Urban Green

February 15, 2016

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Re: ENSC 440 Project Proposal for EcoGarden, a Completely Self-contained Aeroponic Growth System

Dear Dr. Rawicz,

Please find the Functional Specification document for the completely self-contained Aeroponic growth system, EcoGarden- our project for ENSC 440- Capstone Engineering Science Project. We plan to design and build an Aeroponic growth system that allows people to grow plants indoors and in climates not conducive to traditional farming like high population density areas.

This functional specification provides an analysis of the EcoGarden functionality. It describes all the functionality required of each part of the system. Also included are necessary industry standards, environmental and safety considerations to be observed during the initial product design.

Urban Green is a partnership of five ambitious students with variety of knowledges and skills: Eric Ganzert, Timothy Horita, Michael Foo, Mahbod Tork-Tatari, and Anita Khoshnavaz. Please feel free to contact us by email at eganzert@sfu.ca for any questions or concerns.

Sincerely,

Eric Ganzert

Eric Ganzert
CEO
Urban Green

Enclosure: Functional Specification for EcoGarden

Urban Green

Functional Specifications for EcoGarden

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Executive Summary

Eating fresh and healthy vegetables and herbs is prohibitively expensive for those who live in high population density areas and remote areas not conducive to farming. Moreover, even people with farming expertise cannot grow all the specialty crops they want due to the climate they live in. As a result, the self-contained Aeroponic growth system (EcoGarden) by Urban Green will allow people to grow produce indoors on a scale that can feed a large family.

EcoGarden features a self-contained environment with dynamic temperature, humidity and sunlight control. It also provides an Aeroponic watering system that delivers nutrients directly to the roots of the plant. In addition, in order to keep track of the above procedure, it monitors each variable separately using the following sensors:

- Temperature sensor
- Humidity sensor
- Sunlight detecting sensor

Real-time conditions are monitored by an Arduino microcontroller which keeps the environmental conditions within the ideal range using the lights, heater, vent, and fans as well as controlling the watering system. A Raspberry Pi computer runs a display on an interactive screen.

Finally, one of the most attractive features of the EcoGarden is the wireless communication system through cell phones; this feature is used when the user does not want to use the screen or is away from the system. It allows the user to use all of the above features of the screen on their cell phones.

This document outlines the functional requirements for each component of EcoGarden. These requirements are to ensure proper performance, quality, and safety of EcoGarden. User documentation are also provided to prevent confusion and improper use of the system.

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Glossary

Aeroponics: the process of growing plants in the open air without use of soil or a growing medium.

Arduino (Uno): A type of microcontroller programmed using an Arduino integrated development environment.

GPH: Gallons per hour, a unit of flow rate.

GUI: Graphical User Interface, what the user sees and interacts with on a screen.

LCD: Liquid crystal display, a type of display screen.

LED: Light-emitting diode, a p-n diode that releases light when activated.

PSI: Pounds per square inch, a unit of pressure. 14.7 psi is approximately 1 atmosphere.

Raspberry Pi: A small, single-board computer that uses a Linux-based operating system.

1. Introduction

1.1 Background and Scope

There are many people who, right now, have no access to fresh produce. They may be living in an urban centre, in a poor growing climate, or in a remote place where it is expensive bring in produce **[1]**. In any case their quality of life suffers because of their situation. In places where processed fast food is more convenient and cheaper it may lead to increased rates of diabetes, malnutrition and other health concerns The number of people with these problems is just going to increase as the total global population increases. Luckily, there is a solution, and that solution is the EcoGarden; a self-contained produce growing environment.

The EcoGarden is an automated Aeroponics apparatus which allows the user to grow a variety of vegetables and herbs with relative ease. The system controls all aspects of the growing process including:

- Chamber humidity
- Ambient chamber temperature
- Timed watering system
- Timed simulated sunlight exposure

It does so by using a temperature and humidity sensor, in conjunction with the Arduino's built in clock functions to control the timing of the lights and watering system. A Raspberry Pi computer is separately used to host a user interface display screen. EcoGarden features actuators that will tune the environmental conditions to the ideal range for a list of preset plants.

The purpose of this document is to provide a functionality overview of the EcoGarden including all necessary industry standards, environmental and safety considerations observed during the initial product design.

The functional specification document is intended to serve as a references to the member of Urban Green team. The test engineers will use this document during the implementation and development of EcoGarden.

All requirements are labelled **[RXXX-X-V]** where XXX-X is the specification number and V is either I, if it's a prototype specific requirement, or II, if it's a final production requirement.

1.2 System Overview

Before getting into each part of the Aeroponic system separately and in detail, an overall picture of what Aeroponics is and how it works is necessary. Overall Aeroponics is the process of growing plants in an air or mist environment without the use of soil or other growing medium. The mist is composed of water and nutrients, and is absorbed through the roots while still allowing high exposure to the air. This exposure to air allows the roots to take in much more oxygen than in traditional growing techniques or in Hydroponics where the roots are completely submerged in water. Figure 1 illustrates Aeroponics in a conceptual cartoon style drawing. Note that Figure 1 does not include the top environmental monitoring chamber or the microcontroller.

