Product: FarmFriend
Team: The FarmFriends

Abstract

FarmFriend empowers farmers by digitising farms, giving them precise and actionable soil health data in real-time for the entirety of the field. The system is divided into two core functions: a monitoring aspect, responsible for collating soil data, and a reactive element to pH, stabilising the pH of the soil based on the crop being grown. The reactive element is envisioned as a modular system, exchangeable to respond to different stimuli. The robotic system will be able to autonomously navigate through a given field, gathering, and uploading data to a web application, which displays key statistics to the user. For example, the data may reveal that there are specific subsections of the field that are under watered, providing the farmer with the information to investigate these areas (for which the reason may have been due to poor placement of sprinklers).

1. Pitch

The big data revolution has left behind modern agricultural methods. According to (Nathan DeLay, 2020), 38% of farmers surveyed believed data collection too costly, and 35% were unaware of how to use the data effectively. We devised FarmFriend, a cheap rental automated farm surveillance and crop maintenance robot in response to this.

FarmFriend provides the means for farmers to make data driven decisions to optimise yields and maximise profits. The robotic system is equipped with moisture and pH sensors to monitor soil health, from which the system can act by stabilising soil to a pH that is most optimal for the crop being grown.

We envision the pH stabilising component to be modular, exchangeable to cater for other nutrients, such as potassium. Not only does this distinguish us from competition, but it also opens further business opportunities with nutrient providers to meet our goal towards sustainable agriculture. So, why choose pH at first? A recent survey of arable soils in the UK showed that more than 40% have a soil pH less than 6.5. "This indicates that a large proportion of arable land is being maintained below the optimal soil pH" (Holland, 2019).

As the climate changes and severe weather events become more and more frequent, farmers will need to adapt quickly to maintain their yields. (Corey Lesk, 2021) predicts "Rising air temperatures are a leading risk to global crop production" due to the impact on soil moisture. With the help of FarmFriend's moisture sensor, farmers can quickly be notified and react to drying soil pinpointed to specific locations of the farm, increasing the overall yield and saving the farmer crucial time. Furthermore, agriculture accounts for 70% of global water use (OECD, 2018), yet "roughly 40% of the water used for farming every year is underutilised" (Balsom, 2020); FarmFriend aims to minimise water wastage, striving to use less and provide more to those who need it most.

2. The team

Our team has a diverse set of skills that can be applied to this project. All members of our team are competent in programming, with experience in both front-end and back-end development. Several members of our team are confident in their existing robotics skills such as navigation, vision and the three main controlling components: Raspberry Pi, Arduino, and ROS.

Three members of the team studied Introduction to Vision and Robotics in semester one of this year. A large portion of this course was dedicated to robotic vision and control, and so these members have some pre-existing knowledge in this area, and will therefore likely take responsibility for this subsection. This will be helpful particularly in the navigation aspect of the project. The course also provided valuable experience in using ROS, which will greatly help with a large portion of this project, and these members can also help with getting the others familiar with the operation of ROS and its processes.

While there are not any specific working preferences, everyone on the team would prefer to do more work at the start of the semester, as other courses' workloads tend to increase towards the end. If work on this project was also left to the end, it could create an impossible workload and cause the final product quality to suffer. Doing more work at the beginning will also help to ensure that any setbacks will not put a large amount of pressure on completing the work in a short time-frame, and there will still be plenty of time to adjust the plan as needed to keep the project organised.

Specifically, Niveda, Niamh, Alin and Gabriel want to work on the navigation of the robot; Niveda, Niamh and Gabriel have previous ROS and vision experience, and therefore are well suited to working on this aspect. Andrew, Charles, Xingchen and Sury will be working on the sensor component, moving them into place and returning data. Andrew, Xingchen, Niamh, and Charles will work on the reactive aspect of the system. Finally, the web app will be worked on by Gabriel, Alin, Charles and Sury. Gabriel in particular has a large amount of experience with app development, and has expressed interest in leading this particular segment. Other work like documentation will be worked on by everyone, however Alin, Sury and Andrew will help with collating and formatting the work.

As a team we will likely struggle with navigation, due to lack of experience. The members who have not used ROS may find it difficult to learn and develop simultaneously.

