UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT

DOCUMENTATION REPORT

<KARROTS>

<David Lammers>

<Sofia Baltussen>

<Bas van der Steenhoven>

<Stijn Brugman>

<Froukje Temme>

<Noor de Feber>

Table of Contents

Chapter 0: Introduction

Nowadays there are a lot of problems concerning agriculture and the environment. These problems need to be solved as soon as possible to sustain a healthy environment and healthy urban areas for the world population.

We, as first year Creative Technology students, are given the task to invent a smart solution for one of these problems. To find, in our eyes, the most urgent problem, we did research about the most common problems regarding agriculture. The problem on which our group is the fact that there is a lot of space that is being used for agriculture. The population keeps on growing but we can not use more space to produce food, without destroying existing nature. In this documentation you will find information about our research, plan, possible solutions and of course our final result.

Our interests went to a smart vertical garden. The goal is to create an (almost) fully automatic vertical garden. This garden will be a small, consumer usable object. It will include a lot of smart technology, like sensors and updated databases. The plan is that you will have an app, with which users can track the progress of your plant and share this information with other users. The app is not yet developed so this we be a plan for the future.

Of course, you might think that it is a bit ambitious to solve such a huge problem which such a relative small solution. Comparing the lack of space in today's agriculture to the possible size of created space with the vertical garden, there would have to be an enormous amount of vertical gardens sold to combat that lack of space or have a noticeable impact. The reason we have chosen for a small model production, is the fact that if we start at a bigger scale, the amount of investment we need to create a model, won't be reachable without any company wanting to invest in it. The problem with that is the fact that this is quite a new concept in the smart environment industry, which will result in companies being too scared to invest in such projects. Our approach to produce smaller scale products on a smaller scale, will result in people getting to know this new concept of "vertical" farming. There are many people who are interested in buying smart gadgets like that.

So in the first place we are targeting an easier group in society, the people, and not the companies. Eventually we can start producing larger scale modules, because the concept is known. Companies will see the potential this concept has, and they are willing to invest in it, which will allow us to create much bigger models. If we are at these later stages, the impact this project will have is more noticeable and sizeable.

The early stages of this project will be less efficient than the later stages, because it will take a long time before we can actually solve our main problem. But the interesting thing about our project is that it will solve multiple problems. It will stimulate people to eat healthy and food waste will be reduced because people are more attached to their food they grew on their own. So during the process of introducing this concept to the world, we are actually very efficient by solving multiple problems at once. Those problems won't disappear immediately, but we will create more awareness under the people, which eventually will end in a healthier world!

Chapter 1: Literature Review

There are different examples of smart technology in agriculture. Technologies such as advanced data analytics, multiple sensors, robotics, satellites, broadband internet, teleoperation and augmented reality. It's important that we implement these infrastructures in our generation because smart technologies are evolving at a rapid speed in several countries. To ensure food safety you need to keep up with the technologies. There are a lot of people independent on this sector for their jobs and we can help even more people (thing of underdeveloped countries) by developing this sector. It provides economic opportunity.

1. A blockchain is a method of storing data so that it is unalterable. The information can't be copied but only distributed. The data is managed by a cluster of computers, so not owned by any single person. So, there is no central authority, you might call it a democratized system. It's shared an immutable, which means the information is open and for everyone to see. That's why blockchain is very nature transparent and everyone involved is accountable for their actions.

So, what they are doing here is connecting blockchain to agriculture. 'studies indicate that blockchain technology enabled food to be tranced from farm to grocery store in just a few seconds. It helps keeping tabs on sources and reducing illegal harvest/shipping frauds. Examples are IoT sensors that fetch important information from sensors to the blockchain, simplified process of distribution (not so much involvement of multiple agents), and the finance becomes more transparent and fair, 'yet enables shared control accessibility'.

https://hackernoon.com/how-will-blockchain-agriculture-revolutionize-the-food-supply-from-farm-to-plate-f8fe488d9bae

2. This is a project of Tanmay Baranwall, where he focuses on the protection of grain against rodents/insects. This includes the protection of grains in stores but also on fields. The way he did this, is with sensors programmed in python. The sensors give real time notification after sensing the problem. They place the device in the corner and it will sense the heat. When the heat sensor indicates heat, it will start the webcam. Tanmay Baranwall made an algorithm 'based on collecting information to provide accuracy in notifying user and activation of repeller".

https://ieeexplore.ieee.org/abstract/document/8081906 (based on example 3)

3. This is an invention of Nelson Sales, which is about 'Wireless sensor Networks'. They use Cloud Computing in connection with agriculture. Cloud computing is a way of analyzing big processing and high storage. There will be a large amount of data from the sensors, such as temperature and soil moisture. The cloud computing will have 2 main functions: collecting all the information, saving all the information and analyzing it. In the end you will find important information with solutions, such as decreasing water consumption and other environmental aspects.
https://ieeexplore.ieee.org/abstract/document/8081906 (based on example 4)

4. Self-adaptive Partition Sampling (SDPS) is a strategy to collect data from sensors, which will help the current problem of lack of tracing accuracy. This strategy only requires a small portion of end markets samples. This is a big improvement because we now don't have to analyze everything. SDPS applications make use of tracing and backtracking algorithms to provide reliable information about the food supply chain. These algorithms can specify the problem while only using or analyzing a small sample, which will have a sufficient accuracy of provenance tracing over the whole system, and not only of that example.