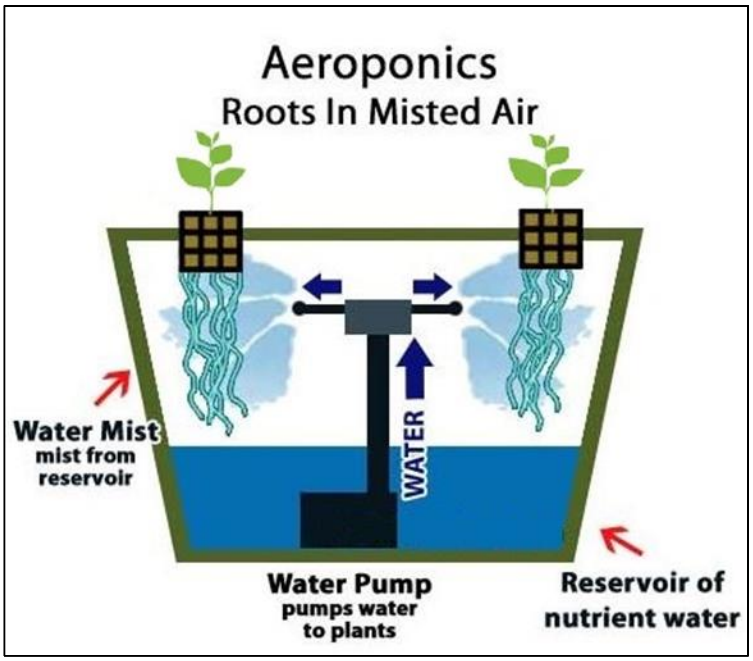


Figure 1: Illustration of Aeroponics

Plants can be installed in 6 growing sites on a thin flat platform where the roots of the plant hang below into the lower enclosure and the main body and leaves of the plant are growing up above. This divides the product into two main parts; the lower enclosure where the watering of the roots takes place, and the upper chamber where the plant is kept in closely monitored environmental conditions. The current design of our system is shown in Figure 2.

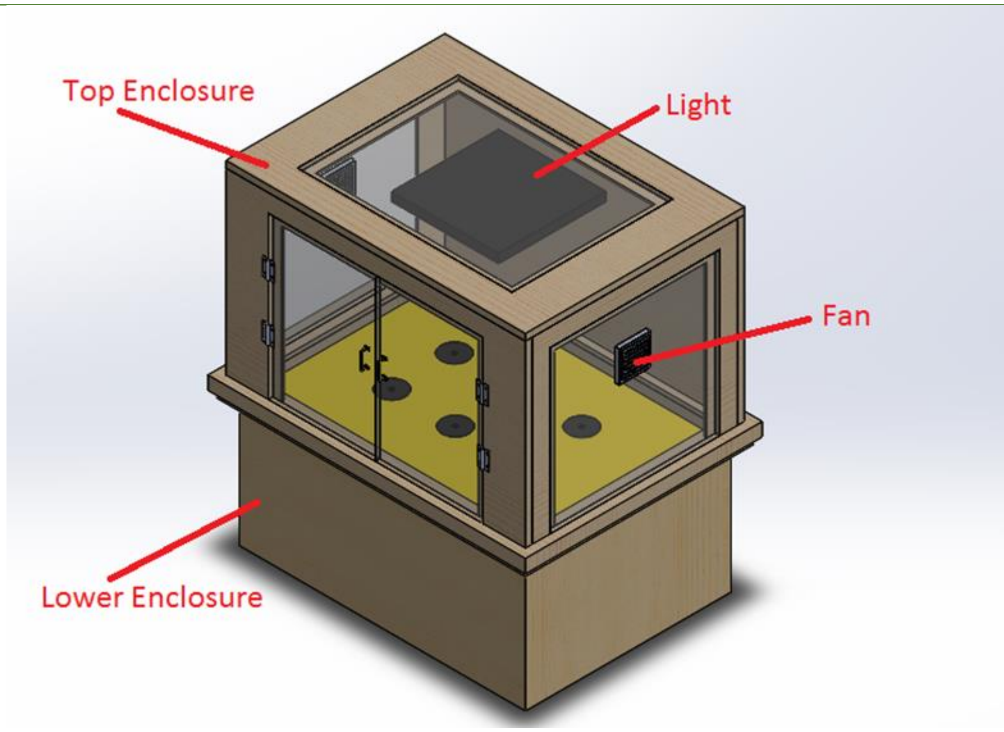


Figure 2: SolidWorks model of EcoGarden

2. System Specifications

2.1 Watering system

The watering system is the method used to spray a fine mist onto the roots, as they hang freely down from above. To accomplish this, we need to use a pump to force water into a system of pipes which have misting nozzles directing the spray of mist onto the roots. The watering apparatus will sit inside a plastic basin where the level of standing water is about 6-8 inches deep. The water pipe system by itself is shown in Figure 3

