CS33020 Assignment – PlantBot Overview and Report

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Contents

1. Introduction

Purpose of this document

This document is a design study intended to fulfil the parameters described in the Assignment specification[1]. The Design is for a gardening system, that from hereafter will be referenced as PlantBot. The client are colleagues from the IBERS department, and the system is not being designed for commercial use, however it is being designed with the intent to be released as an open source project that can be developed further by third-parties.

Scope

This document will cover the problem space, stakeholders, and a design solution for the PlantBot system. It will not include a schedule or roadmap as this is a theoretical project that is not currently being implemented.

Objectives

The objectives of this document are:

- To detail the problem space that has been presented by IBERS
- To analyse the stakeholders
- To define the functional and non-functional requirements
- To define three possible solutions
- To develop one solution further and create a functional failure modes and effects analysis

2. The problem space

The IBERS department want a way to accurately monitor and control growing conditions for plants on raised beds inside of greenhouses. The system needs to be easy to use and extendable so that it can be developed further in the future.

3. Context Diagram

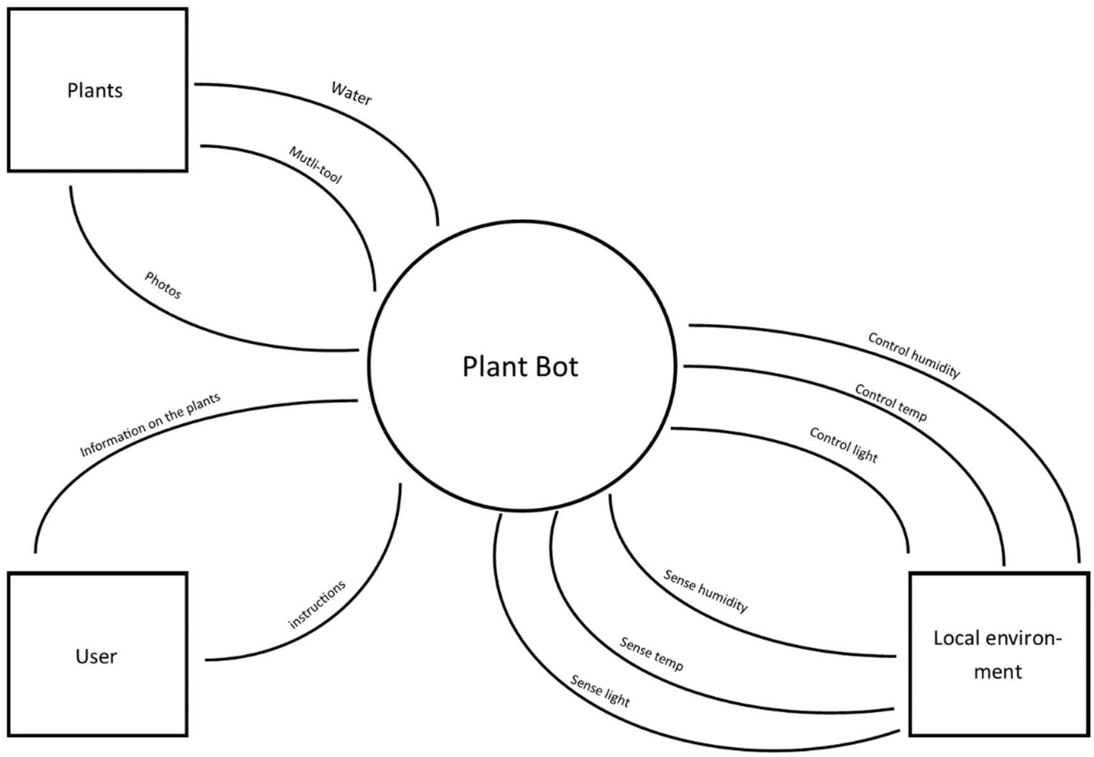

Figure 1 - Context Diagram

4. Stakeholders

Fig. 2. Stakeholder Diagram

The Stakeholders in this project have been grouped into six categories: Supply Chain, IBERS Department, Third Party Users, Maintenance, Competitors and Design Authority. Starting with the supply chain; component suppliers, power suppliers and water suppliers are all stakeholders as PlantBot will require components, power and water to function. The component suppliers are unimportant stakeholders, as once the components have been brought their only concern is if the components break in such a way that is covered by a warranty. The component suppliers are not liable for misuse of the components they provide, although if their components are used in successful project this could potentially be good marketing for them. The power supply company that provides power for PlantBot will be paid according to how much power PlantBot uses, so in a way it's in their best interest for PlantBot to use as much power as possible. That being said, they don't want PlantBot to draw too much power form the grid so that they then don't have enough electricity to the rest of Aberystwyth. However, that number is so high that there are other limiting factors (that we will discuss later) that come into play much earlier on. Additionally, the Power Supplier will want PlantBot to be safe and not damage the power grid, and therefore PlantBot must adhere to guidelines set out for any device that draws power form the mains. PlantBot will need a constant supply of fresh water to water the plants with, and the Water Supply company will also have guidelines on hooking anything up to the water mains, such as systems in place to prevent backflow. However, if PlantBot is attached to something such as a tap, then those systems should already be in place and will not affect PlantBot's design.

Next, we move onto third-party users. As this design will be released as open source once it is completed, it is reasonable to assume that for-profit companies may have an interest in this. Their interests lie in keeping costs as low as possible and productivity as high as possible. Other universities and any charities that may want to use this design will also be invested in keeping the costs low. Future developers will want the design to be easy to modify, so that they can tailor it to their exact needs.

In the IBERs department, we find perhaps some of the most important stakeholders, as they are the ones who commissioned the project in the first place. The installers will want the project to be easy to construct and install- they will also want pieces to within a certain weight so that no one gets hurt whilst building it. They will also want it to be straightforward and fast to assemble. The maintenance team will want it to be easy to clean and maintain, with any parts that may need replacing being easily accessible without having to stop the operations of the whole machine. The financers, which are part of the IBERs department will want PlantBot to be as cheap as possible so that they don't have to allocate too much funding to it. They will probably have a set budget which should be defined before the design phase starts. The people in the IBERs department who will be using PlantBot have already given their requirements, although it is good to keep in mind the usability of PlantBot and how easy it is to learn to operate.

In the maintenance category, there are Disposers and cleaners. What is meant by cleaners are not the people maintaining PlantBot, but rather cleaners who will be cleaning the greenhouses and need to work around PlantBot. They will have an interest in PlantBot not causing mess, and also not being a hazard they might bump into. Disposers, meanwhile, are people who will dispose of the PlantBot at the end of its life. They have an invested interest in it being easy to take apart and recycle, and being made of non-toxic materials that are unsafe to dispose of.

The “competitors” are in this case the creators of FarmBot, however as FarmBot is also an opensource project, they are not competing for a share of the market. Rather, they are working towards a similar goal, and should be viewed as allies not enemies. The creators of FarmBot have an interest in pieces of PlantBot being cross-compatible with FarmBot, so that they can use parts of PlantBot’s design to upgrade FarmBot in the future.

The Design authority- those creating PlantBot- are the technology providers, system designers and software designers. The technology providers and the system designers have an interest in PlantBot being as simple to design as possible, and the software designers have an interest in PlantBot being able to use COTS software for certain automated tasks so that not everything needs to be programmed from scratch.

In the wider community, climate activists have an interest in PlantBot because it’s function is directly linked to climate science. They will want PlantBot to be available for the wider public to use. Additionally, they will want it to be made in a sustainable way, without having a large impact on the environment. Government Legislators only care about PlantBot in so far that it doesn’t break any laws or constraints that exist around these kinds of robots. Local residents have an interest in the robot not being disruptive- either extremely loud (including during the installation and eventual disposal), or creating light pollution. Aberystwyth University students and staff outside of the IBERS department will want the project to succeed as it adds prestige to Aberystwyth’s reputation.

5. Viewpoint Analysis

Having discussed the stakeholders, we can now combine it with the requirements from earlier to create a viewpoint analysis. First, we need to consider the lifecycle of our PlantBot. A typical lifecycle should look like:

- System conception
- Design and development
- Production/construction
- Distribution
- Maintenance and support
- Retirement

A viewpoint bubble diagram can now be created, taking into consideration the different viewpoints of all of the stakeholders identified in the previous step.

