Automatic Pet Feeder

EEL 4914: Senior Design 1- Group 12

Devin Besaw - CpE

Fernando Oviedo - CpE

Gershon Prospere - EE

Jose Tapizquent - CpE

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1. Executive Summary

In the United States alone, more than half of households currently have pets serving as their furry companions and forming part of their family. Pets provide some of the happiest moments a person can have in their life. They serve as emotional companions, service animals and even just roommates and friends for those long at-home work days or those nights where after a long day, they receive you with the happiest and most excited greeting. Pets form a bond with their household that they become part of the family and learn to care for us and protect us at all times. Taking into account how much pets care about their owners, it is important for the owners to care just as much and to ensure that their pets can have a comfortable and enjoyable experience while coexisting and enjoying their days together. One of the ways, and probably the most important way pet parents can care and ensure their pets are receiving their necessary daily intakes and having a proper diet at all times, is by simply keeping a consistent and nutritious feeding schedule for their pets. However, taking into account today's busy and fast paced life, even this task could become complicated due to the fact that sometimes different situations happen where the person responsible for the care of the pet may be out of town, or they are physically unable to provide the pet's food and ensure the water bowl is also filled.

In the past couple years, many gadgets and devices have come to market, all which try to provide some degree of aid and ease of mind when dealing with our pets' care and ensuring their wellbeing. From simple attempts such as, repurposing existing cereal dispensers to more elaborate systems, pet parents are resorting more often to looking for ways to take back some time from repetitive tasks while providing the best care for their pets. Even though many devices provide help with different aspects of our four legged companions' care, automatic pet feeders have become very popular globally among pet parents because of their ease of use and how convenient they can be by providing the user with several settings to accommodate their wants and needs, with features that they can control whether through the device itself or remotely.

Our goal throughout this senior design report and project is to design, program and build a functionally stable automatic pet feeder where the user, in this case the pet parent, is able to control every setting, schedule, and be in the loop on their pet's feeding habits from their phone through a mobile application that interfaces wirelessly with the automatic pet feeder. Providing a user-friendly interface, the user is guided through the initial steps on how to set up the feeder and how to control the basic settings of it. This will allow anyone to feed their pets no matter where they are. Since this automatic pet feeder must behave in an easy to use manner and provide a lot of value to the pet parents, there are several requirements that were put in place to make sure the device is fully functional and behaves as automatic as possible. In the same manner, the device must be able to accurately measure the weight of both the water and food bowl and keep track of their state. Once the water or food level is under a minimum threshold, the device must automatically check for the last pour cycle, confirm with the schedule set in the application and if the conditions and rules set by the user are met, it should pour the predefined amount of food for the pet as well as refill the water bowl to ensure that the pet has enough to eat at their pet parent's desired meal times. At the same time, the device must be able to maintain a two way communication with the mobile application in order to send the user notifications when some tasks require assistance, such as refilling the main water and food containers or cleaning the pet bowls.

2. Project Description

This project aims to fully automate the process of feeding your pet. The intention behind this is to keep them on a consistent diet, which is essential in ensuring your pet lives a happy and healthy life. The automatic pet feeder will be paired with an app that asks for your pet's breed and weight to determine the correct amount of food to give each day. The device will measure the correct amount of food out on its own and disperse it at specific times of day set by the owner. Additionally, the app comes with the ability to send notifications to alert the owners when food or water is low and gives them the option to feed them as well.

The design of the pet feeder will feature two containers where one is used for food while the other is used for water. For the container that is filled with water, it will deliver water into the bowl through the pump at a steady speed. The container filled with food will use a motor that will spin a wheel, allowing food to be dropped into the bowl. The wheel will be a set size, but if the owner decides to put more food, they can tell the application to pour any amount of food more than once.

Our motivation to build a pet feeder is to solve several problems that owners encounter when taking care of a pet. Sometimes, pet owners are busy with other life events or work that they wouldn't have any time to feed their pet. As time progresses, more people are becoming busier each year. So, they would have moments where they would not be able to fully take care of their pet every day. So, sometimes they may overfill the bowl to make sure their pet doesn't starve, but what about filling the other bowl with water. It is also very important for the pet to have water but it's not like you can overfill it like a food bowl.

Therefore, it would be important for there to be a set schedule for the pet feeder where the owner wouldn't have to keep filling the bowl. All they would need to do is make sure the container is filled, and the pet feeder would do the rest of the work. This way, the owner can cross that off the to-do list and take care of the business they have to attend to because the pet feeder will take care of their pet. In addition to taking care of business, the owner also would be able to leave their home and still have the ability to feed their pet, because the pet feeder would be connected to a mobile application where they can feed their pet from anywhere. For example, if it's just one person that lives in a house and they work all day, while they are at work, they can use the app to feed their pet.

Unfortunately, in some situations the pet needs to go on a diet. Our pet feeder will allow the owner to choose how much they want to give their pets so they could limit the amount of food the pet eats. This way, the owner wouldn't have to measure the amount of food given every time it's time to eat. Overall, the pet feeder will give pet owners an opportunity to not only set a schedule to feed their pet, but also feed them whenever they want.

This project will provide an exciting journey for our last few semesters as we will be working with developing apps and using sensors, motors, pumps, and other electronic components we don't get to work with often. Not only will it help us get familiar with these components, but it will help us learn and fully understand how and why they're used.

2.1 Goals and Objectives

In today's busy lifestyle, many pet parents are finding themselves having to compromise valuable time in order to ensure that their loved pets have all the basic needs they require, such as water, food and shelter. According to a report done by Science20, millennials and gen-z are considering their pets as the `new` kids and are increasingly looking for ways to provide them with the best possible care. As other responsibilities arise throughout the day, and taking into account a pandemic that has made life at home a whole lot more hectic and busy, providing pet parents with a way to streamline and automate some of the repetitive and cumbersome tasks of caring for their pet, can alleviate the complications and time required to ensure these basic needs are met.

The Automatic Pet Feeder provides the support that pet parents need in order to keep their pets always cared for. By automating the pet feeding and water bowl tasks, pet parents can focus their time on other activities, such as playing fetch, and giving belly rubs, while always having the peace of mind that their pets will always have food and water. Not only will pet parents be able to automate these tasks but also to adjust the amounts, timing and general setting of the feeder to meet their needs. The motivation for this project is to demonstrate our knowledge and understanding of engineering concepts and processes that we have acquired during our time at the University of Central Florida. Not only does this project serve as a great display of our skills as future engineers, but it also provides us with a chance to collaborate as a team on a meaningful project and get some more hands-on experience that we can carry over to our professional careers.

This project is also composed of several goals and objectives that describe the standards that we abide by when providing an end design and the expectations that we hold for its completion. These goals and objectives include but are not limited to,

Accuracy - Different pets require different care, whether it is a dog, a cat or another household pet that requires eating dry food, the amount of food and meals can differ drastically depending on each pet and the parent's preferences, therefore ensuring that the automatic pet feeder provides accurate quantities on a consistent, accurate schedule is of utmost importance. By providing a reliable schedule, the pet parent can be sure that the dietary needs of their pet are met each and every day without fail. It is important that we achieve a certain level of accuracy, because we must create a device where the owner is confident that it will dispense the amount of it they want it to. If the pet feeder cannot provide an accurate amount of food and water to the pet then the pet owner would not be able to put their pet on the proper diet they decided to put it on. The result of the pet feeder not providing the right amount of food could result in the pet either becoming underweight or overweight. However, if it is able to give the right amount of food every time, then the device can build up trust with the pet owner which will give a sense of satisfaction making the product worth the effort.

Convenience - As outlined throughout the entirety of this document, we aim to provide pet parents with an easy and convenient way to ensure their pets have most of their basic needs covered at all times. By providing an automatic way of serving food and water for the pet, the parent does not need to worry that the correct amount of food has been served and that the water has enough for their pet to easily access and drink whenever they desire. All of this creates an

enjoyable experience for both the owner and the pet. Adding on to the convenience factor of the pet feeder, it saves all the pet owners a bit more of extra time, because they would not need to spend a couple minutes every day to feed their pet. The tank that is going to be used to hold the pet food that the owner chooses, will be able to maintain that pet food for several days. This means that whenever the pet owner buys the food they can pour more into the tank which will allow them to free up space much sooner without spending more money since it is the same amount of food, but they are able to pour maybe the whole bag into the tank. Since water is not something that needs to be bought from the store and generally not something that pet owners concern themselves with too much. However, similar to the food tank, they are able to pour water into the tank and it would be full for a longer amount of time and this would save them a lot of time. Since the food and water would be in a container, that would help prevent the food and water from being contaminated with any pests or bugs that decide they want to have a snack as well. On top of making it more convenient of not having to add food so frequently, the weight of the food can stabilize the pet feeder even more which would prevent the autonomous pet feeder from tipping over depending on how active the pets may be. On the other hand, there are many pet feeders that exist already and have a very little amount of sensors. A lot of these pet feeders are only functional for pet owners to put food in the tank which will pour the food into the bowl based on the clock that it was set to. This is what makes our project different, because we are going to be including several types of sensors which will help us achieve more of the autonomous title which will also be a major improvement compared to the rest of other automatic pet feeders. When feeding the pet from the pet feeder, there may be a bit of noise that would make the pet run away, because they would not be used to hearing a noise like that. It is very similar to when pets hear a vacuum and they run away. We will find a way to make sure that the pet feeder does not make a lot of noise which not only would not make the pet scared, but it would make it much easier for the pet owner to be able to feed their pet since they will be there. One drawback to consider is that most likely the pet feeder would mostly be able to handle dry foods, because it is much easier to pour dry foods rather than wet foods. Pouring wet foods into the tank would not only be difficult for it to pour into the bowl but that would require the pet owner to wash the tank more often which would be very inconvenient. However, this is not too much of a drawback, because most pet owners around the old mostly use kibble to feed their pets anyways. So, although the pet feeder may not be versatile enough to also provide wet foods for their pet, it will still accomplish what it was made for and more. Other pet feeders are made to look sophisticated and aesthetically pleasing, but what happens is with it looking like that, that makes it more difficult to clean, because it is more complicated to take apart. Our pet feeder would not have this problem as we are going to have a very simple design that makes not only the functionality, but also the maintenance very easy to do. Our pet feeder will also have a dual power system, just in case a blackout happens or the home of the pet owners loses power. It will function primarily based on a plug into the home, but if it is not plugged in, then there will be a backup where it will function based on batteries.

Software - One of the convenient features of the automatic pet feeder, and probably one of its most important ones, is its integration with a mobile app. The mobile app will contain settings to set the amount of food that the device dispenses on each meal, how many meals happen a day and a way to halt the automatic process as required, whether this is for purposes of cleaning or because the pet isn’t at home. The software that the mobile app is built on must be free of any major bugs and be reliable in order to ensure that the correct settings are being propagated to the

device and that the core features that the feeder provides are all configurable and easy to modify. The software must also be active and ready to use at all times; any interruption to the service will prevent the parent to even use the feeder as they would expect and would prompt them to regress and use a different more manual alternative to feed their pet.

Hardware - Since pet's exist in a physical space, providing software without its hardware counterpart would not be much effective, and would, in our case, be borderline useless for the purpose of providing a convenient and easy way to feed pets. That is why the hardware that the device is built on must, at a minimum, be able to complete all the tasks that are listed as basic features of the feeder. The feeder must be able to plug in to a power source and stay online while it is receiving enough power. It will also include a microcontroller which will be responsible of controlling all aspects of the feeder, including the dispensing of both water and food, keeping track of when and how much food was served and allowing for notification to the mobile app as well as being able to handle the commands sent by the mobile app in a timely manner. Hardware is the backbone of this device as is it with most devices, because if we cannot have our hardware work, then we would not be able to do anything else. The pieces in our hardware must be able to provide power to every single part of the pet feeder, because in order for our pet feeder to fully accomplish what it was made to achieve, we need to provide power to every single component.

2.2 Block Diagram

The block diagram, as shown in Figure 1, provides us with a broad understanding and big picture view of how all the parts of the device work together to provide an effective solution to the problems highlighted throughout this paper. The diagram shows the device as a whole with all its components connected in a way that highlights how the information flows from one to the other. At the same time, the diagram shows a clear separation between the hardware components and the software application that allows the pet parents to interact with the device. In the design, we see that at its core, the application provides simple functions that allows for either the automatic calculation of the amount of food to be dispensed based on the pet's weight and breed previously registered by the user, or the explicit input for the amount of food that should be dispensed based on the user's preferences for that meal cycle. The application then relays this information to a processor which builds the message and determines the amount that should be sent to the machine via the communication module. The application also provides a notification system, which receives messages from the device, such as when the food containers are running low, or any communication that might be important for the pet parent to know regarding feeding, refilling or general status of the device, in case any manual action is required from the user. Continuing with the diagram, we observe the different components for the hardware side of the automatic pet feeder. The design is currently split between three main clusters. First, we have the microcontroller, which serves as the brains of the operation by processing messages coming from the mobile application, reads sensor input, calculates weight of food and water bowls, and communicates with the motors and pump to dispense the correct amounts based on the settings previously set by the user and the instructions coming in. The second main cluster we encounter is the sensors, these include weight sensors for each of the bowls, sensor for measuring the amount of food and water in the containers and for distance of pet from the device. Lastly, we have the pumps and motors, these are in charge of reading the information from the microcontroller and dispensing the correct amount of water and food to the bowls at the predefined feeding cycles.

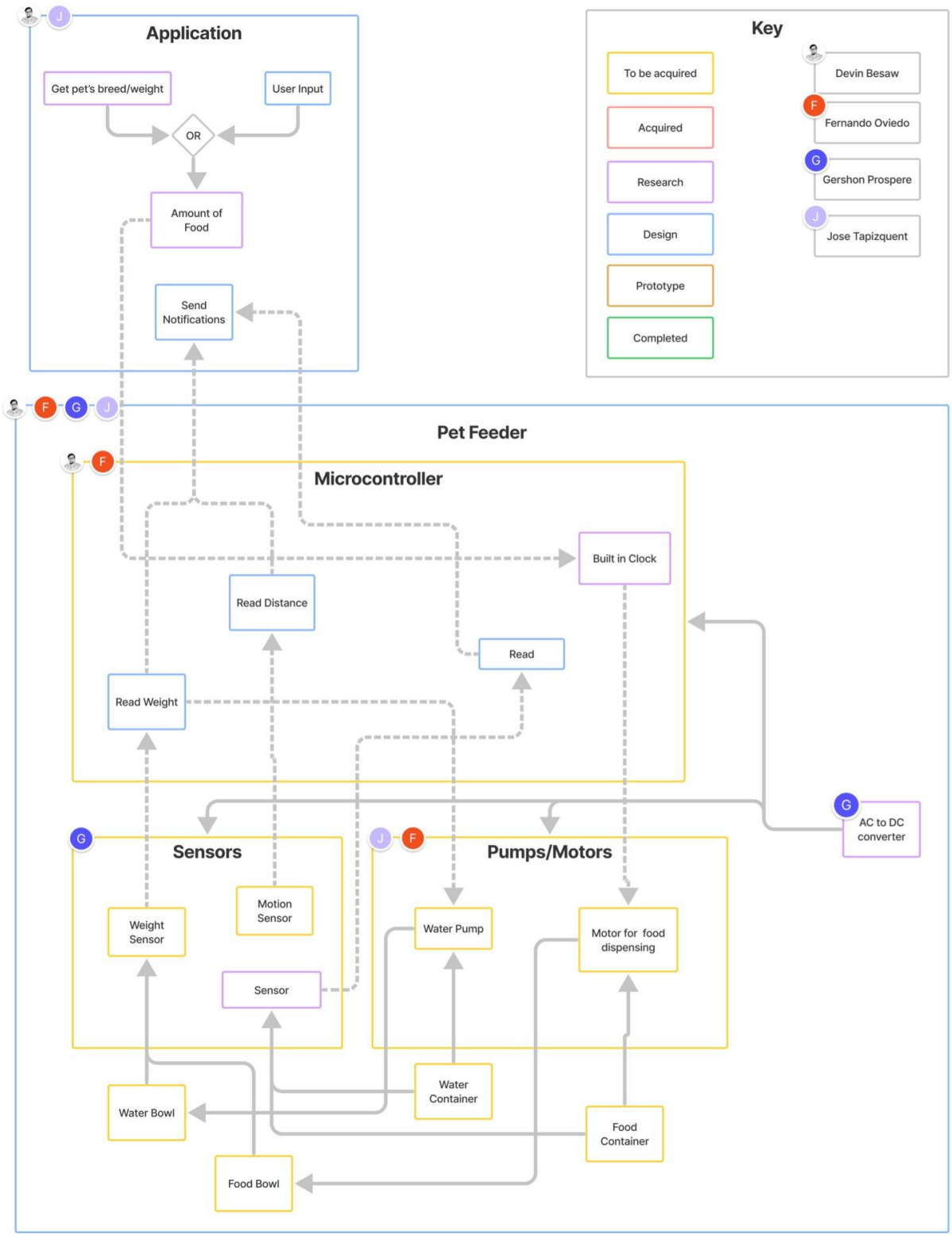

Figure 1: Block diagram of hardware and software

2.3 Design Overview

The current design in Figure 2 consists of two containers which serve to periodically pour food and water into the pet bowls. The two bowls contain funnels at the top in order to allow the user to fill up the containers in an easier manner. Both containers have sensors that will determine when food or water are running low to be able to notify the user for them to refill them at their earliest convenience. The water container contains a pump that is in charge of pouring the desired amount of water into the water bowl; the pump will only activate when the water inside the bowl is running low. In the same manner, the pet food container includes a measuring cup that holds about half a cup of food which is connected to a motor. This motor rotates 180 degrees in order to drop the food into the pet food bowl. If more than half a cup of food is required, the motor spins several times until pouring the desired amount the user configured in the app. Both the water and pet food bowls include weight sensors at the bottom that let the user and inner control know how much is left in each of the bowls and tell the program how to act accordingly. The pet feeder also includes a motion sensor that determines whether the pet is close to the feeder and allows for food to be dispensed.

