Mid-Term Report for the Development of a Physical Computing-based Solution for Greenhouse Automation

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# Aims and Objectives

A backyard greenhouse can provide a stable, warm environment where plants can be grown all year. They can also be used to get a jump start on the growing season by planting early and later moving the plants out to the garden.

However, the environmental control needed in a greenhouse can be very complicated to achieve; shading, ventilation, heating, and soil moisture are only a few of the many dependant variables which have to be supervised. The large number of factors in play make a greenhouse not only very prone to human error but also a monotonous daily chore to stay on top of. A solution to this problem is incredibly relevant to newly started backyard horticulturist that will not only struggle with balancing a full-time day job and their gardening hobby adequately, but also with yielding as many crops as their plants have the potential to.

My aim is to provide a cost-effective automated greenhouse which can tackle and take care of all the environmental variables in play, allowing the user to reap the benefits of self-cultivated non-GMO crops without requiring exhaustive attention or resorting to a fully equipped industrial scale greenhouse.

# Background Context and Market

There is no comparable product in the relevant market available for direct purchase. Industrial scale greenhouses exist with regulating mechanisms for the variables I have mentioned above and more, but that is not my target audience, or my target estimated retail price. On the other hand, there are various DIY prototypes published online, one of the most notable ones being Thangavel Bhuvaneswari and Joshua Tan Hong Yao’s automated greenhouse published on [IEEE.org](https://ieeexplore.ieee.org/document/7295887). Although they didn’t make a commercial product, their research outcomes have been useful when deciding the arrangement of the sensors I will use and how I will carry out my testing based on their published results. However, the facets of plant growth it aims to harness fall short of the ones I believe are necessary for optimal crop yield, so in a sense my product can be seen as an improved iteration of their groundwork, as I will improve on their mechanisms and controlled variables to provide a more user friendly and durable alternative. Their research outcomes will be very valuable, although I fear they may differ largely from the data I will collect while testing as it is to be expected that my meteorological conditions will not be identical to those reflected in their testing data. As my greenhouse structure is fairly different to the one in their modelling, I won’t be able to take away many prototyping methods, but they will still serve as a means of avoiding trial and error modelling.

# Product Features

The automated greenhouse will feature a Raspberry Pi 4 as the “brain” of the prototype. HC-SR04 Ultrasonic depth sensors will be used for measuring the water and fertilizer levels in the drums. A 0.91” OLED module will be used to display notifications and current diagnostic statistics, such as temperature, soil moisture and light intensity to name a few. An RPi Relay board will sit on top of the Raspberry Pi to allow for adequate mains electricity use so that a 220V submersible water pump can irrigate all plant pots at a constant rate with no fluctuations in the stream. A variety of basic electrical components such as appropriate resistors, LEDs, buttons, potentiometers, and servo motors will also be used, though I cannot say their final arrangement just yet. If the servo motor does not suffice for the opening and closing mechanism of the window used to ventilate the greenhouse (which I am certain it won’t), a 3V DC motor will be used and controlled by a L298N driver. Waterproof digital temperature sensors will be placed both outside and inside the greenhouse. A 12V DC solenoid valve will regulate the flow of water to the drum when it needs filling; this too will be connected to the relay HAT. Soil hygrometers will be used in the plant pots to read the moisture levels. Finally, a wide range of water irrigation components will be used, though I have not yet decided the optimal tube diameter or the arrangement of such system.

# Progress To Date

So far, I have managed to standalone test all the electrical components which I will include in the automated greenhouse, and I am in the process of merging their functionality so that they work in unison. I have completely assembled the greenhouse and I am now left with finalising the design for the irrigation system. I have researched the possibilities of adding to the prototype a user messaging system via SMS and a wind detection mechanism so that the ventilation can be more efficient when the window is opened, and I plan to include one, if not both, of these design options. As far as user testing goes, I have not reached that stage yet as I still have a largely incomplete final product so there is no sense in undergoing that process right now, as the feedback would not be very useful or representative of the real problems it may have when it is finished. The major stumbling blocks were the sourcing of components as I had to initially plan the whole project out before I could start purchasing parts for it, so I had a slightly delayed start, but I feel it will pay off because I have had weeks to refine the project plan and perfect it. Secondly the actual building of the greenhouse was somewhat complicated as it was a two-man job which I had to pull of by myself, but I am more than happy with the product thus far.

A picture containing grass, outdoor, tree, field

Description automatically generated

I have also designed the set-up for the water drums, which also encompasses the placement of the solenoid valve (labelled WATER IN) and the water pump (labelled WATER OUT)

Diagram

Description automatically generated

The actual rate at which I will mix the fertilizer and the water is to be determined once I test different tube diameters and running voltages for the water pump further on down the line.

I am currently working on designing the electrical schemas for the hardware components so that I can keep track of the different iterations the prototype will go through and keep a backlog with any important design decisions and weekly progress.

# Personal reflection

I feel like the project is going fairly smoothly and it is sufficiently challenging so that I am engaged and motivated throughout the remaining of the semester. Although I haven’t made as much demonstrable progress as I would have liked to, many hardware components took longer to ship to my country than expected and I had no control over the logistics of the hardware sourcing, but I do however feel very comfortable with the field of work as all the research I have done up to now to make up for the waiting time has been incredibly interesting and rewarding. I do feel like I am on track to deliver the finalised prototype I wanted to make, and I am most excited for the assembling stage which I will be starting on this coming week. So far, I haven’t had any real challenges or learning curves as I haven’t started on the real bulk of this prototype yet and the fact that all the hardware has worked when tested individually doesn’t mean it’ll be a smooth transition onto the greenhouse… So, I am expecting *that* to be the main challenge ahead. I am most happy with the fact all of the hardware has been fairly easy to get up and running and that the building of the greenhouse is finally done and out the way.

# Plans for remainder of project

Diagram

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The main technical milestone left is the assembling and wiring of the hardware onto the greenhouse, together with materialising the irrigation design and water/fertilizer storage system. The way in which I plan on tackling these milestones is by first assembling a disconnected irrigation system, as I know that the position of the plants will be fixed, and the layout isn’t dependant on the hardware to a certain extent. Once the tubing is laid down and positioned, I will begin by connecting the sensors and other hardware one by one, most likely starting with the solenoid water valve and the water pump which will leave the mains electricity aspect of the prototype covered. Only then will I progress onto the remaining sensors and hardware, and finally proceed with the software side of the automation which I plan to code in Python.

The evaluation milestones ahead will be dependent on how the testing goes. I plan to keep a backlog of all progress made in a weekly manner and compile all user testing results together so I can merge them into a single overarching document which will reflect any design changes which derive from the testing results.

An outline of the documentation milestones remaining is mostly made up of the final report, for which the evaluation and testing milestones will be crucial, and the backlog which I have mentioned above. I plan to take an agile approach as far as weekly sprints and sprint retrospectives go for the remaining of the project to force a steady rate of progress from myself.

One standout area of risk is the mains electricity relay HAT setup. Not only is it very dangerous to tamper with mains electricity, but it will also be in close proximity to a water source. I plan on mitigating this risk by firstly completing the setup of the RPi Relay HAT indoors before taking it into the greenhouse, and once assembled, I will keep it in a waterproof case and place it as far away from the source of water as possible.