Figure 3 - Viewpoint Bubble Diagram

Something to note is that government legislation does not define what light levels are considered a nuisance and it is evaluated on a case by case basis [2]. The light levels which are considered a nuisance will vary depending on where the greenhouse is and which lights are being used. As of such, it will be up to the user to make sure they are in compliance with local law.

Viewpoint separation

The requirements are then sorted into three categories: functional, non-functional, and other.

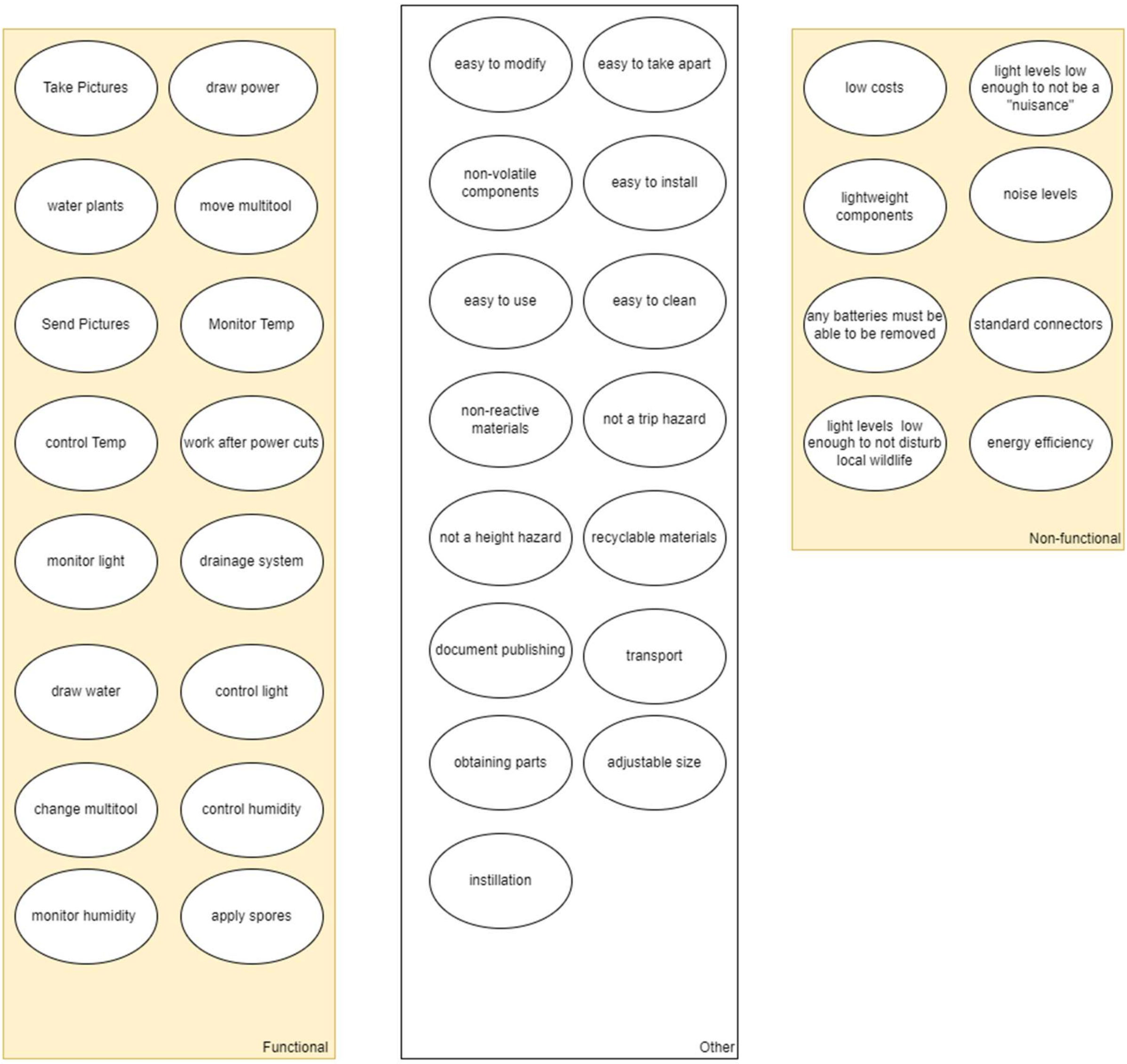

Figure 4- Viewpoint Separation 1

The requirements in other are then reassigned and separated into the first two categories.

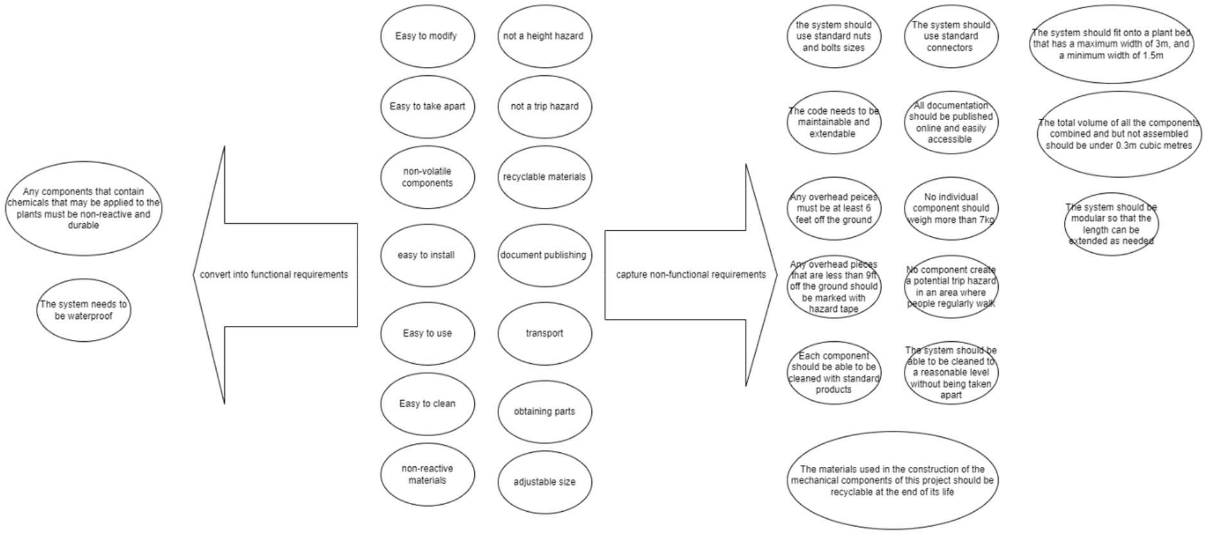

Figure 5 - Separation of Viewpoint requirements

I turned the "Easy to Modify" requirement into three non-functional requirements: standard sized nuts and bolts, standard connectors, and code that is easy to maintain and expand upon. The "standard sized nuts and bolts" requirement also covers part of the "easy to install" and "easy to take apart" requirements. No individual component weighing more than 7kg is also derived from "easy to install". The Health and Safety Executive branch of the government recommends that women shouldn't lift anything above 7kg above their shoulder height[3], and as we don't know who will be installing this system it needs to be accessible for all genders. The document publishing requirement becomes "all documents should be published and easily accessible online", as paper documents can get lost. This also helps with the "easy to use" requirement, as the documentation and manuals will be readily available. The "height hazard" and "trip hazards" become nothing lower than 6ft, and anything lower than 9ft needing hazard tape. The government legislation about trip hazards is unclear but states that "So far as is reasonably practicable, every floor in a workplace and the surface of every traffic route in a workplace shall be kept free from obstructions and from any article or substance which may cause a person to slip, trip or fall." [4]. Easy to clean becomes "Each component should be able to be cleaned with standard products" and "The system should be able to be cleaned to a reasonable level without being taken apart". "Non-reactive materials" becomes the functional requirement "Any components that contain chemicals that may be applied to the plants must be non-reactive and durable". This is because this is going to be used in scientific research- even if the only "chemical" in the system is water, the water will need to not get contaminated with micro-plastics- potentially skewing the data. As an addendum to this, the system will have a watering system, and as of such the system needs to be able to work when wet. The transport requirement becomes the non-functional requirement of "The total volume of all the components combined and but not assembled should be under 0.3m cubic metres”. This size is an arbitrary choice as most car boots have a capacity of around $0.3m^2$ [5]. For the adjustable size, it becomes “The system should fit onto a plant bed that has a maximum width of 3m, and a minimum width of 1.5m” because most of the greenhouses have a width of 6m by 13m, with a walkway down the middle. According to hunker.com, the minimum width for a flower bed is about 3ft or 1.5m [6]. The system also needs to be modular so that the length can be increased as needed, as we don’t know the length of the flower beds that IBERS are using, and other potential users may have different dimension requirements anyway. Finally, recyclable materials becomes “The materials used in the construction of the mechanical components of this project should be recyclable at the end of its life”.

