Information and Control System for Controlling the Irradiation Process Plants

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Abstract

The study is devoted to the technical implementation of methods of controlling the functional activity of plants using electromagnetic radiation at various stages of organogenesis. The authors have developed a set of hardware and software control and management tools for conducting experimental studies of modes of electrophysical effects on plant biological objects. In order to obtain feedback from plants, it is planned to develop a new instrumental method for diagnosing the physiological state of plant organisms.

A computer-integrated control system has been developed for the process of irradiation of plants. A management system has been implemented at the base Arduino microcontroller software that connects to a PC. Created an operator panel based on the LabVIEW software environment, where provided automated and automatic process control and developed subsystem recording of measured data.

Keywords

Electrophysical methods, plants, platform, electrotechnical complex, software, algorithm, automation, control, integrated board, SCADA-system

1. Introduction

In Ukraine, over the past decades, the problem of reducing the profitability of greenhouse farms, their environmental friendliness, and reducing the area of closed soil has become acute. The research is aimed at solving the food and environmental problem - providing the population of Ukraine with high-quality vegetable products in the off-season. The creation of high-yielding varieties of plants requires many years of selection and agronomic work. Adjustment of the vital activity of plants is possible thanks to the change in the spatial and spectral distribution of external electromagnetic radiation. Numerous real and practical effects in crop production, obtained by the method of random samples, cannot provide optimal statistically reliable data. Applied research on the creation of biotechnical systems operating on the principle of feedback will be conducted at the intersection of such sciences as automation, cybernetics, electronics, informatics, biophysics, and nanotechnology.

The scientific significance lies in establishing the regularities of the impact of electromagnetic radiation of various frequency ranges and intensities on seed material and plants at various stages of organogenesis with the creation of relevant innovative technical tools.

To study the development of plants, it is necessary to conduct constant phytomonitoring of the plant and their development environment. To determine the influence of disturbing factors on plant development, a system of phytomonitoring of technological parameters in the phytotron has been

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developed. The developed system uses the approach of Internet of Things technology for remote monitoring of the technological process and switching of connected devices of the electrical complex in the chambers of phytotron cultivation.

An effective solution to the problem of growing (producing) agricultural products in modern conditions of agribusiness is achieved by introducing information and control systems at production sites. In this regard, the problem arises of creating a hardware-software complex based on modern automation tools. In recent years, new directions in automation systems and IT have been actively developing - cloud technologies and the Internet of Things (IoT), which have found successful application in agricultural production, given the length of control objects and their remoteness from decision-making centers. Today, IoT is the most modern tool for industrial automation, which allows remote monitoring of the state of an object (including biotechnical) and remote control of drive mechanisms and devices located at the object.

2. The aim of the study.

Scientific research in this direction is actively conducted at university centers in Rochester, Buffalo, Miami, Iowa, and Taft [1,2]. In the study of the plant as a complete biosystem, until now a paradoxical situation has developed: with sufficient completeness of information about the primary processes of metabolism and a developed theory of the productive process, the description of the vital activity of a complete plant turns out to be extremely difficult. A whole plant behaves completely differently than a collection of cells, and its vital activity is not reduced to a collection of physiological processes. Difficulties that arise when trying to describe the vital activity of a plant are mainly related to the lack of adequate models.

Researchers Azita Shabrangi et al. (2011) [3], Tkalec et al. (2005) [4] were engaged in research on seed treatment with a magnetic-pulse field. The authors carried out experiments to study the effect of a pulsed low-frequency magnetic field on the germination of seeds and the growth of seedlings of garden strawberries. For this purpose, an installation for magnetic-pulse processing of plants was developed in the form of a low-frequency pulsed magnetic field emitter. The use of this device made it possible to stimulate the vital and growth processes of garden plants, vegetables, and crops. During the experiment, various processing conditions were set with a periodic sequence of magnetic induction pulses in the low-frequency range with simultaneous irradiation with light pulses of certain wavelengths of the optical range. It was found that the germination energy of seeds treated with a pulsed magnetic field varied from 29 to 47%, germination from 34 to 48%. Analysis of the data of factorial experiments showed that the most effective irradiation parameter for increasing germination and seed germination energy is irradiation with a frequency of 15.325 Hz, a duty cycle of 16.145 and a magnetic induction in the irradiation zone of 5.05 mT.

