Uluslararası Teknolojik Bilimler Dergisi
International Journal of Technological Sciences
Elektronik Dergi, e-ISSN: 1309-1220
Cilt/Volume: 11 Sayı/Number: 3 Sayfa/Page: 126-136 Aralık/December 2019

Control and Monitoring of Greenhouse System with Matlab GUI

Ferzan KATIRCIOĞLU*[1]
[1] Duzce University, Duzce MYO, Department of Electronic and Automation, 81100, Duzce, Turkey

(Alınış Tarihi/Received: 03.07.2019, Kabul Tarihi/Accepted: 06.11.2019)
*İlgili yazar/Corresponding Author: ferzankatircioglu@duzce.edu.tr

Keywords
Greenhouse Automation
Matlab GUI
Control and Monitoring Systems

Abstract: One of the most effective solutions is to produce the obtained product all year round not only in spring and summer seasons which are suitable for producing the plant. Furthermore, conventional closed greenhouses are converted into high-tech plant production units in as much as micro controllers, smart sensors and wireless technology equipment have become cheaper and easily available in recent years. To this end, a low-cost greenhouse automation system which can be monitored in computer environment by virtue of an interface created in Matlab GUI programming language is proposed in the study. Temperature, air relative humidity and soil moisture levels were measured continuously as input and control of heating, ventilation, drip irrigation, humidification, and lighting system was conducted the way of on-off in the proposed system. Furthermore, input sizes were monitored graphically and numerically on the interface and output systems were monitored instantly to observe if they operated or not. Required conditions in the greenhouse for pepper and eggplant as vegetables and strawberry as fruit was provided and data for 24 hours were provided. The obtained numerical and visual application result revealed the fact that the applied system is more advantageous compared to conventional control systems in terms of ease of use, price, monitoring and simultaneous recording.

Matlab GUI ile Sera Sisteminin İzlenmesi ve Kontrolü

Anahtar Kelimeler
Sera Otomasyonu
Matlab GUI
Kontrol ve İzleme Sistemi

Özet: Elde edilen ürünün sadece bitkinin yetişmesine uygun olan ilkbahar ve yaz aylarında değil tüm yıl boyunca üretilmesi en etkin çözümlerden biridir. Ayrıca son yıllarda mikro denetleyici, akıllı sensor ve kablosuz teknoloji donanımlarının kolay elde edilebilir ve ucuz olmasından dolayı klasik kapalı sera yapıları, yüksek teknolojili bitki üretim birimlerine dönüşmektedir. Bu amaç doğrultusunda çalışmada, Matlab GUI programlama dilinde gerçekleştirilen ara yüz ile bilgisayar ortamından izlenebilir ve düşük maliyetli bir sera otomasyon sistemi önerilmiştir. Önerilen sistemde giriş olarak sıcaklık, hava bağıl nemi ve toprak nemi değerleri sürekli ölçülerek, ısıtma, havalandırma, damla sulama, nemlendirme ve ışıklandırma sistemlerinin kontrolü on-of şeklinde gerçekleştirilmiştir. Ayrıca ara yüz üzerinde giriş büyüklükleri grafiksel ve sayısal olarak, çıkış sistemleri ise anlık olarak çalışıp çalışmadığı noktasında izleme işlemi yapılmıştır. Sera da sebze olarak biber ve patlıcan, meyve olarak da çilek ürünleri için istenen koşullar sağlanarak 24 saatlik veriler elde edilmiştir. Elde edilen sayısal ve görsel uygulama sonuçları, geleneksel kontrol sistemlerine göre, gerçekleştirilen sistemin kullanım kolaylığı, fiyat, izleme ve eş zamanlı kayıt alma noktasında daha avantajlı olduğunu göstermiştir.

1. Introduction

Developing computer and communication technologies have led to huge impacts and benefits in the most part of our living spaces. The fact that, microcontrollers, intelligent sensors and wireless technology equipment have become cheaper and easily available, has paved the way for new researches as to different engineering and industrial applications of control systems. One of these is that conventional closed greenhouses have turned into high-tech plant factories which optimize plant and human productivity. A modern greenhouse comprises a system having multiple controls and is called controlled environment agriculture, controlled environment plant production or Automation system (Ting et al., 2016). The modern greenhouse system increases product yield and leads to production costs in addition to increasing predictability. One of the first improvements made as development is climate-controlled plant growing (Muijzenberg, 1980). The system includes three levels as instant greenhouse climate, and short-term and long-term product development stages in the study proposed by Cate and Dixhoorn, which is shown as one of the first applications of computerized control and automation works of the greenhouses (Cate and Dixhoorn, 1978).

