Urban Green

April 15, 2016

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

Dear Dr. Rawicz,

Please find the post-mortem documentation for a 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 document outlines the details of the project in both technical and non-technical aspects such as rules of each team member, budget and funding sources, problems that encountered in each steps of prototyping, and finally each member comments on their personal learning out of this project.

Urban Green consists of five eager 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 for any questions or concerns by email to eganzert@sfu.ca; we would be happy to address your inquiry as soon as possible.

Sincerely,

Eric Ganzert
CEO
Urban Green

Enclosure: Post-Mortem for EcoGarden

Post-Mortem for EcoGarden

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Executive Summary

Many obstacles may arise preventing the general public from growing their own fresh fruits and vegetables; these barriers can be categorized in the two main groups of economic adversity and climate complications. Eating fresh vegetables and herbs is excessively expensive for those who live in high population density and remote areas due to the transportation requirements. However, beside its economical obstacle, many people with farming expertise are incapable of growing their desired specialty crops due to an unproductive climate.

The goal of Urban Green is to remove this problem by allowing people to grow plants indoors and in climates not conducive to farming on a scale that can feed a large family. EcoGarden features a self-contained environment with dynamic temperature, humidity, and sunlight control. In addition, it provides an aeroponic watering system that delivers nutrients directly to the roots of the plant without unnecessarily wasting water.

This document outlines the details of the project in depth. The final cost of the project, roles of team members, budget and funding sources, timelines, and the problems encountered over the four-month process are all discussed throughout the report. Finally, each member reflects on their experience on the project. Moreover, all of the meeting minutes that were recorded during the term are provided at the end of the report.

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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

Nowadays, the advantages of fresh food have become an incontrovertible fact to the general public. However, the cost of fresh food has put many limitations on a vast majority of people which has led to lack of access to this nutrition source to a wide range of people. As a result, many people have decided to grow their own fresh food in a garden or on a farm. However, this procedure has some obstacles including lack of access to a conducive farming climate, non fertile soil and many other attributes mandatory for growth of fresh green products.

Urban Green aims to solve this problem by allowing people to grow a variety of vegetables and herbs indoors and in climates not conducive to farming in general. The product called EcoGarden is a completely self-contained aeroponic growth system with dynamic temperature, humidity, and UV control. In addition, its aeroponic watering system delivers nutrients directly to the roots of the plants. EcoGarden also features temperature and humidity sensors to monitor each variable separately. The temperature and humidity sensors in conjunction with the Arduino's built in clock functions to control the timing of the lights and watering system. The system diagnostics are presented to the user via an LCD display connected to the Arduino. The EcoGarden features a control panel that will allow the end user to adjust the desired humidity, chamber temperature, and timed simulated sunlight.

2 - Technical & Business Case

2.1 High level system overview

Urban Green's EcoGarden is a self contained aeroponic system for growing produce. Aeroponics is the method of growing by suspending plants on a level and spraying a mist of water and nutrients onto the roots that hang down below into the watering chamber (Figure 1). The constructed realization can be seen in Figure 2.

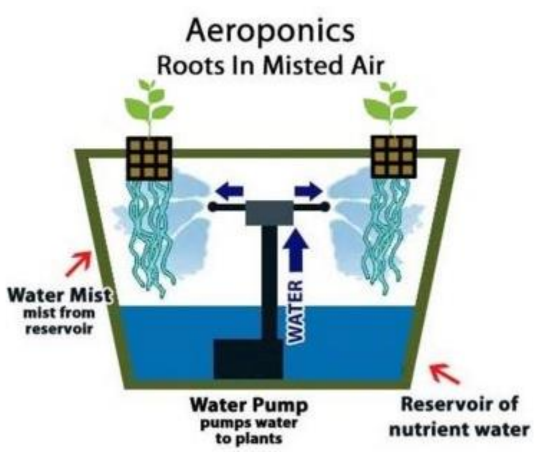

Figure 1: Aeroponics illustrated

Figure 2: EcoGarden

EcoGarden has the ability to control the environmental conditions in the upper growing chamber. A sensor reads the temperature and humidity and actuators work to change the conditions to meet the set point provided by the user. The three conditions that can be controlled are as follows.

1. **Sunlight hours:** An LED array of the ideal wavelengths for plant growth can be set to provide sunlight to the plants for 8-24 hours a day.
2. **Temperature:** Can be increased by an incandescent light bulb being activated, or decreased by activating fans that blow out excess heat. Can be set from a minimum of 15 degrees to a maximum of 30 Celsius.
3. **Humidity:** To increase humidity a pump provides intermittent bursts of mist into the top chamber. Can be reduced by activating fans to blow out humid air.

The sensors and actuators are controlled by a software algorithm on an Arduino microcontroller. The user interface is a control panel (Figure 3) with three potentiometer sliders, one for each environmental control input. There is also a display screen that reads out the sensor values and confirms the settings when you adjust the sliders. The control system can be visualized at a high level by Figure 4.

