

## Informatics solution for Smart Garden based on Sensors

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*This paper aims to develop an application dedicated to the growth and maintenance of plants, whether leguminous or decorative plants, which involves the traditional cultivation method that uses the soil. It consists in two main components: a mobile application that is able to run on the Android operating system, and the physical component, which is referred to, in what follows, by the term "SmartGarden".*

**Keyword:** sensors, Arduino, smart garden, monitoring

### 1 Introduction

It is well-known that fruit and vegetable producers use intensive crop farming, in order to obtain large crops in a short period of time. This method is used both to increase profits and to meet market demand, taking into account that the global population is constantly on the rise. These agricultural practices come at a price. In recent years, there has been a decline in the quality of fruits and vegetables available on the market, both in Romania and all around the world. Moreover, vegetables found in stores outside the season can be toxic because of the chemicals they are being treated with, to increase their resistance in time. They also lack taste and nutrients because they either are hybrid breeds, specially created to be cultivated in greenhouses, or are not grown under optimum conditions.

Considering these aspects, the best and most reliable alternative would be the cultivation of your own vegetables or fruits. However, people today no longer have the time or resources to grow their own vegetables, or are not quite concerned about this. This is why any technology innovation that occurs in this area is very important, as it could radically change the way plants are grown today. Also, developing devices that facilitate the growth and maintenance of plants could lead more people to choose to cultivate their own plants.

Two of the main ways to cultivate plants are: the traditional method, in which the soil is used as a rooting medium and a source of getting nutrients, and the hydroponic culture. Hydroponics means that plants grow without soil, relying on mineral nutrient solutions in a water solvent, from which the roots of the plants directly uptake the necessary nutrients. Most specialists believe that hypotonic products are not organic because they do not use soil as a growth substrate.

The physical part of the informatics solution proposed in this paper is the one that collects information from the environment and transmits it to the database, in order to be further processed. SmartGarden consists in several sensors and other hardware components linked to a motherboard. The main features are the build-in LED lamp and irrigation system. The mobile application displays data coming from sensors and provides remote control for SmartGarden. It also allows users to adjust the settings to meet their needs, and to manage a list of plants and devices.

### 2 Similar applications

The idea of an automated garden has been exploited so far, reaching similar solutions to the one proposed in this paper. The main difference is that most products which are already on the market use hydroponic growing.

The first solution that I am going to present is Plantui6 [1]. It consists of a water tank, an LED lamp and spaces designed for plant development. The first difference is, as we mentioned above, the hydroponic cultivation method. A second disparity is that Plantui6 uses white light, unlike SmartGarden that uses combined red and blue LEDs for greater efficiency. Also, this solution does not come with an application through which the values in the environment can be monitored. At the same time, it does not show any remote control method. An advantage of this solution is that after 16 hours of operation the device will stop for 8 hours called "sleep time" to save energy.

Another solution that resembles the application we propose is AeroGarden [2]. It consists of a water tank, a blue and red light bulb, and seed planting compartments. AeroGarden Wi-Fi is the mobile application for the solution, which promises to monitor the amount of water, light and nutrients. Also, the built-in LED lamp can be remotely controlled via the mobile application.

CLICK & GROW [3] is another solution for plant growth. Unlike the products mentioned above, it is the only one that uses soil instead of water. The soil used is called 'smart soil' and promises an optimal pH, oxygen and nutrient level. The system has the same components as the above-mentioned devices. It also does not come with a mobile application or a LED lamp.

The elements of innovation presented by the proposed application are the functionalities of the mobile application. From the descriptions of the solutions analyzed before, it is noticeable that there were not used sensors to capture information about several factors that could impact on plant development, such as air

humidity, temperature, light, soil humidity. The application, in addition to providing real-time information, provides the option of seeing the changes in the form of a graph for a more eloquent representation that facilitates understanding. Another strength of the proposed solution is the "automatic mode", which allows the device to turn on certain components (lamp or irrigation system) without needing the intervention of a user. Another possible advantage of our solution might be that it is intended for growing plants in the soil and not in the water, considering that most of these products are made for hydroponic crops.

