Artificial Experimental Environment for Indoor Plant Cultivation

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***Abstract*—This paper explains the basic needs of indoor plants. The developed environment uses additional lighting for supplement plant production. The article deals with the control of power light emitting diodes, the optimization and diagnostic possibilities of the spectrum are part of the presented experimental environment. Eventually conclusions were drawn about the feasibility and requirements of such a system to make it possible to implement.**

Keywords—greenhouse lighting, artificial seed germination, grow LED driver, light spectrum control, indoor plant monitoring

I. Introduction

Different plants need specific humidity, temperature and amount of light in order to develop properly. In order to create the right environment and conditions, for plants, it need to know, the plant's natural habitat and its properties. This includes the fact that plants also have a daily cycle, there is a period when the sun does not shine, when it is a little cooler, and when the air around them is drier or wetter. This concept can be extended by adding different plant profiles, monitoring different parameters and implementing schemes.

The proposed concept is based on modular subsystems, due to easier modifiability [1-5]. The optimization of the structure is considered according to the following papers [6-8]. Real time data monitoring and logging is also a significant part of the experimental environment [9, 10] [11, 12]. One effective ways control the operation is closed-loops and compensation of disturbances [13-15]. The electronic circuit implementation enables maintainability and robust operation [16-19].

A. Active period

To ensure daily cyclicity, the system links intervention limits to the local time, such as how long the system is allowed to automatically switch on lights and water. In the evening cycle, the temperature in the plant's natural habitat drops, the humidity increases and the amount of light decreases, for ideal growth, the control system must also follow this scheme.

As a result, a so-called "active period" was defined in the system, i.e. the actuators of the system can intervene during this period. The rest of the day is the "passive period" when only measurements are taken automatically, but no interventions.

B. Software background

In order to store the measurement results in an orderly, transparent and long-term way, it is worth storing the data in a database. With the help of queries, the system can produce easily interpretable, informative graphs. In addition to the database, a graphical display application is also required, which is compatible with the other elements of the system.

The two utilities must also work together with the user program written in python. The time-based database management program InfluxDB and the graphical display program Grafana were used in the experimental environment.

C. Database

InfluxDB is an open source time-based database designed to store data with time stamps, see on Fig 1. The management of time stamps is already basically built-in, so querying by time interval is much more transparent at the user level than in traditional databases. The control system is based on a Raspberry Pi3 base, the storage capacity of which can be expanded to a limited extent, it is necessary to properly compress and average the data at certain intervals, i.e. to implement archiving.

The database keeps high-precision and high-sampling frequency data in the real-time time period, and after a specified time, the data is reduced and averaged, and continues to exist as archival data occupying a smaller storage space. These "aged" data can also be queried, but their accuracy is reduced compared to real-time sampled data.

```
datapoints =
[
        {
                "measurement": "brushEvents",
                "user": "Carol",
                "time": "idoBelyeg",
                "fields":
                {
                        "duration": 127, "intensity": 500
                }
        }
]
```

Figure 1. Inserting data to DB

D. Graphic display

The data must be displayed to the user in such a way that it provides valuable information both about the current values and, upon request, about the values of a given time interval. After starting the Grafana client from the terminal, the user can connect to the appropriate port of localhost, where the graphical interface can be edited and viewed.

After writing the query, you can select a specific form of display (diagrams, graphs or indicators), and these can be given any color, unit of measurement, data accuracy and rounding. On Fig. 2. an example measurement can be seen.

Figure 2. Graphical user interface

II. Design of the environment

The environment was designed to provide the plants with different amount of light, water, air, and humidity. [20, 21]. The test equipment consists of several hardware elements sensors, actuators and a microcontroller. [22, 23].

The main control unit is a Raspberry Pi microcontroller. The output of the DHT22 digital temperature and humidity sensor can be connected directly to the digital input of the control unit.