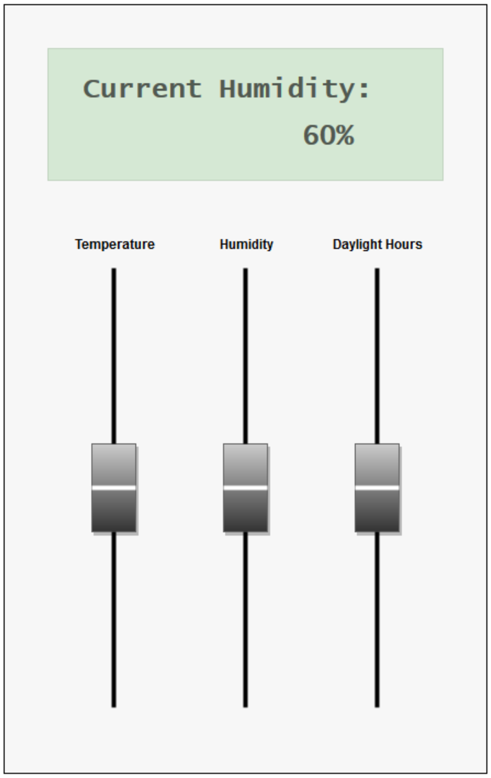

Figure 3: Control panel layout

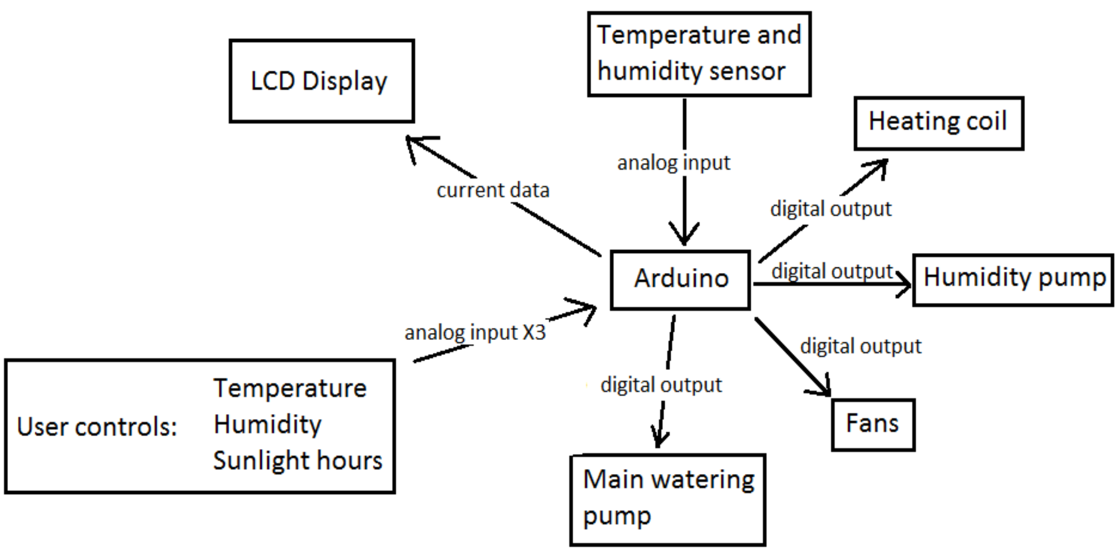

Figure 4: Control system diagram

2.2 Business case

There's a fairly substantial market for a product like the EcoGarden. First consider the primary intended market, urban populations. In just Canada and the US there's about 275 million people living as part of an officially urban demographic [1][2]. Clearly the current sized EcoGarden will not be financially viable for the majority of those people, and many won't be living alone; but if you consider only the top 10% of those 275 million you still get a potential consumer base of almost 30 million. The UN estimates that the global urban population is currently around 4 billion and will exceed 6 billion people by 2045 [3], and as those numbers increase and densities increase there will be an increased demand for fresh produce. That's a very large market to satiate with an incredible ability, and likelihood, for continued growth. That's all without getting into the projected secondary markets. One of the big potential markets is for those who live in extreme climates that make it difficult to grow anything of use. EcoGarden's climate and environment control system would make it ideal for growing plants out of their natural climate. Without going into great detail, the number of people living outside of conducive growing climates is also quite sizable and is thus a significant consumer base to infiltrate. Other potential market demographics could be suburban or rural people who aren't good at gardening and want an easy way to grow plants, or laboratory settings where they want very specific and controlled environments to grow.

There are some competitors for this product, though none of them match EcoGarden's unique blend of functionalities. Two big aeroponics distributors are aeroponics.com and AeroFarms. They both advertise quality aeroponic systems for quality growth. Both of them, though, focus mainly industrial sized equipment which means they're likely to compete directly within the residential markets. Also neither of them have products to control any of the environment, they're mostly just watering systems, some with LEDs. Another potential competitor is AeroGarden, which are smaller systems; the biggest is slightly smaller than the current EcoGarden prototype. This would be a more direct competitor due to its size, but yet again it doesn't have the same number of feature as EcoGarden. Despite its name AeroGarden is actually a hydroponic system, which is generally considered to be an inferior growing method, and it also contains only LEDs, so there is no climate control which makes it reliant on the owner's location. The final competitor is Supercloset, which is fairly similar to EcoGarden in that it's a line of box-type containers that regulate light for plants. Once again it's actually a hydroponic system and even though it's enclosed, all it does it light the plant and circulate air, so there's no climate control.

The cost to create the prototype EcoGarden was approximately $760, as detailed in Section 2.4. The belief within Urban Green is that that price could potentially be reduced below $600. Further, if manufactured in bulk, the price is believed to be able to go as low as $500 per unit. Similar products available now seem to go between $1800 and $2000. So if, to beat the competition, the price was set at the low end of the scale, $1800, Urban Green would still stand to profit $1300 per unit sold.

2.3 Timelines

At the start of the project, a timeline was created in order to establish firm deadlines for all major milestones in the development of the EcoGarden.
The original estimated production schedule is shown below, in Figure 5:

ACTIVITY	WEEK START	WEEK DURATION
Research	1	4
Design	2	5
Software Development	2	9
Hardware Assembly	5	4
Structural Assembly	6	4
Testing	3	10
Proposal	2	2
Functional Specifications	4	3
Design Specifications	7	4

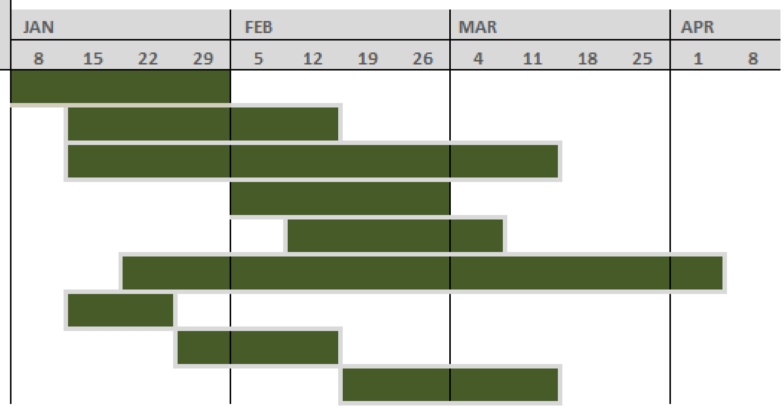

Figure 5: Original schedule

Based on this initial schedule, it was estimated that the bulk of the time would be devoted to testing the system.