The control of the functional activity of plants by coherent light is described in the article [5]. In particular, a methodology, analytical apparatus and technical means for studying the interaction of coherent light with biological systems and structures have been developed, a block-modular principle for designing laser installations and diagnostic instruments for crop production has been proposed and developed. The paper presents experiments on the irradiation of both seeds and ripened fruits. In the research, multifunctional installations of the LIK series (laser research complex) and production installations of the LOS series (agricultural laser irradiator) were used. As devices for irradiation, the LIK-30A complex can be used, which makes it possible to solve a wide range of research problems, including the irradiation of biological objects according to a given program [5]. The LIK-30A control system provides automatic irradiation of one or two biological objects in the mode of single or multiple periodic exposure to optical radiation with the set parameters. The block diagram of the control is given in [5] and includes three blocks connected by electrical signals: BUCF (control and operation control unit), BOS (feedback unit with the irradiation object) and BFPI (irradiation flux formation unit). The most modern device for laser irradiation is Lika-Led (PE "Photonics-plus", Cherkasy, Ukraine) [6]. Development and implementation of a system of phytomonitoring of technological parameters of cultivation in a phytotron and the ability to remotely switch the connected devices of the electrical complex.

Scientists are creating a personal phytotron at an affordable price thanks to a wide range of hardware, cloud computing and the new possibilities offered by the Internet of Things IoT [7].

Temperature regimes, relative humidity and lighting as environmental parameters is presented regimes for growing seedlings or plants in different phases of development are checked in the phytotron chambers [8]. Phytotrons with various electronic control systems are also created to assess the impact of technological parameters on plants for the derivation of new varieties [9].

Many Ukrainian and foreign researchers have dealt with the problems of phytomonitoring in greenhouses and phytotrons. Scientists from Ukraine in the article [10] substantiated phytomonitoring in the greenhouse using non-contact visual assessment of plants. The basis of this assessment is the performance of photography of plants by a special electrical complex, after which the stored images are recognized using wavelet analysis technology. The use of this photo technology as a means of contactless information allows you to assess the growth and condition of plants in the greenhouse and predict their development using mathematical transformations, which will assess future yields. The recognition algorithm developed by the authors is used to recognize biomass in the greenhouse space.

In the work of Ukrainian researchers [11] with the participation of the author of this article implemented software and hardware subsystem phytomonitoring in the greenhouse based on software environment LabVIEW and hardware support Arduino, as well as tested this subsystem in industrial production - OJSC "Greenhouse Plant" in Kyiv region. It is shown that when growing vegetables, along with the temperature characteristics of the environment, information about the temperature of plants is important. The dependence of plant temperature on illumination in the greenhouse is analyzed, the specified mathematical model of the greenhouse suitable for formation of control influences taking into account spatial distribution of control object is received. The article [12] describes the developed energy efficient control system of the electrotechnological complex of industrial greenhouses. It evaluates the quality of plant products as feedback information using the Harrington desirability function, based on which it allows to determine the values of microclimate parameters (temperature and humidity) and plant temperature, this together maximizes production profits. Such a system includes an intelligent mobile robot, which moves the area of the greenhouse, measures the basic parameters of the microclimate of the atmosphere in the building of the closed ground (greenhouse), performs phytomonitoring, including assessing product quality. In the work with the participation of the authors of this article [13] it is proposed to use the technology of Internet of Things in agricultural production, in particular, in the production of feed. The work contains a combination of software and hardware solutions based on the Arduino control board with mathematical models for optimizing the composition of feed by the criterion of maximum yield of the substance with restrictions on the nutrient content of feed components.