https://journals.sagepub.com/doi/full/10.1155/2013/382132

5. Smart GPS based remote controlled robot is a proposed work on IoT based smart agriculture. It is a robot which will do all the things you have to do on a farm, such as farming, weeding, spraying, etc. The robot will be aware of his environment by using multiple sensors. It will make smart decisions based on accurate field data, which is updated constantly.

https://ieeexplore.ieee.org/abstract/document/8081906 (based on example 1)

6. WSN, which is a precision agriculture(PA), is a system which helps the farmers decision making by providing current information about different subgroups in farm king. For example weather, crops, lands, etc. The software for the system collects data from different sensors that are placed around, and then it will provide solutions based on those factors and inputs from the farmer.

https://ieeexplore.ieee.org/abstract/document/8081906 (based on example 2)

7. Intelligent packaging is a package function that switches on and off in response to changing external and internal conditions, and communicate with the customers or end users as to the status of the product.
Intelligent packaging is a system that monitors the condition of the packaged food to provide information about the quality of the food during transport and distribution. Smart packaging is packaging which senses and informs the condition of the product.

https://link.springer.com/article/10.1007/s11694-011-9120-x

8. Smart food packaging is being developed quickly to follow product quality.

https://link.springer.com/content/pdf/10.1007/s13197-015-1766-7.pdf

9. RFID tags can be used to check for conditions in containers. They only checked for temperature, other variables such as humidity have to be tasted. You can give an indication of shelf life and reroute trucks based on real time data. A problem is that there will be huge amounts of data, which most companies lack the infrastructure to handle.

https://www.sciencedirect.com/science/article/pii/S0168169908001993

10. Smart food packaging can be used in smart kitchens. Scan the barcode on your box, and the microwave or oven knows exactly how to prepare it. Scan it with your fridge and the expiry date is set in your food calendar.

https://onlinelibrary.wiley.com/doi/epdf/10.1002/1099-1522%28200003/04%2913%3A2%3C83%3A%3AAID-PTS494%3E3.0.CO%3B2-7

11. Climate-smart agriculture is an approach for transforming and reorienting agricultural systems. CSA supports food security with keeping in mind the conditions of climate change. Climate change disrupts the food markets → wide risk to food supply. CSA promotes coordinated action by farmers, researchers, private sector, civil society and policymakers towards climate-proof pathways through 4 action areas: -1 building evidence -2 increasing local institutional effectiveness -3 fostering coherence between climate and agricultural policies -4 linking climate and agricultural financing.
Climate change is disturbing agricultural growth. CSA identifies and trade-offs among food security, adaptation and mitigation as a basis for informing and refocusing policy in response to climate change.

https://www.nature.com/articles/nclimate2437#essential-elements-of-the-csa-approach

12. Sensors are integrated into packages. To ensure freshness and quality to more efficiently and manage food stocks and product authenticity.
Monitoring of goods is relevant for the transport of fruit, vegetables, meats, and fish.
The application, sensor, contains: sensors, logic, radio, antenna and power.

https://www.researchgate.net/profile/Jeroen_Brand/publication/267987283_Development_of_printed_RFID_sensor_tags_for_smart_food_packaging/links/54e71b9b0cf2b19906095a65/Development-of-printed-RFID-sensor-tags-for-smart-food-packaging.pdf

13. The internet of things can connect farming equipment. This his helpful for acquisition, analysis, dissemination and processing of information. There are multiple information systems for agro-ecological resource management mentioned in this paper.

https://www.researchgate.net/profile/Dheerendra_Gangwar/publication/313254039_Internet_of_Things_Connected_Smart_Farm_Solutions_for_Sustainable_Agro-ecological_and_Rur al_Development/links/5894945eaca27231daf8ef58/Internet-of-Things-Connected-Smart-Farm-Solutions-for-Sustainable-Agro-ecological-and-Rural-Development.pdf

14. An automatic robot with multiple functions related to agriculture. The robot can measure moisture, temperature and the PH value of soil. Depending on these measurements is can decide the amount of fertilizing and seeding done to the land. Sensors and cameras are attached to the robot, it can livestream and it has 6 legs. 3 legs can move at the same time, so it moves like a cockroach.

https://s3.amazonaws.com/academia.edu.documents/34249171/IJAIEM-2014-06-29-67.pdf?response-content-disposition=inline%3B%20filename%3DInternational_Journal_of_Application_or.pdf&X-Amz-Algorithm=AWS4-HMAC-SHA256&X-Amz-Credential=AKIAIWOWYYGZ2Y53UL3A%2F20191115%2Fus-east-1%2Fs3%2Faws4_request&X-Amz-Date=20191115T092254Z&X-Amz-Expires=3600&X-Amz-SignedHeaders=host&X-Amz-Signature=2f762fc1cadfc29318319f843f94e5442a807068fcf057b4938816bfc65ac504

15. To generate the same output of production with decreasing land for agriculture farmers need to increase productivity with smart farming. They use GPS, soil scanning, data management and IOT tech. By measuring the variations within a field and adapting their strategy to it they can increase the effectiveness of pesticides and fertilizers. They can also monitor the needs of their animals and adjust their nutrition to it, decreasing costs/disease and enhancing health.