The mechanical aspect may also present challenges to the group, as only Xingchen has previous experience working with hardware. As a whole communication and teamwork will present a sizable challenge. No member of the team has any previous experience with working on a project with a team of this size. Making sure all subgroups communicate effectively will likely be the main issue in ensuring the project works well as the result of one cohesive effort.

3. Users

Agriculture is extremely important and due to increasing demand from population pressures, farmers are required to produce more food than ever. The aim of this automated farm surveillance and crop maintenance robot is to improve the existing farm environment for farmers. It is currently a very expensive process to test soil usability, because of which most new farmers tend to not do it at all, even though it is an important task to be done regularly (Perry, 2003). FarmFriend makes this extensively difficult task easier.

Currently, farmers are required to physically go around the farm to take care of the crops and the soil. To ease this process, the robot collects relevant data by navigating around the field autonomously, therefore reducing manual labour. The system then builds a detailed picture of crop health, allowing the farmer to infer things such as their expected crop yield more accurately. The system suggests to the farmer to take appropriate action that could be taken to prevent poor yields, or could inform the farmer of a potentially profitable financial year. Such statistics would have a huge impact on farmers, as Katie Stockstill-Sawyer explains "there are no guaranteed paydays and there's no guessing what the pay will be when it arrives". (Stockstill-Sawyer, 2019)

Testing soil pH and fertility is recommended every three years or twice per rotation (Cornell, 2005). However, ADAS, the UK's largest independent provider of agricultural and environmental consultancy, found that farmers were not doing this (Riley, 2019). This is most likely due to the high labour requirement and cost of doing such testing. FarmFriend tackles this setback by not only offering a low-cost, low-labour pH testing feature, but also the ability to adjust the pH of the soil where necessary, in order to optimise soil health, and thus crop yield.

The farmer can simply log into the FarmFriend web application to view the data collected by the robot (ie. photos of the whole farm in subsections, moisture and pH content in various parts of the farm). The farmer (ie. user) will have to initially register and create an account to the web application, from where they will be requested to input their crop type and soil type, from where the application will calculate the optimal moisture and pH content. The farmer can then request to rent the robot whenever necessary. Since data is stored onto a database server, it can easily be fetched and processed to produce many different analytics.

One of the constraints with having so much data is that we need to give careful consideration of how to best visualise this for the farmer, thinking of the farmer's actual needs, rather than presenting arbitrary graphs which may not be of much use to the farmer directly.

Another important consideration to make would be how we handle the data, a study (Leanne Wiseman, 2019) showed that 27% of farmers are 'not comfortable at all' with sharing their data to service providers. We would respect this decision by not retaining customer data, but instead providing data as a service to farmers to keep themselves.

To prevent crop damage we will design FarmFriend to be light weight. Similarly, it will need to be slow moving to reduce soil erosion around crops and limit crop destruction. Since FarmFriend may need to move in between tightly packed crops, a fast moving robot could rip or crush crops. We will also need to account for rough terrain navigation, as soil can be uneven and unstable. Furthermore, due to the robot being used outdoors, we must account for the weather. For example, if the weather conditions are not favourable (rainy or windy), then the robot should not be actively used in the field.

Other users of the system might include data analysts from our company, who would be able to (with permission of the farmer) provide bespoke analysis of key areas that the farmer may be concerned of. For example, the primary user (farmer) might want to understand why crop yields are low at certain locations of the field. The data analyst could process the data, and by applying machine vision techniques on the images for each subsection of the field, might find that this is caused due to weeds being grown in those areas. In this case, data analysts would have access to the same information as the farmers, but would have more expertise in processing data and using it to understand or predict outcomes.

One of the potential conflicts might be related to data retention between the company itself and the farmer. Since retaining data of various farms is not only profitable business model (Leanne Wiseman, 2019), it would also provide more data for our company to use for machine learning models to better understand how soil compositions can affect crop yields for example. In turn, this would also benefit customers, as we could provide them with more in depth information regarding their farms soil health. A simple solution to this is to simply ask the consumer (farmer) whether they would opt to share their farm data with our company or not.

4. Impact

FarmFriend will operate on a rental basis, with the option for purchasing the system for exceptionally large varied farms. It will be given to the farmer to control through the web app. The farmer would then start FarmFriend using the web app at which point it would begin collecting data on each subsection of the field. This data would then be sent to the web app and displayed for the farmer. The farmers would own this data to allow them to do data analysis whenever they want. After the rental time is up, the farmer would then return FarmFriend. This rental model provides farmers with cheap and simple access to field data collection as well as the full control of their data. It would replace large industrial machines that collect data which is controlled by large companies.