Over time, sufficiency and development possibilities of greenhouse conditions have been examined in the study conducted by Seginer and Zlochin. It has been detected that the desired temperature values are not obtained during the winter months while the temperature inside the greenhouse and the relative humidity are high during the summer months (Seginer and Zlochin, 1996). In another study as regards another point of the subject, Teitel and Tanny have developed equations based on the dimensionless mass and energy savings by method of opening the roof windows of inside the greenhouse and changing the interior temperature thereof (Teitel and Tanny, 1999). Jain has researched the heating of the greenhouses and brought a different application to the heating system through utilization of collector on the greenhouse surfaces (Jain, 2005).

Hocagil, in addition to the international greenhouse studies, has conducted a study in Turkey work on "Venlo type" greenhouses (Hocagil, 2003) while (Başak, 2009) has carried out a study on greenhouse heating by thermal energy storage. In 2011, Arı has monitored more than one greenhouse by usage of PLC and SCADA software (Arı, 2011). (Şevik et al., 2014) produced a small-scale greenhouse and they heated the air in the greenhouse by solar energy and made the distribution there of.

Automatic systems have been utilized in order to detect diseases in the greenhouse. Usage of systems with special installations and equipments are required in a number of approaches in addition to automation systems. These systems comprise image processing and learning techniques, high-spectrum techniques, as well as intelligent electrical nose techniques (Patil and Kumar, 2011; Mahlein et al., 2013; Markom et al., 2009).
Recently, dynamic greenhouse systems which can be monitored from remote areas by virtue of wireless sensor and wireless communication which are install cheap and easy to install and detect trouble have been established (Rodriguez et al., 2017; Akkaş and Sokullu, 2017). Control of greenhouses has become possible thanks to automation systems, and works for monitoring industrial automation systems by virtue of advanced internet technology has become possible in our day (Zhang et al., 2017).

Automatic irrigation, heating, humidification, ventilation and lighting systems according to the data of high-resolution temperature and humidity sensors and utilization of Matlab GUI interface are proposed in this article. Arduino Mega card and Matlab between the greenhouses is used as entry and exit card were utilized in the proposed system while control operations were carried out by utilization of the Matlab programming language. Control and monitoring of physical quantities in the greenhouses by using Matlab Gui interface is the uniqueness of the study and its applicability has been proven. In this way, the greenhouse control and monitoring system will be able to provide cheaper prices and ease of use compared to other similar systems. Furthermore, the software developed for the system can be improved and used for different studies and researches thanks to the simultaneous recording and graphing feature thereof. The presentation of the greenhouse system created was made in the next part of the study. Subsequently, the working methodology was defined in the next Section 3. Matlab Gui interface created was explained in details in this part. Graphical and numerical results obtained as a result of experimental studies are presented in Chapter 4 under the title named "Evaluation of The Experimental Data". Evaluations as to the method and studies which can be conducted in future were included in the last part.

2. Materials and Method

The greenhouse made as a small rough model was made with 20x20 mm profiles in 150x75x135 cm dimensions. The lower part of the greenhouse was covered with mdf and then approx. 10 cm-thick brown humic soil was placed. An electropneumatic ventilation cover was placed on the roof. Parts other than the location of the pneumatic cover and ventilation fans are covered with nylon greenhouse cover convenient to use for a long time with high mechanical resistance, thermal and with light refraction property. The following equipments were made in order that requirements according to the plant species planned to be produced could be met.

2.1. Signal sensing elements

The temperature and relative humidity in the greenhouse have to be measured continuously in order to manage the greenhouse effectively. DHT 11 sensor has been utilized as temperature and relative humidity sensor. This sensor has a complex of calibrated digital output, temperature and humidity sensor with high reliability and provides excellent stability in long time measurements. It consists of a resistance type humidity measurement component as well as an NTC temperature measurement component. DHT11 is supported by 8 bit microprocessor and responds in a fast manner and with high quality. This sensor which measures temperature between 0 and 50° C with an error rate of 2° C also measures humidity with a 5% RH error rate between 20 and 90% RH.

The soil moisture sensor is a sensor which can be utilized to measure the amount of moisture in the soil. Measurements are made by inserting soil moisture measuring probes in the soil. Its working principle is based on the fact that a voltage difference is created between the tips of the probes due to the resistance of the soil or the liquid to which it is inserted. The amount of moisture is measured according to the magnitude of this voltage difference. Technical specifications operating voltage: 3.3V-5V, output voltage and current 0- 4.2V and 35 mA (http://www.arduino.cc/ [Access Date: 30.03.2018]).