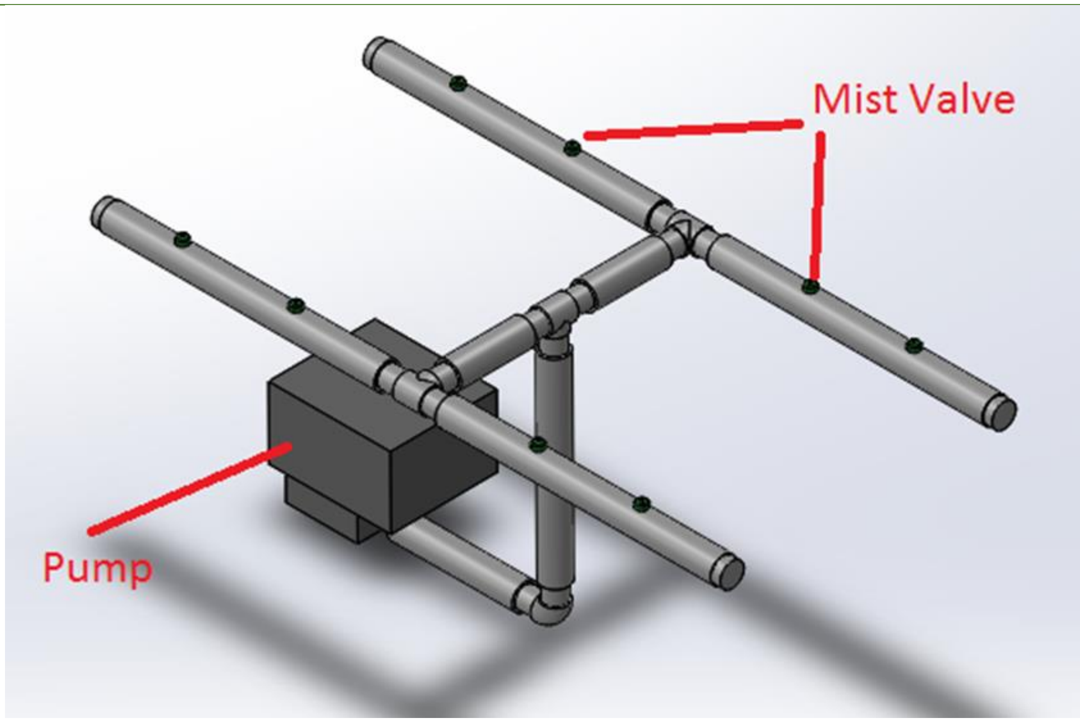


Figure 3: The Aeroponic watering system

It is necessary to choose a pump that can pump at least twice as much water than the minimum Gallons Per Hour (GPH) of what you need **[2].** In determining the suitable GPH for our system we take into account the vertical distance that the water must be pushed up in the pipe structure; the max head height. Of note in our design is that there is only 1 vertical pipe section to minimize the effect of gravity on the pumps workload.

GPH and max head height are standard measurements listed on all submersible water pumps. it is commonly recommended to select a GPH value more than what is expected because it is possible to let off some pressure using a variable flow valve but it is impossible to make the pump increase its GPH.

2.1.1 General Requirements

[R211-1-II] Pump is activated in timed intervals so that the roots remain dampened
[R211-2-II] Pump must be submersible in water
[R211-3-II] Pipe must be affordable
[R211-4-II] Must be compatible pipe fittings such as tees, elbows and end caps
[R211-5-II] Misters are able to be installed directly into pipes as shown in Figure 3
[R211-6-II] High pipe pressure is required to get a decent spray out of the misters and achieve a full 360 degree spread of mist
[R211-7-II] Full coverage of the roots to prevent dry spots

2.1.2 Physical Requirements

[R212-1-II] Pipes must withstand the pressure when the pump is running. Water pressure reducing regulations governed by CSA B356 standard **[3]**
[R212-2-I] Pump should be 300-500 GPH, based on typical requirements for small fountains [R211-3-I] Pipes will be ¾" in diameter; a size that all required fittings can be found in while limiting flow volume in the pipes
[R212-4-I] A total of 8 misters will be installed in the dual pipes (Figure 3); which should provide ample coverage
[R212-5-I] Total (length, width, height) dimensions cannot exceed (28, 19, 15) inches; these are the dimensions of the lower enclosure

2.1.3 Electrical Requirements

[R213-1-II] Pump must be run from main power supply to provide the power it needs
[R213-2-II] Electrical relay used as switch allows Arduino microcontroller to turn the pump on and off from its 5V digital I/O pins
[R213-3-II] All electronics and wires underwater or exposed to mist must be completely waterproofed

2.1.4 Reliability Requirements

[R214-1-II] Maintenance not required frequently
[R214-2-II] Pressure must be monitored to avoid bursting pipes or overheating the pump
[R214-3-II] A release valve must be installed to prevent pressure build-up

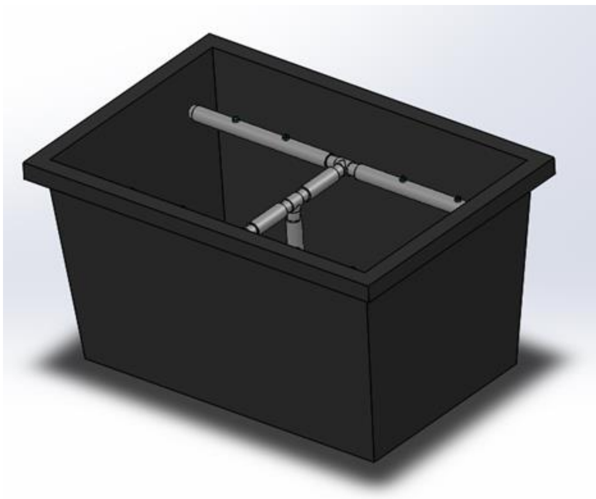
To simplify the system, we will not use solenoid valves that are opened and closed electronically. The misters are always "ON" and they will spray water for the duration that the pump is activated.