### 3 Application design

In Figure 1 the actions that the user can take in the mobile application are presented. There is a simple association relationship between the user and all use cases. As we can see, the include relationship was used to represent that most actions (add plant, add device, check status of parameters, modify account data, choose operating mode) that can only be performed after the authentication has been done in advance. Also, the "Check status of parameters" case extends three other cases: "Turn on irrigation system", "Turn on lamp", "View History". This extension highlights the fact that these extended cases take place optionally or under certain conditions. Thus, in the manual mode of operation of the system, if after checking the state of the parameters, the user wishes to take one or more of the extended actions, they will take place, otherwise not. On the other hand, in the automatic mode, the system will execute the extended cases: "Turn on irrigation system" and "Turn on lamp" when the soil moisture and brightness parameters will drop below the lower limit.

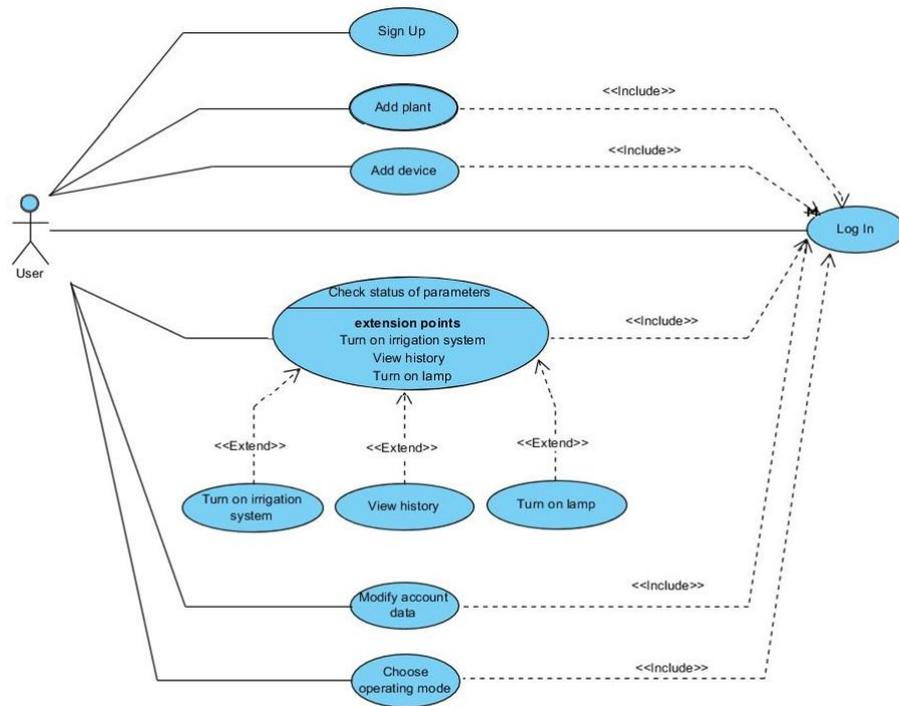


Fig. 1. Use case diagram

Activity diagram for "Turn on lamp". In the "Turn on lamp" activity diagram, we can see the steps taken by both user and system in order to control the lamp remotely (as in Figure 2). The logged-in user can turn on the lamp by pressing the button on the home page of the application.

Once the button is pressed, a request is sent to the database to change the status of the lamp to 0, corresponding to the state "Off", or 1, corresponding to the "On" state. The motherboard reads the values in the database and acts as a result of the change the used made.