Having done all of that, and putting it back into the previous diagram we get the following:

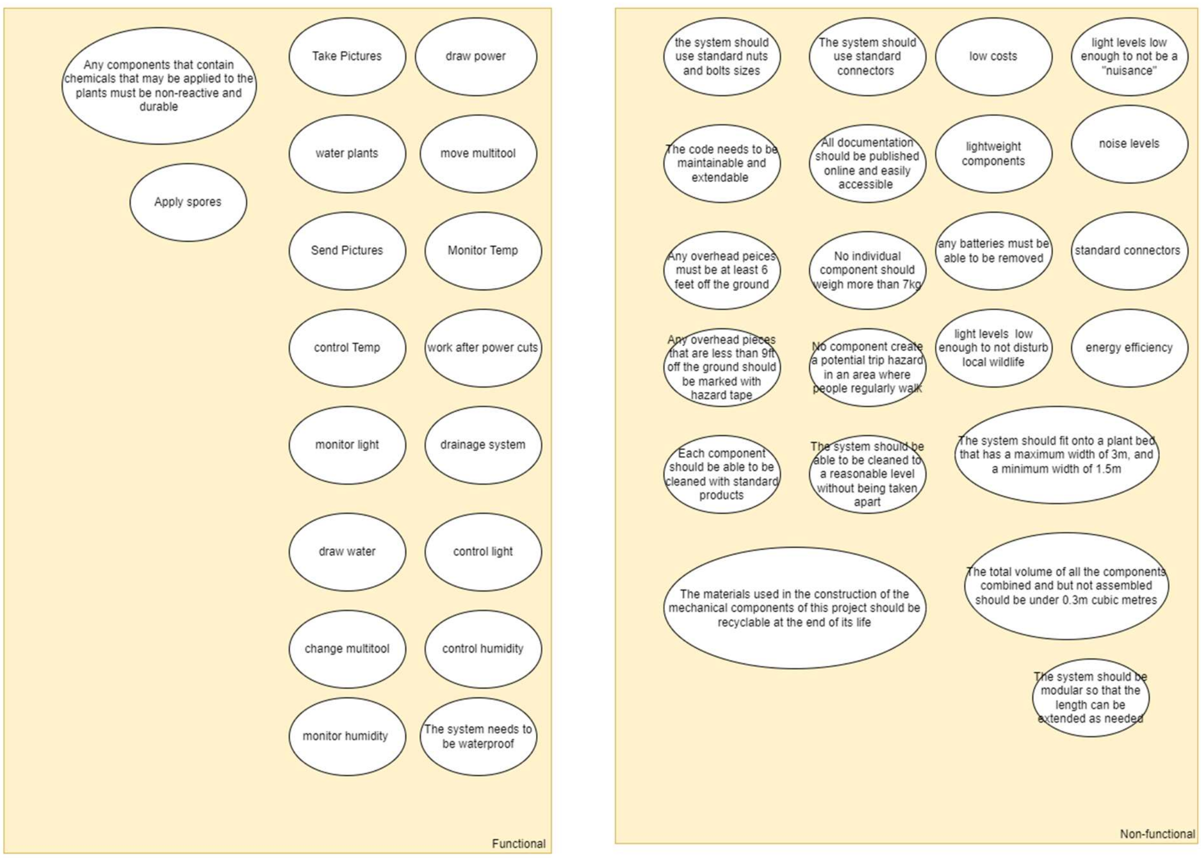

Figure 6 - Viewpoint Separation 2

Functional viewpoint structuring

The viewpoints now need to be separated into external and internal viewpoints. The external viewpoint looks at the prime system from the outside and the internal viewpoint looks at the prime system from the inside. This step only considers the functional viewpoints. Some functions could fall into either category. These are the following:

- Supply/draw power
    - This is internal to the system as the system will need some kind of plug or battery to function.
- Supply/draw water
    - This is internal to the system, insofar as the system turns a tap on and off. The actual plumbing of the tap and the greenhouse is outside the bounds of this project.

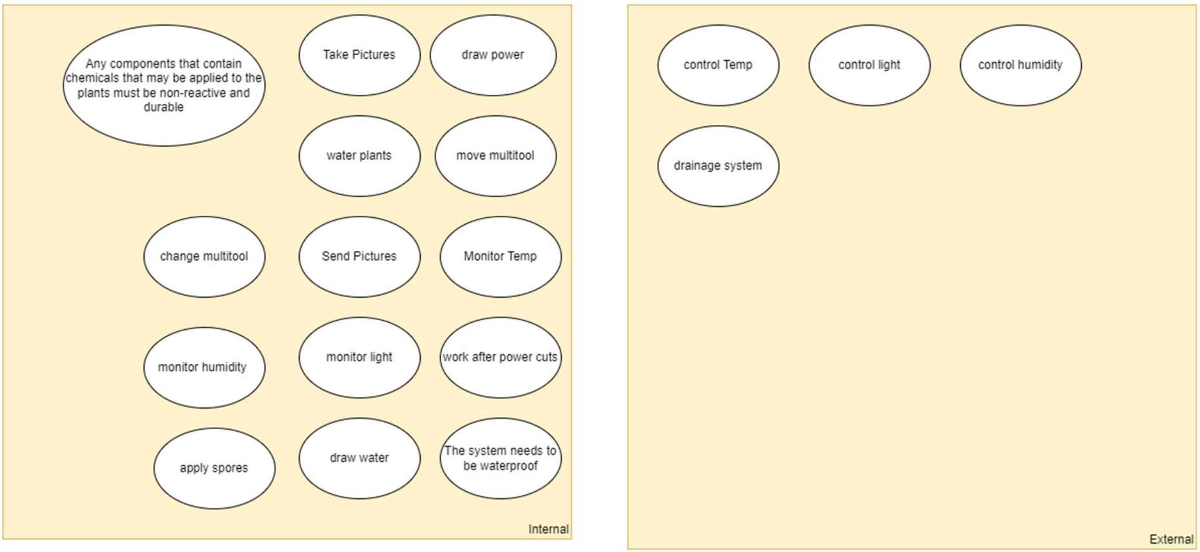

Figure 7 - Internal and External Viewpoints

The temperature, light, and humidity controls all rely on external systems that the PlantBot will instruct to turn on or off. The drainage system is assumed to already be in-place in the greenhouse.

The functions are then split into groups to help refine the system.