Due to unforeseen problems, the actual production schedule deviated from the one initially laid out in the proposal stages of the project. This actual schedule can be seen in Figure 6 below.

ACTIVITY	WEEK START	WEEK DURATION
Research	1	4
Design	2	8
Software Development	2	7
Hardware Assembly	5	8
Structural Assembly	6	5
Testing	3	11
Proposal	3	1
Functional Specifications	6	1
Design Specifications	10	1

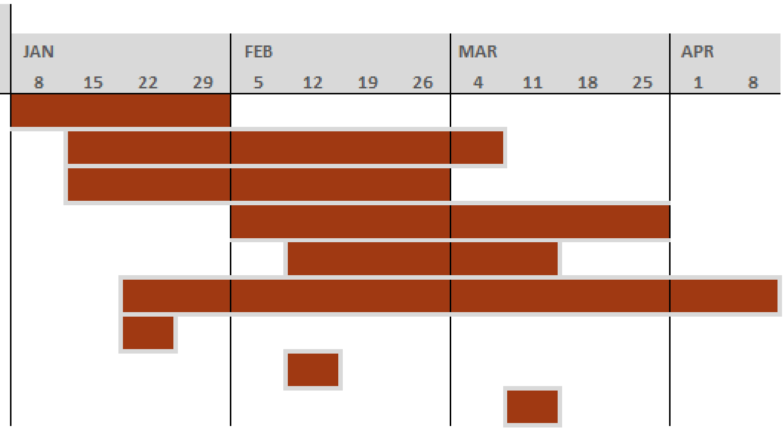

Figure 6: Actual schedule

As seen in Figure 6, the majority of the time was spent in the design and testing phases of the project. There was a one-week delay in the completion of the project that arose mainly due to the deadline being moved from an assumed deadline of April 1st to an actual deadline of April 15th, so the delay had no impact on the final result.

2.4 Budget and funding sources

In general, the project expenditures are divided into two parts: structural and electronics. The money that was spent in order to finish the prototype of the EcoGarden totalled around $760. Our company was granted $415 through the ESSF Endowment Fund, and the rest of expenses were divided equally amongst the partners. Tables 1 to 3 show the proposed and actual expenditures as well as the funding sources for the EcoGarden.

Material	**Estimated Cost**
Raspberry Pi Kit	$90
Raspberry Pi LCD Touchscreen	$107
Arduino Uno	$30
Sensors	$50
Pump	$100
Fans	$50
Lighting	$50
Router	$50
Structural Materials	$200
Plumbing	$120
Electrical Components	$50
Seeds	$10
Estimated Total Cost of Production	**$755**

Table 1: Initial Expenditure Breakdown

Item	Cost
Watering System	$108.51
Enclosure Materials	$302.09
Relays	$65.57
Plumbing	$82.93
Growing Light	$69.92
Electronics	$55.73
Control Panel Materials	$45.00
Plants	$29.89
Total Cost of Production	**$759.64**

Table 2: Actual Expenditure Breakdown

Source	Funds
ESFF Endowment Fund	$415
Group Contributions	$344.64
Total	**$759.64**

Table 3: Funding Sources for the EcoGarden

3 - Problems encountered

One early problem we encountered was how to construct a watering system powered by a pump that could provide mist for the roots at a reasonable price. It was easy enough to locate a pump powerful enough to do the job but we had a hard time figuring out how to install misting valves directly into the pipes. Our initial research found misting valves for $7 each at Home Depot, however we had no solution to incorporate them into the pipe structure. Our first design of the watering system is illustrated in Figure 7.

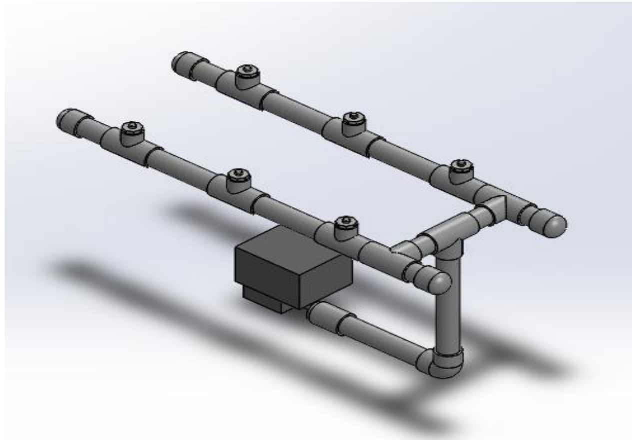

Figure 7: Original watering system design

This design involved a complicated method of installing mist valves into the tee connectors and placing them at various positions along the top pipes. This design was far too expensive costing hundreds of dollars and the coverage offered by six valves was not quite sufficient.

After some more research we decided that the best course of action was to visit an irrigation supply store or a hydroponics supply store. The first place we went to was Jon's Plant Factory which is a hydroponic supply store in Burnaby. Just by showing an employee a diagram of our system he knew exactly what to recommend for us. They had very cheap plastic pipes and pipe fittings. Also they had these simple and cheap misting valves that can be screwed directly into the pipes, eliminating the need for a lot of tee connectors. The finalized design is shown here in Figure 8.