The automatic pet feeder's design is not only composed of a hardware device that holds food and water but it also contains a mobile application which serves as a communication hub for the device. The mobile app serves as a one stop shop for managing all the settings of the pet feeder itself, it allows the user to configure different aspects of the feeder, such as the amount of food it should serve per meal, the amount of meals it should serve per day and allow for other settings such as pouring food and water on command when the user needs it instead of waiting for the predefined timer to be reached, which is a bit of a manual task, we agree. The app not only sends information to the feeder in order to change its settings but it also receives communication back from the feeder. The communications received by the feeder serve as notifications for tasks that the user should be made aware of. These notifications include letting the user know when either of the containers are low on food or water, the device is misbehaving and needs a restart, the water has not been changed in a while for the pet, or any other important information regarding the feeder.

In order to make the app functional, the feeder's main body will contain a microcontroller capable of communicating with an external mobile app. The microcontroller will contain a communications module which will be programmed to listen to incoming commands from the mobile app and react accordingly in order to adjust any settings or process and instructions the user sent. In the same manner, the microcontroller will keep track of the state of the components of the feeder in order to send the respective notifications to the user back in the mobile app.

An initial design prototype of the feeder can be observed in Figure 1 below. It includes an outside view of all the components necessary for the actions to be properly performed in the feeder. As observed, the funnels at the top of the containers allow for easier pouring of both water and food. The feeder also contains a camera, displayed in Figure 2 between the containers, which allows the pet parent to periodically check the camera feed in order to better interact with their pet, even when they are not physically present in the household. The food container also includes at the bottom, a predefined measuring cup which will make it easier to provide different amounts of food depending on the user's preferences.

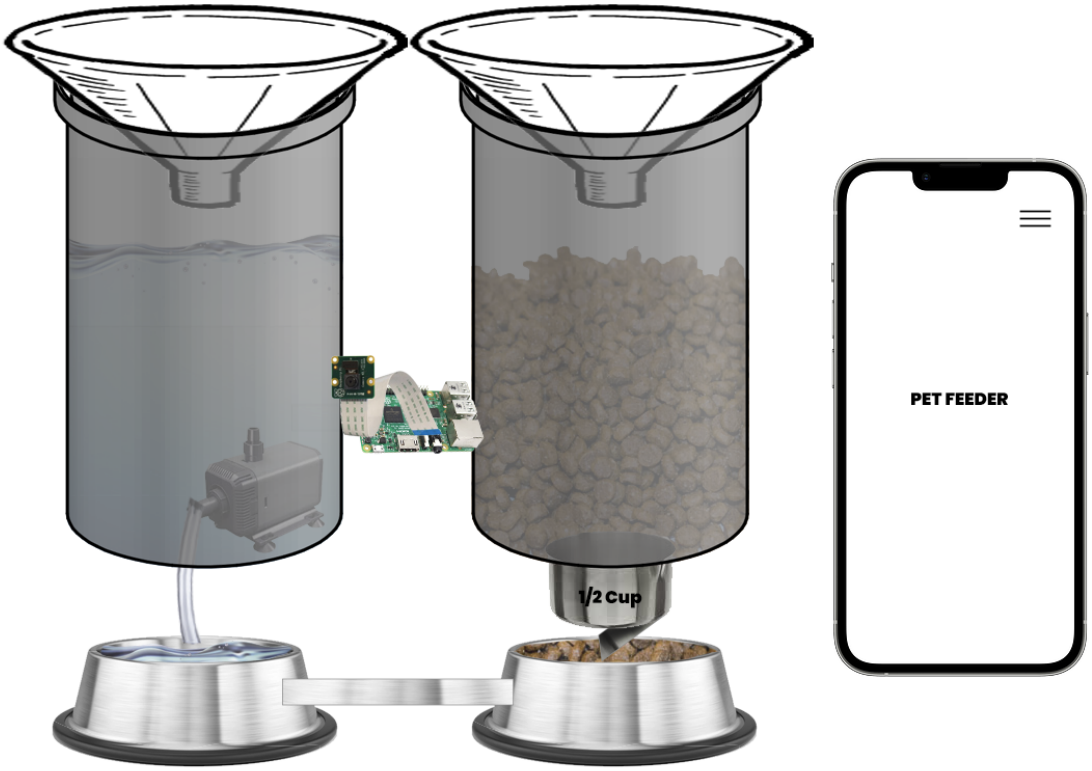

Figure 2: Initial design idea

2.4 Features

This section will mention the many features that the automated pet feeder will have and explain why they are important.

2.4.1 Basic Features

The app will be where almost everything is controlled. It can function like an alarm when there is not enough food and water in the pet feeder. It will also allow the user to pour either the water or food from their device so they would not have to physically be there to feed their pet. When pouring the meals for the pet, the user can make a decision on how much they would like to put in, and once they have made their choice, the pet feeder will then drop however much that the user decides. Another feature of the app would be different options based on the breed of the pet.

There will be different options of dog and cat breeds, and the amount of food poured will vary based on the user's choice. The flood sensor will be able to detect the current water level of the container. Once the water level reaches a certain point, the sensor will activate and this would send a notification to the app on the user's device alerting them that the amount of water in the container is not enough. When the user uses the app to send a signal to the microcontroller, the pump inside the pet feeder will activate and pour water into the bowl. If the sensor does not work properly then that means the pump would pump water continuously which would mean that all

the water in the tank would be emptied and since the bowl can only hold so much water, then it would flood and cause a mess by the pet feeder which the pet owner would need to clean up.

Other than continuously pumping water, the other impact could be that it would not pump water at all. As a result, even if the pet is drinking water, they would not be able to keep drinking water, because it would run out and since the sensor would not be working, the pet would be able to drink water. On top of both of those consequences, that also means there would be no notification being sent to the device that is linked to the pet feeder, because the sensor was never triggered. Overall, without this sensor working there would be a serious problem for the pet owner to provide their pet with the proper amount of water so they can stay hydrated. The weight sensor will be used to measure the amount of food in the other container.

This sensor will operate just like the sensor for the water bowl. These sensors will make it very easy to keep track of how much food and water is in the containers and will alert you as soon as it activates. When the user chooses to add the food into the bowl, they can use the app that is connected to the pet feeder. The app will be connected to the microcontroller inside and will signal the circuit to deliver power to the motor which will then turn the wheel to provide the food into the bowl. The device would have a built-in clock that will turn the motor which will then spin the wheel by a set angle so it can pour the food in the bowl.

The consequence of the weight sensor not working is a bit worse than the flood sensor, because it is simpler to find an alternative to provide water for their pet compared to pouring food. If the weight sensor does not function properly, then the consequences would be similar to the flood sensor. If the sensor does not pick up the fact that there is not enough food in the bowl, there would be no notification sent to the pet owner and they would not know that the food bowl is low or empty unless they continuously check the bowl. However, this is the point of the pet feeder, so the pet owner would not have to keep checking whether the pet has food or not. If the pet is not able to get their food then that could result in them becoming underweight.

On the contrary, if the sensor can’t sense that there is enough food then it would keep pouring food even though it has already met the requirements. If the pet feeder continues to pour food then that would cause a mess the owner would have to clean up or the pet would see all that food and eat it and that would be too much food for them. This could result in the pet becoming overweight which the owner definitely would not want to happen. Therefore, we must make sure the weight sensor is able to properly function to provide an accurate amount of food to ensure the pet stays on the diet so they would not be underweight or overweight. A motion sensor will be used when the user wants to take a look at their pet being fed.

It could also be for something as simple as just wanting to see them since they wouldn’t be home at the time. The sensor will sense any movement and notify the user that something has moved. This can also add a sense of security since the pet feeder would most likely be placed in something like a living room. So, if there’s any event someone breaks in, their pet feeder could actually alert the user and they can take action how they see fit. However, the main focus of this motion sensor is to give the user an opportunity to see their pet whether it be for feeding time or because they just want to see them.

If the motion sensor is not able to function properly then we would not be able to tell whether the dog is in front of it. As a result, the pet feeder would not be able to send a notification to the pet owner whether the pet is eating or not. Although it is not something that would prevent the pet from getting food, it is an important aspect of the pet feeder that completes it. A motor will be used to turn the wheel that will dispense the food. We must make sure we have a motor with enough torque to spin the wheel consistently and accurately at the same time.

Considering that it is able to get enough power from the Printed Circuit Board (PCB) then it will function just fine. However, if it is not able to turn the wheel, then even if the sensor can pick up the reading accurately, it does not matter if the wheel cannot spin enough to pour the food. It is not only the torque of the motor we must consider that the connection between the motor and gear is proper or else the motor would be spinning as it should, but since it is not connected properly to the gear then the gear itself would not spin that much. This means the wheel that contains the food would not pour enough of the food for the pet to eat which would make the entire part of the pet feeder inaccurate and goes against what we require for this project. A pump will be used to provide the water that the pet will be drinking.

Similar to the motor, it is important for the pump to get the right amount of power that it needs so it can properly handle the tasks that it has been assigned to do. Without getting the amount of power that it needs, the pump would not deliver an accurate amount of water simply because it could not function properly without the required amount of power. The problem with the pump is similar to the motor in almost every way, however, the pump can work by itself. With the pump it does not need to move anything else to provide the food or water. However, since it works fine by itself, we just have to focus on getting enough power to the pump.

Although this is an automated pet feeder, it still must be washed. This is why it will include removable bowls and containers so the owner can take it out and wash it whenever they feel necessary. Some may wash more than others, but it’s important for the pet owner to be able to wash the bowls and containers so their pets can eat clean food.

2.4.2 Advanced Features

One of the more advanced features will include a camera that shows a video of the view from the pet feeder. This will allow the user to make sure that their pet is being fed at the time that was set. They can look through the camera to also double check that the food is being poured and that it’s the correct quantity of food. The user can also use the camera to look around to see if the pet is nearby which uses the motion sensors. This feature is one of several features that make our pet feeder different from the rest.

It provides owners with an extra sense of happiness, because even from out of the house the pet owner can have a good time watching their pet. A microphone will allow the user to set voice messages for their pet while they’re away to give a sense of familiarity to the pet. For some people, they call their pet’s name when it’s time to eat. Even though there may be a set time for the pet to eat, that doesn’t mean the pet will come to eat. So, to fix that problem, the user will be able to set a pre-recorded voice message through the app and will play at the time the user set for the pet feeder to fill both bowls.

Once it is time to eat and the voice message plays, the pet will recognize the user's voice and will be more likely to respond. Once it follows where the voice came from, the pet will see that it is time to eat and enjoy their meal. One unique feature that can be added to the Automated Pet Feeder is a door or latch that reacts in each scenario. If, for example, pet Alpha tries to eat from pet Beta's bowl, the Automatic Pet Feeder will close in time to prevent forbidden access to pet Alpha. If, on the other hand, pet Beta has consumed all the food prescribed in his/her diet plan, the Automatic Pet feeder will close to prevent the pet from overfeeding.

Because this feeder can be used for any sort of pet that requires a dry food diet, this component must function well. For this application at hand, two options would suffice in tambour and sliding doors. The Automatic Pet Feeder would be a fantastic fit for a tambour door. A tambour door is a type of door that may be rolled or slid up or down a predetermined track. Different storage devices, such as a small wooden bread storage compartment, use this application.

When the pet feeder is open, a crucial characteristic of the tambour door is the small amount of space it takes up. Because the door may rotate to a bent track and move from a horizontal to a vertical position when it opens, it can be placed as close to one of the walls in the pet feeder as possible, taking up less room. This feature will need the assistance of computer vision to identify whether it is pet Alpha or Beta that is eating the correct serving and not taking it from one another, thus granting full safety of the pet's food and peace of mind for the owner that their pets food isn't compromised. Another feature that can be added is integrating a small speaker to enable music if the pet is suffering from separation anxiety. Pets have musical preferences just like humans according to Psychologist Deborah Wells of Queens University in Belfast, and behave differently depending on the sort of music they hear.

When presented with a scenario that the pet is experimenting with an anxiety attack, music is an excellent solution to help mitigate if not completely calm the pet, but the type of music choice is key to know which is best suited to achieve success. For instance, based on Deborah Wells research, she noticed that the music that was played had a significant impact. The canines grew irritated and began barking when hard rock music was played. Listening to popular music or human speech had no discernible effect on behavior compared to having no sound at all. Classical music, on the other hand, appeared to have a calming impact on the dogs, as evidenced by another study that found that when dogs were listening to Beethoven's Moonlight Sonata, they remained pleasantly silent for the longest period.

The dogs' barking was greatly reduced while listening to classical music, and they laid down and relaxed. Classical music has been shown to have a strong soothing impact on dogs, making it an excellent tool for assisting sick dogs at the veterinarian, dogs suffering from stress or anxiety at home, or simply rambunctious puppies. Meeting your pets has never been easier, with composers like Snowdon and Teie creating music specifically for cats and CDs like 'Dreams for Dogs'. This feature can be integrated with a speaker along with the camera. The owner can view how the pet is doing and if the owner suspects the pet is getting rowdy or anxious, then the owner can play classical music to soothe the pet and make them feel like they have company on a continuous basis.

Another way this can work is to play music autonomously every time it's time to eat. The classical music can be played alongside the serving of food and water to have the pet eat and drink comfortably and potentially increase the 'want' to eat and clean out the bowls. This feature can give the owner another reason to trust the Automatic Pet Feeder with their pet because not only will it provide food and water in a timely fashion, it will provide a proven solution to comfort the pet in time of solitude with soothing musical choices such as classical/instrumental music. There are a slew of issues that can arise with automatic dog feeders, including excessive noise and the incorrect amount of food being dispensed into the bowl due to defective sensors. Feeders can produce a lot of noise when dispensing food, which could bother sensitive pets and cause them to avoid the meal.

Dogs that are terrified of loud noises are less likely to eat from the feeder. Other issues include faulty sensors, which could result in continual or no food dispensing in the bowl. Furthermore, due to low battery, feeders may cease working, resulting in missed food distribution and disrupting the feeding schedule. As a result of the drawbacks, the adoption of automatic dog feeders confronts market hurdles. The Market for the Automatic Pet Feeder is divided into four categories: type, nature, distribution channel and geography.

The possibilities and projected growth rate of the worldwide automatic dog feeder market are examined. The report identifies several factors that drive the worldwide automatic dog feeding market's growth. These include market forecasts, market drivers, restraints, opportunities, and the role of the market's main players.

2.5 Requirements and Specifications

The automatic pet feeder should be of a reasonable household item size; it must not take up too much space and should be easily able to blend in with other appliances and gadgets around the pet parent's residence.

Sensors for detecting movement of pets in order to determine whether the food can be dispensed at the given time.

Sensors for measuring water levels in both, the bowl where the pet will be drinking out of and the container that will hold the remaining water used to fill the aforementioned bowl.

Motor that will be responsible for moving the dispensing gate and serving the correct amount of food to the bowl when the interval or preset time of feeding has been reached.

Water pump that will be connected to the main water container and will be responsible for dispensing to the water bowl whenever this is lower than a certain threshold.

A microcontroller that will be responsible for controlling the motor, reading sensor data and allowing for two-way communication between the feeder and the mobile app.

Ensure the noise level that is emitted by the automatic pet feeder is not disruptive to other activities happening in the household. That is, the feeder shouldn't wake up the whole family, in the event that it dispenses food in the middle of the night.

Both water and food containers should have funnels at the top to allow for easier refilling, assuming the food will be poured from a pet food bag.

2.6 House of Quality

The House of Quality, as shown in Figure 3, is a form of conceptual map that facilitates cross-functional planning and collaboration. The house serves as an engineering development tool which allows people with different problems and responsibilities pertaining to the design to describe and record design priorities while referring to observable data patterns in the house's grid. By using this tool, designers from every level, including marketing personnel, production and engineers are able to collaborate closely from the start while keeping in mind at all times the representation of customers' desires and tastes, which are both at the heart of the development of the house of quality.

In the house of quality presented in Figure 3, we can observe how the customer requirements and engineering requirements intertwine, while also highlighting the correlation, relationships and direction of improvement when comparing each entry to another entry in the grid. By having these comparisons, we can more closely compare how one item, or feature could affect or be affected by other items.

The house of quality also allows us to provide better planning when considering trade offs such as cost of production vs. quality of materials, or when comparing the overall design to the features that must be included. In the same manner, the grid broadens our understanding of how all pieces of the design work together to arrive at the final product, allowing for a more detailed, productive and effective management and organization of tasks that will need to be considered for an effective product that will meet both the needs of the consumers and of the designers and engineers participating in the product development.

Taking a closer look at the house of quality presented next, we can see the strong relationship across several entries such as the relationship between the app accessible feature and the food and water dispensing, and the connectivity from the application to the device. These relationships, along with their correlations and improvements, helped us pick the most reasonable design routes and provided us with a roadmap for completing the project successfully.