40% of the world's land is taken by agriculture (Prof Waler Willett, 2019), and fertile topsoil is running out due to soil degradation (Gray, 2019). Between one billion and six billion hectares of land are now considered to be degraded (Gray, 2019), and part of the reason is due to lack of soil nutrients. We believe that FarmFriend could help contribute by being part of the solution to this problem - autonomously gathering data about the soil composition of vast areas of land, and helping create the bigger picture to understand why land is degraded. The potential wider social impacts of this technology would not only benefit low-income countries suffering from soil degradation, but also the global food production. Many people living in low-income countries "could be forced to leave their homes in search of safety and fertile lands" (Begum, 2021), yet that could be prevented by adding nutrients to rejuvenate soil.

We acknowledge that there are similar existing systems as IoTs in practice (Hughes, 2021), however, these often have little practical use after their first measurements. For example, pH measurements will not deviate very much over the course of days, and so there is heavy investment in infrastructure for the IoT system, but much of the data is only useful over the course of months. This is where the 'data as a service' model of our robotic systems outperforms the IoT system, allowing farmers to 'rent' the system to collect data whenever, wherever they need for a fraction of the price. A lower cost system would be accessible to low-income countries, helping them drive up their yields, and preventing them from leaving land that could be made fertile, like mentioned previously.

A downside is the potential unemployment of farm workers who assist the farmer in menial tasks. If FarmFriend begins automating away their jobs, the farmer may opt to use the robot instead of employing help (Liu, 2020). In addition, getting the amount of acid to spray on the soil is very crucial as it can cause damage to the crops. If soil is too acidic, it creates deficiencies in the available supply of nitrogen, phosphorus, potassium and magnesium (Darling, 2021). Finally, if the cost of the rent is too high for some farmers, it could lead to more inequalities between richer and poorer farmers, with poorer farms not being able to benefit from data collection and automated maintenance.

5. Outcomes

The primary objective of Farm Friend is to navigate through the fields, collecting needful data, and send the data to the website which farmers can interact with. Additionally, the robot will deposit the required amount of acid or base if the soil is pH unbalanced. Therefore, the essential functionalities for our robot would be, firstly a navigation system which enables the robot to find its way through the farm fields. Secondly, it must have the capability of sensing and collecting the desired data from soil, such as the pH value and moisture level. In addition to that, the robot will also be able to release the right amount of acid or base if required. Moreover, there is a website within our system, so that farmers can obtain the status of their fields from the website based on the data provided by our robot.

Our system satisfies the users' needs by directly collecting data on small subsections of the field. This functionality provides farmers with the ability to micromanage their crops. Due to the automated nature of FarmFriend, this will reduce manual labour allowing them to focus on other tasks. Furthermore, due to the repetitive nature of farmers continually inspecting their field, our system allows farmers to quickly inspect their entire field from anywhere.

Field navigation is the highest priority task. The navigation has to function properly so the other vital systems that help the farmer, for instance data collection, can be deployed. Data collection and communication are the next two important tasks. The farmer will only benefit from FarmFriend if the data is collected accurately and in the correct location. Moreover, if the data is poorly communicated on the website, the data would be pointless.

The most important data to collect is soil moisture and pH level. Soil moisture data will tell the farmer exactly where in their field there are low water levels which will reduce crop yield. pH sensing will allow FarmFriend to make adjustments to the soil without the farmer being involved and it will inform the farmer where in the field pH is not optimal.

One of the optional functionalities that we are considering is to mount further sensors, such as a thermal imaging camera. This could be used for many different applications, such as determining plant stress (Bonny Stutsel, 2021), which allows us to understand whether a plant is showing signs of being under watered for example, which would be indicated by higher temperatures. Another application of a thermal camera would be in conjunction with the regular mounted camera, from which machine vision techniques could be applied to perform pest detection (Jwan Al-doski, 2016), helping the farmers avoid crop losses, and target the problem before it gets out of hand.