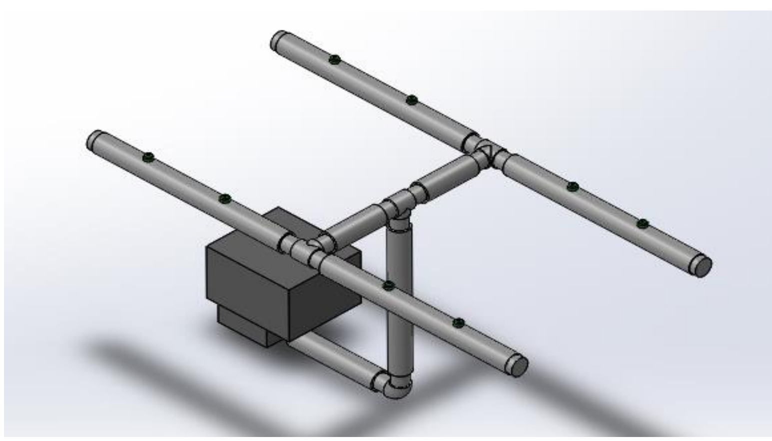

Figure 8: Final watering system design

As can be easily seen this design was much simpler and easier to construct. The green valves were approximately $1 each and the pipe fittings were about $1-$2 each. The pipe was sold by the foot and was very cheap as well. Basically the major problem was the complexity and expensiveness of the system and the solution was to visit a hydroponics store and get professional advice.

Another challenging issue was the problem of how to increase the humidity of the top growing chamber. Since we determined that we wanted the user to be able to control the humidity percentage we needed a way to both decrease and increase the humidity with actuators controlled by the Arduino. It was no problem to solve the problem of decreasing the humidity, we just used two fans installed on either end of the top chamber blowing the same direction to create a wind flow that would clear out humidity until the sensor confirms that it has gone low enough.

An early Idea was to open up a small hatch in the divider box lid that would let some mist rise up from the spraying of the roots below. There were several issues with this solution including the complexity of an actuated hatch. He had a rough sketch of an idea (Figure 9) but it required a DC motor with gears and a track to run on.

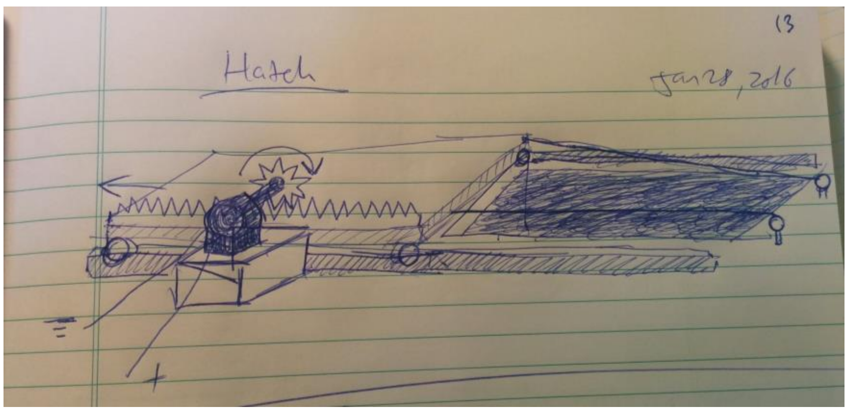

Figure 9: Initial idea for hatch

It wasn't long before most of us were unhappy with this design. Since the digital output of the Arduino is high or low, there is no easy way to have the motor spin forward to expose the hatch and backward and also be still. It is not easy to even find a cheap enough DC motor that can operate in both directions. Also we would have to precisely time the forward and backward operation to not run the lid of the hatch past its track. This does not fit in with the style of software that we want to have. We do not want the functions in the software hold the algorithm still for any significant delay so that all functions could be serviced frequently enough to make the system have a good response time to user input. Finally, the complexity of building a cover and a track for it to run on made it obvious that a different solution was needed.

After many weeks Tim had the idea to have a completely separate miniature pump that would pipe up water from the lower watering chamber up into the top chamber where it could directly spray mist into the growing chamber environment when more humidity is needed. We all loved the relative simplicity of this idea over the poor design idea of the actuated hatch. Another trip to the Hydroponics supply store found us all the parts needed for this solution. Overall the problem was solved by stepping back and looking at the challenge from a different perspective. This allowed us to see a much better solution to the issue.

Maybe the biggest challenge we faced in this project was how to implement the graphical user interface. Originally we planned to have a touch screen interface that would allow the user to have many controls available and lots of data displayed graphically. An early idea of what it would look like is shown in Figure 10.

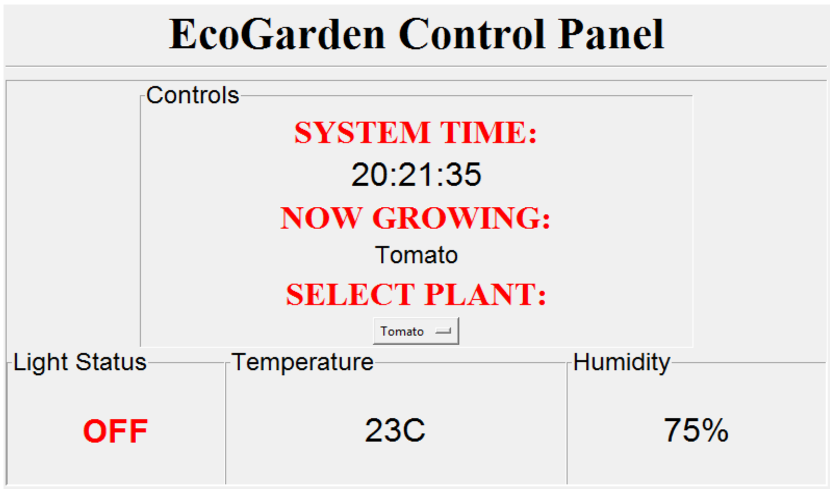

Figure 10: First design of user interface

This was an exciting idea but unfortunately there are several reasons why this implementation was unrealistic. This type of touch screen is too complex to be run from an Arduino microcontroller and we planned to use a Raspberry Pi computer to run it and then connect that Raspberry Pi to the Arduino through a serial connection USB. Information would have to be sent back and forth on this connection, for example instructions would be sent from the screen to the Raspberry Pi to the Arduino. Sensor Data would have to go on this path in the opposite direction. This concept is shown in Figure 11.