2.2. Heating system

Temperature is one of the most significant elements to be created in the greenhouse. Electric heating, among the main heating elements applied in greenhouse heating, was preferred, and the resistance element was placed diagonally across the two side walls of the greenhouse. The resistors in the utilized heaters are made of tungsten. Tungsten was preferred because of its very high melting temperature and the filament temperature reaches 1200° C during operation. The tube of the lamp is made of quartz crystal. Quartz is an element which can withstand high temperatures. It is also resistant to shocks which can take place during sudden temperature changes. Electrical specifications thereof are provided in Table 1 (http://www.tansun. com. [Access Date: 20 04 2018]).

2.3. Pneumatic cover and fan ventilation system

Greenhouse ventilation is made in order to prevent the increase in the temperature inside the greenhouse, keep under control the relative humidity of greenhouse and provide necessary CO_2 to the plants for the food products to be produced through photosynthesis. The movement of fresh air on the soil surface, increase of circulation between the soil and the air, and thus increasing of the circulation in the soil is realized by virtue of greenhouse ventilation. To this end, a fan ventilation system which is mainly employed when the temperature difference decreases and when the wind movement stops was utilized. In addition, a mechanical ventilation system has been created through placement of pneumatic doors in the roof of the greenhouse (Dupont, 1989).

2.4. Humectation

In summer months in regions with hot climate, the temperature inside the greenhouse cannot be kept at the values that plants will not be adversely affected by virtue of natural or forced ventilation applications. Therefore, shading and evaporation cooling applications are made in the greenhouses (Hocagil and Öztürk, 2003). In the realized greenhouse, 24 V ultrasonic mist maker fogging humidity device is used. In the greenhouse, a fan is added behind the humidifier for homogenous spread of the produced noodle. Technical specifications are provided in detail in Table 1.

Table 1. Elements and technical features used in greenhouse system

	Device Name	Voltage	Current	Power	Technical Specifications
INPUTS	Soil Moisture Sensor	5V DC	35 mA		0-4.2V output analog soil probe size: 6 cm * 2 cm.
	Air Humidity Sensor	3.5-5V DC	2.5 mA		20-90 %RH measurement range, ± 5 % RH Humidity accuracy
	Temperature Sensor	3-5V DC	2.5 mA		Rated for full 0˚ to +50˚C range, ± 2°C Accuracy
OUTPUTS	Heater	220V AC	2A	350W	Satin (translucent) quartz. Dimension 128 mm L1 215 mm
	Lighting	220V AC	36 mA	8W	64 LED Fluorescent lamp
	Humectation	24V DC	800 mA	20W	Suitable water depth 3-6 cm
	Pneumatic Cover	24V DC	200 mA	4.8 W	Solenoid Valve PS 5/2-Way Type-C G1/4'' Namur 24V DC
	Fan	12V DC	0.20 A	2.40W	80x80x25MM 2500 RPM
	Drip Irrigation	220V AC	20 mA	4W	4.5x3x3 inch 300L/H capacity

2.5. Lighting

Plants need plenty of light during their development period while they need less light during their resting periods. Measuring the amount of light in the greenhouse, adjusting it appropriately and saving it as a database file is very useful in researches conducted as to the products grown in the greenhouses (Ciğer, 2010). To adjust the amount of light in the greenhouse appropriately, two pieces of 64-LED fluorescent lamps were used in daylight form.

2.6. Drip irrigation

The plants grown in the greenhouse cannot take the natural water they need inasmuch as they are in a closed environment. The water requirement in the greenhouse is generally higher than in the outside environment. Method of dripping by virtue of perforated pipes was utilized as a method of irrigation in the greenhouse. Whether the plant needs water or not is determined by virtue of the information received from the sensors and the irrigation process is started and terminated automatically by the system (Inan, 2002).

3. Greenhouse Automation System with Matlab GUI

Internal environment variables such as temperature and soil moisture can be perceived, monitored and controlled through usage of the developed Matlab GUI based greenhouse automation system. The symbolic representation of the system which has been designed is provided in Figure 1. As it can be seen in the figure, the input and output elements in the greenhouse communicate with the computer by virtue of the Arduino Mega control card. Some of the output units were operated by virtue of the 24V relays in the cabinet inasmuch as the 5V relay is bigger than the contact ampere value.