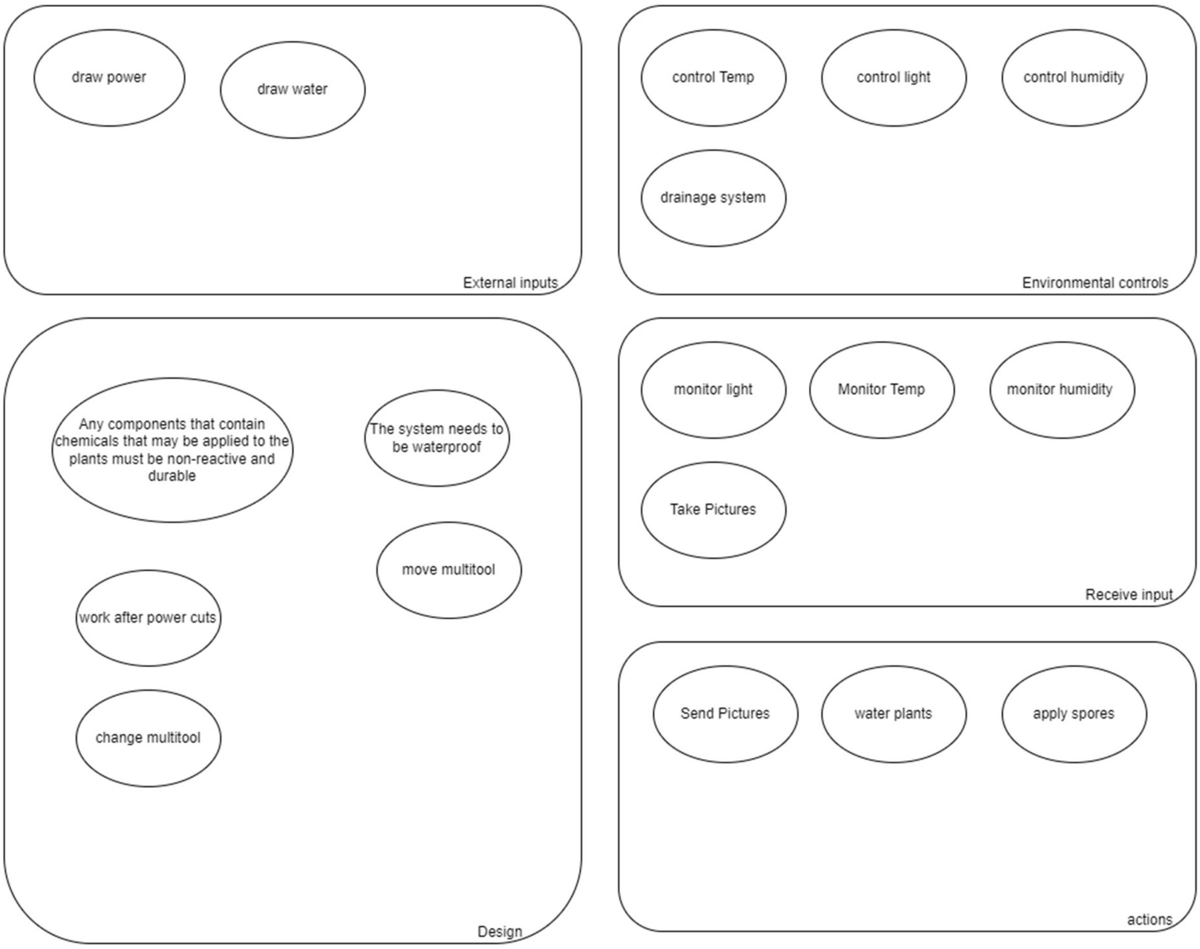

Figure 8 - Functional Groups

The actions group refers to the outputs the systems needs to return, or in other words the operations it needs to "do". The inputs are the data that is put into the system, as opposed to the external inputs which are the physical (electricity and water) that the system needs. The environmental controls are the external systems that control the environment. The Design group is for functions that have an overall effect on the design of the system.

6. Functional Viewpoint structure chart

Now that the requirements from the Stakeholders have been defined it is time to define any other requirements and put them all together.

Functional Requirements (Prime System)

- The system shall take pictures of plants at regular intervals
- The system shall draw power from the mains
- The system shall draw water
- The system shall send pictures of plants to (server/web brain)
- The system shall monitor ambient temperature in Celsius
- The system shall monitor ambient humidity using RH
- The system shall monitor ambient lighting in Lux (lumens per square metre)
- The system shall monitor soil moisture percentage
- The system shall control temperature of the room
- The system shall control humidity
- The system shall control soil moisture
- The system shall water plants
- The system shall have an arm than can move in x, y and z directions.
- The system shall have a multitool head that can be changed out
- The system shall have the ability to do different things to different groups of plants
- The system shall continue to work after power cuts
- The system shall be mounted on a plant-bed
- Any components that contain chemicals that may be applied to plants shall be non-reactive and durable
- The system shall apply spores to plants
- The system shall have a drainage system

Non-functional requirements:

Temperature:

- Temperature monitor should have a minimum resolution of 0.5◦c
- A number of thermometers equal to the area (in metres) squared of maximum ventilation divided by five
- There should never be less than four thermometers

- More thermometers should be able to easily be added for larger greenhouses or taken away for smaller ones
- There should be an alarm or notification of some kind if one of the thermometers is giving a major outlier as a reading
- There should be an alarm or notification if there is a prolonged inability to get within 5◦c of the desired temperature, or if the actual temperature is over a certain amount that can be set by the user depending on the plant
- The temperature controller should aim to get the greenhouse to the desired temperature within a time frame that can be set by the user.

Humidity:

- Humidity sensors should have a minimum resolution of 1%.
- Humidity should be controlled by the ventilation and watering systems
- The system should have some sort of alarm or notification if the humidity is more than 5% away from the desired humidity for an amount of time chosen by the user
- There should be a way to easily add a humidifier to the system, so as to extend the range of humidities the system can reach
- There should also be the possibility of adding an AC unit that will add range to the temperature control and the humidity levels

Luminosity:

- Ability to work with different lights that the user may want to install
- Ability to turn lights on and off
- Ability for lights with adjustable levels to be installed and work with the system

Other:

- The system should use standard nuts and bolts sizes
- The system should use standard connectors
- The system costs should be low
- The light levels should be low enough to not be a nuisance
- The could should be maintainable and expandable
- All documentation should be published online
- Component should not weigh more than 7kg
- The system should not be noisy enough to case a nuisance

- Any overheard pieces should be at least 6 feet off the ground
- Any overhead pieces that are lower than 9ft should have hazard tape on them
- No component should create a potential trip hazard where people regularly walk
- The light levels should be low enough not to disturb local wildlife
- Any batteries included in the system should be able to be removed
- The system should be as energy efficient as possible
- Each component should be able to be cleaned with standard products
- The system should be able to be cleaned to a reasonable level without being taken apart
- The system should fit onto a plant bed that has a maximum width of 3m and a minimum width of 1.5m
- The materials used in the construction of this project should be recyclable at the end of it's life
- The total volume of all of the components combined but not assembled should be in larger than 0.3 cubic metres
- The system should be modular so that the length can be extended as needed

Assumptions:

I have assumed that different plants have different requirements for how much the temperature, humidity and luminosity can vary before the experiment is no longer valid.

7. Requirements

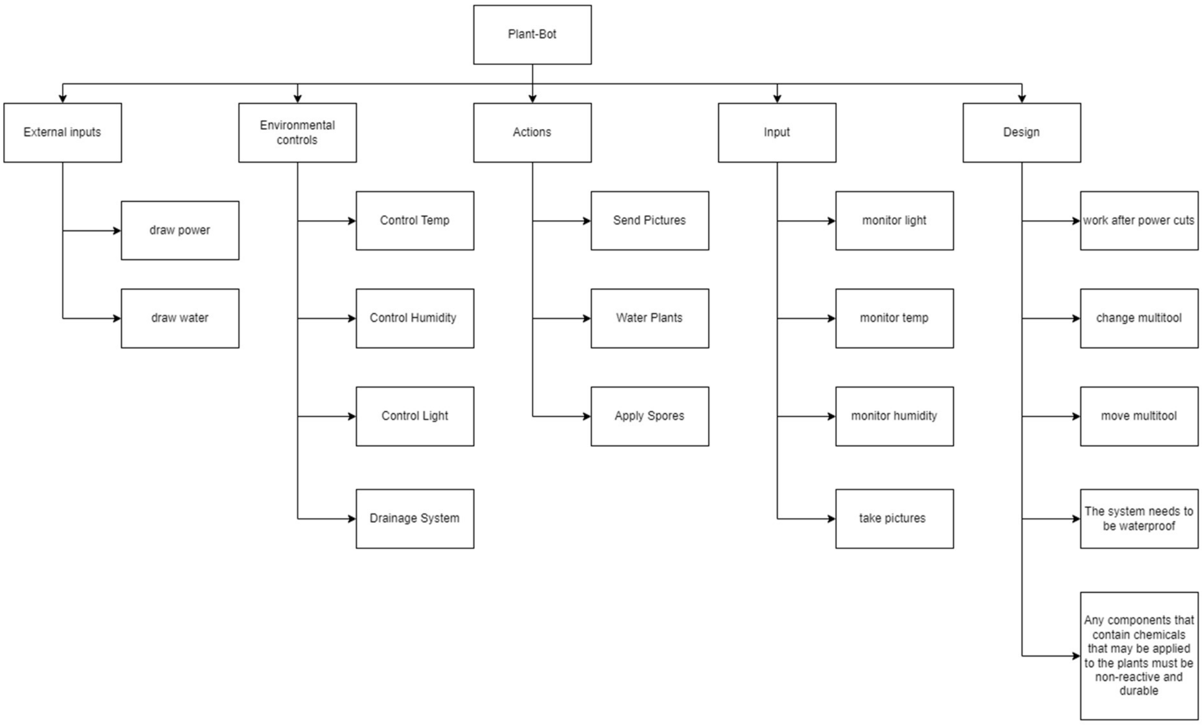

Figure 9 - Functional Viewpoint Structure Chart

The functional viewpoint structure chart helps breakdown everything that needs to be considered into easy-to-understand groups. The non-functional requirements are then added to create a final viewpoint structure chart.