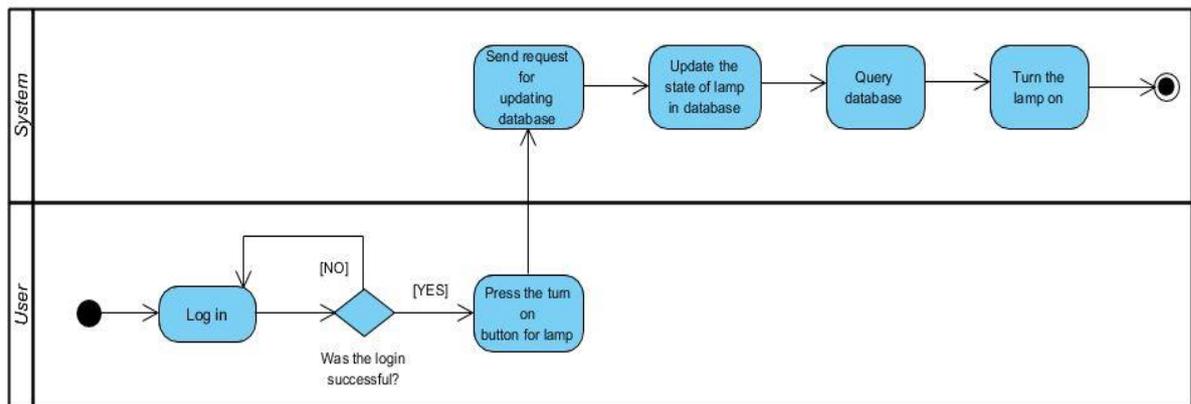


Fig. 2. Activity diagram for "Turn on lamp"

The class diagram is designed to graphically describe the static part of the system by presenting classes and relationships between (as in Figure 3). The

classes used in the project are: Accounts, Devices, Devices\_models, Plants, Default\_plants, Categories, Sensor\_data.