2.1.5 Usability Requirements

User interaction with the watering system is best kept to a minimum.
[R215-1] It must be possible and easy to add more water the basin
[R215-2] There must be a simple way to drain any water if the user so desires intuitively and requiring minimal physical strength
[R215-3] A user can access the watering system to repair it if anything becomes loose or stops working

2.2 Lower Enclosure

The purpose of the lower enclosure is to house the watering system and provide a base for the top chamber to be mounted on. The innermost layer of the lower enclosure is a sturdy plastic box that the watering system sits in (Figure 4a). A tight fitting lid goes on the box and this plastic box is placed inside a wooden case (Figure 4b).



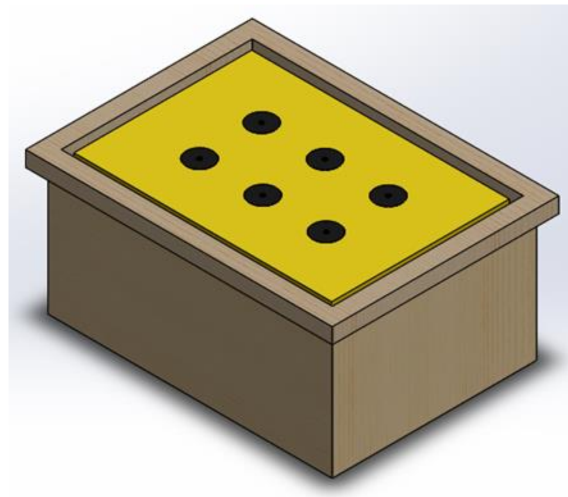


Figure 4:(a) The watering system in its basin (b) The basin with lid inside the lower enclosure

The black circular collars embedded in the yellow lid are for holding the plant right above the roots to keep them in place. We have already selected a strong sturdy box to use as the plastic basin so the enclosure dimensions have been chosen in the requirements to accommodate its size.

2.2.1 General Requirements

[R221-1-II] Plastic box is sturdy and waterproof when the lid is attached
[R221-2-II] Box fits inside the wooden case and can be removed easily
[R221-3-II] Lid can be removed from plastic box while it is still inside the case

2.2.2 Physical Requirements

[R222-1-II] The top enclosure can be mounted onto the thick rim of the lower enclosure's wooden case
[R222-2-I] Wooden case (length, width, height) inside dimensions must be greater than (28.5, 19.5, 15) inches to allow the plastic basin to fit in
[R222-3-II] It must be easy to lift the plastic box out of its case
[R222-4-II] Cords going to pump must enter the box through a waterproof hole in the yellow lid

2.3 Top Enclosure

2.3.1 General Requirements

The top chamber contains the bulk of the plants and provides temperature, humidity and sunlight control. The frame of the top enclosure fits onto the lower enclosure as shown in Figure 5. Important to note is that the base rim of the top enclosure fits around the rim of the lower enclosure like a lid so that it is held in place and can only be lifted off vertically.