https://www.schuttelaar-partners.com/news/2017/smart-farming-is-key-for-the-future-of-agriculture

16. The fourth agricultural revolution caused by smart agriculture has big pros but also cons. The pro's are: increasing the efficiency and productivity of food creation, as well as potentially providing environmental and social benefits. But this revolution can also bring environmental, ethical and social costs.

https://www.frontiersin.org/articles/10.3389/fsufs.2018.00087/full

17. Smart farming causes farmers to make more products, while those products are also from a higher quality. However, food frauds are therefore also on the rise. For example, the E. coli outbreak in Arizona caused by Romanian lettuce, the buyer was unaware of this bacteria. The IoT plays a big role in this, as mass adoption of smart greenhouses is possible and causes exotic products to be produced in non exotic places.

https://www.rfidjournal.com/articles/view?18774

18. Drones are becoming more common in agriculture. First some farmers used satellite views to inspect their fields. Drones are an easier way for a farmer to get a wide view from above, with way more detailed pictures. Drones are, for example, used to find weak spots in

the field. Drone experts are working on making drones with laser detectors, or cameras with specific RGB filters to “read” the quality of the soil from the air.

https://ieeexplore.ieee.org/abstract/document/7194284

19. A small sensor is able to follow a certain product through the stages of the processing and transportation of the product through the agro-food sector. It collects information concerning the state of the product, this to guarantee the quality during all stages. “The aim is to improve the quality and the logistics of the chain and offer therefore, environmentally friendly and cost-effective solutions to optimize production flows, by networking the existing Italian hubs.”

http://ceur-ws.org/Vol-1498/HAICTA_2015_paper70.pdf

20. A new app has been released called 'Nitrogen Index'. This app can be installed on all Apple, Windows and Android devices. The app can be used as " Appropriate nitrogen management, where the right amounts of nitrogen are applied and best practices are used to ensure higher use efficiency, is important for conservation." This is necessary because nitrogen contributes to the greenhouse effect.

https://www.sciencedirect.com/science/article/pii/S0168169912002931

Chapter 2: Identification of General Problems and Challenges

1. Food expires
2. Food waste
3. Water waste
4. The production of certain foods contaminates
5. A lot of co2 and nitrogen emission emerges when food is being produced and transported.
6. For the farmers is it heavy work on the land
7. Climate change
8. It is not clear enough for the consumer how his product is made and what is in it
9. Smart packaging for food can be used to track food quality, improve shelf life and give information to consumers and smart kitchen appliances. There is no standard yet.
10. Diseases are being spread through food (animals and humans)
keeping tabs on sources and reducing illegal harvest/shipping frauds.
protection of grain against rodents/insects
11. A lot of nitrogen is being released during agriculture processes, this contributes to the greenhouse effect which has a negative impact on the environment

Chapter 3: Identification of Relevant Problems

Identify 5 new problems you find relevant, urgent and interesting, not yet been addressed effectively

1. A lot of food is wasted because shelf life is too short. Quality differs too much between products to give products a later “best before” date.
2. Feeding the increasing global population, which will lead into destroying preserving natural resources.
3. Long-term efficiency of farming in third world and second world countries. Many farmers deplete resources from their land too fast, by not altering between crops and not giving their land time to replenish those resources.
4. Food waste
5. Lack of space for farming(in developed countries.)

1. A lot of food is wasted because shelf life is too short. Quality differs too much between products to give products a later “best before” date.
    a. Add chemicals to the plastic packaging, to manipulate the inner climate to prolong shelf life.
    b. Sensors can be added to packaging to monitor the quality of the food to give better information to consumers about the quality of the products.
2. Feeding the increasing global population, but not destroying preserving natural resources.
    a. Find a way to produce more food in a smaller space
    b. Make people eat more plants instead of meat/fish
    c. More efficient farming, by increasing awareness and knowledge in third world countries about the effects of farming on the soil. Better soil use can increase long term efficiency substantially.
3. Long-term efficiency of farming in third world and second world countries. Many farmers deplete resources from their land too fast, by not altering between crops and not giving their land time to replenish those resources.
    a. Create instructions and distribute them over the countries that need them
4. Food waste
    a. Make a mechanism so that when people throw food away they get a notification (will feel bad)
    b. In restaurants make sure people can choose portions and when they don’t finish their plate sth happens idk…

5. Lack of space in developed countries to locally produce biological food.

a. Vertical gardens. Optimal use of space and sunlight. This also does not affect the soul. The vertical garden will change direction, where the sunlight is → vertical garden turns toward the sunlight. Around his axis.
b. Layer gardens. Can only be achieved with customatic lighting and not with sunlight.

Chapter 4: Problem Selection and Motivation

Select of the list of the 5 problems identified in Step 1, one problem you would like to work on for your project. Motivate your choice.

Eventually we choose for the last problem, problem 5. After we discussed all the problems we had found, it was quite clear to us that we wanted to do something with the last problem. In first place we were thinking if it was achievable to solve the problem, or if we could even make a small impact on the current problem. And we thought it was the most doable and most fun to do something with the last problem.

