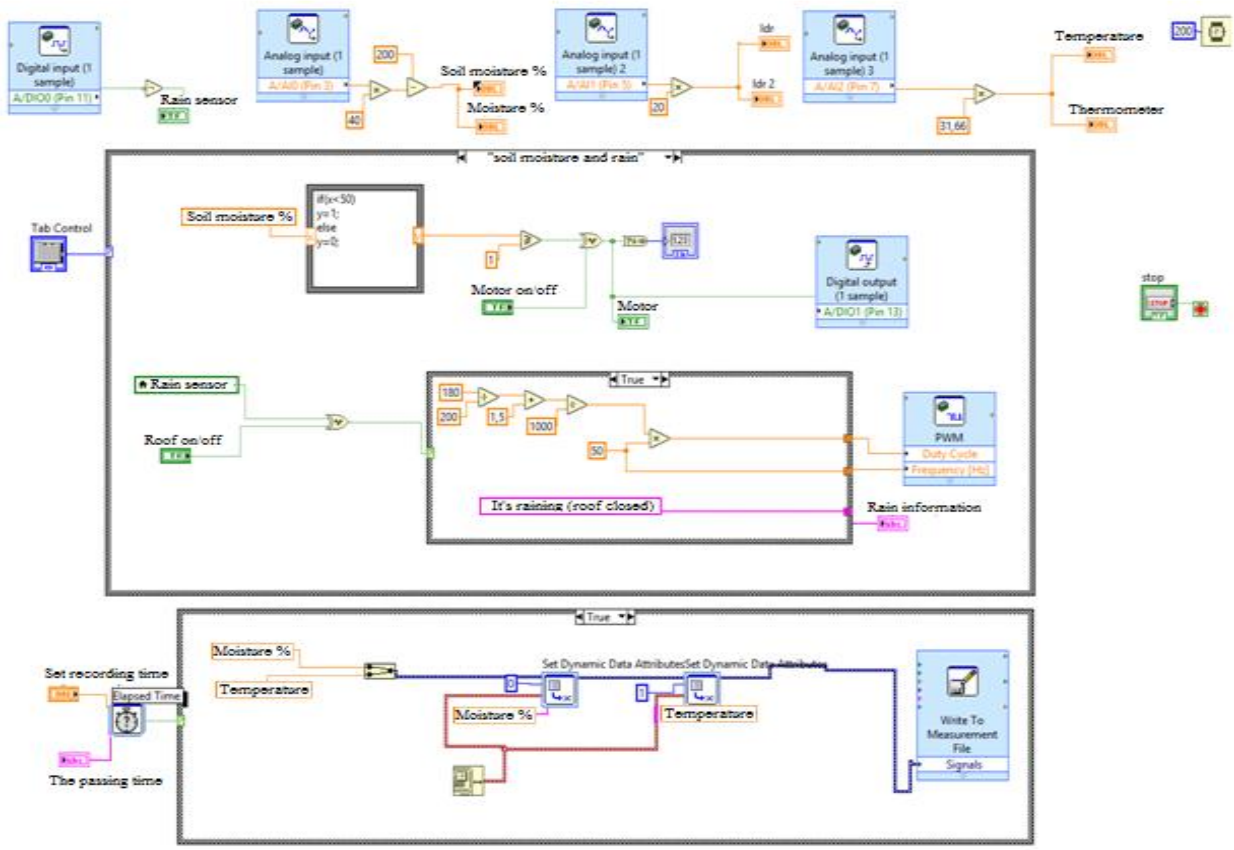

Figure 4. Graphical programming block diagram.

3. RESULTS AND DISCUSSION

On the designed greenhouse automation prototype; the greenhouse roof control software, soil-moisture control software for irrigation, lighting control software, temperature control software for heating, ventilation control software, software for reporting moisture and temperature values in the air conditioning system, and the program have been tested on LabVIEW user interfaces. The LabVIEW interface of the designed system is given in Figure 5.