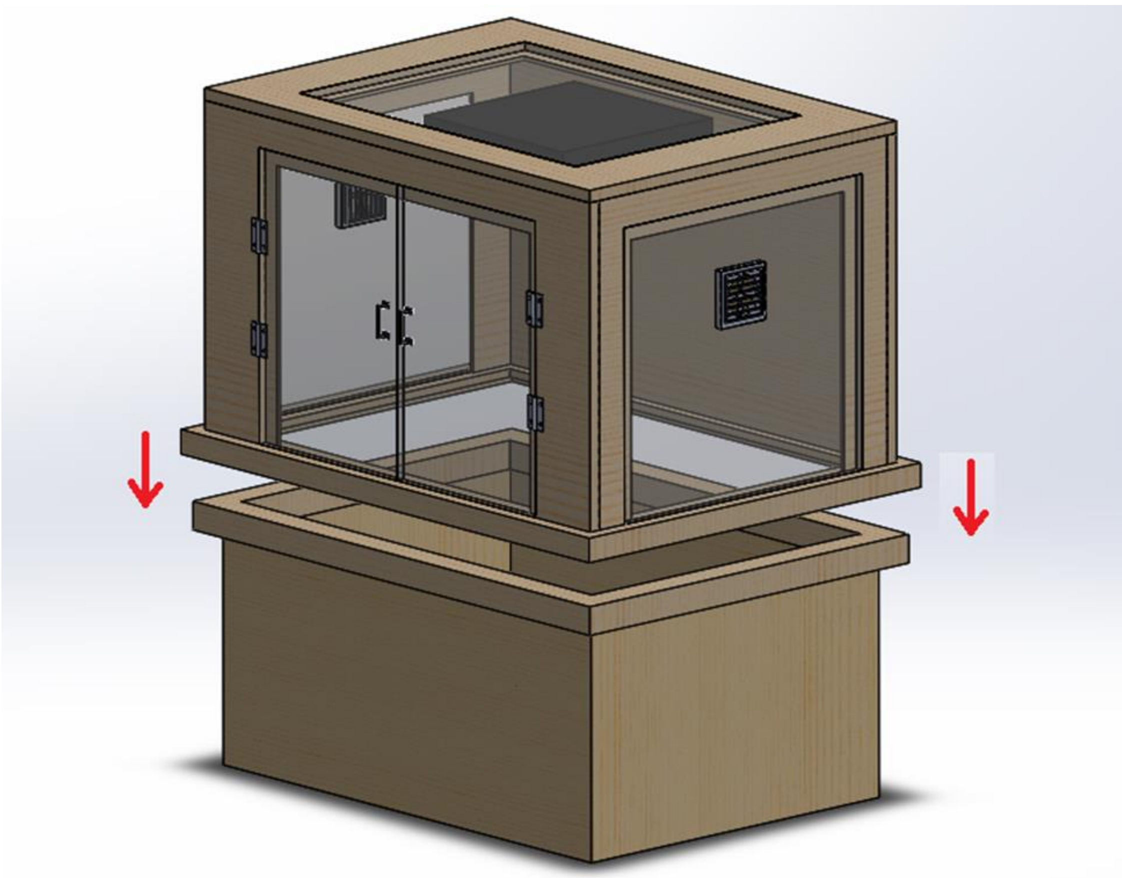


Figure 5: Top enclosure fits onto lower enclosure

2.3.2 Physical Requirements

The top enclosure must fulfill the following requirements:

[R232-1-II] The enclosure must open in order to allow easy access to the interior for the user and must open without very much physical strain by the user.

[R232-2-II] The enclosure must also include a vent for temperature control

[R232-3-II] It must afford the user some visual access to the interior environment while being sealed.

[R232-4-II] The top enclosure's exterior should be visually appealing on some level

[R232-5-II] The top must be stable even when jostled a significant amount; it must avoid falling off the bottom section as well as tipping the entire system.

[R232-6-II] Length and width dimensions must be kept to 28.5 and 19.5 inches to match lower enclosure

2.3.3 Reliability Requirements

[R233-1-II] The enclosure door must be able to withstand repeated opening and closing.

2.3.4 Safety Requirements and Standards

The enclosure lid must meet the following safety requirements and standards:
[R234-1-II] The lid assembly will have as few sharp edges as possible to reduce the risk of injury to the end user.
[R234-2-II] The lid assembly must sit as tightly as possible to the base to reduce the number of "pinch points"
[R235-3-II] Should have sturdy convenient handles to to allow the user to lift off upper enclosure

2.4 Environment Control Actuators

2.4.1 General Requirements

To maintain optimal growing conditions EcoGarden employs a system of sensors and actuators to regulate the environmental conditions in the top chamber. These sensors and actuators must fulfill the following general requirements:
[R241-1-II] The dual purpose humidity and temperature sensor must be able to acquire a reading every couple seconds
[R241-2-II] If the system requires increased humidity, the controller must be able to activate the misting valve to increase humidity
[R241-3-II] If the system requires decreased humidity, the controller must be able to activate two fans to circulate air flow
[R241-4-II] If the system requires increased temperature, a simple heating coil must be activated
[R241-5-II] excess heat can be vented through the roof of the enclosure
[R241-6-II] In order to simulate day/night, the system must be able to control LED growing lights using a timer

2.4.2 Physical Requirements

The environmental control actuators must comply with the following physical requirements:
[R242-1-II] The sensors and actuators must be protected from constant exposure to moisture
[R242-2-II] The sensors and actuators must be firmly mounted to the assembly but still able to be removed

2.4.3 Reliability Requirements

The system's actuators must fulfill the following requirements:

[R243-1-II] The sensors and actuators must be able to withstand ambient temperatures from 0C-50C

[R243-3-II] The sensors must provide a reading accurate to at most a 5% error

[R243-4-II] The sensors and actuators must be easy to access for repair and replacement services

[R243-5-I] The sensors and actuators must be able to be removed with minimal effort by either the user or a technician

[R243-6-II] The system will have minimal latency between the input commands and the actuator response

2.4.4 Safety Requirements and Standards

The system must conform to the following safety standards and requirements:

[R244-1-II] The mounted fans must conform to UL standard 507 (Standard for Electric Fans) [4]

[R244-2-II] Humidity misting valves must fulfill the standards outlined in CSA B356 (Water pressure reducing valves for domestic water supply systems) [3]

2.5 Control System

2.5.1 General Requirements

The EcoGarden utilises a Raspberry Pi and Arduino Uno in tandem to monitor and control the growth chamber environment.

The Arduino independently does all the work of handling the sensors and actuators needed to maintain environmental conditions in the ideal range. Its algorithm collects and stores temperature, humidity, and sunlight data. This data will be sent to the Raspberry Pi which hosts the graphical user interface (GUI). Additionally, the Arduino must also be able to change the ideal conditions variables to adjust to what crop is being grown. Users select pre-set crops on the Raspberry Pi's GUI. An abstraction of the overall control system is illustrated in Figure 6.