Researchers from Qatar, Morocco and Canada Ahmed Ouammi, Yasmine Achour etc. [14] presented a comprehensive energy management system, which is based on centralized management for an intelligent greenhouse. This management allows you to optimize and control the global internal environment for crop growth. The development is to implement a comprehensive energy management platform based on the forecasting control model (MPC), which takes into account the volatile behavior of renewable energy production, the dynamics of energy and water accumulation, as well as uncertainties associated with climatic conditions. The authors propose a multi-purpose integrated optimization system to control the operation of the smart greenhouse, which takes into account forecasts and updated data collected from the available wireless sensor network.

Interesting is the study of Turkish scientists M.A. Akkash and R. Sokulu [15], who presented a prototype consisting of MicaZ units, which are used to measure temperature, light, pressure and humidity of greenhouses. Measurement data were provided via the Internet of Things. With this system, farmers can control their greenhouse from their mobile phones or computers connected to the Internet.

Canadian researchers M. Bozchalui and K.A. Canizares in their article [16] presented a new hierarchical approach to management and new mathematical models of greenhouse optimization, which can be easily integrated into power center management systems in the context of intelligent networks to optimize the work of their energy systems. Greenhouse artificial lighting systems, CO2 production and climate control consume a significant amount of energy. The authors propose a mathematical model of greenhouses, which is suitable for their optimal operation and can be implemented in the form of dispatch control in existing greenhouse management systems. As a result, the total costs of electricity and gas are minimized, the following parameters of greenhouses are stabilized; as room temperature and humidity, CO_2 concentration and lighting level. Thus, the model proposed by the authors includes weather forecasts, information on electricity prices in the greenhouse management system.

In an article by Chinese researchers Yin Ding, Liang Wang and others [17] propose the use of intelligent algorithms in modern agricultural production, which requires the support of a database, which can be complex and difficult to use in practice and requires a large amount of computation. A prediction model (MPC) is proposed, which can provide high-precision control operations with moderate complexity, and also allows you to perform sliding optimization in a limited time interval, which increases accuracy.

Other Chinese researchers Ts. Hou; And Gao [18] propose the development of a solar-based greenhouse greenhouse sensor monitoring system. It transmits data using wireless equipment for receiving and sending without installing wiring. Compared to conventional wireless technology, this system design consumes less energy, costs less money and has a higher Internet bandwidth. Sensor nodes receive solar energy and supply it to a wireless sensor network. This system uses the MSP430 microcontroller with ultra-low power consumption and the nRF24L01 low-power network transmission chip to minimize system consumption. Moreover, this system uses multilevel energy memory. It combines energy management with energy transfer, which allows you to wisely use the energy collected by solar panels. Thus, a self-managing energy supply system was created.

Romanian researchers R.-O. Gregory, A. Water et al. [19] offer temperature control of a greenhouse heated by renewable energy sources. Based on the linearized model, a PID controller was set up, which was used to control the internal temperature in the greenhouse.

3. Experimental conditions.

Three-week seedlings of cucumber (Cucumis sativus L.) variety TSHA-575 were used in the experiments, which were grown in 2-liter sterilized vessels under laboratory conditions in sandy culture on Arnon-Hoagland nutrient mixture. Seedlings had 3-4 well-developed leaves. Fluorescent lamps were used as a background light source, the illumination intensity at the level of the upper leaves was ~ 1 mW/cm2, the light period was 16 hours, the moisture content of the nutrient substrate was 70% of the lowest moisture capacity, the relative air humidity was 60% The air temperature in the daytime was 24°C C, at night - 22 ° C.

To register running electrical impulses ΔU, we used the standard BEP recording technique. Installation diagram for registration ΔU is shown in fig. 5.3. After 1 hour after connecting the silver chloride electrodes to the plant, a stationary BEP difference is established between the measuring electrodes 11 and 12 and the reference electrode 10. The light flux from the radiation source (He-Ne laser, LEDs) 6 passes through a polarizing filter 5, a diaphragm 4, a system of mirrors 2, 3 and is directed to the interveinal region of the plant leaf plate surface. After the start of local irradiation, after some time, an impulse deviation (response) ΔU from the stationary potential difference between electrodes 12 and 10 was observed. After a time Δt, the response ΔU was observed between electrodes 11 and 10. time Δt of passing the response ΔU , displaying and recording signals recorded by the ADC board through channels.