Much of the optional functionality relates to machine learning that can be applied to the data that we gathered for the farmer. An optional functionality that we considered for the navigation system would be to detect individual plants using machine vision, and target data collection more precisely to specific crops individually rather than subsections of the field. However, since this will not noticeably change the readings taken from our instruments, we are only considering this as a low priority optional feature, due to its complexity.

For navigation, we will set up a demo farm which will have prop crops in rows. We will have successfully implemented a navigation functionality if it can navigate the demo farm visiting every sub section whilst avoiding the prop crops and other obstacles. To demonstrate the proper functioning of the data collection system, we will use a container of model soil on which we will test the manoeuvring of the sensors and the return of data. If the system moves the sensors into the correct position and returns data, then the robot will be assumed to be functional. Finally, the pH regulation system will be tested using a variety of test soils with different pH levels. To check if the robot sprays the right amount of chemicals to balance out the soil's pH, we will test it by measuring the duration of the LEDs that represent the sprays.

6. Tasks

As shown in Table 1, the project can be broken down into 5 relatively independent sub-teams, each of which have their own responsibilities that combine to form the overall project.

All of the subsystems require the control system to work. It must communicate properly between the system to prevent any timing issues, like the navigation system starting with the sensors in the ground. The reactive subsystem requires the field sensors to work and give accurate readings, otherwise it will either not turn on or provide the wrong response. The web app also needs the field sensors to work for data to be displayed.

Testing, although not directly constructing the robot, is a vital task that must happen continuously. We must test each subsystem consistently as we develop the system. Each team will be responsible for testing the subsystem they are in charge of. As the development process of each subsystem progresses, testing will be done thoroughly to ensure proper functionality of the system and to detect bugs at an early stage. Testing the overall system's functionality is absolutely crucial. We anticipate to begin with this process approximately a week before the final demo. We will conduct system tests to ensure all subsystems work in tandem and the full functionality of the robot can be utilised.

Other work that is not directly constructing the robot will be presenting the robot at demos. We will need to prepare an oral presentation and a technical demo. This will require planning and report writing. The documentation is another area which will require attention which is not directly building the system. Documents need to be formatted and written about each aspect of the different subsystems and presented after the demos.

Some tasks will take much longer than others. Navigation will take the longest due to its complexity. We predict that the navigation team will need time until week 9 to implement the autonomous moving through a demo field. The field sensors deployment functionality will require the first two weeks of development, after which the implementation of the reactive system can begin lasting three weeks. Concurrently, the web app will begin and will continue to be worked on until the end of week 10. The planning for each demo will occur several days before with the documentation, requiring roughly two days of work.

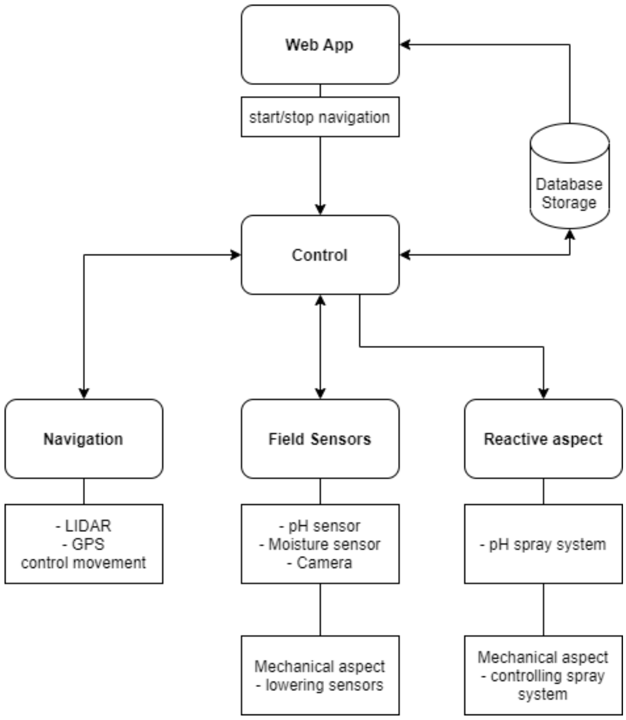

Figure 1. FarmFriend System Design

For demo 1, our goal is to display a working field sensor system, which, as shown in the Gantt chart (Figure 2) forms part of the sensors sub-team. The goal of this demonstration would be predominantly to showcase the lowering mechanism for the sensors to drive them into the ground. Since the sensors are connected to the mechanical system, we aim to have software written on the Arduino driving the sensors and lowering mechanism to display the measurements from the sensors on a small LED screen. As there is a shorter time frame for this demonstration, we will have a relatively simple presentation that is functional and complete for one sub-team of the multiple sub-teams we derived for this project. We chose to demonstrate this mechanism first as it is very much independent from the rest of the components of the system, such as navigation for example, allowing us to not have dependencies on other parts of the system working for the demo.