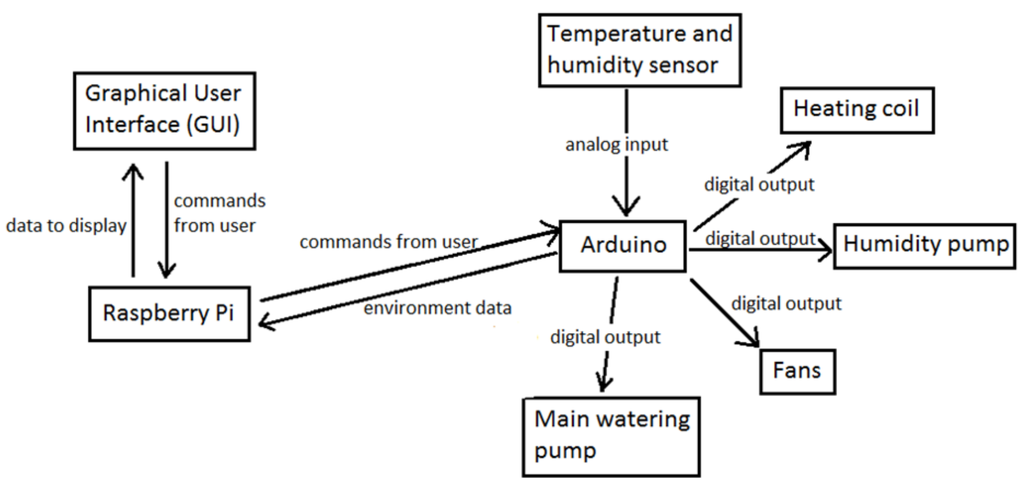


Figure 6: Control system diagram

[R251-1-II] Microcontroller must have digital and analog I/O pins that can tolerate 5V and up to 40mA current draw. This will be sufficient to operate the relays between the power supply and the actuator
[R251-2-II] Microcontroller must be able to run code that implements the algorithm flow chart and allow easy edits and updates
[R251-3-II] GUI host controller must be compatible with LCD display screen
[R251-4-II] GUI should allow user to select what crop is to be grown and reset grow cycle
[R251-5-II] Data history of temperature, humidity and sunlight hours will be displayed graphically on the screen
[R251-6-II] Connection between controllers must be able to send data and commands both ways

2.5.2 Physical Requirements

The environmental control system has the following physical requirements:
[R252-1-II] Be stored in an enclosure that can withstand conditions for both indoor and outdoor environments for temperature range of 0C-45C
[R252-2-II] Be positioned and sized such that the access panels are not obstructed, ideally 10-20 cm from the main hatch
[R252-3-II] Be securely mounted onto the front assembly to allow the user quick and easy access to the touch screen panel
[R252-4-II] Have an access hatch to allow users/technicians to service the controller. Must also have a locking mechanism to prevent unwanted persons from being able to access the controller.

2.5.3 Reliability Requirements

The control system and sensors must:
[R253-1-II] Must be able to be replaced or repaired in the event the system is damaged
[R253-2-II] Must be durable enough to withstand day to day usage
[R253-3-II] Normal and rough use must be considered in the design (i.e. children “playing” with the device)
[R253-4-II] Should be simple enough for end user to conduct simple device troubleshooting
[R253-5-II] Must be serviceable by trained technicians in a quick and timely manner

2.5.4 Safety Requirements and Standards

The control system must fulfill the following safety requirements:
[R254-1-II] The system will run at a safe operating temperature, compliant with UL 60335 (Household and similar electrical appliances) **[5]**
[R254-2-II] Device will conform to the standards outlined in CSA 60950 (Information Technology Equipment - Safety) **[6]**
[R254-3-II] Device will conform to standards outlined in CSA E60065 (Audio, Video and Similar Electronic Apparatus - Safety Requirements) **[7]**

2.5.5 Usability Requirements

The control panel has the following usability requirements corresponding to ease of use:

[R255-1-II] Provide the controls necessary for the user to change the required settings

[R255-2-II] Avoid most accidental setting changes from careless use

[R255-3-II] Allow the user to personalize and customize the display

[R255-4-II] Allow the user access control features from their mobile device

3. Software

3.1 Arduino microcontroller code

The microcontroller will need to run code that constantly takes sensor readings and sends signals to the environment control actuators.

3.1.1 General Requirements

[R311-1-II] Upon start-up the code will declare variables, assign I/O pins and establish connection to GUI host controller

[R311-2-II] At the beginning of the main loop check to see if commands have been sent form user interface and if so change the appropriate variables

[R311-3-II] Determine if the lights should be on by calling the hour of day function, send digital signal to lights through relay switch

[R311-4-II] Take humidity and temperature measurements, store the values in an array. Send the data to the GUI host controller

[R311-5-II] Compare temperature and humidity values to acceptable range and make required adjustments by sending digital signals to environmental control actuators described in Section 2.4

Shown in Figure 7 is the algorithm of the Arduino microcontroller.

