Universidade do Minho
Escola de Engenharia

Mestrado em Engenharia Eletronica Industrial e de Computadores

Smart Greenhouse

Project Plan

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1 Analysis Phase

1.1 Problem Statement

Nowadays, it is known that climate change has emerged as one of the biggest environmental challenges of the world. The main cause of this issue are the human activities that contribute to the greenhouse gas emissions, and thereby the greenhouse effect [Com]. According to the International Energy Agency (IEA), it is estimated that CO2 emissions will increase by almost 5 % this year, being the biggest annual rise since 2010 [IEA].

As reported by the United States Environmental Protection Agency (EPA), 29 % of the greenhouse emissions in the USA come from transportation [EPA]. Food production is also one of the main sources of this problem, contributing around 37 % of global greenhouse gas emissions. Also, the production of animal-based food products generates twice the emissions of plant-based ones [New].

Having that idea in mind, this project proposes the development of a smart hydroponic greenhouse for home use. With this product, it's intended to turn hydroponic agriculture into an easier, more sustainable and efficient activity, in order to attract more people into it. This way, food production and transportation will have less impact in greenhouse gas emissions, because if more people produce their own food at home, their diets will be richer in plant-based food, the need for them to drive to a local grocery store will be reduced and the food transportation, from where it is produced to the local stores, will also decrease.

1.2 Problem Statement Analysis

In order to develop a product for home use that turns hydroponic agriculture in an easier, more sustainable and efficient activity for the client, an automatic control system and user interface must be implemented.

For that purpose, the control system of the product must be able to regulate the air temperature, air humidity, water temperature and the light that the crop receives. Also the user interface must be friendly, easy to use and able to notify the user on relevant information about the status of the greenhouse.

1.3 Market Research

1.3.1 Demand analysis

In a research of the global hydroponics market, some information that can support a good balance of investment in this sector was found.

The global hydroponics market size was valued at 2.1 billion dollars in 2020 and it is expected to expand at a compound annual growth rate of 20.7 % from 2021 to 2028 [Res]. Moreover, a report from Diário do Minho refers that there is an estimation that the Compound Annual Growth Rate of the hydroponics may increase up to 6.5% in the next two years [min].

1.3.2 Bench-marking

For studying the bench-marking it was first decided to do a research on previous studies in the area and then depart from there to search for related companies. According to a hydroponic market study [mar], the COVID-19 pandemic led to an increasing demand on local food production, having a positive impact in the urban hydroponic farming systems. Due to that market boost, many companies saw an opportunity to develop and innovate the hydroponic technologies. Some of the major companies that were studied are presented in the Table 1.

Company	Headquarters
Signify Holding	Netherlands
Argus Control Systems	Canada
Heliospectra AB	Sweden
Scotts Miracle Gro	US
American Hydroponics	US
LumiGrow	US
Emerald Harvest	US
Hydroponic Systems International	Spain
Advanced Nutrients	Canada
Vitalink	UK
Hydrodynamics International	Spain
Logiqs B.V	Netherlands
Grobo	US

Table 1: Companies Studied on Market Research

After an individual study of each of the companies, it was concluded that they can be organized in four different groups with different taget markets. The companies Scotts Miracle Gro, Emerald Harvest, Advanced Nutrients, Vitalink and Hydrodynamics International are ones that focus on selling farming consumables. Signify Holding, Heliospectra AB and LumiGrow are companies that focus on LED technology for greenhouses. There are also companies that are working on products that can be placed in greenhouses in order to automate them, which is the case of Argus Control Systems an Logiqs B.V. The products that are the most similar to this project product are the ones from American Hydroponics, Hydroponic Systems International and Grobo, because they sell complete greenhouse systems.

The Figure 1 shows a product developed by American hydroponics [Amh] that consists in an hydroponic system with no control of its parameters and that is also expensive, costing 1900 $. However, the structure of this product can be used as a reference for the concession of this project product. The product represented in Figure 2 is from the company Hydroponic Systems International [Int] and it also has no parameter control, but it can be a reference for the design of the draining system of this project product.