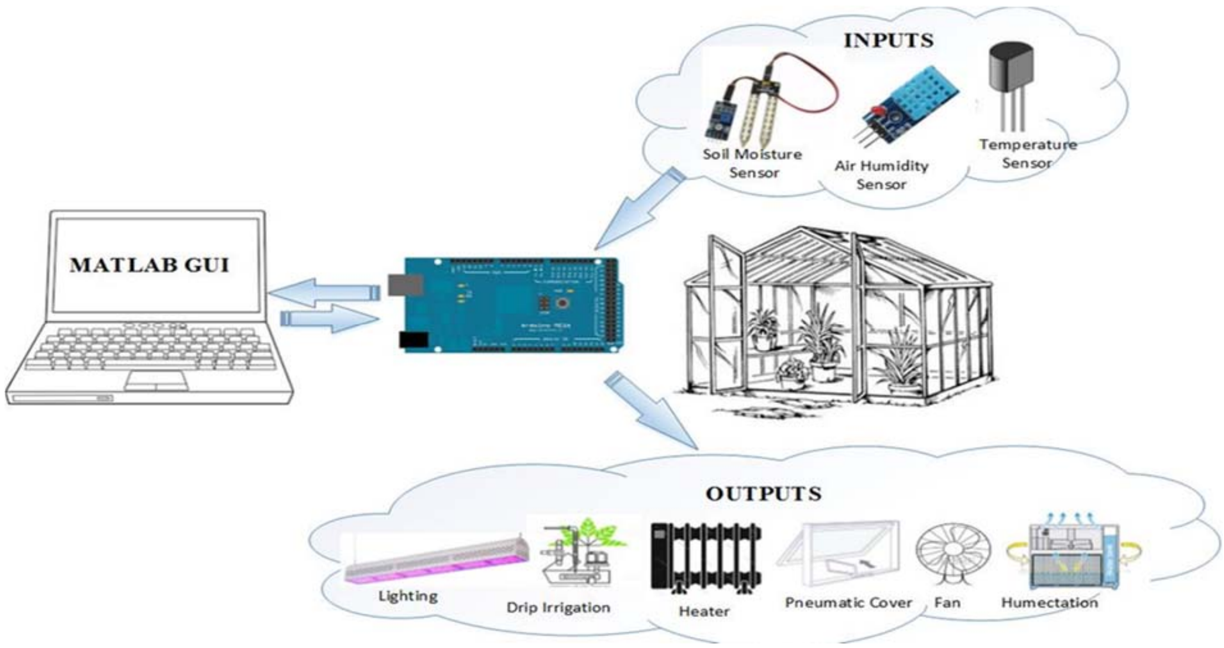

Figure 1. Symbolic representation of the designed system

There is the Matlab GUI interface software, with which users have communication to enter set values, observe output elements, and monitor sera environment values, in the computer section in Figure 1. This software also includes a control process to control the status of the outputs. There are two main programs according to the pseudo code given in Algorithm 1. The user must enter Set_D and Set_Nt for temperature; Set_H for the relative air humidity and Set_M for the soil humidity. A hysteresis band has been created to be ± 1 so that the outputs in the system will avoid continuous on-off. Day program has been arranged to operate between 07: 00 and 20: 00 while the night program has been arranged to operate between 20: 00 and 07: 00. In addition, automatic greenhouse illumination has been conducted between 20:00 and 22: 00 in order that plants can benefit from daylight more.

Algorithm 1. Pseudo Code of Greenhouse Automation System

```
hour=0;
While hour < 24

    Day Program
    if Temperature < Set_Dt
            Heater on;
            Pnomatic Cover off;
        else
            Heater off;
            Pnomatic Cover on;
    end if
    %--------------------------------
    Lighting off;

    Night Program
    if Temperature < Set_Nt
            Heater on;
            Pnomatic Cover off;
        else
            Heater off;
            Pnomatic Cover on;
    end if
    %--------------------------------
    Lighting 20:00-22:00 on;

    if Air Humidity < Set_H
            Humectation and fan on;
            Ventilation fan off;
        else
            Humectation and fan off;
            Ventilation fan on;
    end if
    %--------------------------------
    if Soil Mousture < Set_S
            Drip Irrigation on;
        else
            Drip Irrigation off;
    end if

hour=hour+1;
end while
```

Matlab has been developed through C.B. Moler in 1985 to be used in mathematics environment and it is an interactive package programming language with special purpose modular packages although it can be used also for general purpose in numerical computation, data analysis and graphics processing. Matlab, which is particularly utilized in the analysis of systems in the field of engineering offers an excellent environment for users by including tools such as artificial neural networks, optimization, data acquisation, database, filter design and fuzzy logic (Haigh, 2008). Problems in Matlab can be solved by writing programs that run on the command line while visual software consisting of objects such as forms and buttons can also be created by using the Matlab GUI development tool (The MathWorks, 2002).