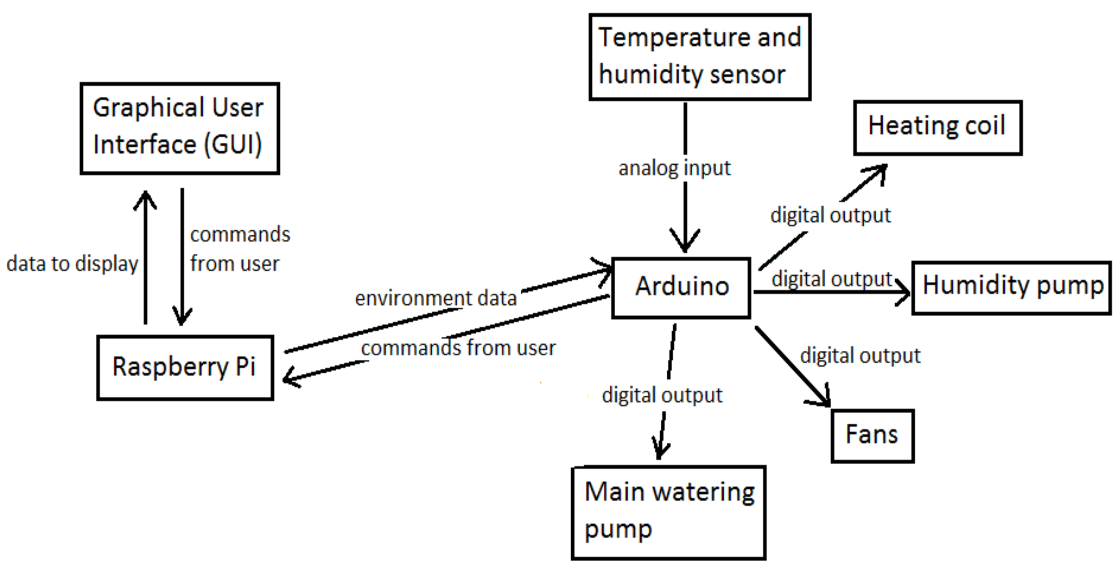

Figure 11: Problematic software system plan

Unfortunately, the farther we got with this touch screen concept to more problems arose. For one thing, the screen code would best be written in Python which does not match the C code running the Arduino. This is not impossible to reconcile but it introduces many challenges with sharing data and instructions. Another big issue was the high cost of the touch screen, about $80 included with the $50 cost of the Arduino and serial connection. Another reason we began to dislike this concept was that there are only a few simple commands the user needs to control.

- Temperature range
- Humidity Range
- Sunlight hours per day
-

We discovered that these could be much more simply implemented by buttons or other hardware controls like potentiometer sliders. These can be analog input to the Arduino like sensors which means that the user controls can be independent of the screen, and run on the main algorithm hosted by the Arduino. With this development we realized that now the screen only needs to:

- Show current conditions from sensor readings
- Provide feedback to the user confirming where they have set conditions

When we started looking for simpler screens without touch functionality we realized that a very basic screen is all we need and that it can run on the Arduino. So we were happy to remove the complicated and expensive Raspberry Pi touch-screen combination from our software system and we now had a much simpler and elegant solution (Figure 4).

This problem is an example of our initial enthusiasm resulting in us biting off more than we could chew with the graphical user interface. Because of the price the time constraints of the semester balancing our time between the many systems of this project we eventually saw the need to reduce the complexity of the user interface substantially.

There were some other features that we initially wanted to accomplish but in time realized were unrealistic due to cost and time constraints. These ideas were considered non-essential to the core value of the project and abandoned at various times throughout the semester:

- Running a local web-server to log in with a smartphone and get control things using a smartphone as well as get updates
- Webcam accessible by smartphone
- Storing a long history of data from the sensor and displaying it on a graph

4 - Group dynamics, work breakdown chart

4.1 Team Organization

To improve productivity, the team was structured into four major roles.

1) Research and development (R&D)
2) Fabrication
3) Software development
4) Support

Each of these roles encompassed each of the high level tasks outlined in the workload distribution chart later in this section, with each group member filling at least one of these roles. These roles had the following duties:

Research and development (R&D)

The R&D division of Urban Green had the following responsibilities:

- Research all necessary information for the completion of the project
- Design the systems to fill all functional and design specifications
- Document the research and design process

All five members of Urban Green were part of R&D.

Fabrication

The fabrication role had the following responsibilities:

- Manufacture all mechanical and electrical components of the main enclosure
- Manufacture the control panel
- Test system for any mechanical or electrical design failures

Eric Ganzert, Michael Foo and Tim Horita were part of the fabrication team.

Software development

The software development role had the following responsibilities:

- Design and develop software
- Debug and troubleshoot any issues in the code
- Write all necessary documentation

Michael Foo and Eric Ganzert were part of the software development team.

Support

The support role had the following responsibilities:

- Source and purchase all necessary components
- Assist in administrative tasks
- Aid in documentation

Each of the five members held a support role in the company.