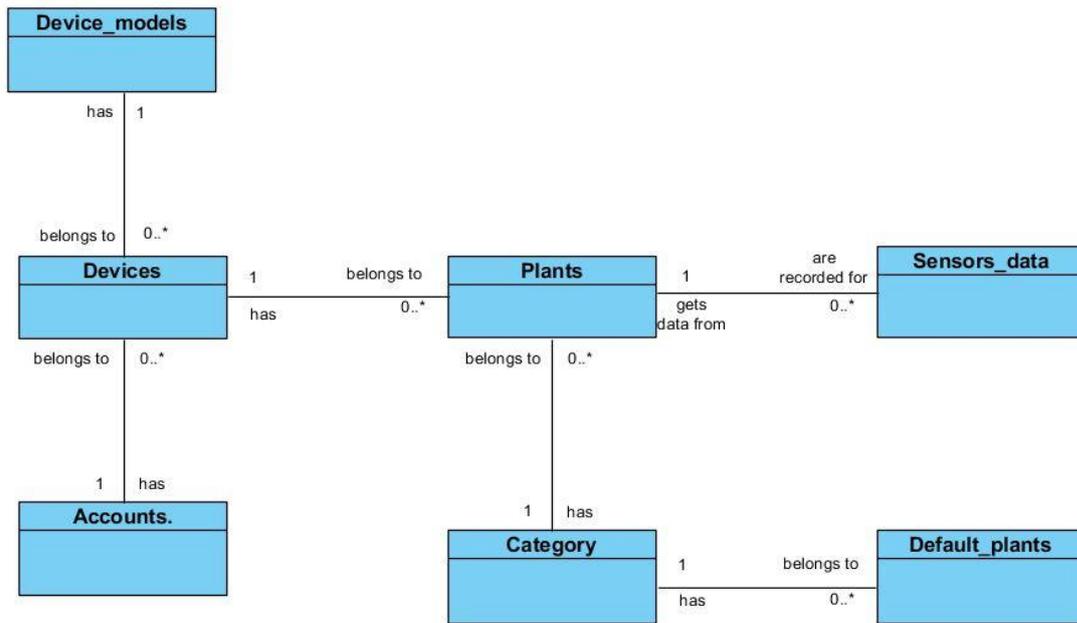


Fig. 3. Class diagram

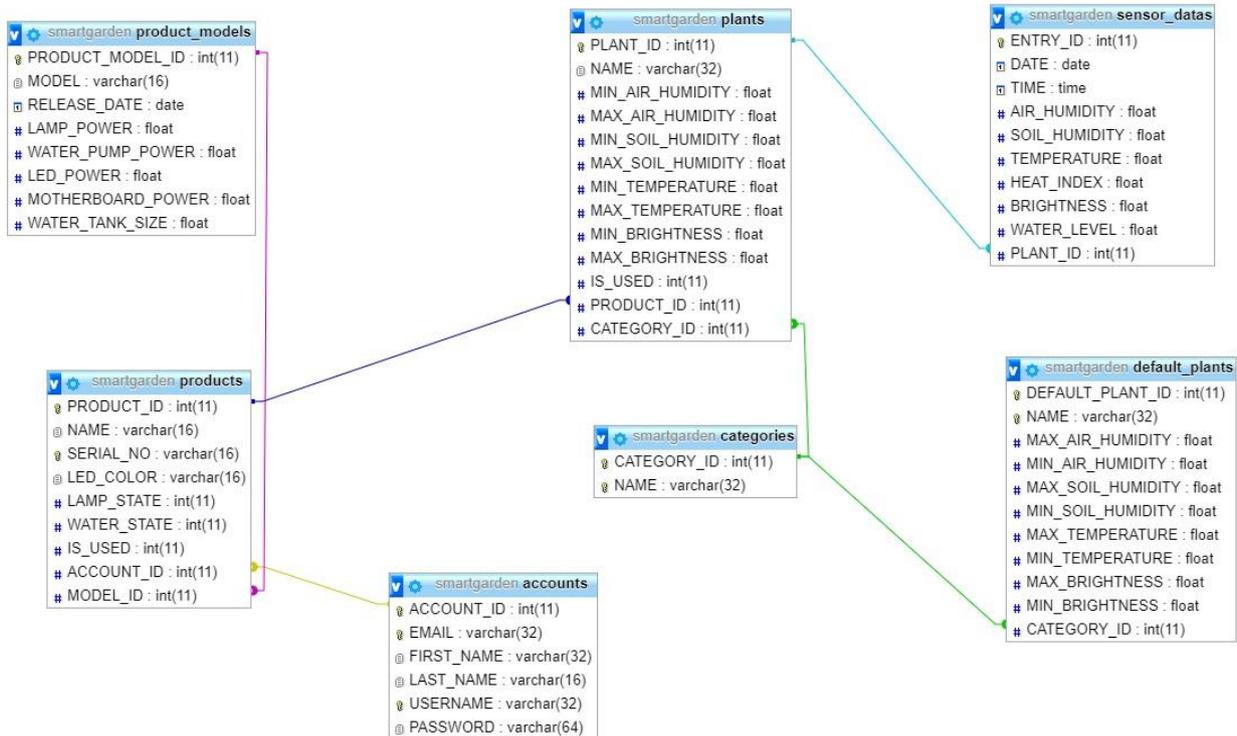


Fig. 4. Database logical schema

Relationships between entities can be expressed as follows: a device model belongs to one or more devices, a device has only one model; an account has one or more devices added, but a device belongs to a single account; a device, over time, can grow one or more plants, and one plant

is grown in single device; a category contains one or more plants, and one plant belongs to a single category; a category contains one or more default plants, and a default plant belongs to a single category; for one plant are recorded one or more

inputs from the sensors, and one input from the sensors is recorded for a plant.

#### 4 Software Technologies

As specified in the introduction, there are two components: the mobile application and the physical component, SmartGarden. The technologies used in the project are the following:

- Android platform and Java language
- Arduino software and C ++ language
- MySQL
- LAMP server

The mobile application is built through the Android Studio development environment using the Java programming language and is compatible with the Android operating system. It can run on devices that have at least Android version 4.4 KitKat, with a minimum API of 19.