Information as regards the structure of the designed graphical user interface will be provided in this section. The user interface is provided in Figure 2 and it is required to press the START button after entering the desired temperature, soil and air humidity values in the greenhouse environment. Instantaneous values of temperature, soil and air humidity data as regards the greenhouse are numerically displayed in the "Graphs of Inputs" window. The change of the data depending on the time can be recorded on the graph at the same time. Transmission of data is provided by virtue of Serial Communication protocol between Matlab GUI and Arduino. The data are analyzed, displayed and recorded instantaneously in the Matlab environment thanks to this program. There are signal lamps on the upper right of the interface which indicate the current operation status of the greenhouse outputs. If the red lamp is on next to the relevant output element, it means that the relevant output element does not operate while if the green lamp is on it means that the relevant output element is operating.

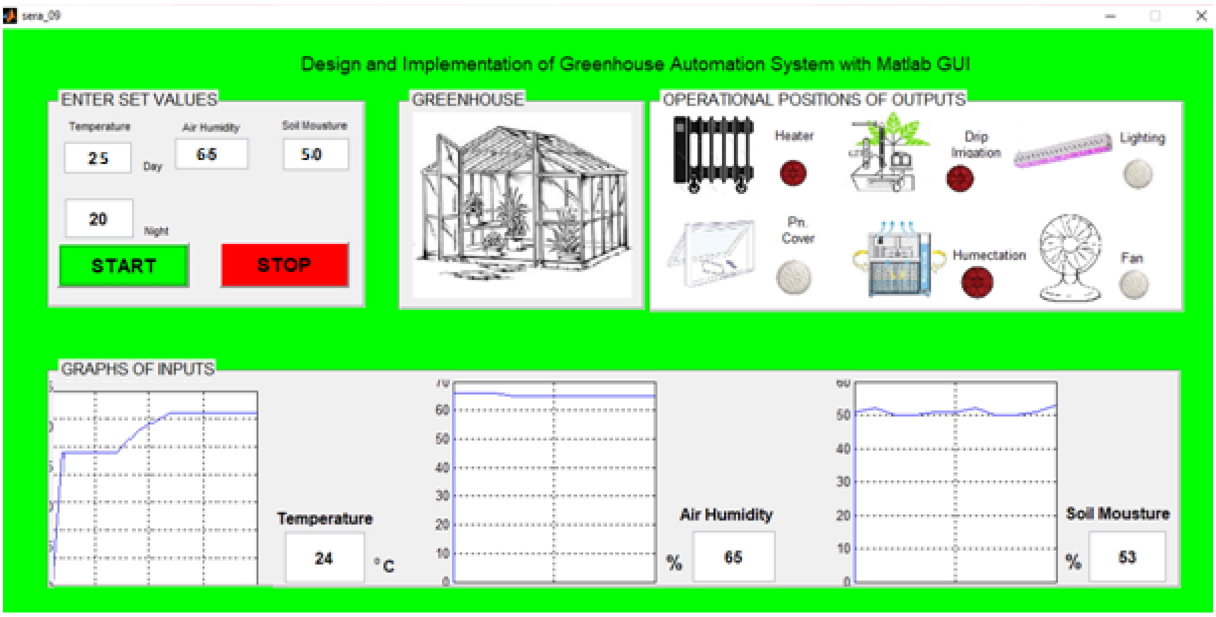

Figure 2. Matlab GUI Interface

4. Evaluation of the Experimental Data

Because soil, water and climate requirements of each plant is different from the other, entering these values according to the grown plant is one of the most important issues to be taken into consideration in greenhouse operations. Three products with different water and climate requirements were selected in our study (http://www.tarimkutuphanesi.com. [Access Date: 20 04 2018.]). The pepper plant requires plenty of watering while the required temperature should be in the normal value. As it can be seen in Table 2, the Cucumber plant requires higher day and night temperature values compared to other two plants. It is desirable that the strawberry's moisture value should be high and accordingly its temperature value should be low.