As the Gantt chart (Figure 2) shows, there is an emphasis on starting work on the sensors, prototyping the physical construction of the robot, and navigation. Obviously, since we identified the work for sensors to be independent and small enough to be shown for the first demonstration, we will start working on it as soon as possible to ensure that we have a functioning sensor model for the first demo. Although prototyping the physical robot will form a major part of sensors and the reactive team, we would dedicate additional hours to this work, as it would require careful consideration for placement of the components of the system. As previously mentioned, we identified navigation to take a considerable amount of time, and thus, we decided to start working on this early in the project to ensure that we have enough time to test its capabilities, and ensure that we have enough time to have a working model for our final demonstration.

For the second demonstration, we aim to show a reactive system that is able to use the sensor readings taken from the sensors (from our previous demonstration). More specifically, this part relates to the acid/alkaline dispersing system, for which we will need to decide on an appropriate way to demonstrate this. Our contingency plan for demonstrating the acid/alkaline dispersion is to show a functioning mechanism for dispersing liquids/solubles, without actually containing any liquids/solubles. Instead, this would be represented by different colours of an LED indicating the quantity of the dispersion, and the colours representing whether this was alkaline or acid. As shown in the Gantt chart (Figure 2), we also aim to have a front-end design complete to showcase in time for the second demonstration; though we anticipate this not to be functional, due to the back-end system needing to be designed in time for the final demonstration.

For the final demonstration, we aim to have a fully autonomous robot navigation system, which accounts for factors such as farm border detection for example. The robot would be able to perform iterations of navigation, lowering the sensor system to take readings, and calling the reactive aspect accordingly if needed. Furthermore, the web application would be able to display numerous metrics collected from the robot, and the robot will be able to transfer data seamlessly to the web application. Finally, we have planned for some tasks taking longer than expected by leaving a 5 day gap between our core requirement features and the final demonstration, giving us enough time to implement testing as well.

7. Risks

A major risk of our plan is if a member of the team is unable to do their assigned task due to external forces such as illness or injury. Due to the ongoing COVID-19 pandemic any team member to test positive would have to isolate for a minimum of seven days, and other team members who are close contacts could also have to isolate. This would greatly affect the ability to work on the project, especially with aspects that must be in person, such as hardware. If members of a team that is reliant on in person interaction are unable to participate, then reassigning team members may be required, in order to keep all aspects of the project running together. Continuing to have meetings online would help to ease adverse effects of continued isolation on the group.

If a particular subsection of the project takes longer than anticipated, this would impact the plan that has been set out. Having regular team meetings to check on progress would help to reduce this risk, as preventative measures could be put in place if it seems like a particular aspect is more challenging or time consuming than previously thought. These measures could be assigning an extra member to the group in order to reduce workload on individuals, or reassessing the method in which the task is being executed. If the section still takes an overly long amount of time, keeping the plan flexible and adaptable is important to recovering.

In addition, lack of communication within the team could also become a potential danger and cause lack of clarity and confusion which will raise more problems in the future. For example, without enough communication, the team may end up with people doing repetitive work without realising, as a consequence, the progress of the whole project gets affected. In order to avoid this, effective and timely communication is a significant work ethic that everyone should strictly follow. Setting up meetings with team members on a regular basis can help to reduce the negative impact of lack of communication.

Project conflicts not resolved in a timely manner can also be a risk when engaging a project plan. Unresolved conflict will bring a negative impact on the relationship between members. For example, it can result in eroded trust, decreased motivation, lowered morale, increased stress and health risks, decreased performance and productivity. The only way to prevent conflicts occurring is to try to avoid any form of aggressive behaviour when sharing ideas, so that conflicts will not exist in the first place.