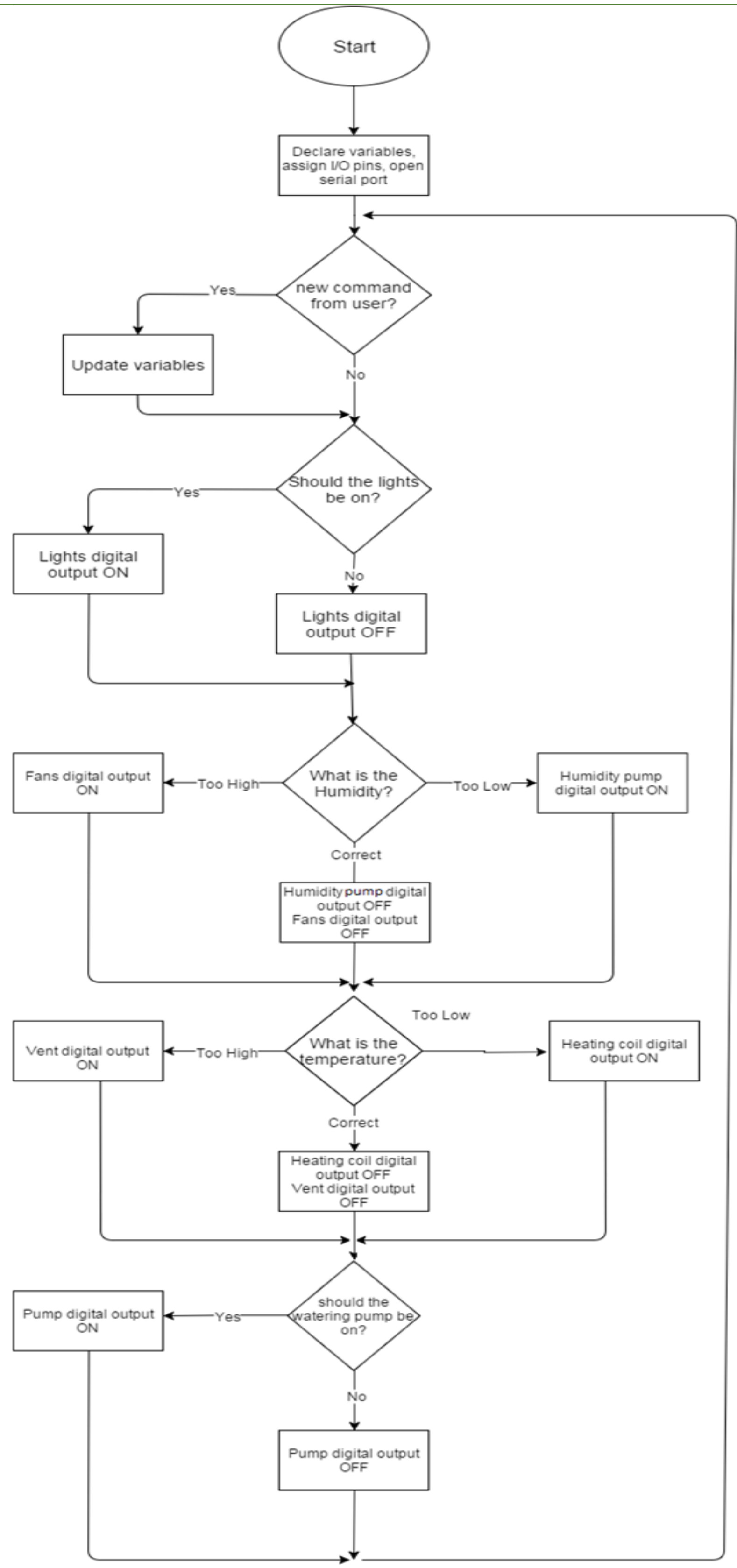


Figure 7: Algorithm of the microcontroller

3.1.2 Efficiency Requirements

[R312-1-II] Temperature and humidity data arrays will not exceed 50 values and will rewrite the oldest values when the limit is reached. This will prevent the microcontroller from running out of memory
[R312-2-II] Main loop will execute rapidly with minimal delay in each iteration. When temperature or humidity must be adjusted the loop will not stall waiting until the right value is reached, rather it will continue running until the sensor confirms that the ideal range is reached and then turn off the actuator
[R312-3-II] Temperature, humidity and sunlight hours data will not be stored in the array and sent to the GUI host controller every loop, rather only once every few minutes

3.2 Graphical user interface code

3.2.1 General Requirements

The controllers have a GUI which allows the end user to interface with the system's settings and receive feedback on its current state. A working model of what the interface will look like is shown in Figure 8.