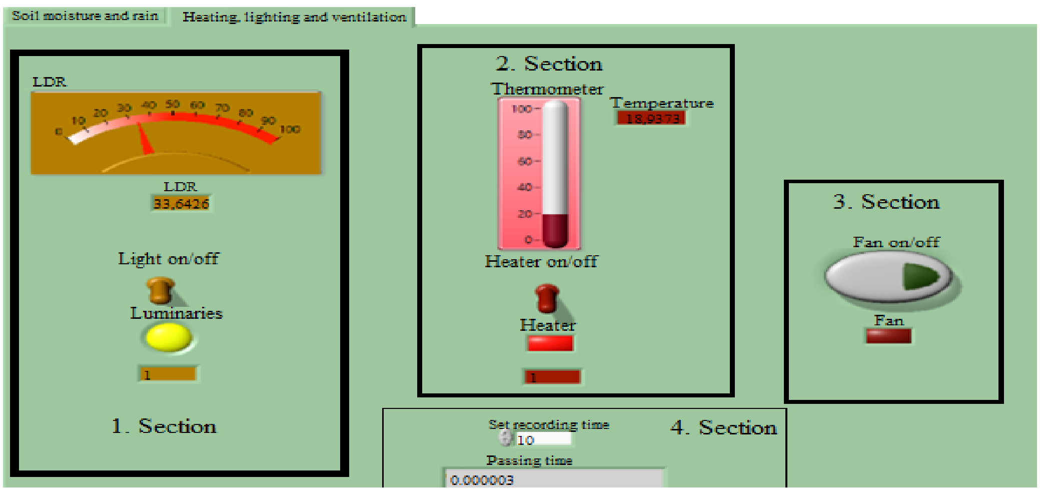

Figure 5. LabVIEW interface of the designed system.

In the LabVIEW user interface, it was tested whether the irrigation system was activated or not and the prototype greenhouse roof was opened and closed in rainy weather. During this process, it was observed that the servo motor rotates in the positive direction at an 90 degrees in the positive direction and leaves the roof open by detecting that it is not raining according to the value obtained from the rain sensor connected to the MyRIO control card. When it rained, it was observed that the servo motor turned 90 degrees in a negative direction and closed the greenhouse roof. Soil-moisture control and roof control experiment LabVIEW interface is given in Figure 6.

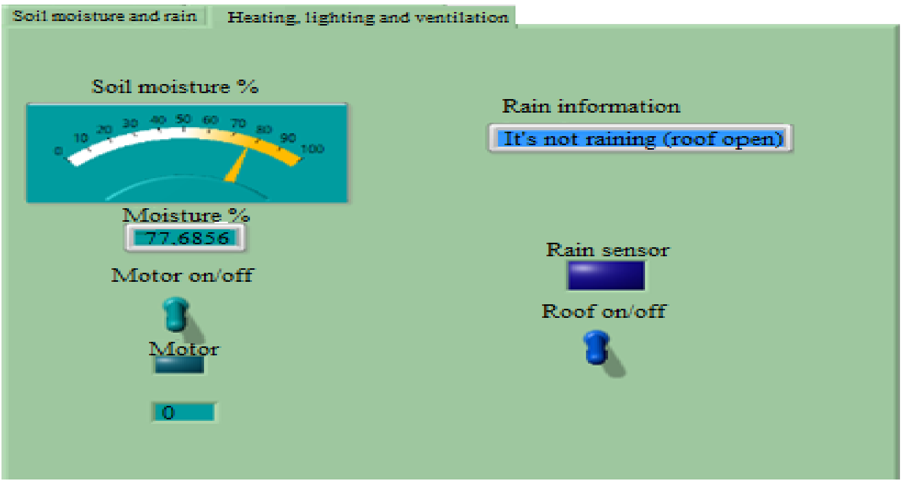

Figure 6. Soil-moisture control and roof control experiment LabVIEW interface.

It has been tested whether the water pump used for irrigation sends water from the water tank to the irrigation pipes. During this test, as can be seen in the figure above, the soil-moisture value was measured to be 77,6856 and it was observed that the greenhouse irrigation was performed (the moisture percentage limit value determined by the user in LabVIEW is 80). The values obtained by measuring the humidity values per hour for 12 hours from the soil-moisture sensor are given graphically in Figure 7.