Furthermore, in case a risk occurs, the team should also have a quick and reliable contingency plan ready for action. The plan should neutralise or prevent further damage and prevent a continuation of a crisis. Bringing as many possible problems into the planning and implementation before they occur and come up with possible solutions.

One of the risks that we have identified is that we have divided the project teams very finely, and this brings the risk of people in different project teams not being very aware of what is happening with the overall project, due to lack of communication with other team members. We have tried to mitigate this from happening as much as possible by having a project lead, who is responsible for overseeing the project in its entirety, in the sense that, each group is on track and their work is able to be integrated to other groups eventually. We also have recurring meetings twice every week, which are set up as SCRUM based team discussion, in which team members can provide any updates to other members, and talk about any ‘blockers’ that might occur.

We have tried to mitigate issues relating to team and time management as much as possible by assigning project leads to each sub-team, who are responsible for making sure that the project is kept on track in accordance to our initial plan, and that any deviations are justifiable.

References

Balsom, Paul. Water usage in the agricultural industry. 2020. URL https://htt.io/water-usage-in-the-agricultural-industry/.

Begum, Tammana. Soil degradation: the problems and how to fix them | natural history museum (nhm.ac.uk). 2021. URL https://www.nhm.ac.uk/discover/soil-degradation.html.

Bonny Stutsel, et al. Detecting plant stress using thermal and optical imagery from an unoccupied aerial vehicle. 2021. URL https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8579776/.

Corey Lesk, Ethan Coffel, Jonathan Winter Deepak Ray Jakob Zscheischler Sonia I. Seneviratne Radley Horton. Stronger temperature–moisture couplings exacerbate the impact of climate warming on global crop yields. 2021. URL https://www.nature.com/articles/s43016-021-00341-6.

Cornell. Soil ph for field crops. 2005. URL http://cceonondaga.org/resources/soil-ph-for-field-crops.

Darling, Leslie. Acidic soil problems. 2021. URL https://homeguides.sfgate.com/acidic-soil-problems-37881.html.

Gray, Richard. Soil erosion: Why fertile earth is being degraded and lost (bbc.com). 2019. URL https://www.bbc.com/future/bespoke/follow-the-food/why-soil-is-disappearing-from-farms/.

Holland, J.E. Yield responses of arable crops to liming – an evaluation of relationships between yields and soil ph from a long-term liming experiment. 2019. URL https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6472519/.

Hughes, Joe. Soil monitoring with iot. 2021. URL https://www.manxtechgroup.com/soil-monitoring-with-iot-smart-agriculture/.

Jwan Al-doski, et al. Thermal imaging for pests detecting. 2016. URL https://ijafp.com/wp-content/uploads/2016/03/KLIAFP2_20.pdf.

Leanne Wiseman, Jay Sanderson, Airong Zhang Emma Jakku. Farmers and their data: An examination of farmers' reluctance to share their data through the lens of the laws impacting smart farming. 2019. URL https://www.sciencedirect.com/science/article/pii/S1573521418302616.

Liu, Jane Alice. Will agricultural robots replace human agricultural labour? | opinion. 2020. URL https://www.foodunfolded.com/article/will-robots-take-over-human-agricultural-labour-opinion.

Nathan DeLay, Nathanael Thompson, James Mintert. Farm data usage in commercial agriculture. 2020. URL https://ag.purdue.edu/commercialag/home/resource/2020/01/farm-data-usage-in-commercial-agriculture/.

OECD. Water use in agriculture. 2018. URL https://www.oecd.org/environment/water-use-in-agriculture.htm.

Perry, Leonard. ph for the garden. 2003. URL http://pss.uvm.edu/ppp/pubs/oh34.htm.

Prof Waler Willett, et al. Food in the anthropocene: the eat–lancet commission on healthy diets from sustainable food systems - the lancet. 2019. URL https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(18)31788-4/fulltext.

Riley, Jonathan. Adas warns farmers over soil test rules. 2019. URL https://www.fwi.co.uk/arable/land-preparation/soils/adas-warns-farmers-over-soil-test-rules.

Stockstill-Sawyer, Katie. How do farmers get paid? 2019. URL https://newtothefarm.com/2019/06/11/how-do-farmers-get-paid/.