4. Computer-integrated system for controlling plant irradiation with a laser device

The computer-integrated system of care was created on the basis of the Arduino Mega2560 hardware, which is based on the ATmega2560 microcontroller (Fig. 2). The platform was set up to live in the spring with a voltage of 5-12 V with a short chirp. The microcircuit receiving the resource provides a stabilizing voltage for the operation of the microcontroller and sensors. For this controller, data exchange with a computer via the USB port is not available. Also, through the port, you can live and live the controller. Arduino operates at a frequency of 16 MHz with 54 digital input/output channels, 16 analog inputs, 14 of which can be used in PWM mode, 4 UART hardware serial ports for communication with a computer and other connected devices. At the time of the wrong request, the button "Skydannya" (Dropping) was transferred.

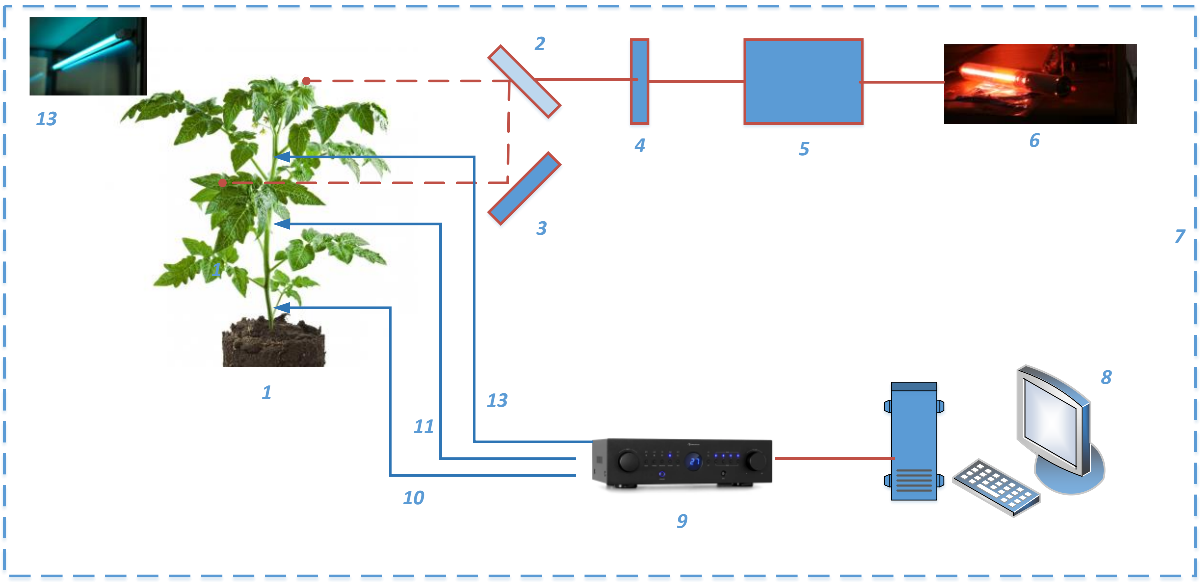

Figure 1. Scheme of the experimental setup.
1 - plant; 2 - translucent plate, 3 - mirror, 4 - aperture, 5 - polarizing filter; 6-source of local radiation (He-Ne laser); 7 - Faraday cage; 8 - recording device; 9 - multichannel amplifier, 10 - reference electrode, 11, 12 - measuring electrodes; 13 - source of non-local radiation (fluorescent lamp Radium).

Figure 2. Arduino Mega2560

To study the development of plants in the management of the technological mode of plant growth, I use phytochambers, in combination with all the equipment is a phytotron. The phytotron is a chamber with the created artificial climate where it is possible to regulate temperatures, humidity and gassiness of air, and also management of watering and lighting.