Everyone in our team already new about smart features in gardens, and even vertical garden wasn't a new thing for most of us. After we did a bit of background searching we decided that Problem 5 was the problem we wanted to improve.

Idea:

We want to make a smart garden, that will be vertical, that you can put on your balcony or in your garden. It is self regulated, it rotates together with the sun, it waters itself and we would like it to fights insect, but we are not sure if we can accomplish that it can fight insects with the materials that we have and the time that we have.
The user has to only buy the vertical garden and set it on the place and from that moment on, the smart garden will do everything itself. The water can be supplied through the pipe lines with rain water

There will be an app connected to the smart garden. The app will provide information about the statistics of the plant, such as the water percentage in the ground, when the plant is fully grown,etc.

This idea is for private use and when companies are interested in this idea, it can also be produced on a larger scale. For example on open fields or on buildings.
But first we have to start on a smaller scale, so only use it for private use. If we do it this way, people will be introduced in this way of gardening, which eventually will end up that bigger companies are wanting to invest in a bigger project of this concept.

This idea has a lot of positive sides. If everyone has a plant like this in his/her house, you will have an enormous increase of self-production. Before people didn't want to put time into gardening, but with this plant you don't have to do anything. Self-gardening has a lot of advantages, such as CO_2 decrease because the food doesn't have to travel to its destination, if made at home. It also increases safety because you know what happened to your food.

Right now there is not enough space to produce enough food for everyone. Also, during the transportation of produce there is a lot of CO-2 emissions. A perfect solution for this is small gardens in cities, this idea already exists but we want to add some innovative touches to this. Instead of simple gardens we want to make small gardens that are (almost) fully self-regulated. The consumer doesn't have to bother about keeping the crops alive. And the food that they

Connected to weather conditions: if it's a dry day: more water to the plant. You can also do it manually with the app.

pros	**cons**
self-regulated	Could be expensive for personal use
You produce your own food, you need less of the food that is being produced by bigger companies	A small surface won't cover a lot of agriculture(small impact)
Less co2 emissions previously used for distribute the food	Less efficient than large farms (space/energy)
Less space	Does not replace much farmland
Can be used for large scale production	

Chapter 5: Potential Solutions

Find 5-8 potential solutions to your problem. Explain how these solutions could work

Solutions:

1. A solution for the lack of space we have in today's agriculture could be the following; nowadays we are only scaling in the horizontal way, by making the growing fields wider and bigger, but what if we also would build up in the vertical way. So that would mean you have multiple layers of growing fields. This will definitely increase the space for growing crops.

   There are a few problems people think you might occur by scaling up in the vertical way; The first one is that the amount of sunlight that reaches the surface of the growing fields will decrease outrageously. Of course, on the top layer, you won't have that problem if you simply have a transparent top. But for the following layers, the only sunlight that's able to reach is the sunlight from the sides, which probably will be minimal. We can solve this problem by implementing "smart"-lights, which will produce the same kind of light that the sun produces, so the plants get everything they normally get from the sunlight. These lights will be powered by sunlight, so it won't cost (much) energy.

   Another problem is about water and other resources the plants need during their growing process (besides light). Because how are they implemented in the system, which isn't very easy accessible Water sprinklers and implementers for resources are systemized in the ground, and all automated.

   The same for the plantation and harvesting the crops, there are built-in systems which make it so much easier for the farmers. Of course, the farmers can access their own farms, and do standard quality checks, or updates if everything goes well.

   This way of farming is besides the fact that it is automated, we can almost say we can extend it in the vertical way over and over again, with no limits, which is a great solution for the lack of space we have in agriculture.

2. A solution for the lack of space for producing food is that we could make agricultural on top of flat building. On every flat building, we could produce something else. For example on building 1, grain, on building 2, lettuce, etc.

   On these "fields" you could make everything automatic, you can also follow the growth of the plants in an app that is connected to the "fields". You can see in the app how the plant is doing, if it is still alive, if there are sufficient vitamins in the ground, etc.

The “fields” waters itself when there is not enough rainwater. The “fields” know when it is going to rain and when not, it has a built-in rain radar. On the app, you can see where all the “fields” are and what they produce. That way you can know how much you produce a product.

3. A solution for the lack of space that we have nowadays regarding agriculture is the gen manipulation of plant seeds. If there is no more space to grow plants on, you need to increase the amount of food produced with the ground you have. This means that instead of 2 corn plants on 1 square meter, you will need 5 corn plants.

   This can (maybe) be done with the manipulation of the seeds. If you can mutate them the way you want, you can create plants that require way less space, but with the same amount of food produced.

   The watering of the plants can still be done the way it works now. With an automatic watering system the plants will all get an equal amount of water.

   A disadvantage of this solution is that you can not make the food itself smaller. The corn or whatever food you want to grow, still needs to have the same size. So a seed needs to be manipulated in a way that the plant itself will require less space to grow, but it will still make the same amount and “size” of food.

4. A solution for the lack of space in agriculture could be harvesting food under the ground / under water. There are several studies that have already shown that this is possible, yet it’s not developed that much yet.

   A more realistic solution and easier to attack would be harvesting on top of things you wouldn't expect. We’re not only talking about building things on top of flat buildings but more next-level, for example have agriculture on top of train stations, boats, cars of busses. If you put agriculture on for example train stations, you will use space that wouldn’t be used anyway + you will also get a nice look. If you put agriculture on for example slow driving cars / city busses, you could make a smart agriculture that turns toward the sunlight.