Viewpoint structure chart

It should be noted that the non-functional requirements identified in part 3 of this document have not been considered here- only the non-functional requirements that were derived from the stakeholders. This is because the diagram would become too cluttered to view properly.

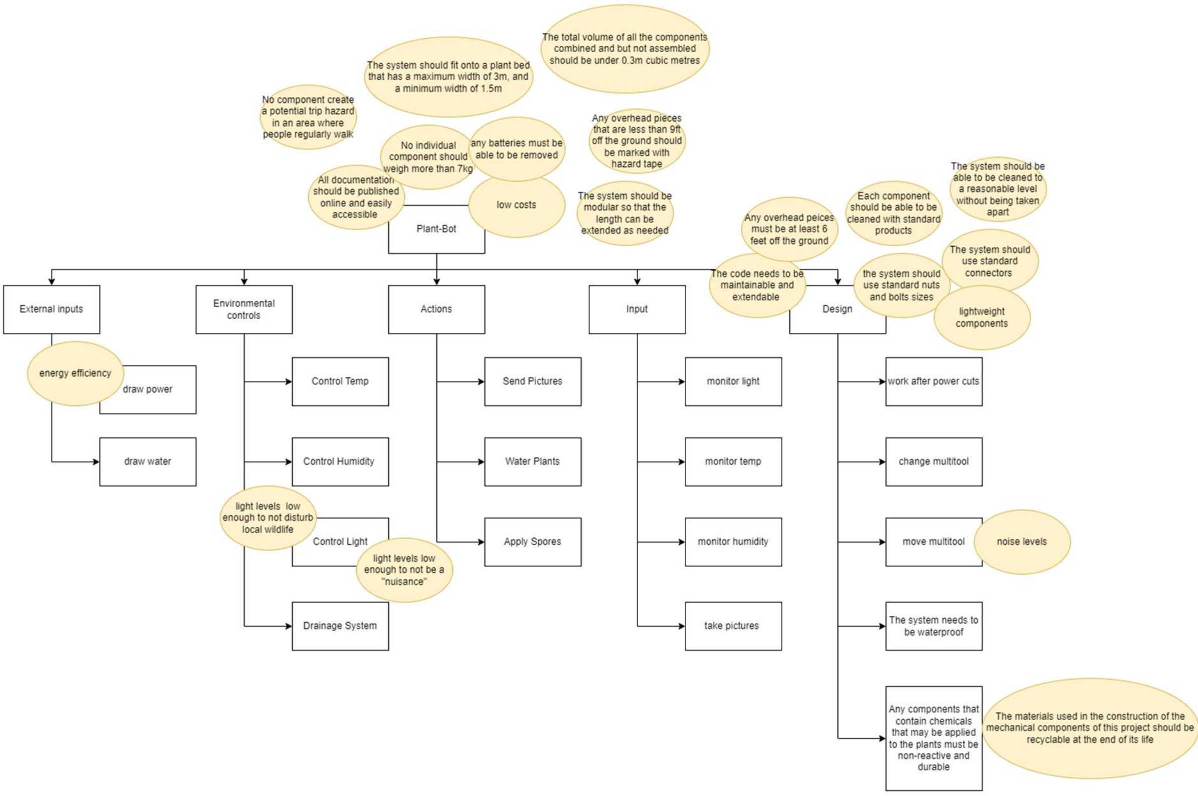

Figure 10 - Viewpoint structure chart with NF requirements

8. Functional Means Analysis

Functional Means analysis						
System: PlantBot	Subsystem	Date: 01/12/2023	Author: Mim Small			
FUNCTION	MEANS					
Draw Power	Mains (3 pin socket)	Large battery	Generator	Solar panels		
Draw Water	tap	pump system	rain collector			
Control Temp	radiators	AC unit	automatic windows	greenhouse effect	hot water bottles	
Control Humidity	humidifier	AC unit	automatic windows			
Control Light	specialist plant lightbulbs	curtains	blinds	glow in the dark panels	electrochromic windows	mirrors
Drainage system	sink drain	channels that go outdoors	industrial drain	water butt	pipes to outside	pump
Send pictures	microcontroller with ethernet	microcontroller with wifi	cables	usb that has to be transported	Bluetooth	airdrop
Water plants	watering cans with robot arms	pump controlled system	garden spray	drip irrigation		
apply spores	robotic arm	pump system	large spray	drip system	specialised tool on multitool	
monitor light	photoresistors/LDR	photodiodes	phototransistor	camera		
monitor temp	digital thermostat	thermoreceptor	infrared detector	liquid/gas thermometer	bimetallic thermometer	probe thermometers
monitor humidity	digital humidity meter	microwave water radiometer	hygrometer			
take pictures	DSLR camera	digital camera	polaroid camera	mirrorless camera	film camera	
work after power cuts	battery powered micro-controller	crash resistant software	non-volatile memory	backup battery	surge protection	
change mutlitool	clip system	screw system	mechanical rod system	Velcro	clamp	spring loaded
move multitool	motors	pulley	chains	linear tracks		
system needs to be waterproof	plastic box for microcontroller	all plastic				

non-reactive components	metal	plastic	glass	wood	mix of materials	
mounted on plant-bed	gantry	clamps	screws	gravity		

Figure 11 - Functional Means Analysis

A few notes about the Functional means analysis:

- Specialist plant lightbulbs refers to the kind of lightbulbs that emit the specific wavelengths of light that plants need to grow
- Electrochromic windows are windows where the amount of light let through is controlled by a electric current
- Mirrors refer to mirrors being strategically placed around the greenhouse to ensure a more even amount of light falls on the plants
- Industrial drain refers to an outdoor drain that is already in place and probably connects to a sewage system
- The water butt refers to a water butt that would need to be frequently emptied (or from which the water could be reused), similar to the system many caravans use
- "Pipes to outside" refers to a drainage system where plastic tubes would go from the plant beds to just outside the greenhouse [description]
- "cables" refer to data cables that would run from the greenhouses to a central server in the university buildings
- Watering cans with robot arms describes a system where watering cans would be on robotic arms with hinges that can rotate and water the plants
- The robotic arm for the spray bottle functional requirement refers to a robotic arm that can hold a spray bottle and clench to use it
- For the change multitool requirement, the mechanical rod system refers to s system where two pieces slot together and a stick or a "rod" is pushed through both parts to hold them together

Deselection criteria

- The system needs to work with the infrastructure that is already there
- The system needs to be able to run with low maintenance
- The system needs to be able to run consistently for months on end

This removes the rain collector as we cannot guarantee that there will be a consistent amount of rain throughout the year to keep the system going. This also removes the hot water bottle solution as they would need to be refilled regularly. Electrochromic windows are also not feasible as they would require replacing all of the windows in the greenhouse. Watering cans with robot arms are unlikely to be reliable or function for months on end without maintenance. The photos cannot be loaded onto a USB drive that has to be retrieved and transported to the server room every day.