Arduino software is a development environment used in the automation process to write code for the motherboard, using C/C++. To simplify code writing, the following libraries: ESP8266, WiFiClient.h, ESP8266WebServer.h, SimpleDHT.h were used. The first three libraries were used for the WiFi module and the last one for the temperature and humidity sensors.

MySQL is used to store data gathered from SmartGarden. Since records are being generated every 7 seconds, a database management system with a large storage capacity is needed. This is the means of communication between SmartGarden and the mobile application. It also manages user accounts, storing either personal data and plant listings or user configurations about how the application works.

The LAMP server is used to establish the communication between SmartGarden and the mobile application. SmartGarden queries or inserts data into the database via

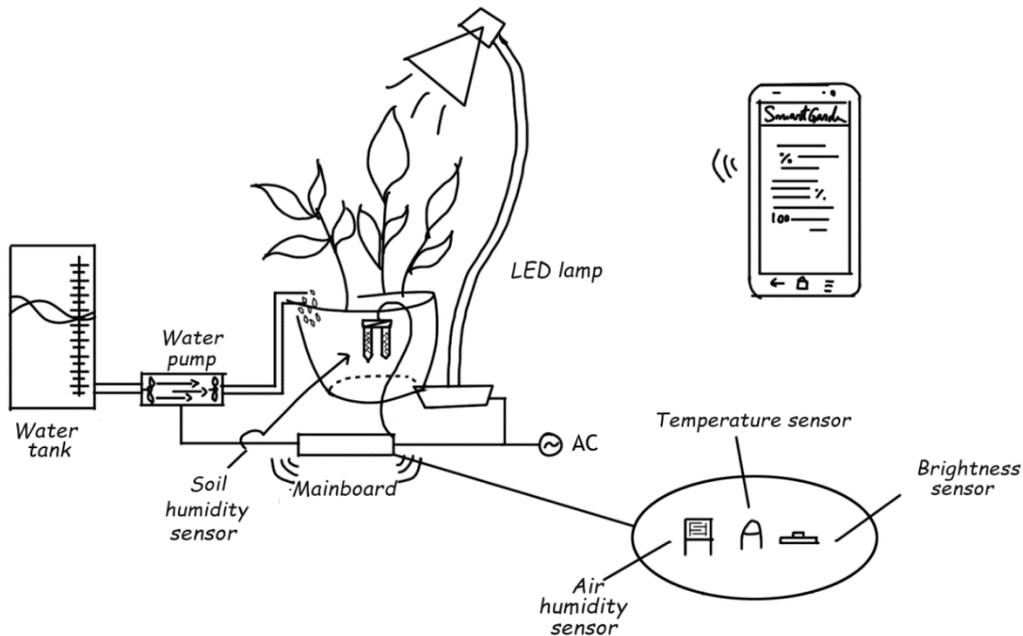
PHP pages running on the server. Both queries and insertions from SmartGarden are done using the POST method. Using the same method, the application queries the database and takes data coming from SmartGarden. There is another method that can execute the task, called GET. The difference between GET and POST methods consists in the security they provide. The GET method is less secure because the values are explicitly written in the link, remaining in the browser's history, and can be intercepted by unauthorized people. The POST method has a higher degree of security because the values are encoded and transmitted via HTTP headers. However, the level of security also depends on the HTTP protocol, so by using Secure HTTP (HTTPS) the level of data protection is higher.

To provide remote control, by using the mobile application, the status of the lamp / irrigation system in the database changes to 1 or 0 when the "turn on" / "turn off" button is pressed. SmartGarden reads the information about the new state of the device, and reacts by turning them on or off.

#### 5 Application interface depiction

SmartGarden contains the following hardware components:

The *motherboard* is the main component of the SmartGarden project. It works as a control center where all the information transmitted by the sensors is collected and it is further made available to the mobile application through a database. The board not only gathers data, but also controls the mechanical part of the project, such as: a mini water pump used for soil irrigation, but also an LED lamp to provide the necessary amount of light (as in Figure 5).