The TSL25911FN chip is capable of detecting electromagnetic waves in the infrared and visible range, as well as measuring Lux. With the two built-in AD converters it can transmit the voltage measured by the photodiode via I2C communication. The module works with 16-bit resolution, so it can provide accurate data on the lighting of the environment.

The output of the soil moisture sensor is an analog signal, and a TLC1543 type 10-bit, 11 channel, high-speed CMOS A/D converter was used to digitize it. Communication with the module is done serially.

DS1302 is a real time clock with an I2C interface.

As an intervention module, a fan is needed for ventilation, a pump for irrigation and an LED for lighting. [24] The operation of these units can be controlled using the Raspberry Pi based on the processed sensor data. [25] A drive circuit was created to power the interventionists. [26] The system design can be seen on Fig. 3. The experimental environment can be seen on Fig. 4.

III. Software solutions

The program needs the ideal parameter list, with the help of which it can set the maximum and minimum temperature and humidity values, the time of artificial light illumination and the frequency of sprinkling. [27].

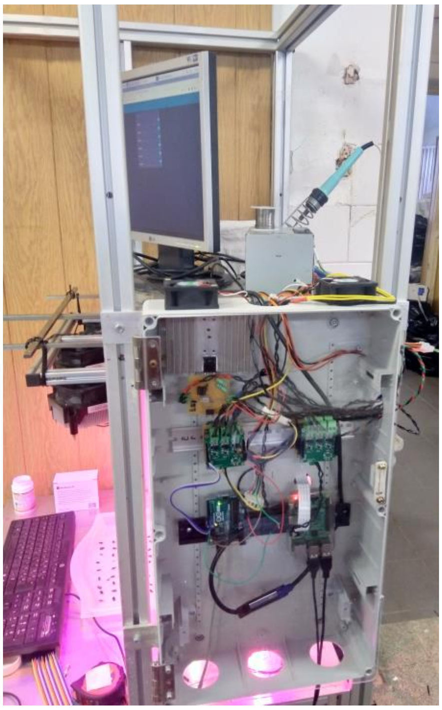

Figure 3. Picture of the test setup

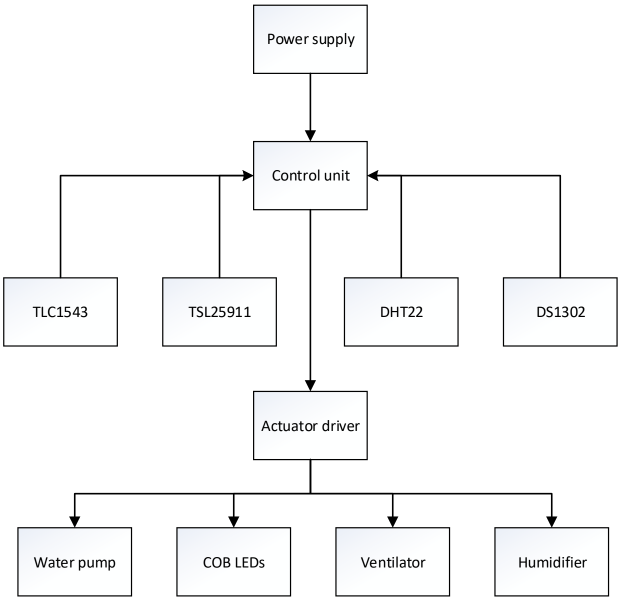

Figure 4. Block diagram of the hardware

A. User interface

The user must select the name of the appropriate plant from a list when the program starts, then the values of the variables are set after a short setup cycle.

The system is basically designed for automatic operation and intervenes in response to the values processed by the sensors, if necessary. However, as an experimental system, user interactivity still plays an important role, so the program was expanded with such functions. All functions, which are basically automatically executed cyclically, can be started at any time as a user. It is possible to have a full measurement performed on the system, to switch actuators on and off, and to modify the daily intervention counters.