The control system operation algorithm is shown in Fig. 3.

Description of the algorithm:

After system initialization, initial values are entered. Then the choice of control mode: automatic or manual. When automatic control is selected, the operation timer is first activated (t). The control system then measures the technological parameters, after which the measured value is compared with the set values. After each comparison, the actuator relay is turned on or off (relay *T*, relay *L*). In automatic mode, after each performed operation, the time of the system timer increases by one step. The automatic mode is performed until the set control time is reached ($t > t_i$). In the manual control mode, technological parameters are measured, and after the operator presses the control buttons, the relays of executive devices are turned on or off (relay *T*, relay *L*). Measurements are recorded in both modes.

The software of the designated system is implemented in the LabVIEW environment, and reading information from sensors is also decomposed into an operator interface. Also, the recorded values were transferred to the database for further analysis. The data is stored in memory in the form of a table, unified with data processing programs, an example of which is Microsoft Office Excel. The graphical representation of the software system in LabView is shown in fig. 4, and in fig. 5 shows the program interface window.

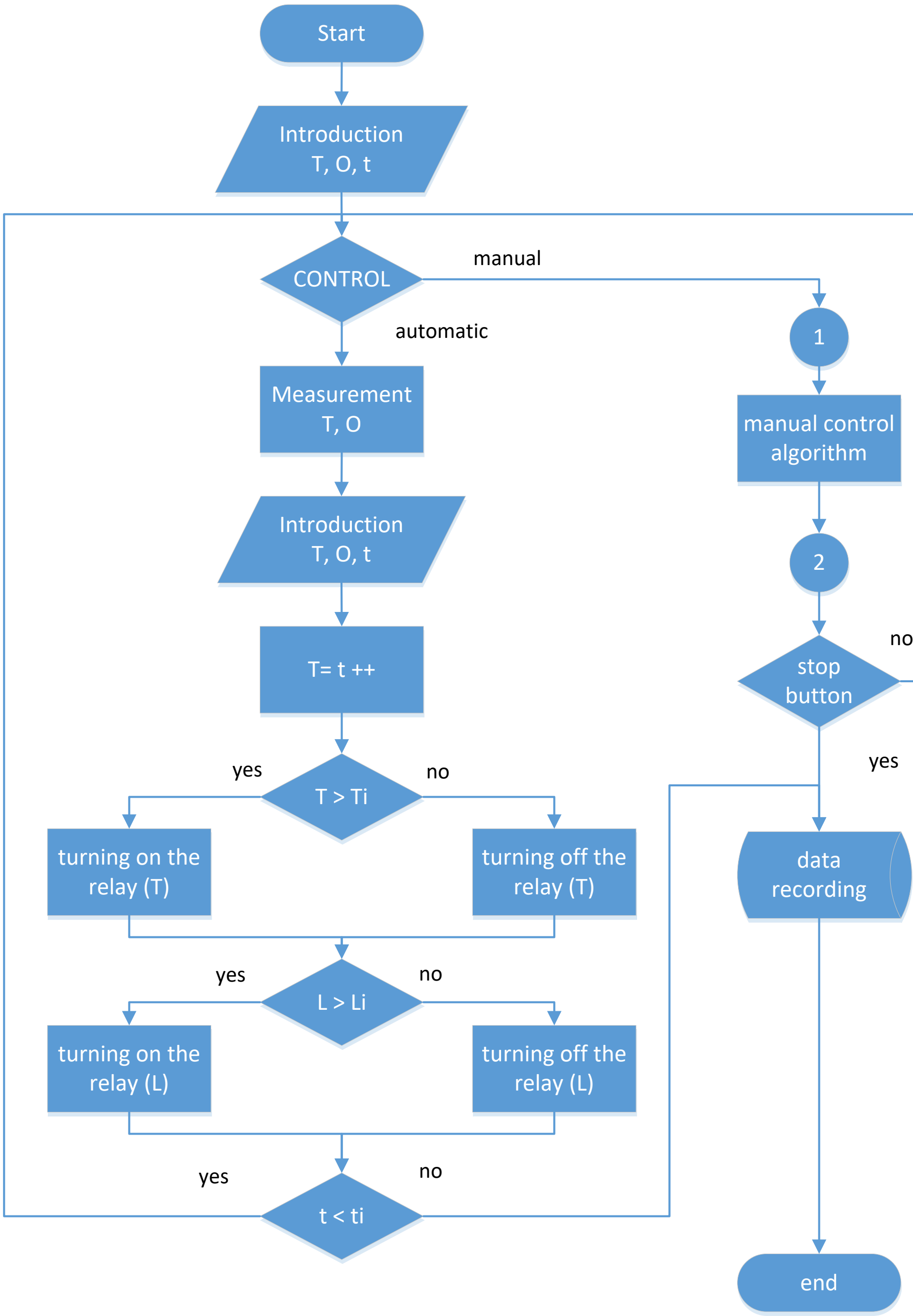

Figure 3: Algorithm for remote temperature (T) measurement

5. Research results.