**Fig. 5.** Schema of components

The mainboard is like a computer, as it contains common elements such as a processor, internal memory, RAM, but also a very important element, a WiFi module capable of receiving or transmitting packets of data on a local network or on the Internet. At the computer level, the mainboard acts both as a server and as a client. On the server side, it provides a web page where you can set the name and password of the router to which it will connect in order to access the Internet, and on the client side it connects to the database.

*Sensors.* In order to get quicker, yet more accurate information, a range of efficient sensors has been chosen. Next, the sensors used in the project implementation and their characteristics are presented:

- a) The temperature sensor - detects the temperature in the air and transmits it to the motherboard in digital format.
  - The measured temperature range is  $-40^{\circ}\text{C}$  to  $+80^{\circ}\text{C}$ ;
  - The accuracy of the measurement is  $\pm 0.5^{\circ}\text{C}$ .
- b) Air humidity sensor - detects relative humidity (RH) in air and

transmits it to the motherboard in digital format.

- The measured humidity range is between 0% RH and 100% RH;
  - The accuracy of the measurement is  $\pm 5\%$  RH.
- c) The soil humidity sensor - detects soil moisture and transmits it to the mainboard in analog format.
    - The measured humidity range is between 0% and 100%;
    - The accuracy of the measurement is  $\pm 1\%$ .
  - d) Ambient light sensor - records the level of ambient light and transmits it to the mainboard in analog format.
    - The accuracy of the measurement is similar to the human eye;
    - The detection angle of the sun rays is  $\pm 60^{\circ}$  and best responds around the value of 570nm of the light wavelength, which corresponds to natural light or the one produced by LEDs. The light produced by incandescent bulbs is detected very poorly because it produces another spectrum of light. This is the desired effect because incandescent light does not help plants grow.

- e) Water level sensor - detects the water level in the tank and transmits it to the motherboard in analog format.

The *LED lamp* will extend the duration of exposure of plant to light. There are certain wavelengths in the visible light spectrum that are ideal for plant growth, the red and blue ones. Different proportions of red and blue light affect different types of chlorophyll differently. Depending on the stage of development, the optimal wavelengths may vary. For example, in the blooming phase, a red light spectrum is most suitable to plants. LEDs are the best choice for this solution because they do not produce overheating and have low energy consumption. Moreover, they produce the same wavelengths as the sun's rays [4].

The *irrigation system* ensures an optimal level of soil moisture. It has the following components: a water pump, two hoses and a tank with a capacity of 0.8L. By using the appropriate sensor, we will know when the soil humidity has dropped below the lower limit, so that the system needs to be turned on. This avoids both water deprivation of the plant and the use of too much water.

*Multiplexer.* Because the motherboard has only one analog input, it was necessary to introduce a 16-channel multiplexer in order to extend the number of analog inputs. It receives from the motherboard the channel (in binary format) from which we want to intercept the analog value and read any input on the indicated channel. The information is then returned to the board.

*Relay module.* In order to turn on and off the lamp and the water pump, it has been used a 4-relay module. It works as a switch, but instead of the mechanical action of pressing a button, a digital signal of 0 or 1 is transmitted to the module, which in turn closes or opens the electrical circuit. The relay module is controlled by the main board

through two pins, one for the water pump and the other for the lamp (Figure 6).



**Fig. 6.** SmartGarden – water and light sources

*Controller for LED strip.* The LED strip is used in the SmartGarden's exterior design. In order to obtain different color shades, it is necessary to build a controller. This is a set of three transistors that, along with the signal received from the motherboard, control the intensity and color of SmartGarden's lights (Figure 7).



**Fig. 7.** SmartGarden – in operation

The LED strip consumes a higher current than the one that the motherboard can support, so an external power supply is needed.