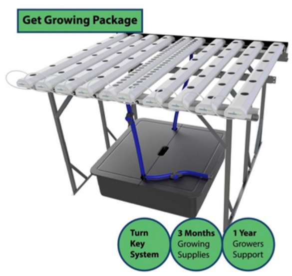

Figure 1: Get Growing NFT 96 Home & Classroom Bundle

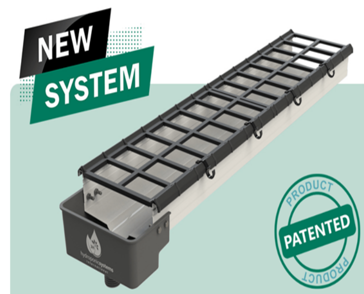

Figure 2: HS Evolution System

The products shown on Figure 3 and Figure 4 are both hydroponic growing beds from the Grobo company [Groa].

The first one is a system with air temperature and light control, but its an expensive product (costing 1800 $) with a design that only allows a single medium sized plant to grow inside and that doesn't provide visual information of the state inside the growing bed. Despite of that, this product helps understanding what kind of control a greenhouse must have.

The second product is a reduced size hydroponic bed with a mechanical water level indicator and a manual light switch.This product, despite not having a greenhouse encasing and an automatic control system it has a competitive low price (80 $) that should be taking into account in the product development costs.

Figure 3: Grobo Solid

Figure 4: Grobo Start

On a further research, there were found other equally relevant companies and products. The Figure 5 and Figure 6 respectively show a product developed by Growtonix [Grob] and another developed by Illiminum [Ill] Greenhouses. The first one provides two automation system products for crop growing environments, which includes hardware and software for setting up a control system on it . The other one is a system that acquires real time information about fertigation and irrigation

These products are not directly competing with this projects product in the market, because instead of being a greenhouse structure, these products are meant to complement an already existing and not controlled system. However, these products are being sold on the market for a reasonable price (arround 500 $ each). Also, the sensors used by those products to monitor a greenhouse can be a reference for this project development.

Figure 5: International Base System

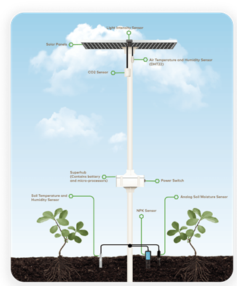

Figure 6: FarmShield

The Figure 7 shows the Grow Cube, developed by Ecosphere Technologies [Tec], which is a crop growing house focused on production maximization that provides good conditions for the plantations and is able to monitor the system behaviour. However, this product has large dimensions and so it doesn't directly compete with this project product in the market. The price for this product was not found during the research.

Figure 7: Grow Cube

1.4 System Overview

The product is composed by different components, which are the controller, the sensors, the actuators, the graphical display, the database and the mobile app. The Figure 8, is the diagram for the system overview, which shows how all components are assembled.

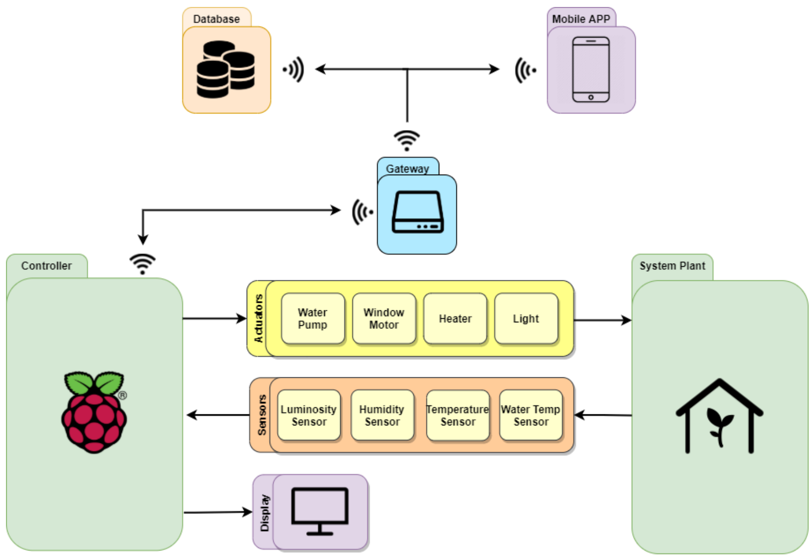

Figure 8: System Overview

The sensors are used for data acquisition from the plant to the controller unit, sending information about the light intensity that the crop is receiving (luminosity sensor), the air temperature and humidity of the greenhouse (humidity and temperature sensors) and the temperature of the nutrient solution that feeds the plants (water sensor). Based on the information that is received from the sensors, the controller will actuate on the system plant through the actuators. The water pump is used to turn on or off the nutrient solution flow and the water temperature sensor is for measuring its temperature. The actuators that vary the air temperature are the window motor, which opens the greenhouse window to decrease its temperature and the heater, used to increase the temperature.