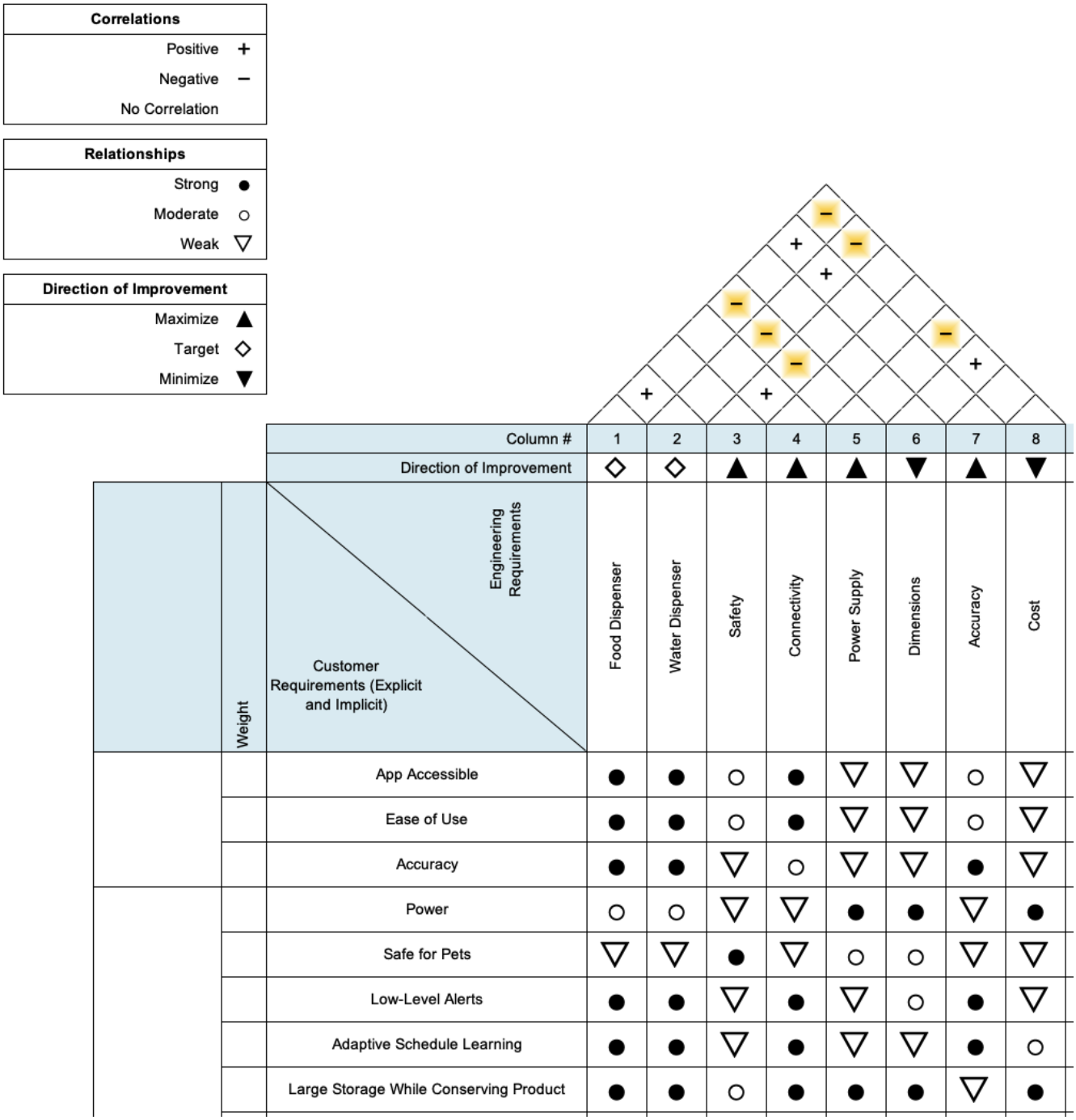

Figure 3: House of quality diagram

3. Research

In the United States alone, about 70% of households own at least 1 pet which is equivalent to about 90.5 million families (Table 1).

Pet	Number
Dog	69.0
Cat	45.3
Freshwater fish	11.8
Bird	9.9
Small animal	6.2
Reptile	5.7
Horse	3.5
Saltwater fish	2.9

Table 1: The number of households, in millions, that own pets in the United States

It is safe to assume that most of these pet owners use some type of animal feeding system to make sure that their pet is well taken care of. A lot of pet feeders require the owner to manually pour the food in the bowl. Although it is the cheapest way to deal with feeding your pet, it also involves human error so they may end up putting too much or too little. Using a measuring cup could fix this problem, but human error is still a factor and sometimes trying to get that perfect amount is too much of a hassle for some people.

So, instead of having to pour the food manually every time you need to feed your pet, they can use an automated system instead which does it for them. There are pet feeders out that are automated, however, they're mostly made to dispense food. Considering that some pet feeders are automated, those tend to be more expensive. Table 2 shows that the amount of money spent by consumers on their pets has been increasing for years. Based on this trend, it will continue to be on the rise especially with the increase in demand for pet products. This includes automated pet feeders whose market size is rapidly increasing as well.

Year	Expenditure (2)
2010	$48.4
2011	51.0
2012	53.3
2013	55.7
2014	58.0
2015	60.3
2016	66.8
2017	69.5
2018	90.5
2019	97.1
2020	103.6

Table 2: The amount of money, in billions, spent in the pet industry

3.1 Existing Similar Products and Projects

Providing pets with their necessary daily intake of pet food and water is no new task for pet parents around the world, whether that is grabbing a cup and scooping some food out of the food bag every time they are going to feed their pets, or leaving food all day in food bowl, or keeping food in a container and having a rotating dispenser for a manual, pre-measured amount of food, this is a common task for every pet parent out there and thus several organizations have released products that help with this tasks coming in various designs and use cases. Exploring the current products provided for the care and maintenance of pets, we can observe several different items that each, in its own way, tries to provide peace of mind for pet parents when it's time to feed their pet.

Currently, many pet parents are using dry food dispensers in order to keep a measured control on their pet's eating habits. During our research, we have noticed that using a dry food dispenser like that showcased in Figure 4 is a common alternative for pet parents to manage the amount of food they provide their pets. By allowing them to store the pet's dry food in a sealed container, pet parents can remove the dry pet food from the bag where it comes from and add it into the dry food dispenser's container, simplifying a bit the need to store this bag in a safe, dry place, as well as minimizing the need for a separate scoop or measuring cup in order to serve the food to the pet. The dry food cereal dispenser dispenses food by turning the knob shown at the front of the

device, dispensing as much food as each of the inner turning compartments hold. If they require a specific amount of food, the user would have to measure how much food each turn provides and then they would have to calculate how many turns they would need in order to feed their pet the correct amount. While this is, in theory, an upgrade to scooping food out of the bag, measuring the right amount and pouring it in the bowl every time the pet needs to eat, it still lacks the automation features and requires tons of manual work in order to properly feed a pet.

Figure 4: Indispensable Dry Food Dispenser

Figure 5 provides a clever and inexpensive approach attempting to automate, to some extent, the task of feeding a pet throughout the day. Per PetSafe's description of the gravity feeder, the feeder lets a pet eat their food whenever they are hungry. This is done by continuously releasing food onto the bowl once the food starts lowering. The feeder includes a container which can hold up to 4 pounds of pet food and PetSafe claims it to be very easy to clean by allowing the user to remove the feeder's stainless steel bowl and drop it in the dishwasher. While PetSafe's Gravity Feeder provides some level of automation, the thematics of the design are quite cumbersome.

Allowing food to always be in the pet bowl while not having a way to measure the amount that has been poured or how much food the pet has eaten could lead to some pets overeating, as well as not having a consistent feeding schedule, causing the pet to potentially get confused about the feeding time and, in cases where the pet might be undergoing potty training, it promotes an

unpredictable potty schedule. It is good to note that this feeder does not account for the water bowl, which is equally, if not more important that the food dispensing itself, requiring that the user acquire an extra separate bowl, probably from a different brand, and have yet another thing to worry about and keep track of to ensure the pet has enough water at all times. This feeder is nonetheless an improvement from having to scoop out food from the food bag each feeding time and comes with a relatively low cost but it still does leave a lot to be desired.

Figure 5: PetSafe Gravity Feeder

The Arspic Automatic Pet Feeder (depicted in Figure 6), on the other hand, provides some more control over the automation of the pet feeding. By providing accurate and programmable timed feeding, the automatic pet feeder allows to schedule a healthy routine for the pet. It dispenses pet dry food up to 4 meals per day with 1-20 generic portions per meal, so that the pet can get a more precise amount of food at a more precise interval. This pet feeder provides a lot more functionality than the previously discussed pet feeders but it still falls a bit short of what could be implemented in order to make the process of pet feeding a whole lot easier. It is also good to mention that this feeder also comes with a higher price tag, making it harder to acquire for some families.

While the feeder provides pet owners with a preset amount of food at specific intervals during the day, the process can still be quite manual. The feeder only allows for the setting of the intervals of food only through the on-device screen and buttons, still requiring the pet owner to be present at the site where the feeder is in order to initially set these meal intervals as well as the amount of food that is going to be dispensed. The preset amount of food also poses some issues;

it only allows for one preset amount of food for every meal the pet requires. While to some pet parents setting the same amount of food for every meal could be enough, it makes it harder on other pet parents who might need their pets to have different amounts on each meal, whether this is due to a dietary restriction, or even their own personal preference.

Figure 6: Arspic Automatic Pet Feeder

3.1.2 Market

Dogs and cats are two of the most common pet species in the United States, and while the Automated Pet Feeder is not specifically marketed to one species, the majority of customers considering purchasing a pet feeder will almost probably be doing so because they own a dog or cat . To fully comprehend the market for such a device, however, one needs to be aware of many essential statistics. Pet Feeders that are both Automatic and Intelligent has been developing at a moderate rate with considerable growth rates in recent years, and it is expected to increase significantly in the anticipated period, i.e. 2021 to 2028.

The majority of smart pet feeders come with a camera that allows pet owners to keep an eye on their animals. Growing worries about pet health have resulted in increased spending on pet service goods around the world. This aspect is expected to drive the globalAutomatic Pet Feeder market forward throughout the forecast period. The report on the Global Automatic Pet Feeder market provides a comprehensive analysis of the industry. The research includes a detailed analysis of key segments, trends, drivers, constraints, the competitive landscape, and other important market variables.

According to Technavio, the Automatic Pet Feeder industry is expected to increase by USD 2.28 billion between 2021 and 2025. Just like it is shown in Figure 7, Technavio’s recent market

research report forecasts a Compound Annual Growth Rate (CAGR) of over 22% for the Automatic Pet Feeder market. Technavio's studies give a deep assessment by way of synthesis and summation of data from different sources, with a focus on identifying prominent industry influencers. This study provides an up-to-date assessment of the present market situation and prediction.

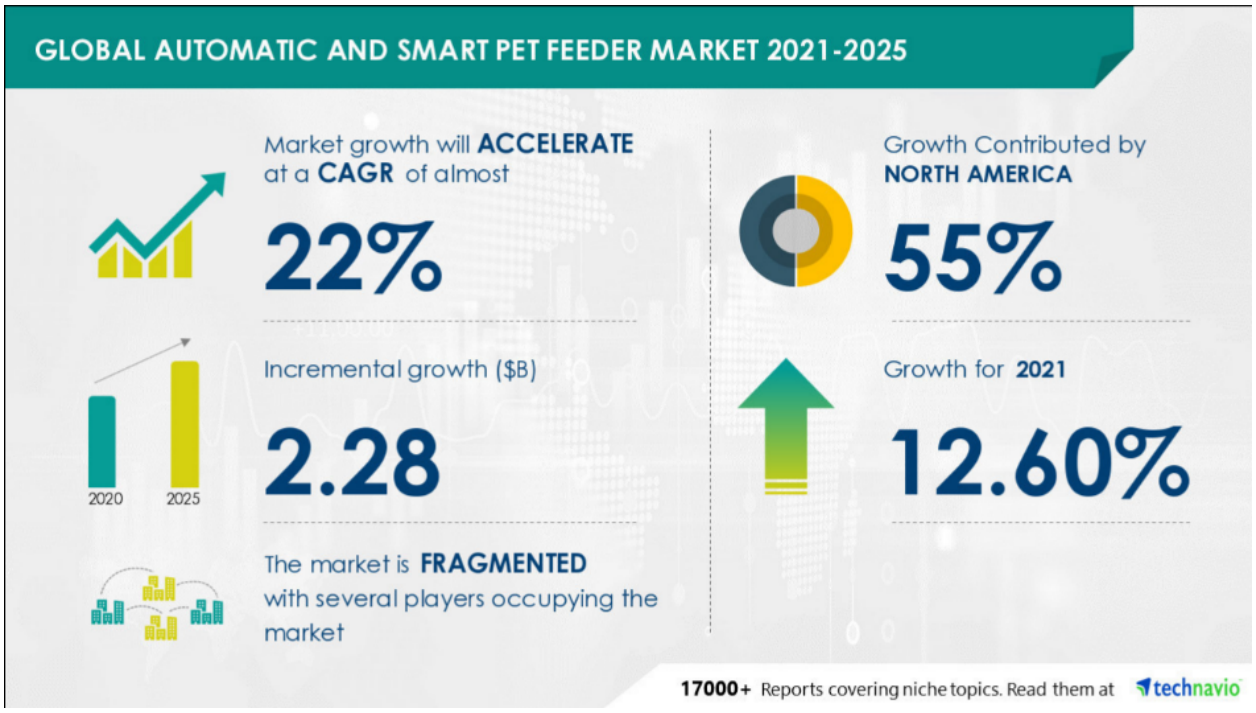

Figure 7: Progression statistic of the Automatic Pet Feeder

A rate equation can be used to calculate the rate at which the United States has seen growth in the ownership of only cats and dogs. While the equation stating that distance equals the product of rate and time may not appear to be appropriate for this computation at first, just replacing the change in growth makes the former equation highly useful. Because of that, the formula for calculating the rate of pet growth is: rate of pet growth equals change in pet growth divided by time.

In consequence, the growth rate of dogs owned as pets in the United States has been 2.9 percent each year since 2015, while the growth rate for cats has been 2.1 percent per year. When comparing numbers from previous years, it is clear that growth has been regular and stable. This expansion is critical to the Automated Pet Feeder's marketability, as it is designed to be a durable system that should not break down over time. In that event, new consumers are necessary to maintain the market available.

The market is divided into two categories based on product: Automatic Smart Feeder and Pet Smart Feeders. The Pet Smart Feeder allows customers to keep track of meal times, quantity amounts, and pet food supplies. Smartphones and computers can control smart pet feeders, allowing them to feed. pet. Automatic pet feeders are designed to deliver a certain amount of food at a predetermined time. Our Automatic Pet Feeder will provide the concept of both trends

in one convenient device that will provide the benefits of both worlds in one flexible and durable, modern device. Making our Automatic Pet Feeder a fantastic answer for pet care. As a result of the expanding trend of smart homes, the popularity of Automatic Pet Feeders is rapidly increasing. This propels the global Automatic Pet Feeder market forward. Furthermore, advanced technologies, such as the use of a video camera to enable adequate pet tracking, are projected to increase demand for automatic pet feeders. Increased spending on pet service goods has stemmed from increased concern about the health of pets around the world. During the forecast period, this aspect is expected to fuel market expansion. Furthermore, the rise in the working-age population, both men and women, the rise in the incidence of dog adoption, and the tremendous rise in pet health awareness are all major factors driving the growth market. Furthermore, increased spending on pet service items has stemmed from increased awareness for the health of pets around the world.

During the forecast period, this aspect is expected to fuel market expansion. The Automatic Pet Feeder business is restricted by a preference for other pets, such as cats, as well as noisy feed intake machinery. Throughout the projected period, higher feeder prices and a lack of product awareness are expected to stifle market growth. The urban population shifted living patterns and hectic working lifestyles, as well as the increase in product accessibility and availability through online retailing, present enormous growth prospects. Market suppliers must improve their presence in fast-growing segments while retaining their positions in slow-growing areas to take advantage of present opportunities. According to Verified Market Research, their market analysis also includes a part dedicated only to such significant firms, in which our experts present an overview of all of the main players financial statements, as well as product benchmarking and Strength Weakness Opportunity and Threat (SWOT) analysis. The competitive landscape section also contains an analysis of the above-mentioned players' global major development strategies, market share, and market position.

There are a slew of issues that can arise with automatic dog feeders, including excessive noise and the incorrect amount of food being dispensed into the bowl due to defective sensors. Feeders can produce a lot of noise when dispensing food, which could bother sensitive pets and cause them to avoid the meal. Dogs that are terrified of loud noises are less likely to eat from the feeder. Other issues include faulty sensors, which could result in continual or no food dispensing in the bowl. Furthermore, due to low battery, feeders may cease working, resulting in missed food distribution and disrupting the feeding schedule.

As a result of the drawbacks, the adoption of automatic dog feeders confronts market hurdles. The Market for the Automatic Pet Feeder is divided into types: programmable feeder and gravity feeder and the growth of each is shown in Figure 8 below, displaying a remarkable difference and showing as to why the demand for the Automatic Pet Feeder is high and will grow exponentially. The possibilities and projected growth rate of the worldwide automatic dog feeder market are examined. The report identifies several factors that drive the worldwide automatic dog feeding market’s growth. These include market forecasts, market drivers, restraints, opportunities, and the role of the market’s main players.

The key benefits for the stakeholders are the following:

- The study examines the existing and prospective trends and opportunities in the Automatic Pet Feeder Market.
- The research includes a complete qualitative and quantitative analysis of current trends as well as future projections to assist in evaluating the current automatic dog feeding market potential.
- The forecast for the Automatic Pet Feeder Market is included, as well as information on major drivers, restraints, and opportunities.
- Within the market framework, the market analysis is accomplished by tracking key product positioning and monitoring the top rivals.
- The study contains in-depth qualitative information on the potential and niche categories or regions with strong market growth.