During operation, the control system for laser irradiation of plants ensures the collection and processing of data in the phytotron in real time, acts as a controlling component of the parameters of plant phytodevelopment and technological parameters of the microclimate, and also regulates the launch of laser irradiation by the Lika-Led device in accordance with the software setting. The set of hardware used in this case is the Arduino software and hardware environment. Their diversity and availability created the conditions for the successful implementation of automation systems.

Control of the plant irradiation process in the phytotron chamber is divided into three hierarchical levels. The system interface in the LabView package is shown in Fig. 4, and the block diagram of the algorithm - in Fig. 5. The phytoclimatic regime is controlled according to the specified cultivation standards, where the daily air temperature is within 22..25°C; at night - 18..20°C; where relative humidity should be within 60..70% and air pollution 350..450 ppm. The control process also provides for the study of the influence of the external environment on tomato plants, provides for the additional introduction of phytotemperature criteria for plant development [6, 8], according to which the plant temperature is equated to the air temperature.

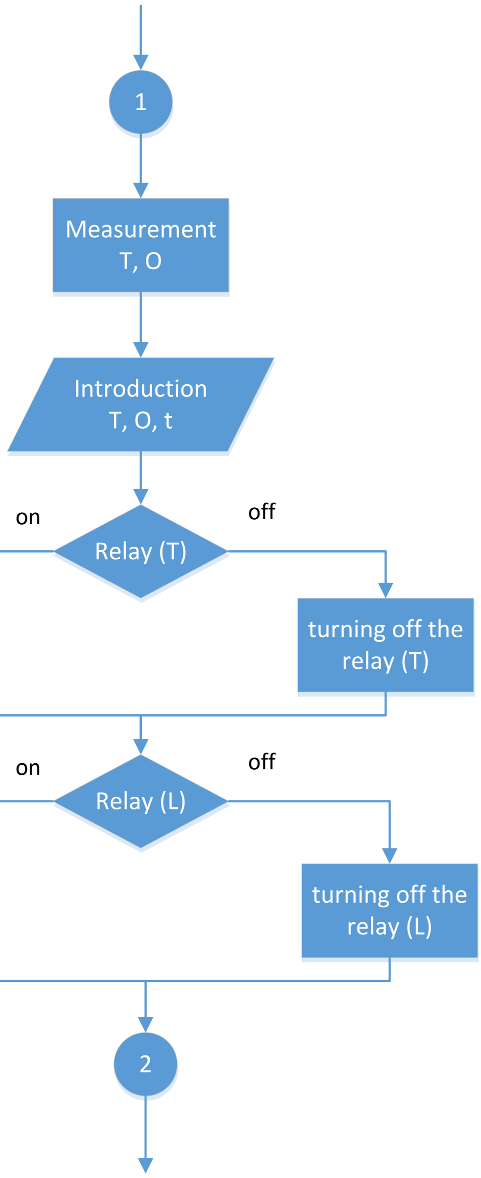

Figure 3: (Continue) Algorithm for remote temperature (T) measurement

The phytotron was assembled in the laboratory of the Department of Automation and Robotic Systems NULES of Ukraine (Kyiv) (Fig. 6). The monitoring system is based on Arduino Uno. An automated control system was built, in which the visualization of the process is displayed on the operator's panel. In system show obtaining measured data from temperature, pressure, humidity sensors and the ability to switch a relay to which phytotron devices and a Lika-Led laser irradiator are connected. In this case, plants are irradiated in the frequency range 440-780 nm.