Table 2. Soil water and climate requirements of plants used in the study

Used Product	Temperature °C		Relative Air Humidity %	Soil Moisture %
	DAY	NIGHT		
Pepper	20	17	55-60	47-52
Cucumber	25	20	50-55	35-40
Strawberry	17	15	55-65	35-40

The maximum amount of water that the soil can hold against the force of gravity is called the field capacity. In other words, field capacity is the percentage of moisture retained in the soil when the water movement is practically stopped after leaked water following rainfall or irrigation, is completely withdrawn. The field capacity constitutes the upper limit of beneficialness of water to the plant. The field capacity is between the saturation rate of 75 % and continuous fading rate of 30 %. The water between the constant fading rate and the field capacity is the beneficial water. Plants benefit from this water (http://www.sapancasulamasistemleri.com.tr. [Access Date: 20 04 2018.]). Therefore, it has been deemed appropriate to determine the soil moisture content of 47-52 % for pepper and 35-40 % and for cucumber and strawberry.

The Matlab GUI based sera automation system created is provided in Figure 3. It has been operated as if there were greenhouse plants for pepper and cucumber vegetables and the results were received during the application phase. As it can be seen in Figure 3, subsequently strawberry was planted as 6 flower beds and the system was taken to continuous operation. The equipment utilized in the design was given as small images around the main image.

Figure 3. The designed greenhouse system and images of the used elements

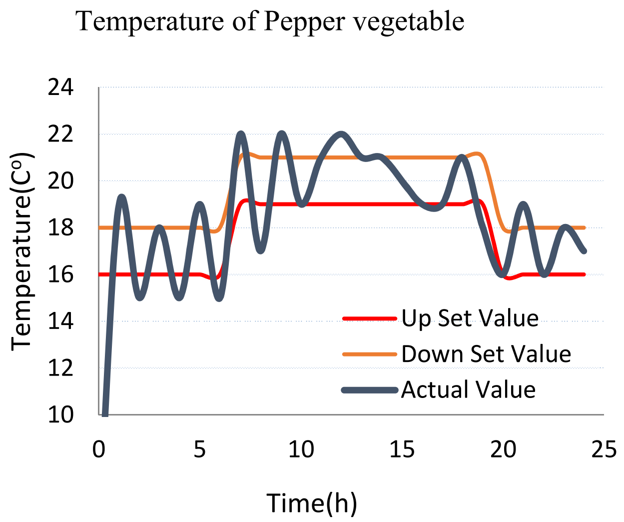

Figure 4. Temperature curve of pepper vegetable

Table 3. Results for pepper vegetable.

	Set value capture time (m)	Time (m)	Number of Works
Heater	15	135	27
Lighting	-	120	1
Humectatio n	22	30	3
Pne. Cover	-	16	4
Fan	-	16	4
Drip Irrigation	4	13	3

Figure 4 shows the change in environmental temperature measured during the daily sampling interval for temperature range desired for day and night working period for pepper. It was seen that the heater turned on and off more, especially during the night time. The number of turning to on and off was more than the number in the chart based on the fact that the temperature values were taken at the beginning of the hours. For example, the heater may be activated and deactivated within one hour, but may not be seen at the beginning of the hour. As such, a counter was placed in the program to determine how many times it operated. The number of operation of output elements and approximate operation times for the pepper is provided in Table 3.

Control of soil moister in the greenhouses is generally in the form of a continuous drip irrigation system during the day, morning and evening. There is a possibility that the amount of water supplied is too high. Instead of it, formation of soil moisture according to the information received from the soil moisture sensor was considered to be a more appropriate irrigation system. Figure 5. Shows the green house soil moisture graphic curve for cucumber. In this experimental application, greenhouse soil moisture value was desired to be 35-40 %. It was observed that after a short period of 4-5 minutes of operating the system, the measured humidity remains constant between the desired values. Here, when the humidity value falls below 35 %, the drip irrigation device is automatically operated and the values are increased to the desired conditions. As indicated in Table 4, drip irrigation has been performed 3 times a day, including the first day of operation.

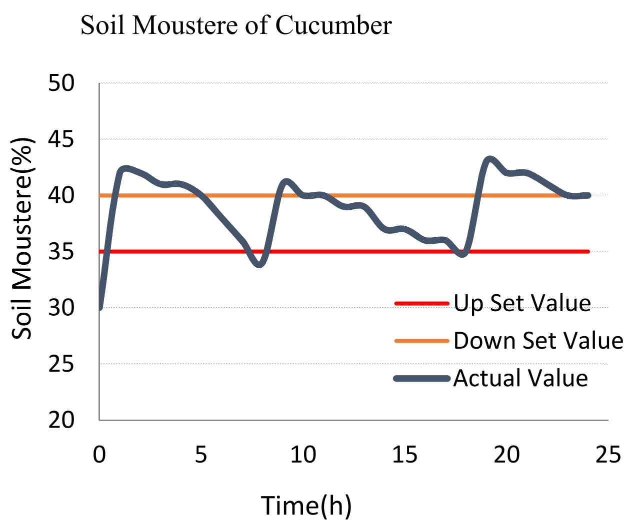

Figure 5. Temperature curve of cucumber

Table 4. Results for cucumber vegetable.