4.2 Workflow Distribution

The workload distribution chart for the company is shown in Table 4:

High Level Task	Eric Ganzert	Michael Foo	Tim Horita	Mahbod Tatari	Anita Khoshnavaz
Research	X	X	X	XX	XX
Systems Design	X	X	X	X	X
Documentation	X	XX	XX	XX	XX
Administrative	X	X	X	X	X
Part Purchasing	XX	XX	X	XX	X
Enclosure/Watering System Construction	XX				
Control Panel Construction		XX	XX		X
Programming	XX	XX			
Electrical Work	X	X	X		

Table 4: Workflow distribution

5 - Conclusion

During the Spring 2016 semester, Urban Green was able to produce a working prototype of EcoGarden which met almost all of the functional requirements specified in the functional specification document. The main goal was to build the self-contained aeroponic growth system with adjustable temperature, humidity and sunlight control for people who live in high population density areas and remote areas not conducive to farming. In the future, Urban Green team could potentially to scale the EcoGarden up for large farms.

Given more time and money some of the initial plans we had for EcoGarden could be implemented. These ideas include smartphone connectivity; where updates can be sent to your phone and the plants can be viewed through a webcam. With this functionality a user could check up on the status of the plants when away from home.

We do not plan to take this product further into the market as a legitimate business because none of the group members wants to pursue it at this point in time.

References

[1] Statistics Canada. (2011, February 4). *Population, urban and rural, by province and territory* [Online]. Available: http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/demo62a-eng.htm

[2] United States Census Bureau. (2010). *FAQ* [Online]. Available: https://ask.census.gov/faq.php?id=5000&faqId=5971

[3] United Nations. (2014, July 10). *World's population increasingly urban with more than half living in urban areas* [Online]. Available: http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html

Appendix A: Reflections on Learning/Personal Growth

Eric Ganzert

For me the learning and growth began well before the semester started as I had to find a group that liked the idea of an aeroponic system. I decided that it would be better to come forward with an idea and try to interest other students rather than ask around hoping to join somebody else's idea and group. I learned some interesting things in the last month of the Fall 2015 semester about group dynamics and the psychology of people who are indecisive about undertaking a large task like this class.

To be clear I don't mean that the current members of this group were indecisive, all of our team have been consistent in their support. I mean the several other people that initially seemed excited about my idea but then mysteriously dropped out forcing me to find replacements. A few people responded to my mail list messages seeming enthusiastic at first but then losing interest and not bothering to notify me promptly that they had found a different group.

Another Skill that I began to develop prior to the semester beginning was familiarizing myself with writing code for Arduino and Raspberry Pi. I purchased both a Raspberry Pi and an Arduino and did many experiments with them using several books that are written for getting started with these computers. Once I was comfortable writing this style of code (Python and C) I wrote a rough draft of the code for this project at Christmas time. Much of the same structure of that code made it to the final program.

A major skill that I will surely use again is how to do proper AC wiring with appliances that plug into wall outlets. At first I installed the relays into the cords of the actuators using a butt splice and crimping method that I had learned in a co-op job for DC circuits. When I learned that this is not allowed for AC wiring I had to look it up and I learned that you have to house all wire splicing inside a metal box with all wires going in and out fixed in place. The connections cannot use butt splices but it has to be those cone shaped caps that you twist onto the two exposed wire ends to connect them together.

Overall looking back on this semester I think that I should have encouraged distinct roles for each group member so that individuals could have gone in depth and became an expert in a specific part of the project earlier. This actually did happen after some time but many of the first stages were shared equally among the whole group requiring us each to be up on all the research being done for every system. The specialization strategy that we eventually employed significantly increased our efficiency.

Mahbod Tork-Tatari

From the beginning of my academic career, my attempt was to improve, not only my technical knowledge but to enhance my personal growth as well. This goal made me more eager to improve many of my personal weaknesses throughout all of my courses and teamwork. Before the start of this semester, I considered this course an opportunity to learn new things. Before joining this group, I was eager to know about other group's ideas until when Eric informed me about his own unique idea, "Modified Aeroponic system". After arranging a meeting to discuss about the details of project, I decided to join the group. The initial intention of the project was appealing to me as it emphasizes on many aspects including health and social development.

At the beginning of the semester, I continued my technical research and various possible ways that could result in an decrease in cost while keeping the performance the same. As I was seeking for an specific component such as pump and LED lights, I developed a lot of valuable technical knowledge. Among these technical accomplishments were the knowledge of examining many possible solutions; evaluating them all, both in long and short run, and comparing their advantages and disadvantages. Another major technical achievement I gained from this project, was learning the suitable approach to market a specific product, by technical documentations including proposals, functional and design specification reports.

On the other hand, through this project, I was able to improve many beneficial skills such as teamwork, time management and problem solving; and learned how all of this factors must be handled simultaneously. Similarly, I learned how competence could come side by side with communication and commitment.

Anita Khoshnavaz

Over these past few months, our team has put a great effort working on self-contained aeroponic growth system. The main focus was to design, implement and build a prototype that actually works and meet all the features that we specified in our design and functional specifications. There were numerous challenges in the process of designing a product from the ground-up.

One of the most challenging parts of this project was to design the proper watering system that is needed to spray a fine mist onto the roots. It was necessary to choose the right pump that can pump the water into the vertical distance that the water must be pushed up in the pipe structure. Therefore, I have done so many researches in the first two months in order to choose the proper pump and other products in our watering system. Soldering the components properly with the right amount of cable was another important factor to properly place the components in the housing.

Time and budget estimation is essential in order to have a well-organized product design and prototype manufacturing. One of the main challenges was to keep an eye on our budget and thus avoid unnecessary delays in our project due to lack of funds.

During the completion of the project, I have learned how to work in a group, where every person has experience and knowledge in a specific subject. We all used our experiences and knowledge we gained during our undergraduate studies to design and build a project for people who don't have engineering skills. I have also learned that the most important factor in working with a team is to be able to communicate with each other and do not make any decisions based on false assumptions that just comes into my mind. In addition, I have learned how to manage my time in order to finish all the written documents before the due dates.