   These are just basic ideas, you can make them smart by adding sensors and gaining information from several node networks with data processing.

5. A solution for the lack of space in agriculture could be to let everyone harvest their own food.. If people work together in a neighborhood everybody could grow their own crops and share those with others. Through a network you can let other people know what kind of vegetables you have and what kinds you need. This way you won’t have large scale agriculture so less waste and also people are more responsible for their own food.

   The smart thing about this is that you create a social network that lets you trade your food with others. Maybe could even add some features that let you share the condition of your crops so that you can make your friends proud.

6. A solution to the lack of space in agriculture could be soil manipulating. By providing extra nutrients to the soil and planting different crops every year, you can get a higher yield, without depleting nutrients from the soil.
   Different crops require different nutrients, so by first planting crops that need nutrient A, and then crops that need nutrient B, you give the soil time to replenish nutrient A. This will be most effective in countries with less developed agriculture. In those countries you can gain the largest benefits. If you have higher yields, you can make the same amount of food with less space. You monitor this with smart sensors. These measure the amount of nutrients in the soil and can give feedback and automatically add nutrients to the soil.

Chapter 6: Solution Selection

For our Smart Environment project we want to make a smart, vertical garden. Each person has their own area on which they can work. Below is described how each area of the product will be made and what the thoughts are behind these choices. The final product will consist of a garden which follows the position of the sun so that it gets the optimal amount of sunlight. Also there will be an app in which you can communicate with others, this makes it very smart.

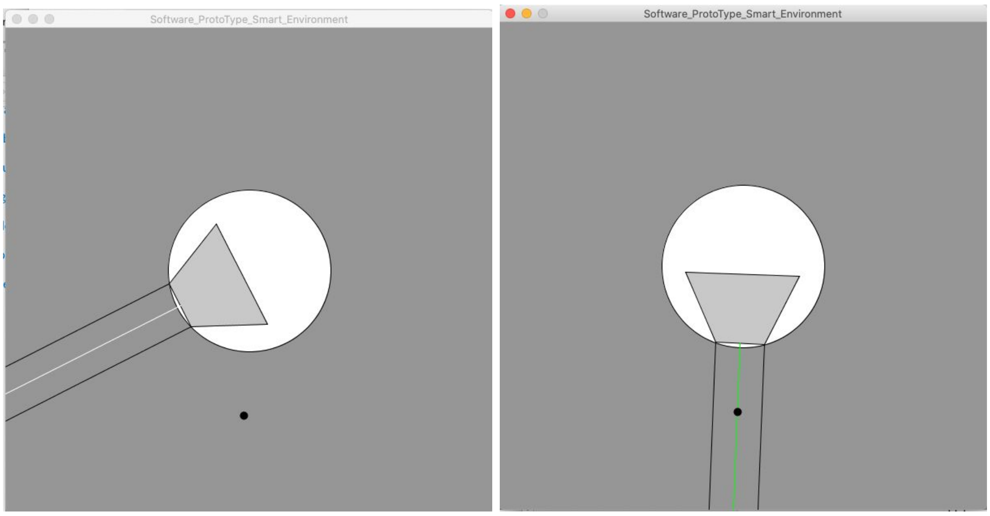
Why is our product a smart environment product?

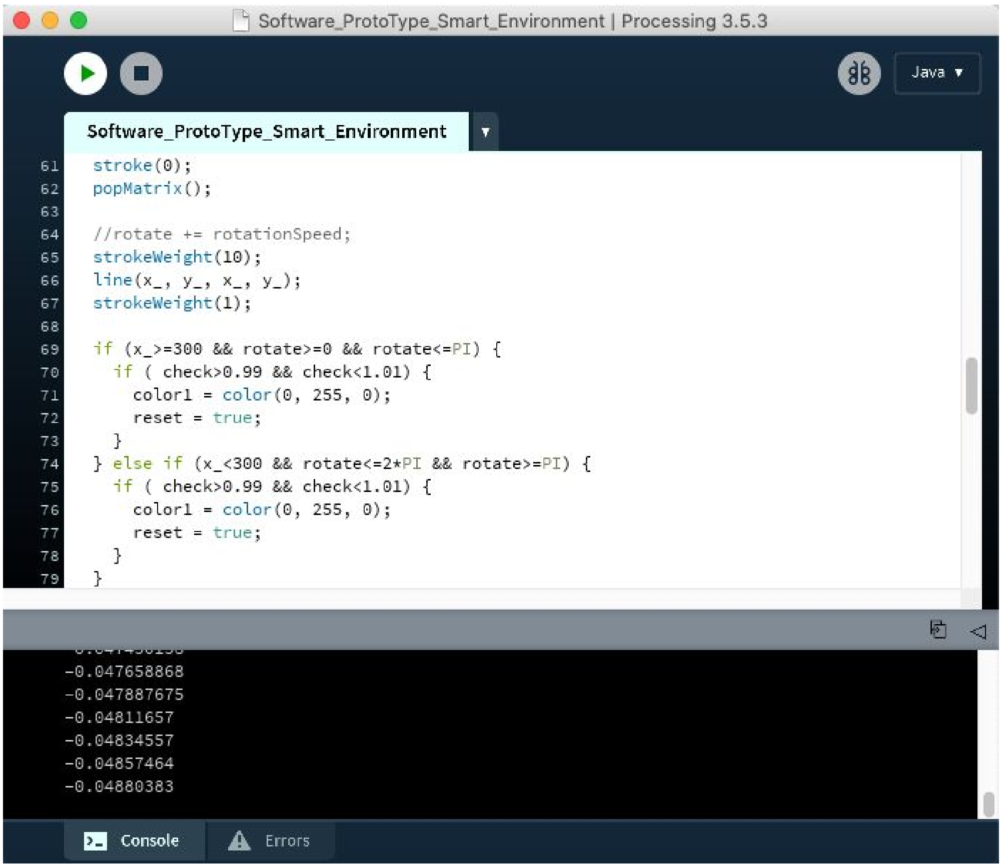
Our product is a smart environment because the garden is working on itself. I will only alert the user if really necessary. For our future plans, it will become an even smarter environment because you can communicate through the app with your neighbors about what you plant. If you have cucumbers and you also want to plant for example strawberries, you can first look in the app and see if some of your friends have strawberries or someone else in your neighborhood and you could, for example, exchange a few cucumbers for a few strawberries. That way you can plant something else.
You can also ask a question about your smart garden to other users of the smart garden.