The user can interact with the system with a mobile application, where he can get information about the greenhouse parameters referred in the last paragraph, manually control the actuators of the system and receive notification warnings from the system. The product also provides an interface display to show real time information about the user crops.

The system will store the data in a database server, which can be accessed by the mobile application and the controller unit through a Wi-Fi gateway.

1.5 Requirements

Down bellow there are listed the functional and non functional requirements that should be taken in account during the development of the project. As it can be seen, the functional requirements describe what the system must be able to do while the non functional requirements describe how that should be accomplished.

1.5.1 Functional Requirements

- Measure the nutrient solution temperature.
- Measure the air humidity inside the greenhouse.
- Measure the light intensity received by the crop.
- Measure the atmospheric temperature and humidity inside the greenhouse.
- Control the nutrient solution flow.
- Regulate the temperature inside the greenhouse.
- Regulate the light intensity.
- Show the greenhouse status in a display.
- Interact with the user via a mobile application.

1.5.2 Non Functional Requirements

- Reasonable power
- Soft-Real Time Embedded System
- Structurally strong
- Appealing
- Easy to use and user friendly
- Minimal cost

1.6 Constraints

Down bellow there are listed the constraints for this project. The functional ones impose design restrictions that must be respected since they have a direct impact on the product design.

1.6.1 Functional Constraints

- Must use a Raspberry PI in a linux environment.
- must use buildroot to generate the embedded Linux system.
- Must use FreeRTOS.
- Must be coded in C/C++.

1.6.2 Non Functional Constraints

- Reasonable budget.
- Must be concluded until the end of this semester.
- The Group is composed by 2 elements

1.7 System Architecture

The system architecture is divided in two distinct components, the hardware architecture and the software architecture.

1.7.1 Hardware Architecture

The Figure 9 shows the hardware of the system. As it can be seen, it can be decomposed in 3 subsystems, which are the sensors, the actuators and the processing subsystem.

Starting for the last one, it was decided as a constraint that the processing unit should be a Raspberry PI, and it's function is to process the information from the sensors, process it and actuate over the system, as well as present the real time status of the greenhouse in a display.

Inside the sensor subsystem, there is an atmospheric humidity sensor, an atmospheric temperature sensor, a water temperature sensor and a light sensor. All of them acquire data from the physical plant of the system and send it to the processing subsystem.

The actuators subsystem is composed by a water pump, that pumps the nutrient solution to the plants, an automatic window controlled by a motor, that regulates the humidity and temperature inside the greenhouse, a LED that provides light when the plant crops need it and a heater that warms the greenhouse when it is needed.

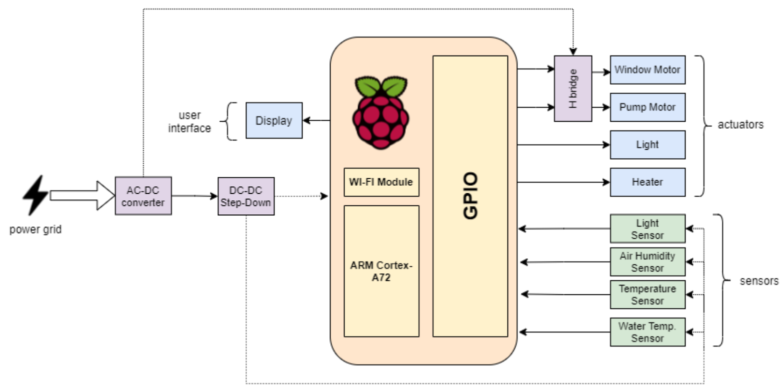

Figure 9: Hardware Architecture

1.7.2 Software Architecture

The system software is represented in the Figure 10 and it is divided in 3 layers, which are the application, Middleware and the Operating system.