Michael Foo

Working on the EcoGarden for the last four months has been a unique experience. This felt like working on my ENSC 100 project all those years ago but with a greater emphasis on technical skills and documentation. Also, having to take on so many different roles ranging from engineer to accountant was a great learning experience which helped improve my technical skills, other soft skills and working in a team. I also got to learn about the field of aeroponics which might be applicable for space colonization.

Working on this project helped develop my technical skills by exposing me to different technologies. I got the opportunity to work extensively with a variety of sensors and other modules for the Arduino. This was a great chance to further develop my programming skills with the Arduino as well as learning how to implement the wide range of sensors and actuators. This project gave me the opportunity to improve my soldering skills by learning how to use solderable breadboards to manufacture our prototype. I also had the chance to refine my troubleshooting and testing skills as well, which I feel should be useful in the future.

This whole experience provided a lot of opportunities to develop and refine my soft skills. Working with new people was a good way to improve communication skills, which will always be useful as well as developing good interpersonal skills as well. Before undertaking this project, I never fully understood the importance of good communication as well as group dynamics to the success of a project. If group members are not in the same page, progress might be stalled and the project might have to start again at square one.

While this was a great learning experience, it also came with its share of challenges. Having to juggle a full course load while working on the project while writing all the documentation led to some sleepless nights, which was a good way to learn time management on the fly. All in all, I'd say that this whole experience was a good crash course on skills that would help in my future career.

Timothy Horita

This was the longest I've spent working on a single project since I began my university career, perhaps unsurprisingly since very few classes have you begin planning the semester before starting. I remember thinking that meeting up with the majority of the group in December with a plan gave us a real head start on other teams, but looking back now I would say that we didn't really get a head start so much as teams that met later were unnecessarily handicapped. The unfortunate part about beginning early is that it likely added to a slight false sense of security in the new year. We had plans and had made real design progress while other groups were still in their infancy which gave us a temporal confidence that may have overstayed it's welcome slightly. Luckily for us Eric never succumbed to the schedule swagger and ensured that we never swayed too far from our goal.

One of the major lessons of the semester for me is that it's much better to hurry early than to hurry late. As I said, there was a confidence early that we had plenty of time, which was true if you thought that this project was all that was going on. One of the issues was that most classes start slow then pick up in time and effort required as they go on, so those carefree January days weren't a good indication of our workload in March as deadlines closed in. So learning to properly budget my time, even when it seems I have it in spades, was a big lesson.

The other main team-based lesson for me was that in long-term group work you really need to know your team. Very few of us had met, let alone worked together, prior to the advent of this project, so there was a definite feeling out period that occurred. Early on it seemed like productivity was slowed slightly by people being unsure of how they fit within the group. I believe that we successfully worked through that stage and managed to get to place where we could maximize our efficiency and the quality of our work by knowing exactly what to expect from the other members. Using the power of hindsight, we probably should have done some quick team bonding just to get a sense of the people we didn't know very well.

The technical side of things is less exciting to debrief but no less important in the grand scheme. I improved my soldering skills immensely for this project by making the transition from the SFU standard practice of breadboarding everything to soldered breadboards. If you're looking for a nice tip: don't solder pin headers from the outside in because it becomes fairly tricky to not mess up the adjacent pins that are already finished. I also got the chance to use a laser cutter from the design process up to the actual cutting, which I had never done before and enjoyed immensely.

Appendix B: Meeting Agendas & Minutes

Listed here are the meeting agendas and the notes taken during our meeting throughout the semester. Meetings generally lasted about an hour, with everyone bringing topics needing to be discussed. Exact minutes spent on each subject weren't recorded, but they are in chronological order. Apart from weekly meetings there was near constant communication in a group Facebook chat that proved to be very helpful in asking each other questions and clarifying tasks. If necessary, that chat log may be submitted upon request.

January 8th Agenda

- Meet
- Discuss Research required for hardware and software
- Discuss potential design choices

January 8th 2016 Meeting Notes

1) **Hardware Research**

- Find a water pump
    - what pressure range is appropriate
    - flow capability Liters/minute
    - needs to connect to a pipe fitting
    - can be electrically controlled with a relay
- Size of pipe required
    - maybe ½" or whatever the pump is fitted for
- Manifold
    - must have ports for the solenoid valves
- Misting valves
    - solenoid valves
    - waterproof
    - intended for garden misting
- Fans
    - low power bathroom fans
    - RP electronics has these
- Structure
    - overall dimensions about 4' x 2'?
    - maybe find a plastic aquarium to use as the lower part
    - what will the middle tray that the plants grow on be made of?
    - should the top level be made of plexiglass or plastic?
- Lights
- 1 way valves for water flow pipes

2) **Watering System Design**

- Determine the structure
  - pump sends water into a chamber monitored by pressure sensor
  - from chamber through a pipe to the manifold that the valves are installed on
  - when a valve is opened water is drawn from the chamber and is misted out
  - additional mist valve above plants for humidity control
  - when the pressure in the chamber is reduced a certain amount the pump kicks in to restore the pressure
- Make an early model
  - think about where 1 way valves need to be used
  - how to arrange misting valves to get best coverage to the plants above

3) Plant type

- What types of herbs and what value do they have?
  - find a few options
- How many can we fit in a given area like 4' x 2'
- What temperature range and humidity range do they grow best in?
- can they be grown in sand or gravel?

4) Software

- Phone internet interface
  - run Raspberry pi as a web server (Flask web framework)
  - what kind of router will we need?
  - python script runs when someone accesses the root URL of the server
  - put ip address in web browser of phone
  - HTML web page is sent to the phone from a template saved on the Rpi
  - when a user changes a setting from the phone the python script will activate I/O pins to do the function requested
- Main Arduino code runs routine functions of the system
  - connected to Rpi in serial connection
  - keep updating flowchart
  - stores data from the past in an array to be graphed
  - graph can be viewed on mobile phone?