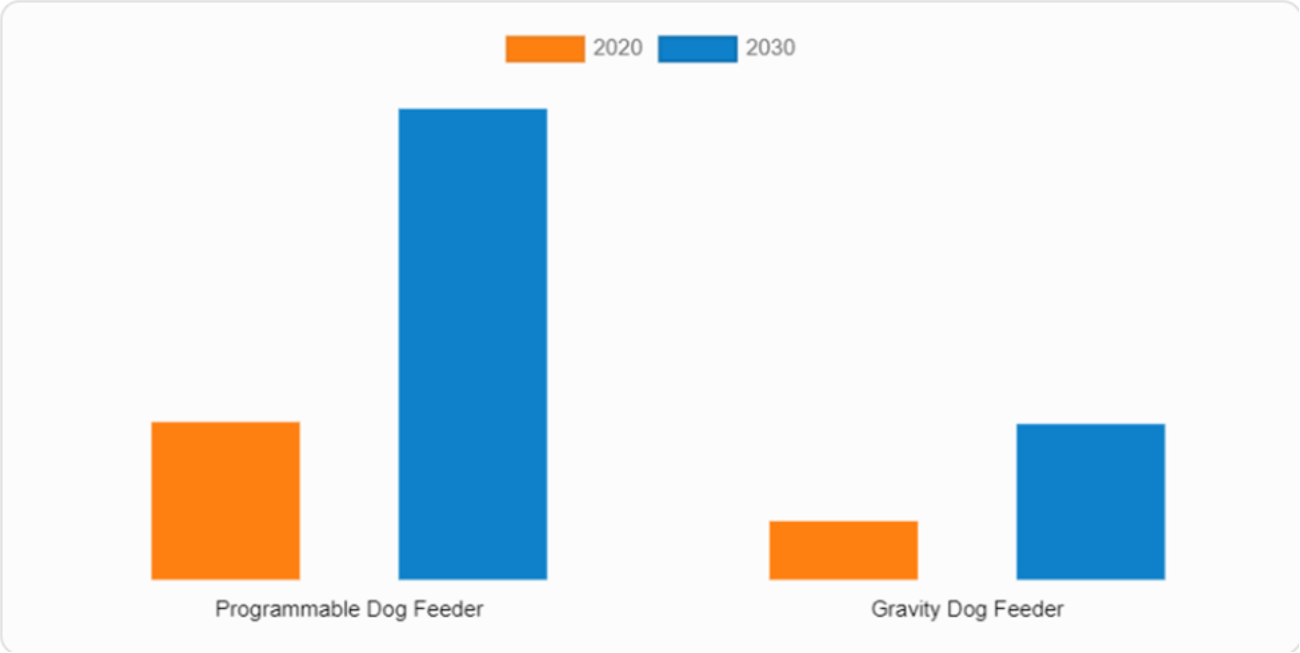

Figure 8: Displaying the CAGR of both types of pet feeders

3.2 Housing

Now that we've looked at other similar products, it is time to consider what we will use to encapsulate everything. This class and our project is focused on the hardware and software. So, for this section, we will be looking at already existing housing we can repurpose. This is to avoid wasted time on mechanical engineering and designing an enclosure.

3.2.1 Dry Food Dispensers

For the most basic of housing, we could simply go with a dry food dispenser that has a simple mechanism for letting food drop. This means we would just need to use a motor to open and close the mechanism. So, for example, in Figure 9 we would need to set up a track around the dial so that the motor could turn both ways to either dispense the food or hold the food in the reservoir above. The biggest upside to something like this is the low price tag and how easily we

could accomplish this. But, the downside would be that we would have to come up with something else for the water because these dry food dispensers aren't water tight. Another downside would be the positioning of the bowl. If we had a dispenser like in Figure 9, the pet would have a difficult time eating out of it because it would have to be directly under the dispenser. Most dry food dispensers have this problem and the only way around it would have to be building an attachment which is what we are trying to avoid.

Figure 9: Zevro Dry Food Dispenser

3.2.2 Existing Pet Feeders

The next option we have for housing is buying an existing pet feeder and gutting it out. This lets us focus on software and hardware engineering. The main problem with this option is that most automatic pet feeders online don't have the water feature except for gravity feeders (Figure 10). But, with the gravity feeders, there's no mechanical engineering which defeats the whole purpose of our project. Although, if we aren't able to find a good prebuilt one that fits our needs, this could be a good base to start with instead of building our own. Going back to smart pet feeders shown in Figure 6 in section 3.1, the main problem besides not having a water feature would be the cost. We would have to pay a premium just to gut out what made it cost so much in the first place.

Figure 10: Hipidog Automatic Pet Feeder

3.2.3 Custom Build

With a custom build we have complete control over everything. In Figure 11, we would get to implement all the features we want with the only thing holding us back being our skills in mechanical engineering and woodworking. Because the enclosure to hold everything would have to be made out of wood unless we had access to a 3d printer. But, even with access to a 3D printer we would have to take the time to learn how to use it. A fully custom build within the time frame we have over the summer, which is about 3 months, doesn't seem that plausible. There will have to be custom parts on the housing but creating all the housing from scratch will take up too much time. Some ideas from our custom build can be implemented in the final product but because of time and our skillset, we will probably end up going with a combination of a custom build and an already built petfeeder.

Figure 11: Mockup of a custom built housing

3.2.4 Comparison

This part of the project is going to be one of the harder decisions we have to make. While building a custom built one or modifying an existing one is ideal, it takes time away from what matters which is the software and the hardware. But, with the direction we want to take this project, we will most likely end up having to build our own housing in some way. Because even if we go with an existing pet feeder, we will still need to implement our water feature as you can see in Table 3. Whichever way we go the price will most likely be the same because we'll have to buy additional parts to make modifications or add additional housing. The dry food dispensers are the only one out of the four in Table 3 that is an absolute no go. This is due to the poor quality of most of the dispensers and because of the poor placement most of them would have. In conclusion, the housing will most likely be a combination of the housings discussed.

	Dry food dispensers	Existing Pet Feeders	Gravity Pet Feeder	Custom Build
Size	7.5 x 6.5 x 16.3 in	7.5 x 7.5 x 12 in	15 x 12 x 6 in	≥ Other feeders
Weight	2.09 lbs	4.65 lbs	2.34 lbs	5 lbs - 10 lbs
Capacity	0.5 L	4.5 L	3.8 L	5 L - 10 L
Water Feature	No	No	Yes	Yes
Price	$15 - $40	$60 - $100	$15 - $40	$50 - $100

Table 3: Housing comparison table

3.3 Motors

When it came to the design of the pet feeder, every idea involved using a motor. There has to be an automated way for the food to be dispensed into the bowl. The motor will be used to turn a wheel that will have a certain amount of food in it. The several parameters we needed to take into consideration when choosing a motor were the noise, size, torque, accuracy and power output. The noise isn't a major factor, but it would be annoying for the consumer if every time they were to pour food they heard an unfavorable sound. It shouldn't be big, because it will be inside the product and the smaller it is, the lighter it would weigh. Since the wheel will have food on it, the motor must be able to properly turn. So, the torque must be good, because if it's not then it wouldn't be able to pour the food. Adding to the inability to turn, that would decrease the accuracy as well, because it struggled to turn. Nonetheless, since it's a product that will be placed inside a home, it's important to find one that does not use up a lot of power. Figure 12 shows each of the different motors that can be used for the Automated Pet Feeder.

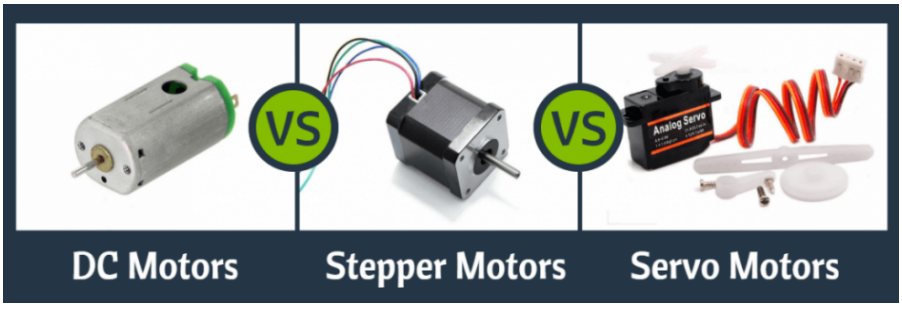

Figure 12: Different types of motors

3.3.1 Servo Motor

Servo Motors are basically DC motors that don't run continuously. Instead, they turn as far as 180° .They offer several advantages compared to other motors. One of these advantages include a high output power considering their size. The servo motor also has a good acceleration and a high ratio of torque. A major plus is that it's quiet and accurate in comparison to the other motors which is something on the list of requirements for the motors.

The Servo motor consists of a DC motor, control unit, and a potentiometer. All of the components of the Servo motor are located within the enclosure. The gears are connected to the motor to control the output of the wheel which can be seen in Figure 13. As the motor rotates, the potentiometer resistance changes and the circuit will know how far it is moving and the direction it is going. The motor will measure the distance needed to travel and adjust its speed accordingly and as accurately as possible. To ensure the motor is in the correct position, it will send signals continuously of its position until instructed otherwise and repeat the process. This is very advantageous because the Automatic Pet Feeder needs to know the position it is in or it can miss the target and risk overflow or underflow. Also, Servo motors are very flexible because they can run both on AC and DC power supplies.

Figure 13: See through servo motor

3.3.2 DC Motor

The DC Motor is the most straightforward motor that we could choose. It's as simple as just plugging it in and then it works. The higher the voltage, the faster the motor spins. Since the motor has two leads, there's a connection for positive and negative and depending on the orientation of the connection determines what direction the motor spins. It will be controlled through the microcontroller since the product is automated. There is a concern on using a DC motor for the Automatic Pet Feeder due to how much resistance it applies before the motor fails. The motor has to be powerful enough in order to continuously spin and force the blade of the paddle to bend as it dispenses food accurately to the bowl. Since the DC motor operates consistently depending on the amount of voltages it is receiving, this cannot afford to fail, otherwise the system will not complete the task of feeding the pet on time.

Making sure that the proper amount of voltages are being taken into account will prevent the DC motor from failing. This is applied by using an AC to DC converter that will supply a maximum of 24V. The goal of using such a motor is to have it as a low power consumption device and having the Automatic Pet Feeder use 24V will not perform in that manner. It will have to operate at 6V to consume less power while providing the necessary voltage needed to properly rotate at an adequate speed. The speed in which the motor needs to operate has to be slow enough to give time for the weight sensor, located beneath the bowl, to calculate how much it has to be dispensed at a time. This is important to know because if the speed of the motor is faster than the calculation of the scale, the risk of overflow gets exponentially high. Therefore, the need of a low RPM DC motor is needed to prevent such risk.

We have to take into account the size of a low RPM DC motor since our goal is to have an Automatic Pet Feeder that doesn't take much space. When it comes to DC motors, the size can dictate the amount of power and torque it will provide. The DC motor has to be small, yet powerful enough to give enough torque and rotation per minute needed. Although having a DC motor with those attributes is feasible, those are usually pricey.

3.3.3 Brushed VS Brushless DC Motors

To further understand the depths of DC motors, we have to dive deeper in such matters. There are two types of DC motors, one of them being Brushed DC motor or BDC and the other one is Brushless DC motor or BLDC. When it comes to BDC, it consists of stator, rotor, brushes and commutator, in which the function of the brushes and commutator is to switch direction. Unlike BDC, BLDC consists of rotor and stator only without the need of brushes or commutators. Both bring their own characteristics and different functionality but these are the differences in choosing either BDC or BLDC which you can see visually in Figure 14.

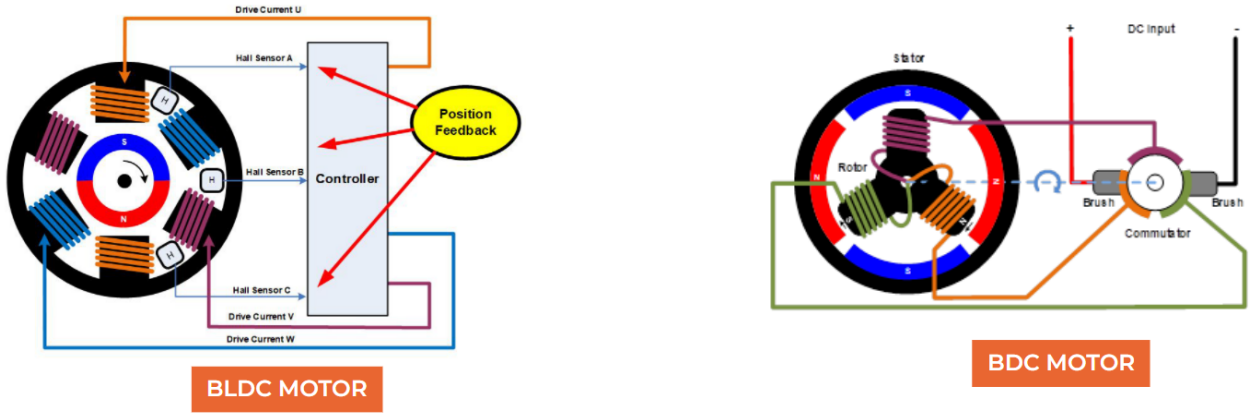

Figure 14: Difference between BLDC and BDC motors

For the case of BDC, when the motor rotates, the carbon brush slides over the commutator to create a rotating magnetic field that is to the static magnetic field of the stator. The armature and stator winding currents come from a battery or other DC power source. Permanent magnets are used to provide a static magnetic field. These magnets are typically placed on the inner surface of the stator on the outside of the rotor. To generate the torque that rotates the rotor, the rotor`s magnetic field must rotate continuously so that the magnetic field attracts and repels the stator`s

fixed magnetic field. The electric slide switches are used to rotate the field. The switch consists of a commutator, which is usually a segmented contact attached to the rotor, and a fixed brush attached to the stator. To drive a brushed motor, apply a DC voltage to the brush. This causes a current to flow through the rotor windings to rotate the motor. Brushed motors do not require any drive electronics if they only need to rotate in one direction and do not need speed or torque control. In such applications, the motor can be turned on or off by simply turning the DC voltage on/off. This is common in low-cost applications such as electric toys. If inverting is required, it can be done using a 2-pole switch.

For BLDC, Brushless DC motors operate on the same magnetic attractions and repulsion principles as brushed motors, but with a slightly different structure. Instead of a mechanical commutator and brush, the magnetic field of the stator is rotated by an electronic commutator. This requires the use of active control electronics. Brushless motors have permanent magnets attached to the rotor and windings attached to the stator. Brushless motors can be designed with the rotor inside or outside the winding as described above (which are split in 3 phases). Below in Table 4, the differences between the BDC and BLDC motor's specs can be seen.

	Brushless Motor	**Brushed Motor**
Speed and Acceleration	High	Medium
Efficiency	High	Medium
Lifetime	Long due to no brush wear	Short due to brush wear
Electrical Noise	Quiet	Noisy
Torque Ripple & Acoustic Noise	Medium or Good (Depends on the phase)	Poor
Cost	Medium	Lowest

Table 4: Difference overall by specs

3.3.4 Stepper Motor

Another option to choose is called a Stepper motor. Unlike the DC motor, the Stepper motor does not have brushes or commutator. It has a permanent rotating magnetic rotor interior and rotating coils around the perimeter. The surrounding electromagnets that change between the electrical states cause the rotor to rotate due to the repulsive and attractive interactions between the poles and the magnets. An overview of the different parts can be seen in Figure 15. The advantage of

using a Stepper motor is that you can control the movement via a defined step or movement angle within the motor. Another great feature is that it tends to be cheaper than Servo motors. Now, the disadvantage of using a Stepper motor is that it tends to move jerky due to the calculated movement steps. High torque and low speed were the deciding factors in choosing a motor to distribute the supply. Also, high torque is required to ensure that the motor pushes through the pebbles that can get stuck between the dispensing paddle and the wall of the bin.

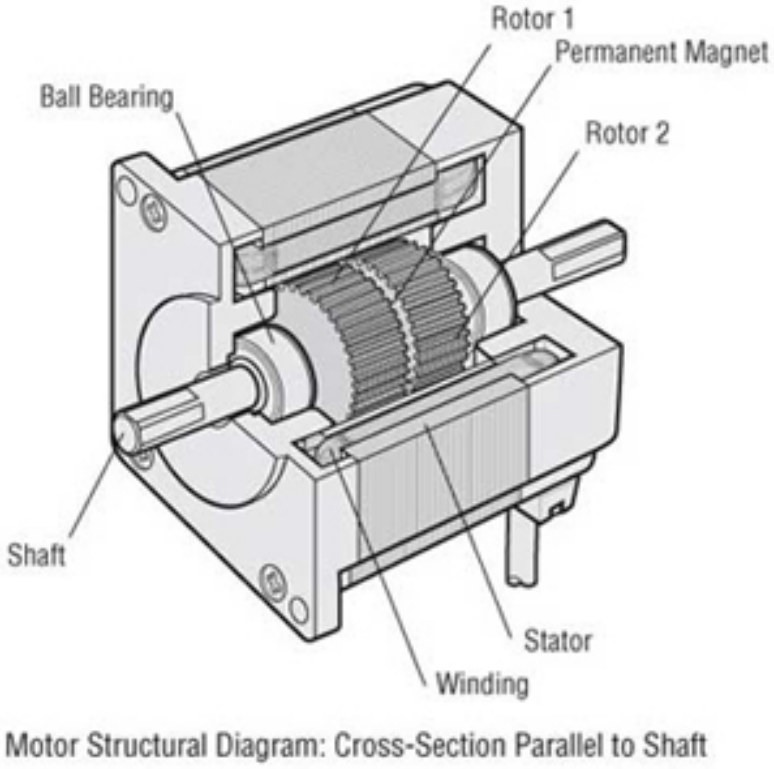

Figure 15: Diagram of a stepper motor

3.4 Sensors

Our product will require the use of several sensors that will allow it to be fully automated. The first sensor is the water sensor, which is supposed to be able to detect the water levels and alert the user that it is low. The next sensor is the weight sensor that will measure the weight of the food bowl to determine whether it is low or not. After the weight sensor, there will be a motion sensor to detect movement, which would let the owner know that their pet is in front of the pet feeder.