Functional Means analysis - Deselection						
System: PlantBot	Subsystem	Date: 01/12/2023	Author: Mim Small			
FUNCTION	MEANS					
Draw Power	Mains (3 pin socket)	Large battery	Generator	Solar panels		
Draw Water	tap	pump system	rain collector			
Control Temp	radiators	AC unit	automatic windows	greenhouse effect	hot water bottles	
Control Humidity	humidifier	AC unit	automatic windows			
Control Light	specialist plant lightbulbs	curtains	blinds	glow in the dark panels	electrochromic windows	mirrors
Drainage system	sink drain	channels that go outdoors	insutrial drain	water butt	pipes to oustide	pump
Send pictures	mircocontroller with ethernet	microcontroller with wifi	cables	usb that has to be transported	bluethooth	airdrop
Water plants	watering cans with robot arms	pump controlled system	garden spray	drip irrigation		
apply spores	robotic arm	pump system	large spray	drip system	speicalised tool on mutlitool	
monitor light	photoresitors/LDR	photodiodes	phototransistor	camera		
monitor temp	digital thermostat	thermoresitor	infared detector	liquid/gas themometer	bimetallic themometer	probe themometers
monitor humidity	digital humidity meter	microwave water radiometer	hygrometer			
take pictures	dslr camera	digital camera	polaroid camera	mirrorless camera	film camera	
work after power cuts	battery powered micro-controller	crash resitant software	non-volatile memory	backup battery	surge protection	
change mutlitool	clip system	screw system	mechanical rod system	velcro	clamp	spring loaded
move multitool	motors	pulley	chains	linear tracks		

system needs to be waterproof	plastic box for microcontroller	all plastic				
non-reactive components	metal	platsic	glass	wood	mix of materials	
mounted on plant-bed	gantree	clamps	screws	gravity		

Figure 12 - FMA deselection 1

Functional Means analysis – Deselection removed						
System: PlantBot	Subsystem	Date: 01/12/2023	Author: Mim Small			
FUNCTION	MEANS					
Draw Power	Mains (3 pin socket)	Large battery	Generator	Solar panels		
Draw Water	tap	pump system				
Control Temp	radiators	AC unit	automatic windows	greenhouse effect		
Control Humidity	humidifier	AC unit	automatic windows			
Control Light	specialist plant lightbulbs	curtains	blinds	glow in the dark panels	mirrors	
Drainage system	sink drain	channels that go outdoors	industrial drain	water butt	pipes to outside	pump
Send pictures	microcontroller with ethernet	microcontroller with wifi	cables	Bluetooth	airdrop	
Water plants	pump controlled system	garden spray	drip irrigation			
apply spores	robotic arm	pump system	large spray	drip system	speicalised tool on mutlitool	
monitor light	photoresitors/LDR	photodiodes	phototransistor	camera		
monitor temp	digital thermostat	thermoresitor	infrared detector	liquid/gas thermometer	bimetallic thermometer	probe thermometers
monitor humidity	digital humidity meter	microwave water radiometer	hygrometer			
take pictures	dslr camera	digital camera	polaroid camera	mirrorless camera	film camera	
work after power cuts	battery powered micro-controller	crash resistant software	non-volatile memory	backup battery	surge protection	
change mutlitool	clip system	screw system	mechanical rod system	Velcro	clamp	spring loaded
move multitool	motors	pulley	chains	linear tracks		
system needs to be waterproof	plastic box for microcontroller	all plastic				

non-reactive components	metal	plastic	glass	wood	mix of materials	
mounted on plant-bed	gantry	clamps	screws	gravity		

Figure 13 - FMA deselection 2

9. Design concepts

Some gardening experts were consulted during the design concept phase. The following extra statements were deduced:

-The water needs to water around the roots if the plants are big.

-Spray heads can get clogged up with calcium because hard water, and therefore need maintenance.

-There may be a need to jab holes in dry compost so that water can get into soil. Deep roots get water top roots get nutrients.

-Some pesticides cannot be put down mains drains

This informed the selection of design concepts and the future ranking with selection criteria.

Functional Means analysis							
System: PlantBot	Subsystem	Date: 01/12/2023	Author: Mim Small				
FUNCTION	MEANS						
Draw Power	Mains (3 pin socket)	Large battery	Generator	Solar panels			
Draw Water	tap	pump system					
Control Temp	radiators	AC unit	automatic windows	greenhouse effect			
Control Humidity	humidifier	AC unit	automatic windows				
Control Light	specialist plant lightbulbs	curtains	blinds	glow in the dark panels	mirrors		
Drainage system	sink drain	channels that go outdoors	insutrial drain	water butt	pipe to oustide	pump	
Send pictures	microcontroller with ethernet	microcontroller with wifi	cables	bluethooth	airdrop		
Water plants	pump controlled system	garden spray	drip irrigation				
apply spores	robotic arm	pump system	large spray	drip system	speicalised tool on mutlitool		
monitor light	photoresistors/LDR	photodiodes	phototransistor	camera			
monitor temp	digital thermostat	thermoresitor	infared detector	liquid/gas themometer	bimetallic themometer	probe themometers	
monitor humidity	digital humidity meter	microwave water radiometer	hygrometer				
take pictures	dslr camera	digital camera	polaroid camera	mirrorless camera	film camera		
work after power cuts	battery powered micro-controller	crash resitant software	non-volatile memory	backup battery	surge protection		
change mutlitool	clip system	screw system	mechanical rod system	velcro	clamp	spring loaded	
move multitool	motors	pulley	chains	linear tracks			
system needs to be waterproof	plastic box for microcontroller	all plastic					
non-reactive components	metal	platsic	glass	wood	mix of materials		
mounted on plant-bed	gantree	clamps	screws	gravity			

Figure 14 - FMA design concept paths

From this Functional Means Analysis, three design concepts can be distilled. For the sake of clarity they have been turned into their own tables here:

Design Concept 1	
Date: 01/12/2023	Author: Mim Small
Draw Power	Mains (3 pin socket)
Draw Water	tap
Control Temp	automatic windows

Control Humidity	automatic windows
Control Light	blinds
Drainage system	insutrial drain
Send pictures	microcontroller with wifi
Water plants	drip irrigation
apply spores	drip system
monitor light	photoresitors/LDR
monitor temp	liquid/gas themometer
monitor humidity	digital humidity meter
take pictures	digital camera
work after power cuts	non-volatile memory
change mutlitool	clip system
move multitool	motors
system needs to be waterproof	all plastic
non-reactive components	platsic
mounted on plant-bed	gantree

Figure 15 - Design concept 1

Design Concept 2			
Date: 01/12/2023	Author: Mim Small		
Draw Power	Mains (3 pin socket)		
Draw Water	tap	pump system	
Control Temp	radiators	AC unit	automatic windows
Control Humidity	humidifier	AC unit	automatic windows
Control Light	specialist plant lightbulbs	curtains	
Drainage system	insutrial drain	channels that go outdoors	
Send pictures	microcontroller with wifi		
Water plants	pump controlled system		
apply spores	speicalised tool on mutlitool		
monitor light	phototransistor		
monitor temp	digital thermostat		
monitor humidity	digital humidity meter		
take pictures	dslr camera		
work after power cuts	non-volatile memory	backup battery	
change mutlitool	mechanical rod system		
move multitool	linear tracks		
system needs to be waterproof	plastic box for microcontroller		
non-reactive components	mix of materials		

mounted on plant-bed	clamps		

Figure 16 - Design Concept 2

Design Concept 3				
Date: 01/12/2023	Author: Mim Small			
Draw Power	Mains (3 pin socket)			
Draw Water	tap	pump system		
Control Temp	automatic windows			
Control Humidity	automatic windows			
Control Light	blinds			
Drainage system	pipe that goes outside			
Send pictures	microcontroller with ethernet			
Water plants	garden spray			
apply spores	robotic arm			
monitor light	phototransistor			
monitor temp	bimetallic thermometer			
monitor humidity	hygrometer			
take pictures	mirrorless camera			
work after power cuts	crash resistant software	non-volatile memory	backup battery	surge protection
change multitool	screw system			
move multitool	chains			
system needs to be waterproof	plastic box for microcontroller			
non-reactive components	metal			

mounted on plant-bed	screws			

Figure 17 - Design Concept 3

Validation criteria

Next, the validation criteria for this project were selected so that each design concept could be evaluated against it.