5) Temperature control

- Find a method of controlling the temperature
  - fans could be used to cool the temp but they are needed for controlling the humidity
  - should be able to vary temp without affecting humidity

January 15th Agenda

- Compare watering system designs
- Discuss research conducted
- Discuss design decisions
- Assign tasks for the week

January 15th 2016 Meeting Notes

- Compared designs for the watering system and refined it into a working model
- Discussed pump requirements
- Pipe material, we decided on ¾" PVC
- Mist valves, what GPH will they pass through
- Top chamber design
  - heat vent
  - fan covers
  - hinged door
- What plant to grow
  - bell peppers
  - basil

What to work on

Do as much as you can for tuesday, we won't be able to complete all of this stuff most likely. We should have answers for all of this stuff for the proposal.

Eric:

- look for PVC pipe, pipe fittings, mist valves at home depot
- share Arduino code with Mike
- SolidWorks model of water system, top chamber
- BOM
- Fans covers to prevent humidity leak
- humidity control for top chamber

Anita:

- Find pump options
  - GPH/PSI
  - power consumption
  - price
  - max head height
- Research crops
  - Basil, Bell Peppers

        - how much space required
        - how tall does it grow
        - how much space do the roots take up
        - temperature range, humidity range, sunlight hours

Tim:

- Growing sites
    - neoprene collar
    - how to plant sprouts
- Water nutrients
- Top chamber humidity problem
    - how to open, close the one top misting valve or
    - hatch opens to let some mist come up from below

Mahbod:

- Find LED growing lights
    - price
    - heat
    - power consumption
- Top chamber walls material (clear)
    - premade plastic box or
    - make out of separate pieces
    - hinged front door
- Chamber should allow for plant height

Mike:

- Github, become familiar with current Arduino code and Python Raspberry Pi code
- Top vent to release heat
- Power source
- BOM
- Research crop details
    - top space
    - height
    - root space
    - temp/humidity range, sunlight hours
- User interface screen

January 22 Agenda

- Discuss Proposal
- Discuss potential logo designs
- Discuss research conducted

January 22 2016 Meeting Notes

Everybody except Eric was present. Eric was electronically present.

11:45 Begin

Discussed proposal. Really good talk.

Discussed previous meeting topics.

Discussed logo.

Congratulations were given on a good presentation.

Used positive self-talk to improve morale.

Tearful goodbyes.

12:00 Adjourned

February 1st Agenda

- Discuss Functional Specification
- Discuss case design
- Discuss watering system
- Status update
- Assign Tasks

February 1st 2016 Meeting Notes

Item 1: Functional Specification Document (**IMPORTANT!!!**)

- Need to start the report this week, due Monday <u>after</u> reading week
- Need to research various specifications relating to the project (Mike)

Item 2: Discussed Case Design

- Eric and Tim are working on this
- We are using wood for the lid (or another cheap material)
- Changed to double door design for the lid
- Discussed accessibility of the watering system
- Maybe add a drain system for the water tank

Item 3: Watering System

- Eric is looking into opinions on design

Item 4: Task Updates

Item 5: Need to Clean Drive Folder!!

Item 6: Electric Ventilation System (Mahbod)

Need to design or find one on the market(Anita)

Item 7: Humidity System (Tim is doing this)

February 14th Agenda

- Status update
- Discuss material acquisition
- Discuss control system

February 14th 2016 Meeting Notes

- Collect materials for building enclosure
  - Hinges
  - Hose clamps
  - Acryllic
  - Plywood
  - Door handles
- Visit irrigation supply store to look for pipes and misters
  - Jon's plant factory
  - PNW supply
- Design of control Panel

February 23rd Agenda

- Discuss Design Review
- Discuss water nutrients
- Discuss water replacement strategy
- Discuss Power system

February 23 2016 Meeting Notes

- Design Review
- Get plants start growing(anita)
  - Root cups
- Nutrient in water
- Plan to replace water
  - Notification?
- Power supply
  - Relays

March 1st Agenda

- Discuss heating elements
- Discuss display screen
- Discuss water system
- Discuss enclosure
- Discuss control panel
- Discuss Design Specifications

March 1st 2016 Meeting Notes

- Heating element
  - Tim, Anita, Mahbod
  - 110 AV plug
  - Get next week
- Display screen
  - Use with sensor
  - Solder get fred to help
  - Use the code from the book
- Water system (Eric)
  - Construct watering system pipes
  - Build humidity pump system
  - Buy pipe fittings
- Finish construction of enclosure
  - Get more acryllic
  - Install lights
  - Install fans
  - Install handles
- Work out potentiometers for control panel
  - Get involved with the code
  - Design control panel layout
- Work on Design specs

March 8th Agenda

- Discuss Design Specification, make sure it gets finished

March 8th 2016 Meeting Notes

- Design specs
  - List of figures
  - Table of contents
  - Wiring and hardware installation
  - Size 11 text
  - Sustainability and life cycle
  - Test plan

March 21st Agenda

- Discuss control panel completion
- Discuss display screen
- Make sure it will be finished

March 21st 2016 Meeting Notes

- Control Panel
  - Finished in 1 week
  - Laser cut
  - Other options
- Display Screen
  - Code
    - Minimal delay
    - 5 second update when slider is adjusted
    - No waiting
  - What pins are we using for it?

April 14th Agenda

- Discuss Demo attire
- Discuss presentation logistics and content
- Practice presentation
- Discuss Post-Mortem

April 14th 2016 Meeting Notes

- Semi-formal wear
- Anita's bringing fruit
- Eric will bring nutrient container/back-up laptop
- Tim will bring computer/adapter
- Meet 10:00
- Discussed order of operations
- Practiced presentation
- Editted presentation
- Practiced again
- Discussed Post-Mortem