The software side of our product

After we decided how our product should look and what function we (eventually) want to have, we focused on, what should be the main concept of our product. We decided to focus on the aspect of letting our smart garden have the most efficient sun-rotation system. This concept requires a system where-in the smart garden is capable of getting information of the suns position, translate this into its own optimal position and then translate this to a real physical movement.
At first the software developers just tried to state what this system should require on paper. In particular the part what should be the optimal position? This question seemed in the first side quite hard, but eventually it was simpler than we thought. Because our smart garden will only turn horizontal, the suns z-position doesn’t impact the position the garden should have. We tried to sketch and think of a position the garden should have looking at the sun, and we concluded that if you have an infinitive (non-visible) field perpendicular to the garden, and the sun is inside this field you will have the best position, where the garden

catches the most light. Also an important thing is that the non-visible field actually is infinitive big in the z-axis, because this doesn't influence the position of the garden.
After we concluded and had an idea what our garden should do, we tried to create our first sample software. In processing we re-created the situation of the garden and sun, and we created a software where the garden could conclude when it had its optimal situation, every time moment(changeable; check every minute, hour, etc.). We did this by drawing non-visible lines which had changing direction coefficients. When those coefficients were the same, the garden knew he was in the right position. This is roughly how our program works.
But already we encountered problems or things that were quite hard to do. First of all, how could we have the position of the sun. There were a few things we thought about. There could be an online database, which contains the position of the sun. But how can we translate that rough information to readable information for our software, and wouldn't this to big of a file. A solution for the second problem was that we would only check the position of the sun every half an hour, so there would be less coordinates. Another thing we could use is an algorithm which predicts the position of the sun. How we are going to do this, we are going to discuss this with the professor of smart Environment, and another professor which actually now is working on predicting the position of the sun.
Lastly of all of the above works, so we have a smart garden which can know what it position should be, and which is able to update this every wanted timeframe, now we should translate this into moving wheels which will represent the perfect rotation. We haven't come to a part wherein we starting thinking about how we are going to do this.
Another attachment to this main aspect of our project is that we want to use light sensors which won't serve as the main impactor or "decision maker", but which will preserve as an auditor, which will check if it actually is getting light. And if not it will alarm the owner of the garden. The sensors won't be that hard to program and install, we will use multiple sensors in different positions. The hard part will be designing a system which can estimate if the hole garden really isn't getting (enough) sun, or if it is just a shadow in front of the shadow.
In the pictures below you can see the first prototype software we made on our project. This is just a simple model, which shows a "from the top" - viewed representation of our setup. We simply gave the black dod, which represents the sun, random positions, which the smart garden could detect. The lines we drew are to understand better what the optimal position is. The line are perpendicular on the surface of our garden.
Of course in a more developed software prototype, we want our product to be able to get information from an algorithm or a database which states the position of the sun. And the garden of course has to resets its position every time the night has fallen.





The app connected to the smart environment (future plan):

Along with the smart vertical garden, we thought of a related app that can help the user and make the product idea better. The app will consist of 3 parts: a part for everyone one the world (global), a part for just you and your friends (local) and an information part.

The first part is the information part. In this part of the app you can find information about your current plants and their status. To begin we want to start with prototypes of 5 different plants, and put only the information of these 5 plants in it. Of course we can elaborate it later if it's successful. The information part will give you information about the plant and its characteristics, and at the same time the status/level of the plant, regarding to humidity, water level, progress status, vermin status, sun position, etc. We can even add the rain application for more accurate statistics.

Secondly we have the part for you and your friends. In this part of the app you can share the status of your plants with your friends. It's just like facebook but then for plants. You can share the status of your plants, post pictures, like/dislike posts and comments. on them. You can also share information with each other.

The third part of our app is the global part of our app. This is especially interesting for big cities where people live really close upon each other. In this part you can share your resources with people in your area. So say you have planted a lot of cucumbers, and your neighbour in the same flat building has too much tomatoes, you can trade with each other. This will also be a minor solution for food waste. In the app you can put what you have too much on, and at the same time look for what you need.