Hours	Percentage of moisture
1	25,4779
2	48,5589
3	56,4906
4	66,4873
5	70,4678
6	70,6987
7	72,2556
8	73,8492
9	75,1065
10	75,6801
11	77,5269
12	80,9863

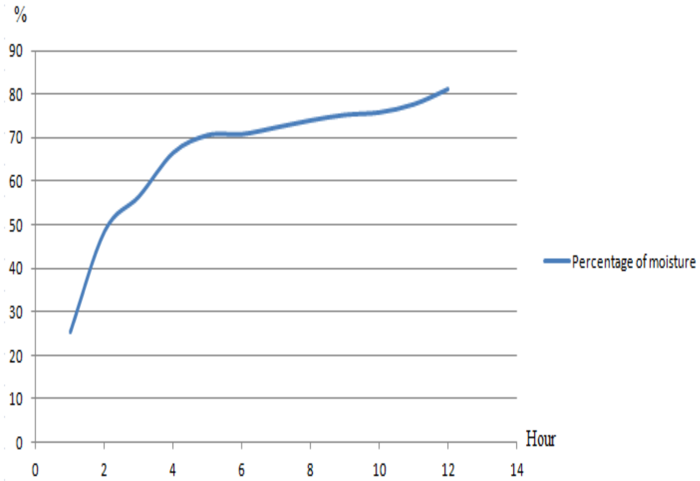

Figure 7. Values taken from the soil-moisture sensor every hour for 12 hours.

It was observed that the water motor stopped the irrigation process with the order received from the MyRIO control card when the soil moisture percentage value within the scope of the 12-hour greenhouse soil moisture percentage values read from the soil-moisture sensor of the MyRIO card was 80.9863.

In the test of the lighting software part, the information received from the LDR sensor is received by MyRIO control card and the information received by it is evaluated according to the value specified in the LabVIEW and it is decided whether or not to illuminate. In the test for application control, the LDR sensor measured the illumination value as 33.6426. It has been observed that the measured value of the MyRIO control card is below the value determined by the user in LabVIEW and the greenhouse lighting is performed by commanding the white strip LEDs used in the study to perform the lighting operation (the value where the light measured from the LDR sensor is closest to the dark is 80). LED luminary have been used in lighting due to their savings, long life, lighting efficiency and low maintenance costs. For example, if 10 number incandescent luminaries were used instead of 10 number LED luminaries to be used, energy consumption would be higher. Incandescent and LED lamp comparison is given in Table 1.

When Table 1 is examined, in the case of using an incandescent lamp for the same number of luminaries with close luminous fluxes, 1000 W will be consumed, while in the case of LED luminaries 150 W will be consumed. In terms of energy efficiency, the use of LED luminary is very important in this respect. In addition, it has been observed that the inside of the greenhouse is illuminated from 23:00 to 06:00 according to the values read by the LDR sensor of the MyRIO control card at different times during the day. It was observed that the value (85,2789) detected by the MyRIO card through the LDR lighting sensor at 07:00, exceeded the value determined by the user in the LabVIEW program and exceeded the value of 80 where the darkness ended and the light

Table 1. Characteristics of the Luminaires.

Luminaire type	Power (W)	Luminous flux (lm)	Number of luminaire used (pc.)	Colour rendering index (CRI)	Total power (W)
Incandescent	100	1380	10	100	1000
LED	15	1521	10	80	150

started, so the lighting system was automatically deactivated with the command received from the MyRIO control card. Graph of values taken from the LDR sensor per hour is given in Figure 8.

Hours	LDR sensor values
23:00	25,3645
00:00	28,6189
01:00	39,3546
02:00	42,3149
03:00	53,1874
04:00	57,2958
05:00	68,2697
06:00	74,6459
07:00	85,2789

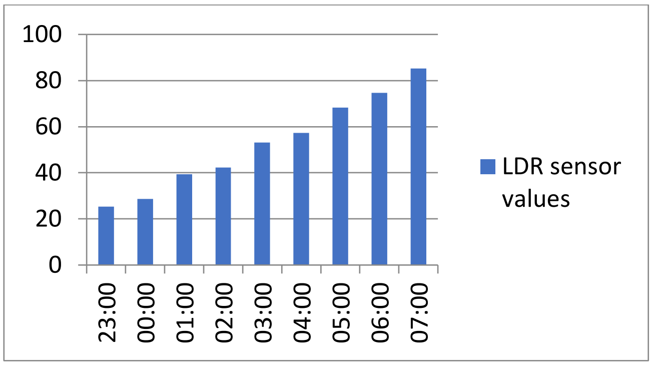

Figure 8. Graph of values taken from the LDR sensor per hour.