	Set value capture time (m)	Time (m)	Number of Works
Heater	14	152	32
Lighting	-	120	1
Humectation	21	35	4
Pne. Cover	-	15	5
Fan	-	15	5
Drip Irrigation	4	11	3

Lastly, the system was operated for strawberry. Figure 6 shows the indoor air humidity graph curve while Table 5 shows the data obtained for this fruit. Humidity value was desired to be 55-60 %. It is observed that the measured humidity remained constant between the desired values following a very short period like 19-20 minutes after the system is started. Especially at night and in the morning, it was seen that air humidity did not change much, so neither drip irrigation system nor moisturizing system were not activated. At the same time, pneumatic covers and fan were activated when the desired value is exceeded, to reduce the inner greenhouse moisture.

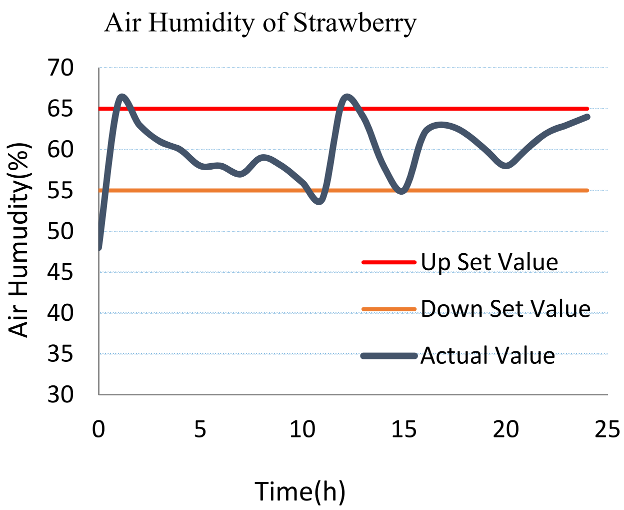

Figure 6. Air Humidity curve of strawberry

Table 5. Results for strawberry.

	Set value capture time (m)	Time (m)	Number of Works
Heater	14	122	28
Lighting	-	120	1
Humectation	19	34	2
Pne. Cover	-	11	3
Fan	-	11	3
Drip Irrigation	4	11	3

Application results have shown that the control system designed by using Matlab GUI has a satisfactory performance to maintain the desired temperature, soil and air relative humidity values and is applicable. However, monitoring of the the physical quantities and control outputs with low cost could not be realized in a possible manner.

5. Conclusions

The humidity, heating, irrigation, ventilation and similar greenhouse climate features which should be in the greenhouse was controlled by computer through utilization of Matlab GUI interface and kept within certain ranges according to the characteristics of the product to be grown in the greenhouse. It was proved, as a result of the experiments carried out, that the greenhouse can be controlled successfully thanks to such a system and the physical quantities such as temperature, weather and soil moisture can be followed up. The system, prototype of which was established, has been operated successfully in a greenhouse where heating, humidity watering and ventilation control are necessary.

It was shown that the developed system can be operated in greenhouse type applications. The system can be enlarged and utilized efficiently in product growing for commercial purposes. The most prominent feature of the presented system is that it has an easily applicable structure for other agriculture, poultry and stockbreeding areas with small changes in the software infrastructure. Pneumatic ventilation window used in the work done has achieved moisture control easily. Temperature and humidity control could be made more effectively especially in summer by virtue of the fan system added. Greenhouse control and monitoring system can provide decrease in price and ease of use compared to similar systems. Electronic circuit used elements used in the study are cheap to easily available elements. The Arduino Mega controller used is the controller with the most abundant technical support in this field. The software developed for the system is easy to program for the user and can make recording and draw graphs simultaneously. In addition to monitoring greenhouse systems online via internet usage and development of complex and advanced level control systems like fuzzy logic should be done in the next stage of this study.

References

Akkaş, M. A. and Sokullu, R. (2017). An IoT-based greenhouse monitoring system with Micaz motes, Procedia Computer Science, 113, 603-608.

Arı, Y. S. (2011). Birden fazla seranın, plc ve scada yazılımı ile kontrolü ve internet üzerinden izlenmesi, Yüksek Lisans Tezi, Marmara Üniversitesi Fen Bilimleri Enstitüsü Mekatronik Anabilim Dalı, İstanbul.