The first is the application, which is the interface with the user where he can access to all the system information and where there is also the system database. The second layer is the middleware of the system, where the data is acquired, processed from the drivers and sent to the application layer and where can also be found the WI-FI services.

The third layer is the operating system that includes all the drivers from the sensors and actuators. It also creates an interface between the transducers and the rest of the system software.

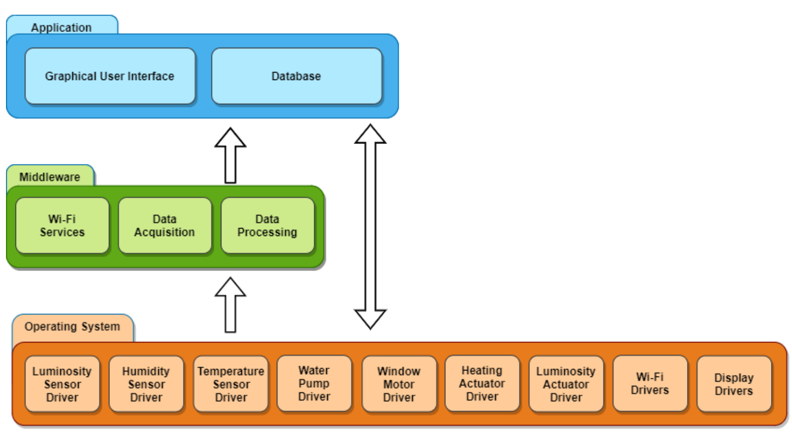

Figure 10: Software Architecture

1.8 Gantt Diagram

For organizing the project development timewise, a gantt diagram was elaborated with the main tasks and the respective allocated time. The diagram is presented in the Figure 11.

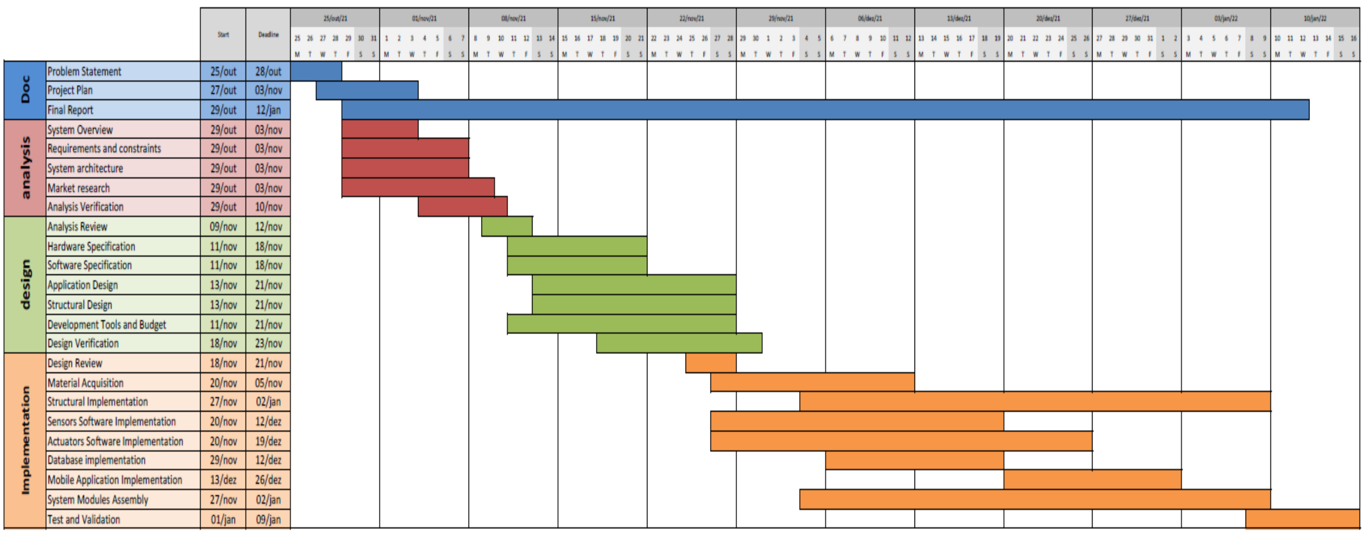

Figure 11: Gantt Table

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