A temperature test in the greenhouse has been carried out in the designed system. Here, MyRIO card has determined that the temperature inside the greenhouse from the LM35 temperature sensor is 18.9373 ° C and this value is between the lower-upper (15-30 ° C) limit value determined by the user in LabVIEW. For this reason, it has been observed that the heater is not activated. However, it was determined that when the temperature value was 13.6598 ° C, it was automatically activated with the command it received from the MyRIO control card. Temperature value and moisture percentage values are given in Figure 9.

Hours	Moisture %	Temperature °C
17:51:09	77,6856	18,9373
17:51:19	74,4573	17,9876
17:51:29	75,4965	17,6379
17:51:39	73,8492	18,0694
17:51:49	76,3873	18,8567
17:51:59	76,4906	16,5348
17:52:09	75,5589	16,6519
17:52:19	75,0201	17,5259
17:52:29	76,6987	18,6623
17:52:39	76,5228	18,2698
17:52:49	77,4779	18,8628

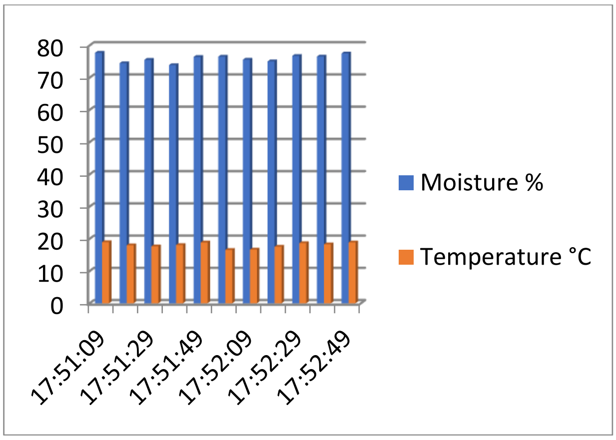

Figure 9. Temperature value and moisture percentage values.

The ventilation process on the greenhouse prototype was tested in the program in the user interface. During this process, it was observed that the temperature value was at its normal value (18.9373 ° C) and therefore it was determined that the DC Fan was not activated.

4. CONCLUSIONS

The main objective of this study is to design and implement a remote access control and monitor system for greenhouse. Greenhouse system consists of many systems such as lighting, heating, irrigation control systems that controlled by LabVIEW software. This system was supported by remote control and connected to the internet to monitor and control the greenhouse equipment's from anywhere in the world using LabVIEW. In addition, it is aimed to bring the greenhouse automation application to the agricultural sector. For this purpose, the feasibility and usability of the study was tested on the designed greenhouse prototype. Various sensors were placed in the greenhouse model to adjust the amount of moisture, temperature and light required for the plants to be grown in the greenhouse prototype, allowing it to be remotely controlled remotely via a computer tablet or mobile phone with the MyRIO control card and LabVIEW interface program. In terms of energy efficiency, the use of LED luminary is very important in this respect.

Remote access greenhouse automation application with MyRIO control card has several advantages. These are;

- The system designed with the MyRIO control card; it can be controlled remotely in real time with computers, tablets and smart mobile phones.
- Since the system is remotely accessible, it can be intervened when necessary.
- Since the infrared heater used in the heating system directly heats the plants in the greenhouse, the amount of heat needed by the plants can be obtained by consuming less energy, thus providing energy savings.
- Although the operations of the codes written using microprocessors/ microcontrollers and various electronic control cards are difficult to display by creating an interface to the user, the data is presented to the user easily on the front panel graphically thanks to the LabVIEW program we use in our study.
- The codes that are written in pages of computer programming languages can be easily written in the LabVIEW program we use in our work.
- Thanks to the LabVIEW graphical program used, the data obtained from the climate conditions in the greenhouse during the day can be reported in Excel, allowing the user to check the data again.

By using renewable energy sources (such as sun, biogas, geothermal resources, etc.) instead of traditional heating systems (such as stoves, radiators, etc.) in greenhouse heating, the damage to the environment can be reduced to even lower levels and the rate of global warming can be reduced since carbon-based fuel is not used.

In greenhouses, electrical energy is generally used in every part of the air conditioning system. Hence, the cost spent for energy increases. In order to prevent this, if the greenhouses to be established are established close to geothermal resources, the cost spent for energy in greenhouse heating can be reduced.

Author Contributions

The first author wrote and edited the article. The second author took part in the preparation and implementation of the prototype of the system. This study was produced from the second author's Master's Thesis conducted under the supervision of the first author.

Conflict of Interest

The authors of the article declare that there is no conflict of interest between them.

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