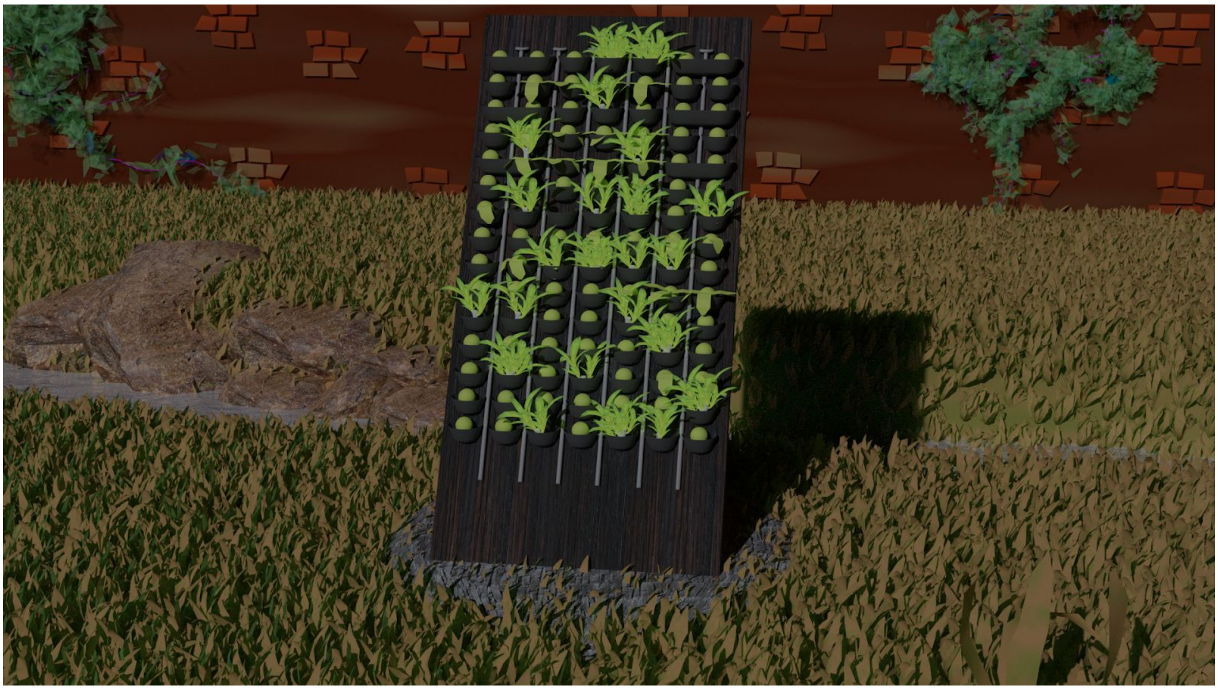
Product design, materials and sensors

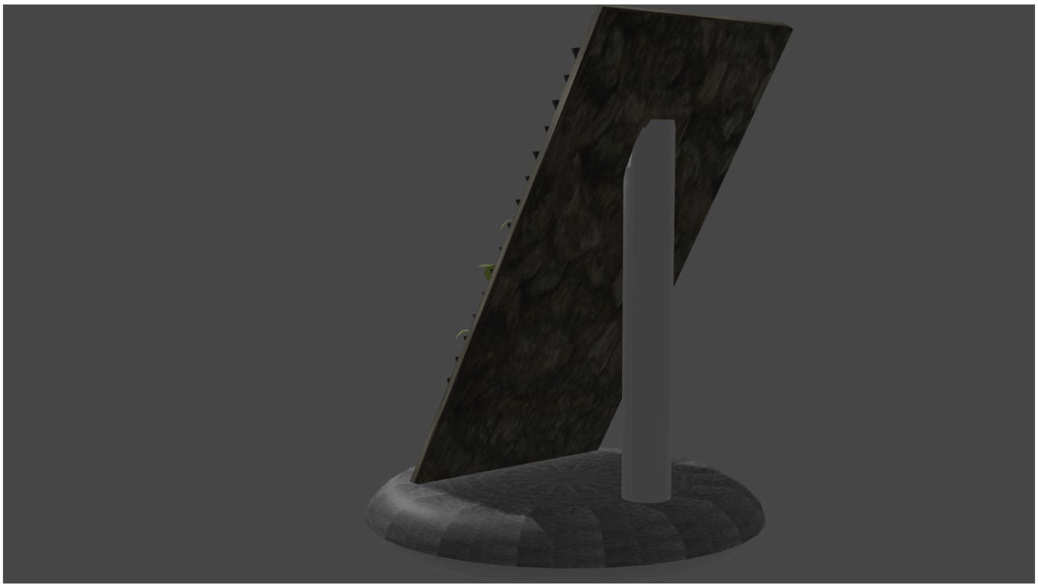
Our garden will be standing on a plate, which can turn to let the plants face the sun at all times. This plate will cover the base, in which the hardware will be stored. The plate will fully cover the base from the top and sides, so that no water will be able to enter the base.
Our vertical garden will have a 30 degree angle from perfectly vertical, as to maximise the amount of sunlight that will hit the plants.
The plants will be inserted into small sockets. That way, the plants can easily be changed out for new plants.
Between the sockets will be small water tubes with small holes in them to distribute water and feed the plants. These run from top to bottom.
The base has a water reservoir that supplies the water and makes the garden stable by providing extra weight.