6. Conclusions

A phytotron model for the study of plant development has been developed and implemented. The structure of the control system has been created, the functional-algorithmic system of the control object has been built and the system of phytomonitoring of plant growing parameters with the use of Internet of Things technology has been implemented. An automated control system has been built, which provides for the display of technological parameters on the operator's panel. The system provides for receiving measured data from sensors of temperature, pressure, humidity and the possibility of switching the relay to which the devices of the electrical complex are connected.

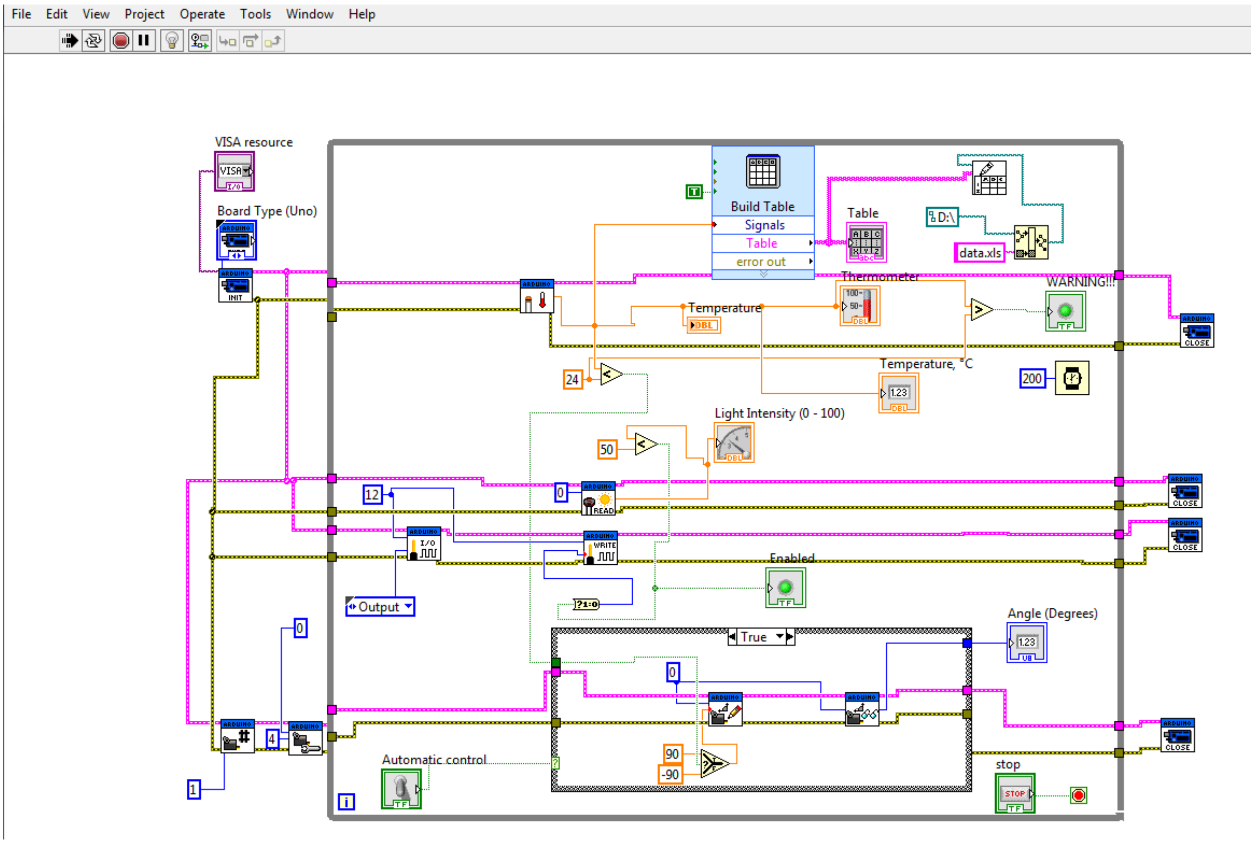

Figure 4. Block diagrams of system implementation in LabView

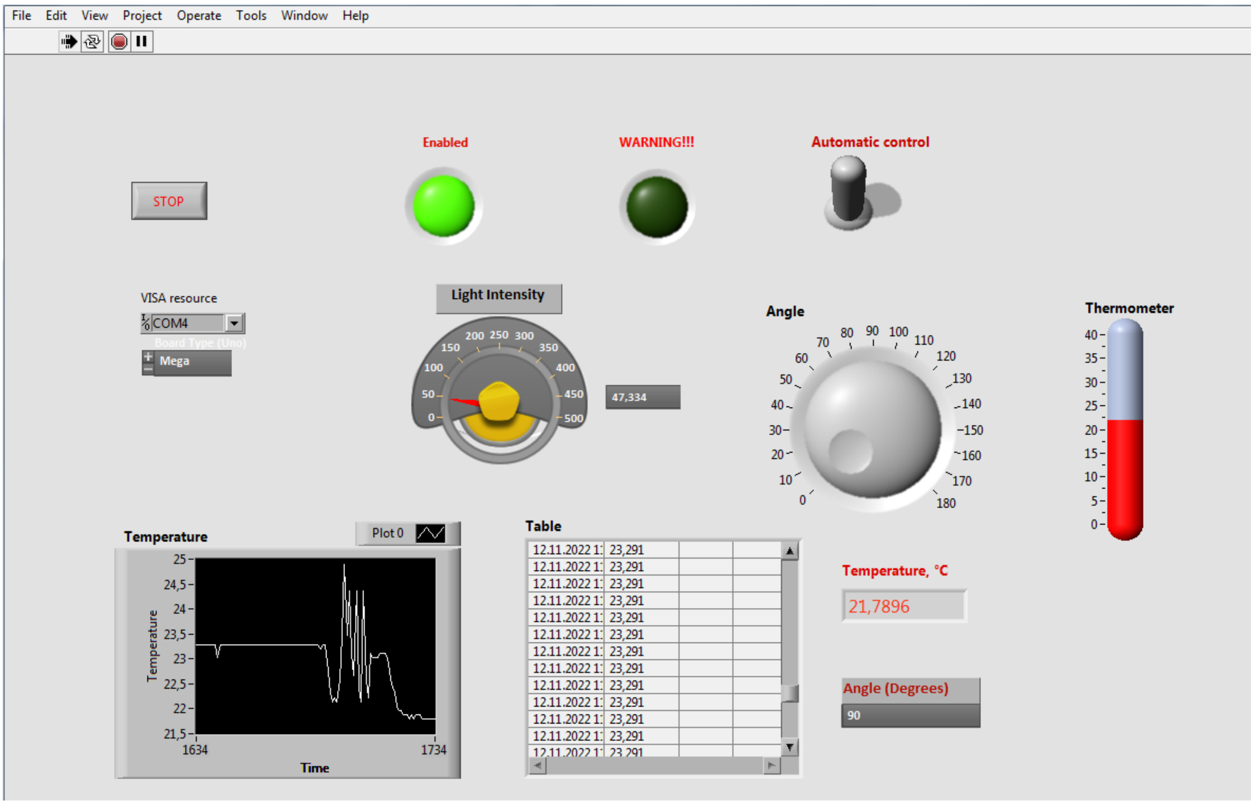

Figure 5. Control system operator window

Figure 6. Phytotron camera

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