The Android application will provide the following features:

*Register of a new user.* When creating a new account, the user must provide some personal data (name, surname, email, username, and password) that is filled into

a form of the application. These data will be stored in the database. Taking into account that the table containing users will contain sensitive content such as personal info and passwords, the information is encrypted using the bcrypt algorithm, because it is considered to be the most secure and efficient.

*Authentication.* After the account is created, the user will provide the username and password in order to login and be able to use the application. To verify the correctness of the data entered, it will be checked in the database whether the username and password combination belongs to a user. If they are correct, authentication will be made successfully, otherwise, the application will display an appropriate message to let the user know

that one of the information they provided is incorrect.

*Display the values from sensors.* The sensors integrated in Smart Garden will record the values of environmental parameter every 7 seconds. These values will be stored in the database, in a table dedicated to sensors data only. The mobile application will retrieve this data and display it both in the main menu (Figure 8) for a quick check and on separate pages dedicated to each sensor. Individual pages will also allow you to view a history of recorded values. Thus, we can see the evolution of certain parameters that influence plant development, throughout the day. The graph and report option will also be available for easier viewing and understanding of the changes that have taken place (as in Figure 9 and Figure 10).

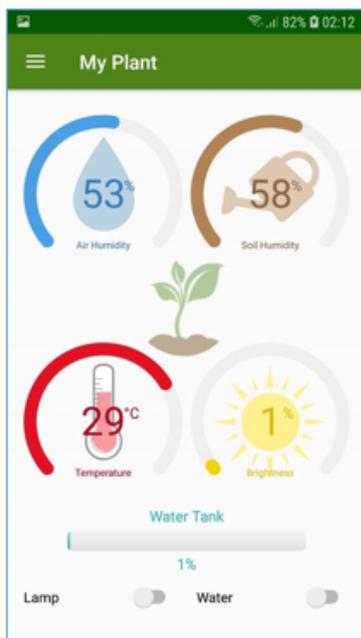


Fig. 8. Home page app



Fig. 9. Graph for the evolution of brightness



Fig. 10. Report for the evolution of brightness

*Adding a plant.* The option to add a plant can be accessed via the side menu of the mobile application. Here will be provided information about the plant such as: name, optimum parameter values (air humidity, soil humidity, temperature and ambient light intensity). If the user does not know the optimal values for good development of the plant, he can choose to add a default plant provided by the application.

Subsequently, the user will be able to modify the entered data provided previously or remove a plant from the list, if desired.

*User notification.* One of the most important features of the application is the notifications sent to the user when the values of a parameter exceeded the optimal interval limits. It will also signal when the water level in the tank has reached a low

level. Depending on this, the user can make certain decisions in order to fix the situation.

*Remote control.* Smart Garden has a plant watering system and a special LED lamp for plant growing. It provides two modes of use: automatic and manual. If we choose the automatic mode, SmartGarden will no longer need our intervention to take care of the plant. It will take into account the measured values of the sensors and the optimal values and will automatically turn on the irrigation system or LED lamp when needed. If we choose the manual mode, the application will send a notification to the user, indicating that the irrigation system should be turned on because the soil humidity has dropped below the lower limit. Also, if the exposure time to sun light is too short, it can be substituted by using the LED lamp, which can also be turned on or off remotely, without the need for physical presence.

## 6 Conclusions and future works

We consider that the resulting application has achieved the goal set in the beginning, namely to automate the plant monitoring and maintenance process.

The application could be improved by the following aspects:

- improving both the mobile application design and the physical component aspect;
- more detailed analyzes on the evolution of parameters values over time;
- a system that holds the flower pot in place or a system that notifies the user when the pot have been removed, in order to avoid the situation in which the irrigation system is turned on in the absence of the pot, which could be damaging for the hardware components;
- plant growth monitoring;
- predictions;
- control of temperature and air humidity;
- notifications via email or SMS.

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