Having discussed the project with some gardening experts (see acknowledgements) and having another look at the functional and non-functional requirements, the following criteria were selected:

Primary	Secondary	Importance (%)
Ability monitor growth	take high quality photos	6.00%
	send photos to server	6.00%
Monitor the environment	Monitor temperature	4.00%
	Monitor humidity	4.00%
	Monitor luminosity	4.00%
Control the environment	Control Temperature	4.00%
	Control humidity	4.00%
	Control light levels	4.00%
To different things to different plants	Water plants different amounts	6.00%
	apply different insectisides or spores	6.00%
Work for a long amount of time	work for months on end with low maintenace	4.00%
	continue to work after power cuts	8.00%
Ease of use	Easy to install	6%
	Easy to clean	7%
	Easy to find parts for	6%
Cost effectiveness	upfront costs	7.00%
	costs to run	14.00%

Figure 18 - Validation Criterea

Pugh Matrices

		Pugh Matrix	Concept 1	Concept 2	Concept 3
			Design Concepts		
Selection criterea	Ability motior growth	take high quality photos	S	+	++
		send photos to server	S	S	+
	Monitor the environment	Monitor temperature	S	+	+
		Monitor humidity	S	S	S
		Monitor luminosity	S	+	S
	Control the environment	Control Temperature	S	++	S
		Control humidity	S	++	S
		Control light levels	S	++	+
	To different things to different plants	Water plants different amounts	S	++	S
		apply different insectisides or spores	S	+	+
	Work for a long amount of time	work for months on end with low maintenace	S	+	++
		continue to work after power cuts	S	+	++
	Ease of use	Easy to install	S	--	S
		Easy to clean	S	+	+
		Easy to find parts for	S	-	--
	Cost effectiveness	upfront costs	S	--	-
		costs to run	S	--	-

Total +	0	15	11
Total -	0	7	4
Total	0	8	7

Figure 19 - Pugh Matrix 1

		Pugh Matrix	Concept 1	Concept 2	Concept 3	importance
			Design Concepts			
Selection criterea	Ability motior growth	take high quality photos	S	1	2	6.00%
		send photos to server	S	0	1	6.00%
	Monitor the environment	Monitor temperature	S	1	1	4.00%
		Monitor humidity	S	0	0	4.00%
		Monitor luminosity	S	1	0	4.00%
	Control the environment	Control Temperature	S	2	0	5.00%
		Control humidity	S	2	0	4.00%
		Control light levels	S	2	1	5.00%
	To different things to different plants	Water plants different amounts	S	2	0	6.00%
		apply different insecticides or spores	S	1	1	6.00%
	Work for a long amount of time	work for months on end with low maintenance	S	1	2	4.00%
		continue to work after power cuts	S	1	2	8.00%
	Ease of use	Easy to install	S	-2	0	6%
		Easy to clean	S	1	1	7%
		Easy to find parts for	S	-1	-2	6%
	Cost effectiveness	upfront costs	S	-2	-1	3.00%
		costs to run	S	-2	-1	6.00%

Total +	0	15	11
Total -	0	7	4
Total	0	8	7
Weighted Total	0	0.43	0.4

Figure 20 - Pugh Matrix 2

These two Pugh Matrices clearly show that Design concept 2 is the best the criteria are both weighted an unweighted. The second Pugh Matrix uses numbers instead of the more common notations of + and -, so that excel could calculate the weighted total automatically.

10. System Design and architecture

Whilst working on this design, it quickly became apparent that using curtains to block out light was not actually practical to control with a microcontroller, and a blind is better.

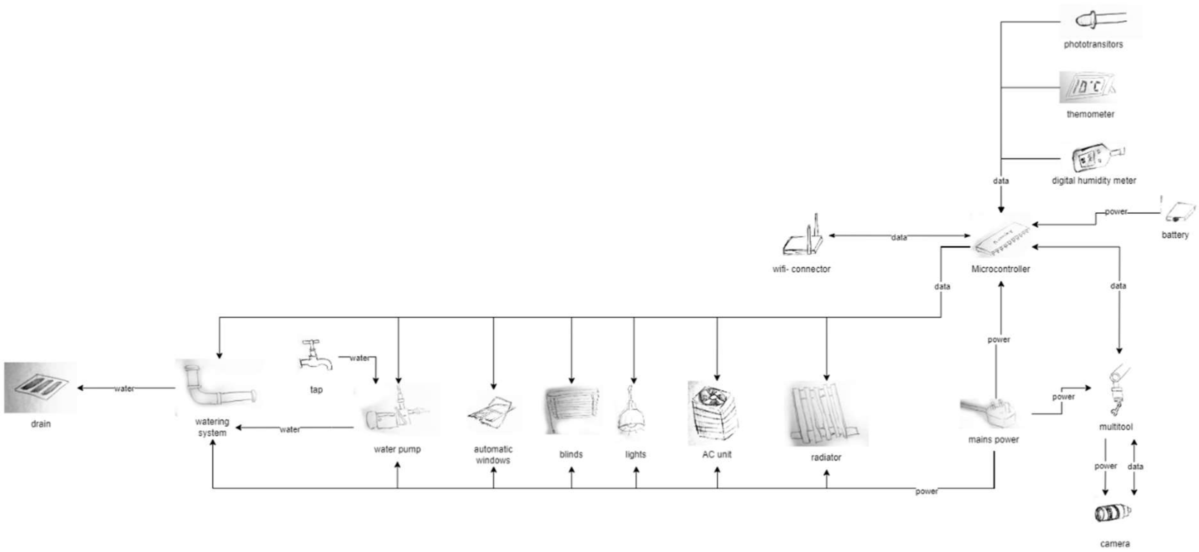

Figure 21 - System Architecture Map

11. Functional failure modes and Effects analysis

Architectural functions

Based on the Design described in the previous section, the following architecture functions were identified:

- Delivery power to separate elements
- Transfer data between elements
- Transfer Water between elements

Next, a function failure modes and effects analysis was made.

Functional Failure Effects Analysis

System: PlantBot	O - Probability of occurrence	1: very rare → 10: Frequent	Date: 06/12/23	Version: 1.0
	S- Severity of occurrence	1: no effect → 10: most severe	Author: Mim Small	
	D- Probability of detection	1: certain to detect → 10: canot detect		

FUNCTION	FUNCTIONAL FAILURE MODE	EFFECTS	S	CAUSES	O	DETECTION: current employed method	DETECTION: D	RPN	DESIGN SUGGESTIONS/ COMMENTS
Take pictures of plants at regular intervals	Take too many pictures	Run out of memory	3	User Error	2	No more photos will be taken when the memory is full	3	18	There needs to be some kind of alarm for when the system is running out of memory. There could also be a system that lets the user know how long it will take to fill up te memory with the current rate of photos the system is taking
	Take too few pictures	Analysis software can't work	6	User Error	2	None	10	120	There needs to be a minimum number of pictures that the user can set for the system to take
	Take no pictures	Analysis software can't work	6	Hardware/software error	1	None	10	60	There needs to be a system test that checks x number of photos have been taken every specified increment of time
	Take bad pictures	Analysis software can't work	6	Dirty camera lense/ badly configured hardware	3	None	10	180	There needs to be an automated test to check the quality of the images every specified increment of time. Perhaps a colour chart that the camera takes a photo and compares to, and sets off a user alarm if it's too far off
	Take unintended pictures	Confuse Analyis software	6	User error	2	None	10	120	Some kind of system to compare pictures of the same plant, so that if they are wildly different the system can
Send pictures of plants to web server	send mutliples of the same picture	Confuse Analyis software	6	Software error	1	None	10	60	Some kind of test to check the metadata of the images so that the software knows it hasn't received the same image twice
	not send all of the pictures	Confuse Analyis software	6	Software error	1	None	10	60	number the images so that software can check none are missing
	send no pictures	Analysis software can't work	6	Software error	5	The software won't work	4	120	Have a test that gets passed when an image is sent. If no images get sent for a period of time then the user is alerted
			6	network error	5	The software won't work	4	120	test to see if the network is working, and if it's not then save the image and wait until it is woring to send it
	send bad pictures	Confuse Analyis software	6	image compression issue/files corrupted	2	The software won't work	10	120	have a random test that will occasionally send two copies of a picture and check that they match. If they don't then the user will be warned
Monitor ambient temperature	Read the temperature as too high	System tries to cool the room and messes up the experiment or kills the plants	8	incorrect calibration, broken hardware	4	mutiple sensors so that discrpency can be detected	2	64	there should already be multiple sensors in place, so for this system to fail all of the sensors would have to go wrong at once
	Read the temperature as too low	System tries to heat the room and messes up the experiment or kills the plants	8		4		2	64	
	Read no temperature	No data to work with	6	software issue, user error	2	none	10	120	There could be a system that checks that there is temperature data and if there isn't then it warns the user
	intermitently read temperature	insufficient data to work with	6	software issue, user error, hardware fault	2	none	10	120	there should be a system that checks that all of the requested temperature data is there and if it fails a set number of times then it warns the user
	only reading the tempertaure in certain spots	insufficient data to work with	6	software issue, hardware fault	2	mutiple sensors so that discrpency can be detected	2	24	there should already be multiple sensors in place, so the system will catch this