User commands are sent using hotkeys, but user intervention cannot interrupt the cyclical running of the program. A software monitoring channel monitors the set of incoming keyboard interrupts. When a given keyboard combination is pressed, it is transferred to a frozenset of virtual keys, to which a function is individually assigned. The given function will be executed on a secondary thread, the main thread will deal with the automatic execution completely independently of this and will continue to run unharmed.

With this method, pressed button combinations can be observed for the entire Linux operating system, i.e. they take effect even after opening the graphical interface.

B. Daily cyclicity

The part of the software responsible for intervention operates according to the conditions described in point I/A. With the help of the built-in DateTime library, it is possible to query the system time and decide whether it is permissible to intervene in the given time interval.

In order to facilitate monitoring, new variables were also introduced, which track how long the given actuators were switched on a given day. These variables can also play an important role in deciding the necessity and limitation of the intervention. During the "active period" defined with DateTime, it is possible to determine, for example, how many hours of artificial light the system should provide. These counters can be deleted every experimental period.

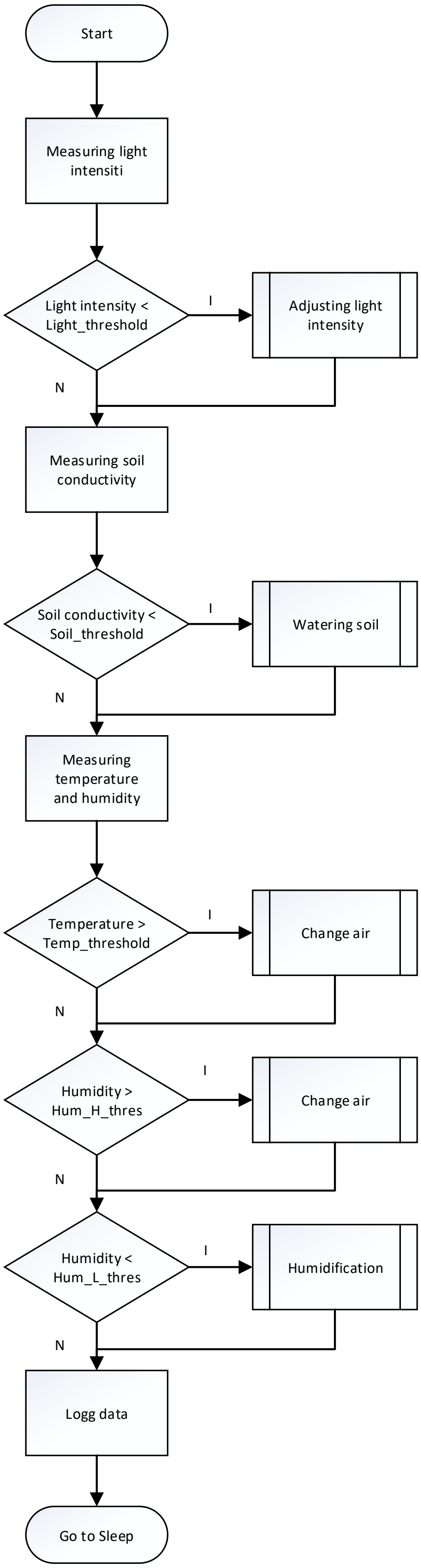

Figure 5. Flowchart of the software

C. Operation of the system

Taking into account the needs of the plant, a specific operating diagram can be defined:

• If the system temperature is too high, the fan will turn on.

• If the humidity is too high, the fan will turn on.

• If the humidity is too low, humidification is necessary.

• If the soil is too dry, it should be watered.

• If there is not enough light, the lamp turns on.

In summary, a flowchart shows the system operation in Fig. 5. The specific comparison levels were determined empirically.

IV. Conclusion

This paper aimed to show an optimized indoor plant production environment. The design contains power LEDs and driving circuits, a control system and a data logging application. The shown modular design can also be used for other indoor plant production applications. The proposed architecture is easily scalable, user-friendly, and robust. The article describes the relationship between the system components and includes an algorithm that demonstrates the control and measuring options.

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