3.4.1 Simple Water Detection Sensor

This simple water detection sensor shown in Figure 16, is a perfect sensor to put inside the pet's water bowl. The water sensor can easily go inside the bowl and detect any level the water is at under the text "Water Sensor" in Figure 16. This means that we can easily implement some code to refill the water bowl when the water level nears the bottom of the sensor. This sensor is also compact and can easily fit on the inside of a pet's water bowl. The goal of this sensor will be to read water levels with a microcontroller to then trigger a pump when the water level is read as low.

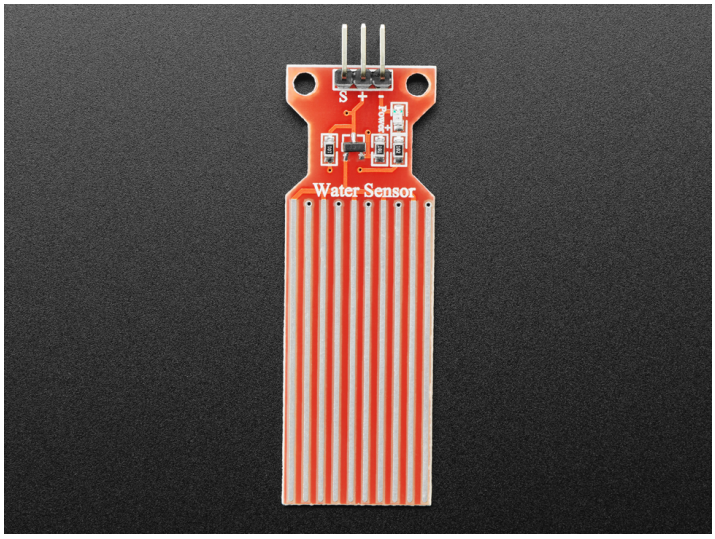

Figure 16: Simple water detection sensor with digital output

3.4.2 Weight/Pressure Sensor

To detect how much food or water is left in the bowl, one of our solutions was to have a sensor that checks the weight of the bowl. The theory is that there will be a notable difference in weight when the bowl is full of food and when the bowl is empty. So, when the weight is low, the microcontroller will take that information and send it to our application. When setting up the limit, it must be calibrated to the weight of the bowl, because it isn't weightless and we don't want that to be a factor in the measurement. Looking into a weight sensor brought to our attention a pressure sensitive conductive sheet. This is a cost effective solution that detects pressure with the reduction of resistance. So, the pressure sensitive conductive sheet shown in Figure 17 would need to be between the bowl and another surface. Then, we can read how hard the bowl is pressing on the surface with the sheet connected to our microcontroller. We would just need to connect the sheet to ground and a pin on the microcontroller.

Figure 17: Pressure-Sensitive Conductive Sheet (Velostat/Linqstat)

3.4.2.1 HX711 with Load Cell

The HX711 (Figure 18) is a precision 24-bit analog-to-digital converter (ADC) designed for weighing and industrial control applications that directly interface with bridge sensors. It is specially designed to amplify cellular signals and report them to another microcontroller. The ADC (HX711) for load cells is a 24-bit analog-to-digital converter specifically designed for load cells. It features an on-chip low-noise programmable amplifier with 32, 64, and 128 gain options. The HX711 chip combines a regulated power supply, an on-chip clock oscillator, and various peripheral circuits for high integration, fast response, and excellent anti-interference performance.

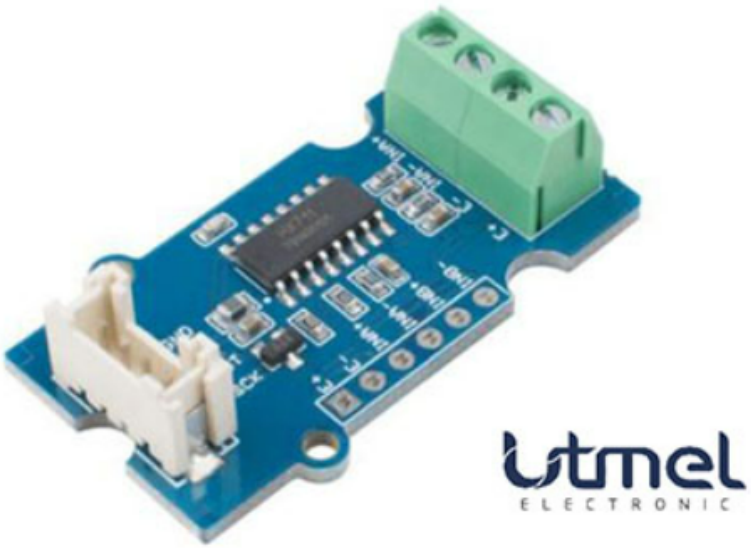

Figure 18: Weight Sensor HX711

A load cell is a device that measures the magnitude (force or weight) of a load and converts the force into a measured electrical output. They perform a variety of functions, such as determining the weight of an object, tracking changes in weight over time, and measuring surface strain and stress. When a force is applied to the load cell, it becomes a metal core containing a series of electrical resistors. However, it will return to its original state when the power is turned off. The reversibility of this material determines the quality and accuracy of the load cell.

3.4.3 Motion Sensors

Motion sensors can be used for a variety of features in this project. The main reason we'd want to use a motion sensor would be for detecting how far away something is from the sensor. We could use motion sensors to detect when there is food in front of the sensor in the food reservoir. This indicates that the reservoir doesn't need to be filled up. But, when the food isn't detected in front of the motion sensor, we could send a notification to let the owner know that they should fill up the reservoir.

3.4.3.1 HC-SR04

The HC-SR04 Ultrasonic Sensor is a sensor to determine the distance of the object in front of it. It operates at 5 V DC and 15 mA. The minimum range is 2 cm while the maximum range is 4 m. Although it can measure as far as 4 m, we need to make sure it's accurate and this device has an accuracy of 3 mm. It's also not too big with a dimension of 45 x 20 x 15 m. Looking at the HC-SR04, there are four pins that need to be connected. The first pin is the VCC, which is what powers the device and it would most likely be 5 V that will be put into it. The second pin is the trigger pin which is used to trigger the ultrasonic sound pulses. The third pin is the echo pin which triggers a pulse when the device receives a reflected signal. The last pin is the ground pin that must be connected to ground on the microcontroller board. In Figure 19, the whole module is presented along with the pin's location and brief explanation of its functionality.

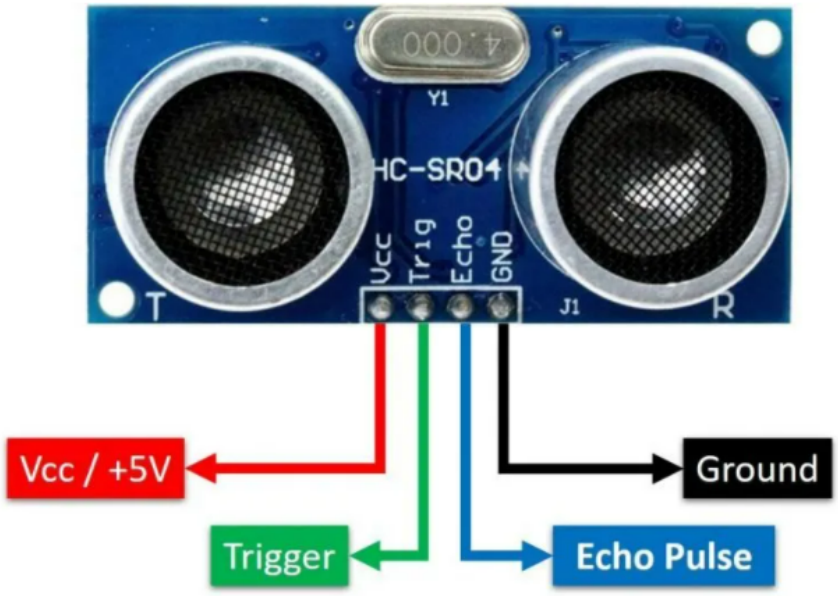

Figure 19: HC-SR04

To further understand the ultrasonic sensor, we have to be familiar with its modules, transmitter and receiver. The ultrasonic sensor emits a signal from the transmitter, receives the reflected signal, and returns it to the receiver. The distance between the sensor and the object is calculated from the time difference between transmission and reception. When measuring distance with the HC-SR04, send a pulse of 10 microseconds to the trigger pin of the sensor. In response, the transmitter circuit sends eight 40kHz pulsed ultrasonic waves into the air. Therefore, the transmit circuit converts the electrical signal into an 8-pulse 40kHz burst.

While the ultrasonic transmission circuit completes the transmission of 8 pulses, the echo pin goes up. After hitting the object under test, the echo pen remains active high until the ultrasonic waves reflect off the receiving circuit and never return. After hitting an object, the echo pin goes low as soon as the receiving circuit receives the ultrasonic signal. The amount of time the pulse remains high is equal to the total time it takes for an ultrasonic burst to travel from transmission to reception. With that being said, the distance can be measured by measuring the amount of time the output of the echo pin has been in the logic high state (pulse width or pulse width).

3.4.3.2 Infrared Sensor

An infrared sensor was the second type of distance measuring technology that was explored for our research. The principle of triangulation is used by infrared sensors as it shows in Figure 20 below. This means that the sensor uses the angle of a reflected beam to calculate the distance between itself and the item in question. The way the infrared sensor works is the following sequence. The Infrared LED emitter produces infrared light. Then the light beam strikes item X and is reflected at an angle. Next, the Position Sensitive Detector (PSD) will receive the reflected light Y. Finally, the PSD's sensor will then determine the reflective object's position and distance.

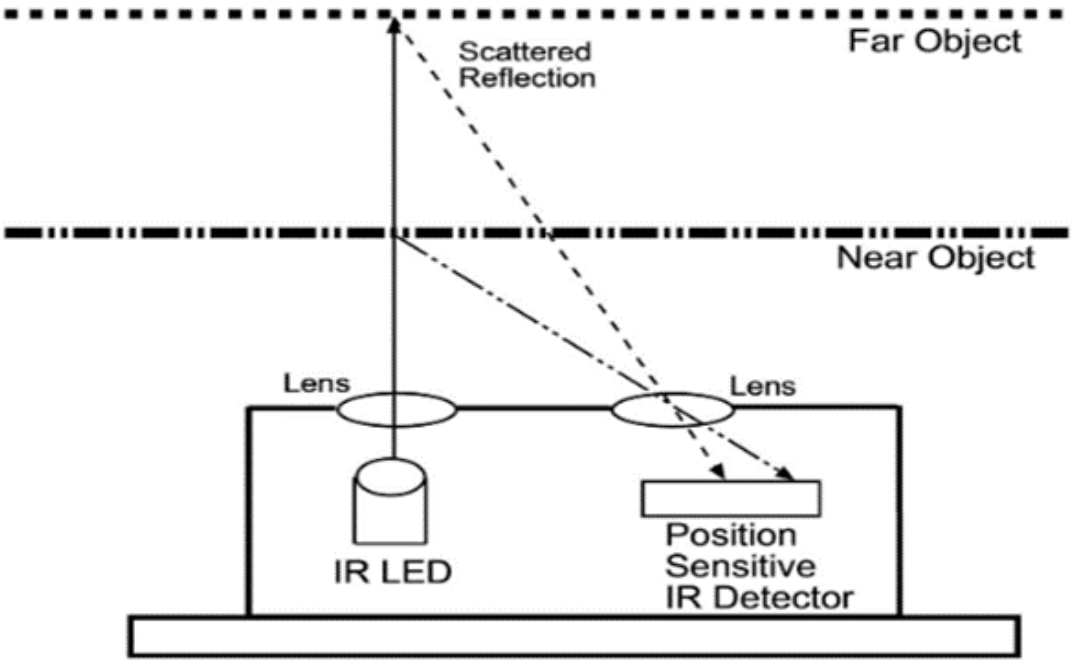

Figure 20: How IR distance sensor works through triangulation

Some of the advantages of using IR sensors are that they are small from the factory. Sharp's IR sensors, for example, are typically smaller in size. It can be used both during the day and at night. Through a line of sight, secure communication is possible. Unlike ultrasonic sensors, it can measure the distance between objects with complicated surfaces. The downside of using infrared sensors is that they have a limited measurement range that is influenced by environmental conditions and hard objects. You might be asking what the difference is between IR and Ultrasonic sensors now that we've covered both. Table 5 compares each and shows the distinctions.

Type	IR Sensor	Ultrasonic Sensor
What it does	Distance is measured using reflected light waves	Distance is measured using sound waves
How it measures	The angle of a reflected IR beam is measured by triangulation	The amount of time that passes between transmitting and receiving sound waves is measured
Human Interactions	Invisible	Cannot hear
Object Requirements	It's ideal for measuring complex items	Objects having complicated surfaces are not suited for measurement

Table 5: Comparison of IR sensor vs Ultrasonic Sensor

3.5 Pumps

The use of pumps for this project is to fill a bowl with water when needed. Pumps can be easily triggered through some simple code turning them on or off when needed. In this section, we will go over different pumps we can possibly use for this project and which pump we inevitably go with.

3.5.1 Aquarium Pump

The first option that comes to mind when deciding on what to use as a water pump for our project is an aquarium pump. Aquarium pumps come in many different shapes and sizes and are readily available. Most also come with the added benefit of being submersible. A submersible pump can be placed on the inside of our reservoir and pump water through the bottom of it into the water bowl. Figure 21 shows how this can be even more convenient with the addition of suction cups to position the pump nicely on the inside of the reservoir.

Figure 21: PULACO 95GPH 5W Mini Submersible Water Pump

The main features that differ between each option is their flow rate, power requirements, noise pollution, and size. Flow rate should remain low so that we have ample time to turn off the pump to prevent it from overflowing. Power consumption should also be low enough to have the ability to be powered by a microcontroller. If we were to use an aquarium pump, we would have the downside of also having to use a relay to trigger it. Ideally we'd like a pump that produces barely any noise. Noise from the pump could potentially deter pets from using our device which can be a downside to an aquarium pump. Lastly, the size of the pump (assuming we're using a submersive pump) should remain compact to assure it fits inside our reservoir.

3.5.2 Submersible 3V DC Water Pump

This next pump is also a submersible water pump, but it comes with some added benefits over the aquarium pump. Compared to the aquarium pump, this pump is cheaper, smaller (Figure 22 for size), and easier to use. It also consumes less power, which makes it highly compatible with a microcontroller. This also means that we don't need a relay to control the pump. The downsides to this pump come in when we consider the fact that the water has to be consumed. The tubing that is used with this pump is PVC tubing which is not food safe. Also, the fact that the water has to go through the plastic pump itself, is not a good thing when it comes to consumable water. Another downside to this pump is that it needs to be primed before use and it always needs to be submerged in water.

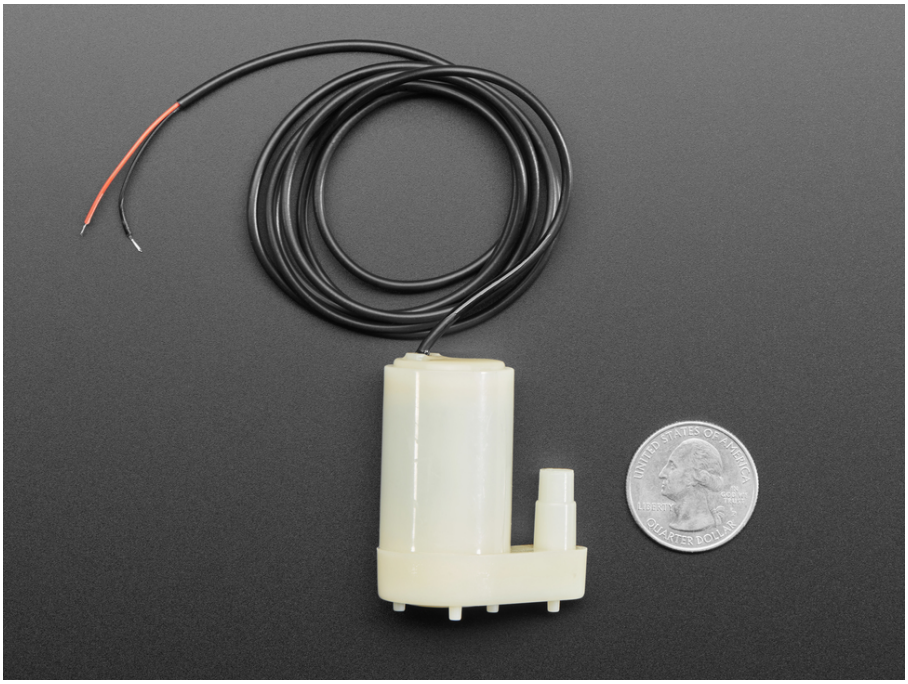

Figure 22: Submersible 3V DC Water Pump

3.5.3 Peristaltic Liquid Pump

This last pump is the perfect pump for our use case and it is known as a Peristaltic pump. The way this pump works is by using rotary motion to squeeze the tubing and move water through it. In Figure 23, you can get a general idea for how this works. A rotor is used with rollers attached which can be spun in both directions to move water both ways. This has lots of benefits, with the main one being the pump never actually touches the fluid. This allows us to use food safe tubing that is FDA approved which gives us the peace of mind that the water is consumable because it only passes through the tubing.