Sub-team	Responsibilities
Navigation	Implementation of an autonomous navigation system that is able to move the robot in order to traverse a field and avoid colliding with various obstacles using robotic vision.
Control	Directs the movement and function of various parts of the robotic system, acting as an intermediary that communicates with all other subsystems. One of the main features of the control system would be to ensure that the lowering of the sensors is synchronous with the navigation, for example the sensors should not be lowered whilst the robot is moving.
Sensor	Will control the deployment of the array of sensors, return the data to a central system and retract any sensors that are in the ground.
Reactive	Create the system responsible for deploying the required amount of chemicals to the soil or crops. For demonstrative purposes LED's will be used to simulate the chemicals
Application	Develop a web app that displays the data collected by the sensors in a readable UI, as well as status data of the robot. The application also has start and stop buttons for the user to remotely control the deployment of the robot.

Table 1. The sub-teams with their responsibilities.

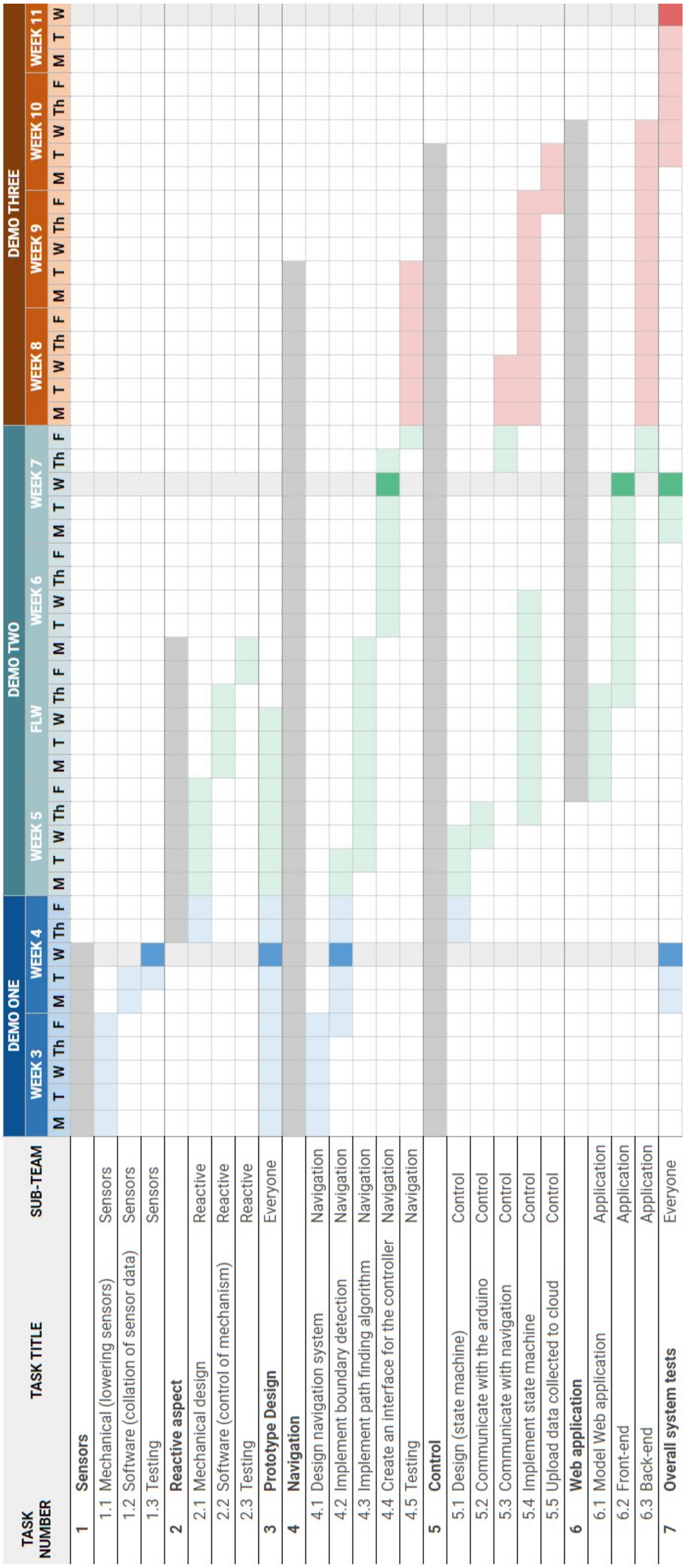

Figure 2. Gantt chart