The base rotates to follow the sun. This will increase the amount of sunlight the plants get. The speed of the rotation will be calculated using the known times of sunset en sundown. There will be multiple sensors embedded into the garden. In the base, there will be a light sensor. This sensor will be useful, for example, to track sunhours to give information about the expected growth, to see if the rotation is still following the correct path and to give advice about the location of the garden in or around the house.
Inside the sockets, there will be humidity sensors. These will track the amount of water in the soil, so the watering of the plants can be regulated.

Ultimate product design, 3D model

As explained under the title "Product design, materials and sensors" there is already a design for our smart environment. Due to the limited amount of material knowledge and time, we can not make the prototype exactly like our desired design. Because of these reasons, there will be a more realistic 3D model provided by our final project result. In this 3D model, we can show the materials that are going to be used for the official design, compared to the material used for the prototype. We will use this 3D model while building our prototype to make it look like our original design. The alpha version of the 3D model is already made and is visible in the pictures below.





Chapter 7: Methodology

Physical build:

As explained earlier in this documentation we made a design for our smart vertical garden. Due to the limited amount of knowledge and resources we had to make quite a bit of changes to get our prototype working. Preliminary we knew our prototype was not going to look the same as our original, planned idea. The biggest change we made to get it working, was using gears to rotate our garden. We planned on making a rotation device inside the stand of the vertical garden, so it would not be visible for the people reviewing the prototype. This was, to our knowledge, to hard to do so we changed it to gears, powered with the use of a cordless drill. We laser cut some gears in different sizes, and made the smallest one exactly the size we needed to attach it to a drill. By doing this we were able to make a "network" of gears to rotate the bigger gear, where the garden was standing on. We have dismantled the cordless drill, and separated the rotating parts and the battery. Attaching these separate parts to an arduino circuit, we were able to let the drill rotate by itself. More information about this under the programming part in this chapter.

Below you can find a complete list of items and equipment needed for our project with an elaboration.

The equipment we need is:

- MDF plates
- Plates that are laser-cut into gear.
    - Two small gears
    - One medium sized gears
    - One large gears
- PVC tube
- Drill
- Wood
- green plate with the 6 bags
- Arduino
- Arduino board
- Water tank
- Dirt

The drill is held up by a construction of wood. This drill is connected to a small gear. This small gear turns the medium sized gear. This medium sized gear is connected to a small gear, which turns the largest gear. This setup slows the turning speed down while remaining the amount of torque produced by the drill.
The large gear is also the base of our garden, which has a layered second plate made of MDF. The sloped garden is made of MDF. The garden is supported by a PVC tube, which also acts as a pipe for the water hose and electrical wiring.
The wiring goes from the sensors to the arduino. A water reservoir is installed on the base under the second layer to protect it from the elements, but it will turn with the garden to keep the tubing simple. In the reservoir is a pump controlled by the arduino.
The drill is also connected to the arduino.

Chapter 8: Results and Conclusion

Results & findings

Due to the limited time we did not have enough time to properly test out prototype. For the prototype we used a pretty old drill, and the battery was barely strong enough to rotate the device. Because of this we were not able to leave our garden running for 24 hours, to get the best test results.
Because we were limited by a few things, we searched products and research related to our project. There are already rotating solar trackers. These can be single-axis or dual-axis rotatable. Our garden can only rotate around one axes, and is not able to adjust the angle of the height of the garden. There has already been a lot of research around this topic. A single-axis “solar tracker” gets a positive performance change between 25% and 35%, which means it will catch 25-35 % more sun. Our garden is also single-axes with a sun tracking system. We predict that our garden will catch 25% to 35% more sun than with a normal garden as well.
Another interesting thing is that a double-axis rotation device gets this 25-35%, and another 10% improvement due to the rotation around the other axis. This can be added to our ambitious plan if we decide to continue with the project.

Conclusion

We are very happy with our final result of our product. We had really ambitious plannes, so we could not include everything that we wanted. The most important part that we couldn’t make for now is the app. It in an important part in our Smart Environment, but due to the time limit we were not able to make it. We did make a small part of the app on a website, to show the people what our intentions were if we had more time. Making the app is in our ambitious plan, and maybe will happen in the future! But, besides this, we achieved a big part of our goal which is the automated vertical garden.

The collaboration in our group was fine. Everyone got a job he or she had to work on and we had communicated a lot with each other. If there was a problem with something or if you did not understand a certain aspect, we often came together for a group meeting. Everyone had a specific talent in our group, but he or she did not do that part alone. We always had multiple people working on the same parts of the project so they could help each other and they could learn from each others skills. By working this way our knowledge about a lot of subjects increased, and not only the subjects we were already good at.

There is always room for improvement, and we also learned this the hard way sometimes. For the next time it is better to start earlier with the physics(building) of the product. That way you have more time to realize, that maybe how you wanted to build the product at first, is not possible and that you have to find a good solution for your problem.

https://news.energysage.com/solar-trackers-everything-need-know/