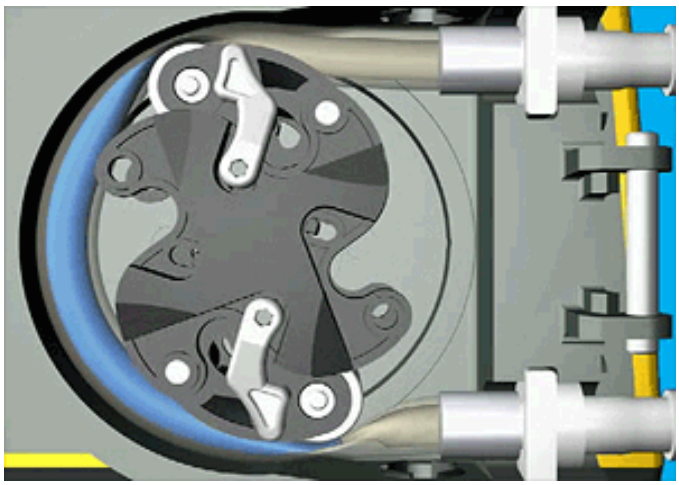

Figure 23: Peristaltic pump in motion

Other benefits of this pump compared to the other pumps include size, noise, power and usability. The size of this pump can be seen in Figure 24 next to a quarter for scale and is similar to the submersible DC water pump in section 3.5.2. This pump is also nearly silent which is better than both of the other two pumps. For power, this pump needs 5V to 6V DC power and either a power transistor or a motor driver chip works well. The pump also does not need to be primed and can self-prime itself with barely any water (half a meter).

Figure 24: Peristaltic Liquid Pump with Silicone Tubing

3.5.4 Comparison

Between all three of the pumps covered in this section, the Peristaltic pump is the clear winner. The main reasoning behind going with the peristaltic pump is usability and food safety. Taking a look at Table 6 below shows us the differences between the three different styles of pumps. The aquarium pump is the only one that runs on AC power which makes its usability the worst out of the three. Getting the aquarium pump to work with a microcontroller would be a lot harder than the two DC pumps. The aquarium pump's flow rate is also too high for our application. With a flow rate of 1.5 gal per minute, we would struggle to not overflow the water bowl and would likely scare the pet away. So, it came down to picking between the 3V DC pump and the peristaltic pump. The 3V DC pump would be a good option if it wasn't for the lack of longevity rating. The 3V DC pump just can't be trusted in the long run when it comes to drinkable water. The Peristaltic pump is also the only pump that doesn't need to be primed and doesn't need to constantly be submerged. In conclusion, the peristaltic pump is the pump we are going to use with our project. The only downside to it is the price, but all the pros make up for the one con.

	Aquarium Pump	Submersible 3V DC Water Pump	Peristaltic Liquid Pump
Size	46 mm x 36 mm	45 mm x 23.5 mm	27.8 mm x 66.8 mm
Weight	250 grams	30 grams	104 grams
Flow rate	Up to 6057 mL/min	Up to 140 mL/min	Up to 100 mL/min
Motor voltage	110-120 VAC	3 VDC	5 to 6 VDC
Needs to be primed	Yes	Yes	No
Submersible	Yes	Yes	No
Price	$13	$3	$25

Table 6: Water pump comparison table

3.6 Cameras

Adding a camera to our project increases the intractability for our users. This is really important for pet owners because they'll want to interact with their pets even when they're away. The owner will be able to record or take pictures from our device through our application. A camera also opens up the possibility for implementing software with object identification and animal recognition. This could eliminate our need for a motion sensor and allow us to just detect when a pet is in view of the camera. This section will be about the different cameras we can use with our project. The goal is to explore all their capabilities and compare to one another to figure out which one we want to use.

3.6.1 Raspberry Pi Camera Board v2

This is the latest camera board officially released by the Raspberry Pi Foundation. It is an upgrade from v1 from 5 megapixels to 8 megapixels with a Sony IMX219 image sensor. The static pictures from this camera can go up to 3280 x 2464 pixels. There's also a NoIR version of this camera which removes the IR filter, allowing you to use infrared to see in the dark. The main benefits of this camera come with its compatibility with the Raspberry Pi. It supports all models except with the Raspberry Pi Zero, it requires a different cable. It attaches to the Raspberry Pi by inserting a ribbon cable into a dedicated CSi interface, which was designed especially for interfacing with cameras (Figure 25).

Figure 25: Raspberry Pi camera hooked up to the microcontroller

In addition to the easy hookup of this camera, Raspberry Pi has a dedicated software library called libcamera which has the goal of supporting complex camera systems through the Linux operating system. The library drives the camera system directly from open source code running on ARM processors. Libcamera also gives developers the ability to use a C++ API that works with configuring the camera and allows for requests of image frames. This is also known as image buffers and can be found directly in the system's memory. Next, the images can be passed through image or video encoders to get formats such as JPEG and h.264. This will allow us to easily store photos and videos on our app in order to supply them to our users.

3.6.2 Spy Camera for Raspberry Pi

This camera is a small and flexible option with the enclosure being smaller than a thumbnail and a ribbon cable that stretches to almost a foot in length (11.4”). This camera connects to the BCM2835 processor on the Raspberry PI via the CSi bus seen in Figure 26 below.

Figure 26: Small spy camera shown hooked up to a Raspberry Pi

The CSi bus carries the pixel data and is capable of extremely high data rates from the ribbon cable to the processor. The sensor is only capable of 5 megapixels though, which results in a 2592 x 1944 pixel static image. This is a downgrade in image quality compared to Raspberry Pi's camera but the video quality is nearly identical. The biggest downfall to this camera is the lack of documentation and library support compared to the Raspberry Pi camera. So, implementing this camera via software could be a difficult challenge to overcome.

3.6.3 Arducam

This last section involves the company that supplies many different types of cameras including the official Raspberry Pi camera. They also create cameras compatible with the other popular microcontroller known as Arduino. In Figure 27 you can see the Arducam OV2640 hooked up to an arduino via it's I2C interface and the SPI interface for the camera commands and data stream. This would be one of our only options if we solely went with arduino microcontrollers. Arducam seems to be the distributor to go to when it comes to microcontroller cameras. They even have a new camera coming out that's capable of 64 megapixel images and 1080p 60fps video. With their variety of options, an Arducam is a viable option to consider.

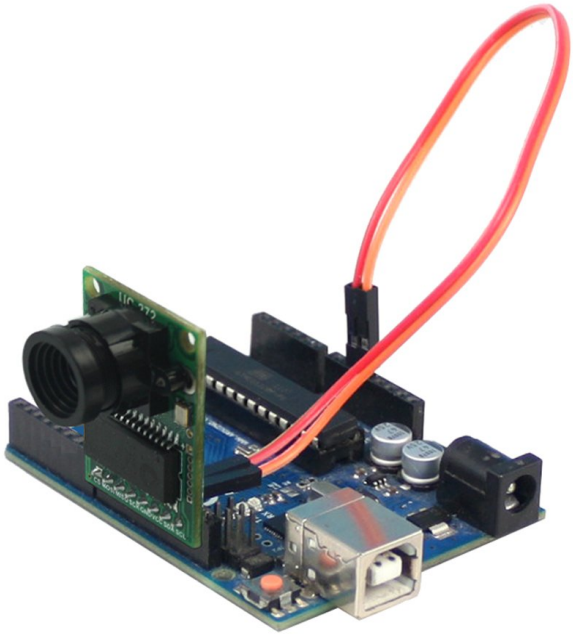

Figure 27: Arducam OV2640 hooked up to an Arduino

3.6.4 Comparison

When comparing the four different cameras below in Table 7, it becomes clear which camera would be ideal for us. If it weren't for low availability, the Raspberry Pi Camera Board v2 would be a good choice. But, nothing beats the value you get out of the Arducam OV5647. With the camera we are able to get pretty decent images and video for what we are using it for and its price is only $10. Additionally, Raspberry Pi's camera library is compatible with third party cameras so it should still be a relatively low learning curve as far as software goes.

	Raspberry Pi Camera Board v2	Spy Camera for Raspberry Pi	Arducam OV5647	Arducam OV2640
Size	25 mm x 23 mm x 9 mm	8.5 mm x 11.3 mm x 7.4 mm	120 mm x 5 mm x 2.5 mm	34 mm x 24 mm
Weight	3.4 g	1.9 g	9 g	20 g
Megapixels	8 MP	5 MP	5MP	2 MP
Video	1080p 30fps, 720p 60fps, 640x480p 90fps	1080p 30fps, 720p 60fps, 640x480p 60/90fps	1080p 30fps	N/A
Availability	Out of stock	In stock	In stock	In stock
Cost	$30	$40	$10	$26

Table 7: Camera comparison table

3.7 Radio Frequency Identification RFID

There are multiple ways to determine or identify an incoming pet to our Automatic Pet Feeder but a really effective option without relying on complex computer vision algorithms is by using a Radio Frequency Identification. RFID is a type of passive wireless technology that allows you to track or match objects or people (in this case, pets). The system consists of two basic parts: tags and readers. Readers emit radio waves and receive signals from RFID tags, which use radio waves to send IDs and other information. RFID is a technique that uses electromagnetic fields to identify and track tags attached to items. Radio transponders, receivers and transmitters form an RFID system. These devices are generally very small and can store large amounts of data. Although it does not always emit power, some power sources may have a built-in power supply or battery. The scanner used to read these devices can also provide enough power to read the microchip. This technology has many uses, but it is commonly used to track products, animals, and currencies, making this product very beneficial and advantageous for our Automatic Pet Feeder.

3.7.1 RFID Tags

RFID Tags are electronic tags that exchange data with RFID readers via radio waves. Most RFID tags consist of at least two main parts. One of them is an antenna that receives radio frequency waves. The second part is an integrated circuit (IC) used to process and store data, and to modulate and demodulate radio waves transmitted and received by antennas. Even though RFID tags sound very similar to the application of a barcode, they are more advanced than that. For

example, reading information from an RFID tag does not require a direct line of sight and can be done at a distance of a few meters while barcodes you have to be very close to the targeted area. This also means that one tag can serve multiple readers at the same time compared to having only one barcode tag.

The term “tag” also includes labels and cards. The type of tag depends on the body or object to which it is tagged. RFID systems can operate at either Ultra High Frequency (UHF), High Frequency (HF), or Low Frequency (LF). Therefore, tags can also change in terms of how often they are manipulated. These tags can be attached to almost any object. Typical targets are clothing, luggage, containers, building materials, animals, cars, even people, but of course, our focus is on animals or to be specific, domestic household pets. Some RFID tags are designed for rugged outdoor applications. These are designed to withstand natural and incandescent lights, vibration, shock, rain, dust, oik, and other harsh conditions. It is usually passive because it does not require a battery and can operate 24/7 without power outages. In Figure 28, we show the RFID tags and how it would look on a pet.

Figure 28: RFID Tags and Label cards

Now, time to choose which of the three types of frequencies is best for the consumer's pet without providing them harm to their loved ones. Both LF and HF frequencies are at the lower end of the RFID electromagnetic spectrum, indicating that RFID tags with these frequencies have a relatively short read range but are capable of transmitting and receiving in all directions. In addition, transmission will be slower under all conditions, but the success rate of operation under high humidity conditions will also be high. Both have the ability to change tags, often to work in metallic environments. Low frequency RFID can activate tags behind thin metallic materials, while high frequency RFID handles tags on metal surfaces, but the prepositions make a subtle but significant difference. For example, a cat with an LF RFID (mainly water) uses an Automatic Pet Feeder with an LF RFID reader to access food. Cats may gain control of food access at both frequencies, but the LF feeder is slightly more reliable and the LF tag is cheaper

than the HF. The cat's low frequency RFID device is, of course, close to the reader because the LF reading range is limited to centimeters or inches. With that being said, there's no need to acquire an UHF or HF tag since the proximity isn't very far at all and thus, the low frequency tags are most commonly used for access control and animal identification. For our Automatic Pet Feeder, the best option is described in Table 8, which shows the difference between UHF/HF/LF.

	Low Frequency	High Frequency	Ultra-High Frequency
Frequency Range	30 - 300kHz	3 - 30MHz	300MHz - 3GHz
Common Frequency	125KHz or 134KHz	13.56 MHz (NFC, near field communication)	860 - 960 MHz(UHF Gen 2)
Read Range	Less than 10cm	Less than 30cm	Less than 100m
Benefits	More resistant to interference by liquids and metals.	Higher memory capabilities, NFC tags can function as both reader and tag	Lower cost, with good read range and fast read rates
Applications	Animal tracking, automobile inventorying	Higher memory capabilities, NFC tags can function as both reader and tag	Lower cost, with good read range and fast read rates
Cost	$$	$$-$$$	$

Table 8: Explaining the difference of the RFID UHF/HF/LF

3.7.2 RFID Reader/Scanners

When it comes to RFID readers, we can choose one of many that are fixed and ready to go but the cost would be too high. Some readers have an option to perform read/write functions, allowing the user to control how many times a tag can be rewritten with. Another option to secure authentication is with a reader with a biometric scanner. Readers with these additional features push costs up, and for this product, it's overkill and unnecessary. The RFID that we are going to put our focus on is integrated circuits (IC) readers, USB readers, and near field communication (NFC) readers. First let's start with integrated RFID readers, these combine RFID readers/antennas in one device and can support additional external RFID antennas. To give

a vivid example, IC Readers are the devices that employees in companies like WalMart, Home Depot, etc would use to scan their items named First Phones. Some commercial solutions are integrated systems where both the reader and the antenna are built into the same device. This provides a compact solution for most retail or pharmaceutical applications. However, unlike fixed readers, the antenna cannot be changed, so the RFID system cannot be completely designed based on the deployment scenario. In a commercial integrated HF RFID reader, the radiating element is represented by a coil properly tuned to 13.56MHz. USB RFID readers provide an efficient way to read/write RFID tags in any application. These USB RFID readers are available in a variety of frequencies including low frequency, high frequency, and ultra high frequency and active 2.45GHz/433MHz. This type of reader is controlled and powered by a desktop or laptop via a USB interface. Some of these USB readers also work in dual frequency mode. These readers include Bluetooth, USB, RS232 serial ports, TCP/IP network ports, and WiFi communication ports. Lastly, we have Near Field Communication (NFC), a technology that allows valid devices in close proximity to exchange data wirelessly. NFC technology evolves from RFID technology and is finely tuned. NFC has become a popular term in the payments industry in recent years due to the rise of contactless payment via mobile wallet. A good example is Google Pay, Apple Pay, ‘tap’ system if the debit/credit card has that integrated in it among others. Even though NFC has taken a more advanced method than RFID especially in the contactless payment method, it is not as effective for an Automated Pet Feeder since we earlier discussed that a LF tag is best for this project and NFC works primarily in HF and provides more noise. For our Automatic Pet Feeder, we will be using two RFID models, one being integrated in the PCB while the other will be in a USB. In Figure 29, it shows how a Raspberry Pi is using an RFID tag and scanner.

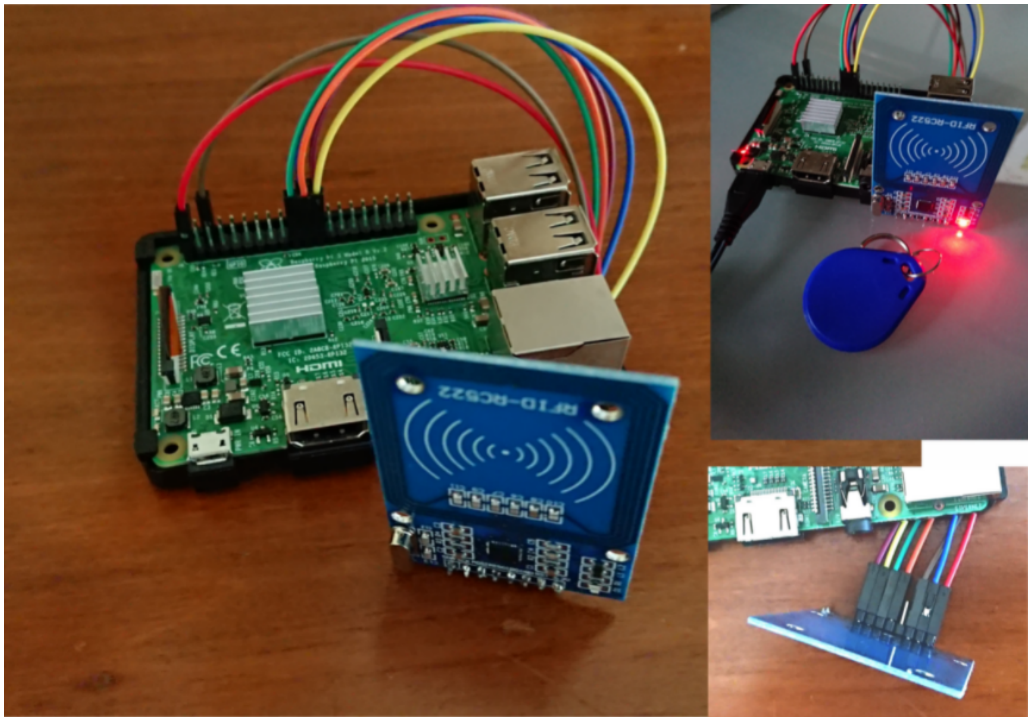

Figure 29: RFID tag using Raspberry Pi RC522 Reader and Arduino

3.8 Microcontrollers

A microcontroller is a compact integrated circuit that is used for a specific task within a system. The features that are usually included in the microcontroller include a processor, memory, and input/output (I/O) peripherals on a chip. The processor is the brain of the controller, because that is where all the information is processed. Without the processor, the other features would not know what to do, because they need a certain kind of information to function and the processor is what takes the input and translates it to something the other components can understand. However, the processor will only provide the information that is asked for from the code.