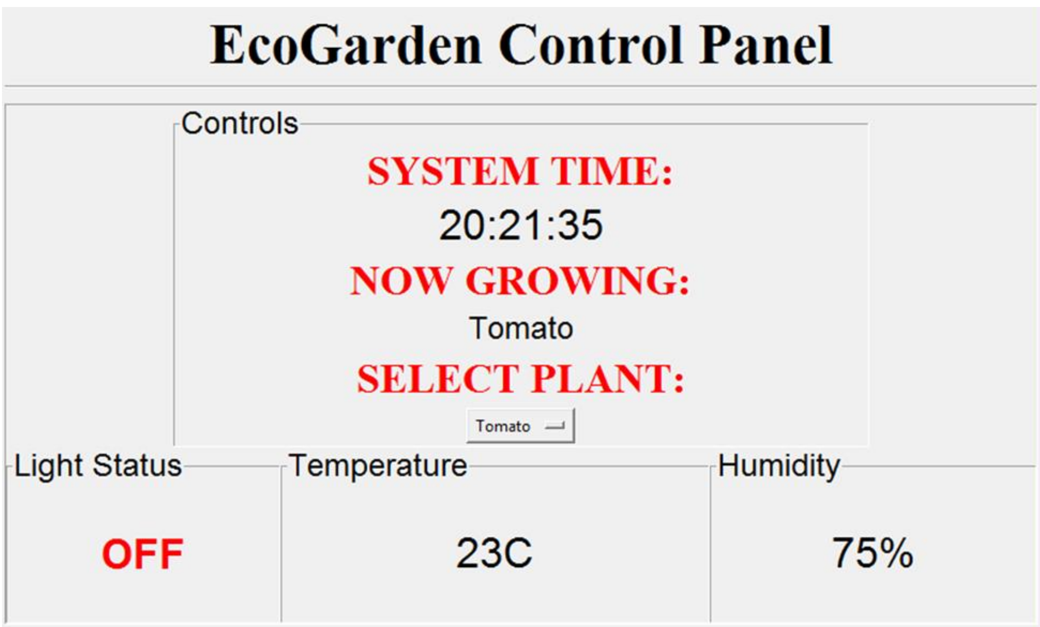


Figure 8: the GUI display screen

The control panel GUI must fulfill the following requirements:
[R321-1-II] The control panel will display the growing chamber's current time, humidity level and temperature
[R321-2-II] The control panel will also allow the user to select the plant setting which determines the necessary humidity and temperature levels
[R321-3-II] The control panel will have a simple layout with the minimum amount of controls for the user's ease of use
[R321-4-II] The control panel will send the command signals to the controller to control the actuators to adjust the humidity and temperature of the chamber (where necessary)

4. Sustainability

The EcoGarden must be designed in such a way so as to be as sustainable as possible. This means that it must reuse as much water and nutrients as possible within the confines of the system, to avoid wasting resources unduly. It also must be easily recyclable at the end of its life. So the outer enclosure as well as any interior structural elements should be constructed out of materials that are either not harmful to the environment, or easily broken down to be reused. This should also limit the use of any exterior or interior protective coatings to only those that have no known long term hazards. Any coatings should also not impede the recycling of the materials, so they should either not permanently alter the materials in any way that stops them from being reused.

An important part of the EcoGarden is the electronic controls and display. These raise more difficult sustainability problems since they are generally not easily broken down. The entire system is a combination of electronic and non-electronic materials that aren't necessarily recyclable in the same way. Products that are too complicated to recycle easily are often just thrown in a landfill and since the goal of cradle-to-cradle design is to avoid tossing products into landfills, one of the key functions of the EcoGarden must be that it can be easily deconstructed into recyclable subunits. This means that the electronic components must be removable in a way that does not cause excessive hardship to the user.

4.1 General Requirements

The EcoGarden must:
[R412-1-II] Collect and reuse >95% of water not absorbed by the plants
[R412-2-II] Be structurally made of recyclable materials
[R412-3-II] Not use any toxic or harmful chemicals as environmental protection
[R412-4-II] Be able to be disassembled into distinct recyclable parts

5. Cost Considerations

The prototype functionalities described above must be implemented with approximately $650. The required breakdown should be something similar to the following:

- $108 for watering system parts: pump, pipes, pipe fittings, mist valves (Jon's Plant Factory prices)
- $200 for structural materials to build the top and bottom enclosures with: plywood, clear plastic acrylic, plastic tub with lid, door handles, hinges (Home Depot prices)
- $75 for the Arduino microcontroller and Raspberry Pi computer
- $38 for sensors: temperature, humidity, soil moisture, photocell (RP electronics prices)
- $34 for an LCD display to run the user interface on
- $100 for a power supply
- $40 for the LED grow-light array
- $30 for electric heating coil
- $20 for electric relays to allow the microcontroller to turn on and off the devices

The fans have been acquired free of charge.

6. Conclusion

Overall the goal of the EcoGarden project is to provide a valuable product for those who cannot access fresh healthy produce at a reasonable price. This document lays out the requirements that each component of the system must have to make the system run correctly and efficiently as a whole.

The EcoGarden should be a self-contained system that controls its own temperature, humidity, sun cycle, and water cycle. It should be capable of being employed by a non-expert user on a reliable and user-friendly way.

We offer justifications to design choices for the hardware and software systems that run EcoGarden. Safety concerns are explained along the way and sustainability is addressed. Design constraints shaped the way we chose the requirements for each section. Engineering standards are observed and referenced along the way.

References

[1] "Yes, It’s Expensive to Eat in Nunavut: Food Price Survey." *NunatsiaqOnline 2013-08-22: NEWS.* Web. 14 Feb. 2016.

[2] "Sizing a Pump for Your Hydroponic Systems." *What Size Pump Do I Need for My Hydroponic System?* Web. 14 Feb. 2016.

[3] CSA Group. (2010). *CSA B356: Water pressure reducing valves for domestic water supply systems* (3rd ed.).

[4] Underwriters Laboratories (UL). (1999). *UL 507: Standard for Electric Fans* (9th ed.).

[5] Underwriters Laboratories (UL). (2011). *UL 60335: Safety of Household and Similar Appliances* (5th ed.).

[6] CSA Group. (2012). *CSA 60950: Information Technology Equipment - Safety* (2nd ed.).

[7] CSA Group. (2012). *CSA 60065: Audio, Video and Similar Electronic Apparatus - Safety Requirements* (3rd ed.).