Figure 22 - FFMEA 1

Monitor ambient humidity	Read the humidity as too high	System tries to humidify the room and messes up the experiment or kills the plants	8	incorrect calibration, broken hardware	4	mutiple sensors so that discrpency can be detected	2	64	there should already be multiple sensors in place, so for this system to fail all of the sensors would have to go wrong at once
	Read the humidity as too low	System tries to dry out the room and messes up the experiment or kills the plants	8		4		2	64	
	Read no humidity data	No data to work with	6	software issue, user error	2	none	10	120	There could be a system that checks that there is humidity data and if there isn't then it warns the user
	intermitently read humidity	insufficient data to work with	6	software issue, user error, hardware fault	2	none	10	120	there should be a system that checks that all of the requested humidity data is there and if it fails a set number of times then it warns the user
	only reading the humidity in certain spots	insufficient data to work with	6	software issue, hardware fault	2	mutiple sensors so that discrpency can be detected	2	24	there should already be multiple sensors in place, so the system will catch this
Monitor ambient lighting	Read the lux as too high	System darken the room and stunts the plant growth	8	incorrect calibration, broken hardware	4	mutiple sensors so that discrpency can be detected	2	64	there should already be multiple sensors in place, so for this system to fail all of the sensors would have to go wrong at once
	Read the lux as too low	System tries tolight up the room and messes up the experiment	8		4		2	64	
	Read no light data	No data to work with	6	software issue, user error	2	none	10	120	There could be a system that checks that there is light data and if there isn't then it warns the user
	intermitently read light data	insufficient data to work with	6	software issue, user error, hardware fault	2	none	10	120	there should be a system that checks that all of the requested light data is there and if it fails a set number of times then it warns the user
	only reading the lux in certain spots	insufficient data to work with	6	software issue, hardware fault	2	mutiple sensors so that discrpency can be detected	2	24	there should already be multiple sensors in place, so the system will catch this
Control temperetaure of the room	Make the room too hot	experiment is void, plants can die	8	software issue, hardware fault	2	temperture sensors will detect that the temperature is not the target temperature	2	32	
	Make the room too cold		8		2		2	32	
	not control the temperature		7		2	if the temperature in the room does not mtach the target temperature the sensors will pick it up	3	42	there could be a situtation where the ambient tempertaure met the target temperature by coincidence, and therefore the sensors would not realise something was wrong
	only sometimes control the temperature		7		2		3	42	
Control the humidity of the room	Make the room too humid	mould could start to grow, contaminating the experiment	8	bad weather, broken hardware, software issue	4	the humidity sensors will detect that something is wrong	2	64	
	Make the room too dry	the plants could dry out and die	8	broken hardware, software issue	2		2	32	
	not control the humidity	the experiment could become void, the plants could die	7		2	the humity sensore might detect that something is wrong	3	42	there could be a situtation where the ambient humidity met the target humidity by coincidence, and therefore the sensors would not realise something was wrong
	only sometimes control the humidity		7		2		3	42	

Figure 23 - FFMEA 2

Control the lighitng of the room	Make the room too bright	the experiment could become void, the plants could die	8	broken hardware, software issue	2	the light sensors will detect that something is wrong	2	32	
	Make the room too dark		8		2		2	32	
	not control the luminosity		7		2	the light sensors might detect that something is wrong	3	42	
	only sometimes control the luminosity		7		2		3	42	
Water Plants	over water plants	the plants could drown	8	broken hardware, software issue	2	none	10	160	We need to add sensors so that we know how much water is being given to each plant
	under water plants	the plants could die of dehydration	8	broken hardware, software issue, drought	3	none	10	240	If there is a drought and there isn't water in the taoos the users will porbably know about it already
	don't water plants		8		3	none	10	240	
	intermitently water plants	the experiment could become void, the plants could die	7	broken hardware, software issue	2	none	10	140	
Move multitool	move multitool too far	the mutlitool won't be able to reach the correct plant	6	broken hardware, software issue, calibration issue, user error	3	none	10	180	there really needs to be a sensor that checks that the multitool is in the correct posoition after it's moved
	don't move mutlitool far enough		6		3	none	10	180	
	don't move mutlitool at all		6	broken hardware	1	none	10	60	
	multitool moves intermitently	the mutlitool might get stuck or hit something or even break	8	dirty tracks, broken hardware	6	none	10	480	
Change mutlitool head	change mutlitool when it's not needed	the wrong tool will be used, and the incorect procedure done, nullifying the experiment	8	software issue, user error	2	none	10	160	this is a major issue, and a sensor needs to be put in place to check the current tool in use. This could be in the tool bed to check what tool is currenlty absent.
	not change mutlitool when it is needed		8		2	none	10	160	
	multitool cannot be changed	the wrong tool could be used	7	hardware fault, rust or dirt buildup, hardware contracted or expanded due to temperature	4	none	10	280	
Deliver power to elements	Power surge	fry the circuits,	9	lightning strike, power grid surge	2	none	10	180	there should be a power surge protector between the system and the mains
	insufficient power	elements work inefficiently	6	poor connection, broken hardware	3	if the environmental controls are not working properly then the sensors should pick it up. The microcontroller also controls how much current many of the elemnts have and should be able to detect if the fault is between the microcontroller snd the mains	4	72	
	power outage	elements stop working	6	power grid outage, user error (unplugged system)	4	the microcontroller will detect when there is a power outage	1	24	
	unreliable power	elements work unreliably	6	poor connection, power grid fault	2	the microcontroller should be able to detect that the volatage is varying if the fault is between the microcontroller and the wall	5	60	there needs to be sensors on each element that needs power to check it's receiving the right amoutn of current
Tranfer Data	repeat data	elements try to perform actions twice. Microncontroller rceives wrong data	7	poor connection, software fault, hardware fault	1	none	10	70	the commands / packages of data should have unique IDs so that the subsystem recievibng the data can check if it is unique
	loss of data	elements skip actions they were supposed to do. Microcontroller has lack of information.	7		2	the microcontroller will be waiting for feedback from certain actions before telling the next action to go, so it will know if soemthing doesn't happen	6	84	every action should retrun some kind of end statement to let the moicrocontroller know that it happened. The microcontroller should always check that it has the data it needs
	no data	elemnets are not given commmands. Microcontroller has no data.	7		3		6	126	
	wrong data	elemnts are given the wrong commands. Micorcontroller is given wrong data.	7		2	none	10	140	the system has no way of detecting this as it will think it's working poerpley, the obcious solution is to have someone manually check the readings every set period of time
Pumping Water	too much water	pump could break, leak could form	8	hardware fault, software fault	1	none	10	80	the system should have a sensor to check how much water is being drawn and how much water is being used so that it knows where it's all going and can detect if there is a leak
	not enough water	watering system can't function	8	hardware fault, software fault	2	none	10	160	there should be a sensor to check that water is coming out of the tap
	no water	watering system can't function	8	hardware fault, software fault, user error (tap turned off)	3	none	10	240	
	intermitent water	pump could break, watering system will not work as expected	8	hardware fault, software fault	1	none	10	80	the system should have a sensor to check water is going through the pump at the expetcted rate

Figure 24 - FFMEA 3 (prev page)

Conclusion

Overall, whilst there is now a feasible design for PlantBot it still needs to be further developed. Many issues were identified during the functional failure modes and effects analysis, and many new requirements could be derived from this. For example, it has quickly become apparent that there needs to be sensors to check that the different components are working correctly, and that the transfer of data and power between components is also working correctly. Design Solutions for subsystems in the PlantBot should be considered and evaluated. A functional means analysis for the microcontroller would be very helpful for example. Overall this is a good start, but a final and complete design far from being reached; the next steps should be to revisit the requirements and then to start working on subsystems and design specifications for them.

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