The memory is what stores the information that went through the processor. It is found in several products like cars, robots, computers and other devices. The input/output is what connects the microcontroller to the outside world, because it has to take the input that goes through the processor which would create the output we see. However, to make things easier, there is a feature called ADC, which stands for Analog-to-Digital converter. The ADC will take an analog signal as the input and output a digital signal. This is what allows the processor to interact with analog devices like the sensors we plan to use. The use for this component is to control the small parts of bigger devices. This makes it easier for a device to work, because each task that is required for the overall machine to work is taken care of by a microcontroller. For this product, the microcontroller must receive several inputs from each of the sensors and compute the values that will help understand the status of what the sensor is measuring. The microcontroller may or may not include different methods of communication like UART, SPI and I2C.

UART stands for Universal Asynchronous Receiver/Transmitter and the role of UART is to transmit and receive serial data. Out of the three types of communication, UART may be the simplest one, because it only uses two wires directly connected to two separate devices to transmit data. UART communication involves transmitting data from a device like a CPU into serial form to the receiving UART. Then that data is converted back into parallel for the receiving data. There are two pins used in this process with the Tx and Rx pin. Since the transmission of data is asynchronous, that means there is no clock signal. This means there is nothing that will synchronize the bits from the transmitting UART to the receiving UART. Instead, the UART that is transmitting uses start and stop bits to data that is being transferred. This way, the UART knows when to start reading and stop.

SPI is another method of communication that stands for Serial Peripheral Interface. SPI communication is used, because one of its benefits is that the data can be transferred without interruption. SPI works through a master-slave relationship with four connections that are Master Output/Master Input (MOSI), Master Input/Master Output (MISO), Clock (SCLK), and Slave Select/Chip Select (SS/CS). MOSI is the line where the master sends data to the slave. MISO is the line where the slave sends data to the master. SCLK is the line for the clock signal. SS/CS is when the master chooses which slave to send data to. For SPI, the clock signal synchronizes the output of the bits from the master and send some of the sampling bits to the slave. Since SPI uses a clock, that means it is synchronous. For one clock cycle, one bit of data is being transferred. The signal for SPI is always initiated by the master since it’s the master that configures and generates the clock signal.

I2C is the final method of communication and it stands for the Inter-Integrated Circuit. I2C is like a mixture of both UART and SPI. In this, you can connect several slaves to a single master similar to SPI. However, a difference is in this one you can connect multiple masters to control multiple slaves or just one. The similarity to UART is I2C also uses two wires to transmit data between the master and slave. There are two connections which are Serial Data (SDA) and Serial Clock (SCL). Since it is a serial communication protocol, data is transmitted by each bit through a single line. This section is used to show the different microcontrollers that were considered and under investigation to determine which one would be included in our product.

3.8.1 Arduino UNO R3

The Arduino UNO, shown in Figure 30, is a high-performance, low power 8-bit microcontroller board that uses the ATmega328 microcontroller. The great thing about it is that since it's so popular, there are many sources online that can be used for us to learn more about it. The simplicity it offers is a huge bonus as it makes it easier to be coded. It has 23 general purpose input/output pins, a 16 MHz crystal oscillator and a USB connection. The operating voltage is set to be around 2.7 to 5.5 V. Out of the 23 input/output pins, 6 of them are used for Pulse Width Modulation (PWM). There are also 6 analog pins provided with the board. The flash memory has a storage of 32 KB, SRAM of 2 KB and a clock speed of 16 MHz. For the 14 pins, pins 0 and 1 are Rx and Tx respectively, which is used for UART. Pins 3, 5, 6, 9, 10 and 13 provide an 8-bit PWM. Through SPI, pin 10 is SS, pin 11 is MOSI, pin 12 is MISO, and pin 13 is SCLK. With the analog input, pin 4 is for SDA and 5 is used for SCL. Both are used for I2C. Another important feature is that this microcontroller gives us a 10-bit ADC, which determines the accuracy of the sensors' measurements. It also provides low power consumption. When in Active mode, the current would be 1.5 mA at 3 V and 4 MHz. In Power-down mode, it will reach 1 uA at 3 V. This microcontroller can be programmed using the Arduino software.

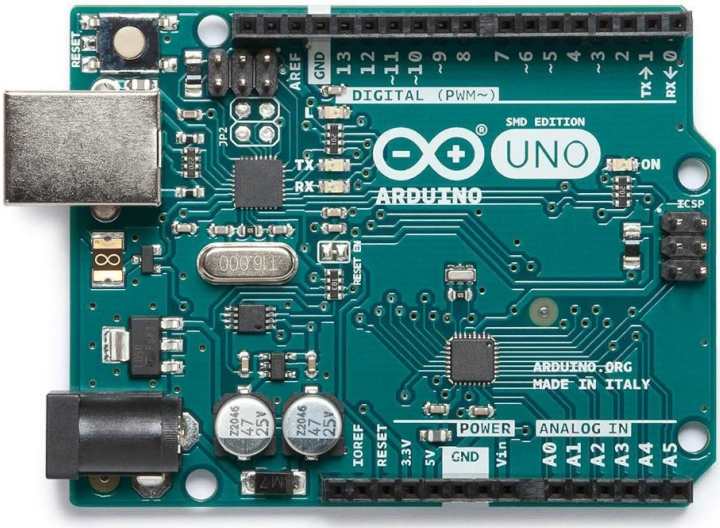

Figure 30: Arduino UNO R3

3.8.2 MSP430FR6989

The MSP430FR6989, shown in Figure 31, is a microcontroller that is made by Texas Instruments, and is a part of the MSP family. It is an Ultra-Low-Power microcontroller and it operates between a voltage of 1.8 V to 3.6 V. This board has a 16-Bit RISC architecture that has a clock that performs up to 16-MHz. This microcontroller comes with several Ultra-Low-Power Modes. When the microcontroller in active mode, the current reaches up to approximately 100 µ A/MHz. In Standby Mode, the current typically goes to 0.4 µA. Real-Time Clock mode has the current go up to 0.35 µA. The last mode is Shutdown mode, which is when the current only goes up to 0.02 µA. The Non-volatile memory of the microcontroller only goes up to 128 kB, while the Random Access Memory (RAM) is 2 KB. This device is capable of three different methods of communications. These three methods are I2C, UART, and SPI. There are two UARTs, two I2Cs, and four SPIs. It also provides 83 General Purpose Input/Output (GPIO) pins. A super important feature we need is an Analog-to-Digital Converter, and the MSP430FR6989 provides a 16 channel 12-bit ADC. It also has advanced sensing, DMA, an LCD, Real-Time Clock, and a scan interface. The microcontroller can be controlled using programs like Code Composer Studio. Also, as a result of classes we as a group have taken before, we already have access to a MSP430FR6989. So, that would make it very easy to use as we would not have to wait for it to be delivered or have to worry about it being out of stock.

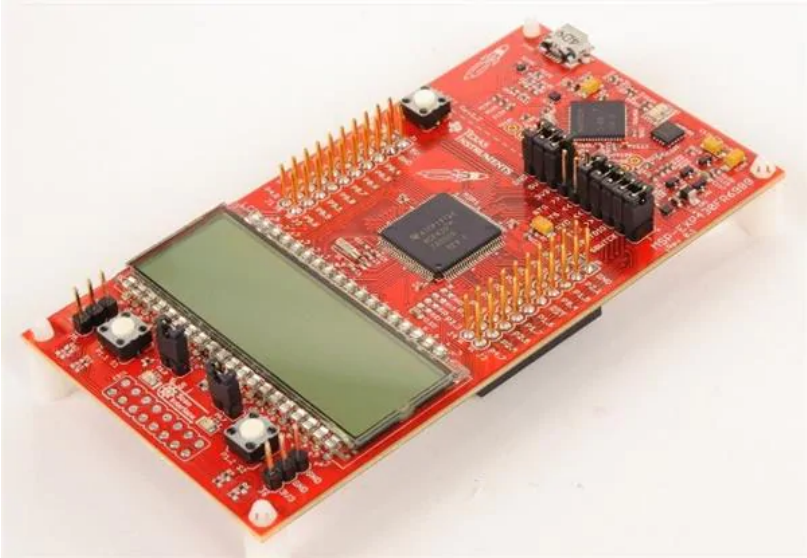

Figure 31: MSP430FR6989

3.8.3 Raspberry Pi Model B

The Raspberry Pi Model B (Figure 32) is the enhanced version of previous devices by Raspberry Pi. It comes with the option of either one, two, or four gigabytes of RAM. It provides their users with a bluetooth interface with Bluetooth Low Energy. There are a total of 40 GPIO that are included on the board. Up to six pins for UART, six pins for I2C, and five pins for SPI. The Raspberry Pi needs an input voltage of 5 V at 2 A when connected to a USB-C. The Raspberry Pi also comes with many derating system caifferent software libraries as well as great documentation. Additionally, a linux based operating system has been created for the microcontroller called Raspberry Pi OS (previously known as Raspbian). This allows for a better

user experience and more interactibility with the hardware. The development environment is the best out of any microcontroller and also comes with the ability to code in Python which is a modern day language that focuses on the ease of developing software.

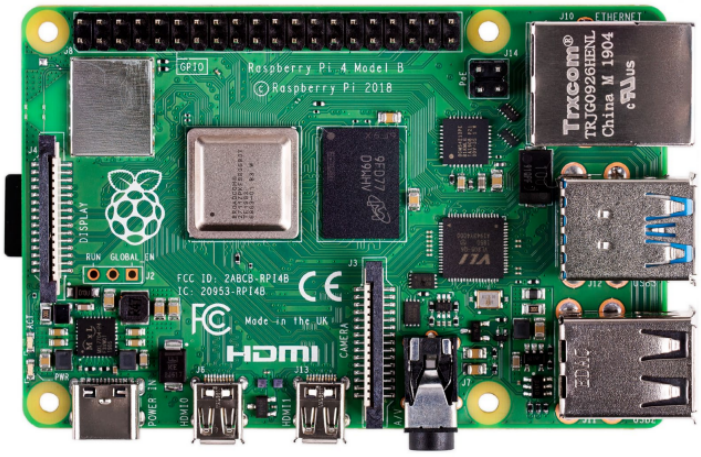

Figure 32: Raspberry Pi Model B

3.8.4 Comparison

In Table 9, we can see an in depth comparison of the specs between the three different microcontrollers we discussed in this section. Our main microcontroller will be a Raspberry Pi but it could be valuable to use an Arduino too. An arduino could relay information from our sensors to our Raspberry Pi if needed. The main reason for using a Raspberry Pi is the software capabilities. With a Raspberry Pi, we can use Python instead of having to use C (which is required to use an arduino and a MSP430). Raspberry Pi's also have the ability to run a Linux operating system which can be useful in many ways. In conclusion, we will most likely end up using a Raspberry Pi as our main microcontroller and an Arduino as a secondary microcontroller.

	Arduino UNO	MSP430FR6989	Raspberry Pi
Memory	32 KB	16 KB	1 GB
Clock Speed	16 MHz	16 MHz	1 GHz
Low Power Mode	Yes	Yes	Yes
Architecture	8-bit	16-bit	64-bit
# of GPIO Pins	23 pins	83 pins	40 pins
Operating Voltage	2.7 V - 5.5 V	1.8 V - 3.6 V	5 V/ 2.5 A
RAM size	2 KB SRAM	2 KB RAM	512 MB SRAM

UART	Yes - USART	Yes - 2	Yes
SPI	Yes	Yes - 4	Yes
I2C	Yes	2	Yes
Operating Temperature	-40 C to +125 C	-40 C to +125 C	0 C to 50 C
Cost	$18.40	$0	$27.37

Table 9: Microcontroller comparison table

3.9 Power

While the mechanical and electrical parts of the Automatic Pet Feeder are crucial for its usefulness, all work performed by the Automatic Pet Feeder would not be conceivable without a sufficient stockpile of energy conveyed to it. This energy should be conveyed to every part, at different rates, changing electric possibilities. As various parts require various voltages, buying a main power supply will not suffice. Generally, cheap ones don't convey the different required voltages, and thus, the power supplies that really do offer numerous voltages will not come from a solitary Automatic Pet Feeder. Therefore, a viable solution to this would be a customizable power supply to provide power across all components needed without fail to the Automatic Pet Feeder.

The significance of the Automatic Pet Feeder has a dependable power source that will give capacity to the whole framework. The choice to utilize the power given by the customer`s divider outlet was made for several reasons. Since our Automatic Pet Feeder will be continuously active through a timer, application commands, among other features, it is best to use an AC power source due to the Automatic Pet Feeder being active all the time even when it's not in use. We need to add a feature such as RFID (Radio Frequency Identification) tag reader that will check every microseconds, or scaling the data being sent every few minutes and any other features that continuously monitors the system is the reason why using an AC power source of the customer`s wall outlet will be optimal for the Automatic Pet Feeder. Not only will AC be the best solution due to constant power draw but it also gives more flexibility when designing the voltages that would be converted to DC power to certain components of the system. With the continuous power draw that the system is using, it would not be wise for the user to use batteries and constantly change it due to it being drained at a very fast pace. Without a reliable power source like the customer's home power supply, the Automatic Pet Feeder will not draw sufficient power to fully function continuously and it will inevitably fail.

Although using the customer`s wall power source is ideal, the need for a backup battery source is a needed part for the Automatic Pet Feeder design. This will need to be a reliable system that the customer can trust with the nutrition to their pets in the hands of an autonomous system. By adding a backup battery-operated power source, it will provide extra security measures to prevent the system from failing from lack of power or power loss. The configuration of the backup battery will give sufficient power enough to last between 48-72 hours and will give

enough time for the customer to react to the system's condition and take measures of the Automatic Pet feeder and make sure the food of the pet is taken care of.

3.9.1 Battery

It is crucial to have a backup battery for the scenario that the main power source (wall-mounted) drops. The preference is for a rechargeable battery that gets active whenever the Automated Pet Feeder receives a signal from the main power source is zero or off. Whenever the Automated Pet Feeder triggers the red indicator light, it means the feeder has received the notification that the main power source is zero. The backup battery is designed as a short-term alternative in the event of loss of external power. If the pet feeder is working on the backup battery power, the Automated Pet Feeder will go to sleep mode and some features will be restricted. There will be a small delay between the screen display and the scheduled time supply.

The audio recording that was stored in the app will be played once during this stage of power saving. There will be an indicator red light that will periodically flash to remind the owner that the Automated Pet Feeder is working on battery power saving mode. To work on the Automated Pet Feeder directly, press any button to get it off sleep mode. These are the projected features that will be implemented on this pet feeder to indicate to the owner that it is relying on a backup battery and needs to be addressed. Also, these features, although limited to what the Automated Pet Feeder can fully provide, is for the intent to save as much power from the backup battery while still providing the essential functions that this project can accomplish. For the Automated Pet Feeder size, the need of a huge backup battery isn't necessary, in fact, it can be used with 3-4 AA batteries attached to the Raspberry Pi of our choice (model B or greater). In Figure 33, it shows, hypothetically speaking, how a backup battery will be in the Automated Pet Feeder.

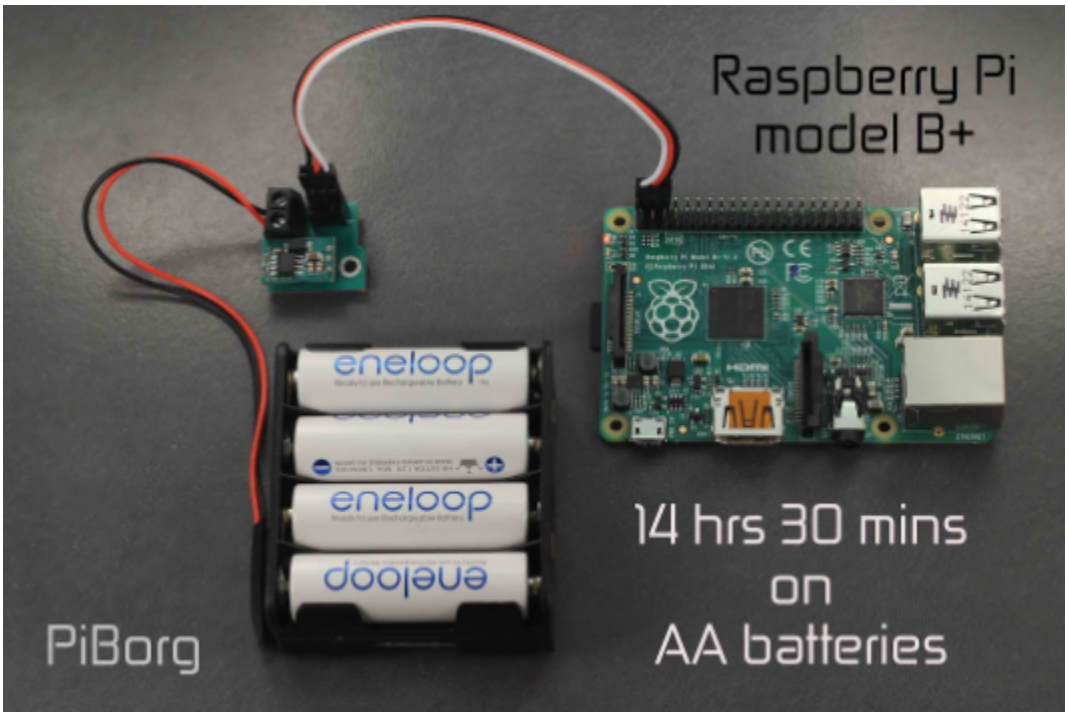

Figure 33: Use of 4 AA backup batteries on Raspberry Pi

3.9.2 Switch

The operating principle of the switch differs depending on the ON/OFF mechanism. Various electrical or electronic circuits use switches to control or trigger owl circuits. Two important components, such as poles and through, allow you to see what type of connection the switch can make. These two components are also used to define variations of switch contacts. Poles and throws can be defined as: The number of circuits controlled by the switch is called the pole, and throw can be defined as the number of positions the switch can take. A one-way switch consists of a pair of contacts for opening and closing. The Double-Throw switch consists of one contact that can be connected to the other two contacts. When the switch is activated, current flows between the two terminals of the switch. When the switch is OFF, no current flows between the two terminals of the switch.