Başak M., (2009). Santral Atık Isılarıyla Seraların Isıtılması, Yüksek Lisans Tezi, Yıldız Teknik Universitesi, İstanbul.

Ciğer M., (2010). Bilgisayar kontrollü, internet destekli sera otomasyonu, MSc, Cukurova University, Adana, Turkey.

Dupont D. L., (1989). U.S. Patent No. 4,815,365. Washington, DC: U.S. Patent and Trademark Office.

Inan, S. A. (2002). Meyve Fidanı Çoğaltılmasında Kullanılan Köklendirme Seralarının Otomasyonu. Yüksek Lisans Tezi, SD Ü. Fen Bilimleri Enst., Bahçe Bitkileri AD, Isparta.

Hocagil, M. M. and Öztürk, H. H. (2003). Seralarda sıcaklık ve bağıl nem kontrolü üzerine bir araştırma. Tarım Makinaları Bilimi Dergisi, 1(3).

http://www.arduino.cc, Ardunio Official Site [Internet Resource], [Access Date: 30.03.2018].

http://sapancasulamasistemleri.blogspot.com.tr. [Çevrimiçi] Sapanca Sulama Sistemleri. [Alıntı Tarihi: 20 04 2018.]

http://www.tansun. com. Tansun Limited Spectrum House Unit 1 Ridgacre Road West Bromwich West MidlandsB71 1BWUK. [Access Date: 20 04 2018].

http://www.tarimkutuphanesi.com. [Çevrimiçi] [Alıntı Tarihi: 20 04 2018].

Jain, D. (2005). Modeling the performance of greenhouse with packed bed thermal storage on crop drying application, Journal of Food Engineering, 71(2), 170-178.

Mahlein, A. K., Rumpf, T., Welke, P., Dehne, H. W., Plümer, L., Steiner, U., & Oerke, E. C. (2013). Development of spectral indices for detecting and identifying plant diseases, Remote Sensing of Environment, 128, 21-30.

Markom, M. A., Shakaff, A. M., Adom, A. H., Ahmad, M. N., Hidayat, W., Abdullah, A. H., & Fikri, N. A. (2009). Intelligent electronic nose system for basal stem rot disease detection, Computers and Electronics in Agriculture, 66(2), 140-146.

Patil, J. K., & Kumar, R. (2011). Advances in image processing for detection of plant diseases, Journal of Advanced Bioinformatics Applications and Research, 2(2), 135-141.

Rodríguez, S., Gualotuña, T., & Grilo, C. (2017). A System for the Monitoring and Predicting of Data in Precision Agriculture in a Rose Greenhouse Based on Wireless Sensor Networks, Procedia Computer Science, 121, 306-313.

Seginer, I. and Zlochin, I. (1997). Night-time greenhouse humidity control with a cooled wetness sensor, Agricultural and forest meteorology, 85(3-4), 269-277.

Şevik, S., Aktaş, M., Doğan, H., & Yılmaz, A. (2014). Küçük Ölçekli Sera Tipi Bir Kurutucuda Kırmızı Biber Kurutulmasının Termoekonomik Analizi, Politeknik Dergisi, 17(4), 143-152.

T. Haigh, "Cleve Moler: Mathematical software pioneer and creator of Matlab, IEEE Annals of the History of Computing, 30(1), 87-91, 2008.

Teitel, M. and Tanny, J. (1999). Natural ventilation of greenhouses: experiments and model, Agricultural and Forest Meteorology, 96(1-3), 59-70.

The MathWorks, (2002). Inc., Creating graphical user inter-faces, The MathWorks, Nantick, MA.

Ting, K. C., Lin, T., & Davidson, P. C. (2016). Integrated Urban Controlled Environment Agriculture Systems, In LED Lighting for Urban Agriculture (pp. 19-36). Springer, Singapore.

Udink ten Cate, A. J., Bot, G. P. A., & Van Dixhoorn, J. J. (1978). Computer control of greenhouse climates, In Symposium on Potential Productivity in Protected Cultivation 87 (pp. 265-272).

Van den Muijzenberg, E. W. (1980). A history of greenhouses, Institute of Agricultural Engineering, Netherlands.

Zhang, Y., Yong, C., Wu, Z., Hua, J., Liu, J., Hu, J., & Yao, L. (2017). A Study on the Operating Model of Internet+ QQ Farm, Asian Agricultural Research, 9(6), 11.