The different types of switches we will be focusing on for the Automated Pet Feeder are SPST (Single Pole Single Throw), SPDT (Single Pole Double Throw), and DPDT (Double Pole Double Throw). The application of the SPST switches are the light switches shown below, also known as toggle switches. This type of switch has one input and one output. This light switch circuit controls and connects a single wire. It is an ON/OFF switch, so, when the switch is turned on or closed, current flows through the two terminals and the light bulb in the circuit flashes. When the switch is turned OFF or open, no current flows through the two terminals as explained earlier. SPDT switch applications are primarily concerned with three-way circuits for turning lights ON and OFF from two locations, such as the top and the bottom of stairs. When switch A is closed, current flows through the terminals, but only light A is ON and light B is OFF. When switch B closes, current flows through the terminal, only light B turns ON and light A turns OFF. In a scenario with an ON-ON or ON-OFF-ON mode, they act as two separate SPDT switches operated by similar actuators. Only two loads can be turned on at a time. DPDT switches can be used in all applications that require open and closed wiring systems.

3.9.3 Voltage Regulator

With power supply being one of the most important aspects of this product, we must make sure that we’re sending the right amount of power to our components so they are able to work efficiently. Simply plugging our product into the wall may send too high of a voltage into our product, we wouldn’t want someone to turn the pet feeder on and send all that power into the device, because that would result in not only the consumer getting hurt, but the parts inside would be destroyed. Therefore, we need to have a voltage regulator that will decrease the amount of voltage coming from the outlet into the pet feeder. Each component in our product will require either a 3.3V or 5V. At the same time as decreasing the voltage, but it will also provide a steady voltage to make sure that the product is safe to use at all times it’s turned on.

With that being said, this voltage has to be decreased earlier than beneficial strength may be provided to the multiple components in use. There are different ways to reduce the voltage to a useful electric potential. Simplest way is to have a resistor or multiple resistors in series to achieve a significant voltage drop across the resistors, in which it will achieve the voltage reduction needed to supply to each component of the Automatic Pet Feeder. This method however will only work if the current source is constant and the amount of power consumed is the same (basically static). But if the load is dynamic, which means the amount of power consumed varies over time, the current passing through the resistors will fluctuate and change

the voltage drop and ultimately provide too high of an electric potential load and possibly destroy the load.

These regulators can be implemented by integrated circuits or discrete component circuits. Voltage regulators are classified into two types, Linear regulators and switching regulators. These regulators are primarily used to regulate the voltage of the system, while linear regulators are less efficient and switching regulators are more efficient. High efficiency switching regulators can transfer most i/p power to o/p without loss. The two voltage regulators have different types within themselves. For instance, Linear voltage regulators have two types, Series and Shunt while Switching has three in Step-up, Step-down, and Inverter voltage regulators. As it shows in Figure 34, it displays how the circuit design is for a typical Linear voltage regulator and Switching voltage regulator.

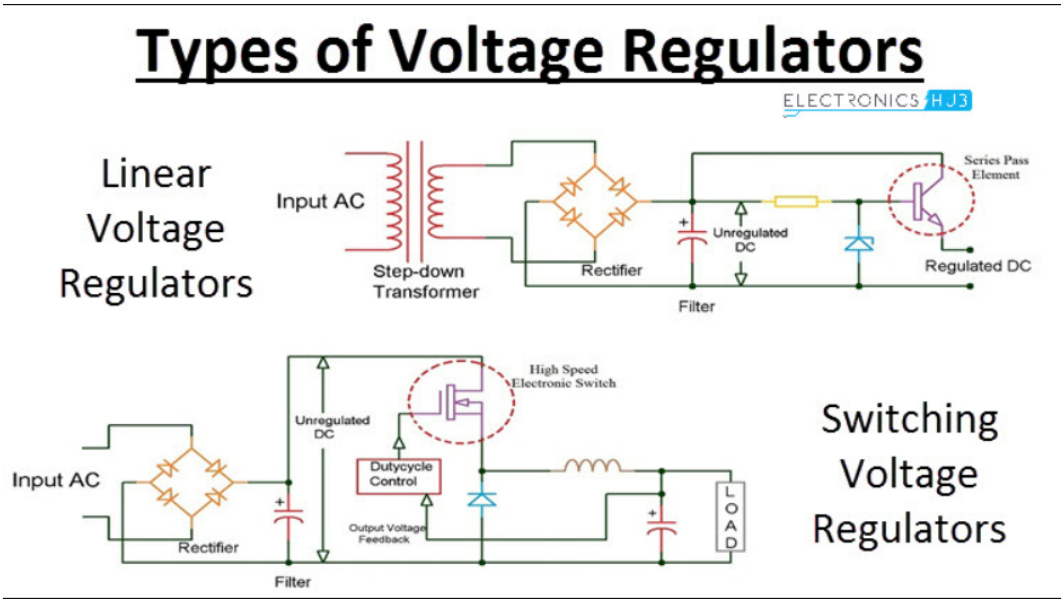

Figure 34: Circuit design of both Linear and Switching Voltage Regulators

When it comes to Linear voltage regulators they act like voltage dividers. Making the resistance of the voltage regulator vary with the load and resulting in constant output. It is also important to know that the Linear Voltage regulator is the original type of regulator to use for power supplies and works very similarly to an active pass MOSFET or BJT when it comes to the output voltage. These kinds of voltage regulators dissipate a lot of power due to the net voltage dropped within the transistor to dissipate heat. The benefits of using a linear voltage regulator is that it gives a low output ripple voltage, it provides a fast response time to either change lines or load, and gives a low electromagnetic interference and less noise. Although those traits sound advantageous for our project, it does have drawbacks. One of which is that the efficiency is very low, it emits excessive energy in terms of heat and requires a large space or something to mitigate it (such as heatsink or liquid coolant) and the input voltage originally used cannot be altered. The fact that one of the disadvantages of a Linear Voltage Regulator is that it requires a large space or additional components for our Automatic Pet Feeder, we have to look at another alternative.

Switching voltage regulators quickly turn devices in series on and off. The duty cycle of the switch determines the amount of the charge transferred to the load. It is controlled by a feedback mechanism similar to a Linear voltage regulator. Switching voltage regulators are efficient because the series elements are either completely conductive or turned off because they consume very little power. Unlike Linear Voltage regulators, Switching voltage regulators can generate an output voltage with a polarity higher than or opposite than the input voltage. Which makes the Switching voltage regulator quickly switch on and off to change the output. This requires the use of a controlled oscillator and also charges memory components. This brings in a Pulse Rate Modulation with the Switching voltage regulator that changes the frequency, constant duty cycle, and noise imposed by the PRM, which is more difficult to filter out the noise. For the Automatic Pet Feeder, this particular voltage regulator has great advantages such as efficiency, size, weight, a more complex design which can handle higher power efficiency. The Switching voltage regulator has certain drawbacks such as a higher output ripple voltage, an electromagnetic interference that produces very noisy output and can be very expensive.

The use of a voltage regulator for our Automatic Pet Feeder is ideal since some of the limitations of the voltage regulator include the efficiency of the regulator can be restricted to 3V or 5V and that means the application will have fewer Vin/Vout differentials. It seems more suitable to use a Switching voltage regulator because it is highly efficient, size/weight, and it is more complex, even though it provides a lot of noise due to EMI if the exterior components are not chosen wisely to mitigate it.

3.9.4 Diodes

The importance of a diode for our Automatic Pet Feeder is that it protects the circuit by limiting the voltage and also transforms AC to DC. Even though they transmit current in one direction through the Anode (+ terminal) to the Cathode (- terminal), they do so in different ways. Diodes can be made from one of the two semiconductor materials, silicon and germanium. If the anode voltage is more positive than the cathode voltage, the diode is said to be forward biased and easily conducts with a relatively small voltage drop. If the cathode voltage is more positive than the anode voltage, the diode is said to be reverse biased.

The arrow on the diode symbol indicates the transitional direction of current when the diode is conducting. Knowing the voltage drop and the positive value if it exceeds the negative value can dictate which type of bias we are dealing with. If the diode is forward biased and current is flowing, there will be a small voltage drop across the diode. The forward voltage is 690mV for silicon diodes and 300mV for germanium. The potential energy of p-type materials is positive and the potential energy of n-type materials is negative. When the battery voltage drops completely, the diode becomes reverse biased. The blocking voltage is 20micro-amps for silicon diodes and 50 micro-amps for germanium. The potential energy of p-type materials is negative and the potential energy of n-type materials is positive. There is also a possibility that the voltage potential across the diode is zero in which it makes it a zero biased diode.

There are different types of diodes, and each type has its own use. One of them is used in many electronic devices today and will be used in this project and that is the Light Emitting Diode (LED). These types of diodes work by having an electrical current between electrodes pass through the diode and light will be produced. That is, light is generated when a sufficient amount

of forward current flows from the anode to the cathode. For many diodes, this generated light is not visible because it is at a frequency level that does not allow visibility. Another type of diode is a Zener diode. This is the most useful type of diode because it can provide a stable reference voltage. They operate in the opposite direction and fail when a certain voltage is reached. When the current through the resistor is limited, a stable voltage is generated. Zener diodes are commonly used in power supplies to provide a reference voltage. A P-N junction diode is also called a rectifying diode. These diodes are used in the rectification process and are made of semiconductor materials. The P-n junction diode contains two semiconductor layers. One layer of semiconductor material is doped with P-type material and the other layer is doped with N-type material. The combination of these P-type and N-type layers forms a junction known as P-N junction. Therefore, it is named P-N junction diode. The P-N junction diode allows current to flow in the forward direction and blocks current from flowing in the reverse direction.

3.10 Programming Languages

When it comes to programming languages, there are many options to consider, all of which have their own pros and cons that we will be exploring throughout this section. We will highlight the languages we have decided to work with and the reasons why these languages would be a good option for us to use which provide the necessary tools to complete the tasks within the scope of the project.

3.10.1 Pet Feeder Main Device

We encounter embedded programming in almost every aspect of our lives, whether that is inside modern appliances, or in tools and automations used across multiple organizations to facilitate work and productivity. For this reason, many languages have been optimized and accepted as embedded programming languages that provide tools and frameworks to make the development of embedded systems easier, with interfaces familiar to the user and with well known design patterns in mind. These languages are particularly helpful because they provide access to low level functionality and access to core system resources that are key in the process of programming an embedded device that will meet all the requirements necessary to provide all the functionality and ease of use that we aim to have throughout this project.

Many aspects are to be analyzed when considering a specific programming language to start development for systems that in the majority of cases have much less resources than regular home computers or modern mobile devices. Since embedded systems are, in most cases, bound to low power and low memory constraints, as well as processing power constraints, the language chosen that will run in the microcontroller of the automatic pet feeder's core functions must allow, and ideally be optimized to meet these constraints and provide a smooth performance for the device that will run and respond to the user at an excellent time.

Since these pet feeders will reside inside the pet parent's home, the feeder must also have security modules to provide safe communication between the mobile application and the device. With this in mind, we examine the different languages we could use for this project and compare them in terms of ease of use, memory efficiency, power efficiency, and their security configurations.

3.10.1.1 C Language

C is a widely used general-purpose computer language that is simple to learn and use. It's a machine-independent structured programming language that's widely used to create a variety of apps, operating systems and other complicated programs such as version control softwares and even other languages interpreters. C has been very popularly used for embedded programming for a long time made possible through an extension called Embedded C.

Embedded C is a C extension for developing programs that run in microcontrollers. Embedded C varies from the regular C languages in terms of I/O Hardware Addressing, fixed-point arithmetic operations, accessing address spaces, and other properties.

Microcontrollers such as AVR, ARM, or maybe PIC32(MIPS) are all recommended, even though almost every microcontroller can run Embedded C and could be used to program a large range of devices and automations as long as they have a C compiler available for it. For this reason, many of the devices we see nowadays are all written in C. C also provides the required low level access to interact with the communication modules of the microcontroller, and many companies have released packages and extensions that allow for easier use of the language and come equipped with variables, functions and classes with meaningful names that interact directly with that specific microcontroller. The MSP430FR8969 is an example of a microcontroller that provides a series of packages with variables and functions that interact with a board which they call a LaunchPad. This package provides a variable for every pin in the board in order to control the different sensors, buttons, ports or other external devices added to it.

Even though C is widely used for embedded development across multiple platforms and would be a great option to program the code for the automatic pet feeder, we also have to keep in mind that C is a relatively old language. Having been released in 1972, C lacks several elements that are considered standard for systems nowadays and are prone to failures in the system and also several security issues. It is also somewhat hard to program in and some of the documentation is outdated. New systems coming out that provide a greater range of features also might not support C or are optimized to run in other programming languages such as Python.

3.10.1.2 Rust Language

Rust is a multi-paradigm programming language making it concurrent, functional, generic, imperative and structured. Rust serves as a general-purpose programming language designed with performance in mind, along with a variety of safety features, especially safe concurrency and memory management. Being first released in 2010, Rust provides a larger set of features with a much richer and updated syntax.

In some cases Rust programs are optimized quite well and provide better performance than programs written in C. While C is appropriate for developing simple code in a low-level environment, Rust provides significant tools for integrating numerous functions or even whole libraries. Rust is also much faster and can be more than twice as fast as some of the other languages that rely on interpreters. Since Rust is compiled directly into machine code, there is no need for an interpreter or virtual machine between the code and the hardware.

Rust has gained a lot of popularity in the past few years as it allows programmers to design applications that are very efficient. Due to the growth of the web3 community, the community around Rust has also grown tremendously, contributing to language features and providing extensive documentation on how to accomplish certain solutions by providing tons of real life examples.

Although Rust seems to match and, in some cases surpass the performance of its competitors, it still comes with drawbacks of its own. Rust can present a large learning curve and can be quite complex to learn and in the same manner, developers might take longer to learn Rust due to its complexities. Also, since the language is fairly new, there are not that many third party tools or libraries and most of the features must be implemented from scratch by the developer, which could cause longer development times.

3.10.1.3 Python Language

Python is a high-level, general purpose programming language designed with code readability in mind with the use of significant indentation, that is that as opposed to languages like C, where the brackets and semicolons determine where each instruction begins and ends and indentation is ignored, Python does care about the indentation and is what tells the compiler how the program is structured. Its language is based on an object-oriented approach, amining to help programmers with a clear and logical code for small and large scale projects.

Having its first release in 1991, Python now includes large libraries for every type of application, ranging from machine learning and data analysis to home automations and embedded systems. Python looks and feels as plain english making it quite easy for programmers to understand what the code is doing at all times as well as make it easier to program and write complex statements that facilitate the behavior of some applications, and thanks to its interpreter, many tools allow for easy unit and automating testing for the software written with the language.

Just as with C, Python has its own library that serves to write programs that run properly and efficiently in embedded systems called MicroPython. MicroPython is a lean and efficient implementation of the Python 3 programming language which contains a small portion of the Python standard library and is intended for microcontrollers and limited contexts like the one we're dealing with for the automatic pet feeder. MicroPython provides a tool called pyboard which is a small electrical circuit board that runs MicroPython on bare metal, providing a low-level Python operating system for controlling various electronic applications. These packages provided for Python are very similar to those provided by organizations such as Texas Instruments for their MSP430X LaunchPads and provide similar functionality depending on the microcontroller chosen. Since Python provides an easy to use interface, many developers have opted to use it for embedded development. Interfaces such as a Raspberry Pi have been optimized to work with it and actually, the Pi from its name comes from Python. Python, along with the Raspberry Pi, are aimed to encourage anyone to begin exploring with automations and embedded systems.

It is good to note that Python is not a one-case-fits-all solution either. Python can in a lot of cases be significantly slower compared to languages like C or Rust due to its interpreted nature. Since vanilla Python relies on its interpreter to dynamically translate the code to instructions that the

system running the program can understand, there is a significant amount of time added to processing and compilation that can, in some cases, tremendously affect the performance of programs written in Python. Even after considering the possible drawbacks of Python, the language still poses great advantages that would make the development of the pet feeder much easier. Ultimately, since we decided that our best choice of microcontroller for building all the functionality that the pet feeder requires would be a Raspberry Pi, Python would be the language of choice we are going with. It is a language that it's at the core of the programming for the Raspberry Pi, includes vast amounts of documentation of how to program along with many examples and tutorials specifically aimed at developing with the Raspberry Pi and also, the participants of our group are already familiar with the language, which will help us to save time in having to learn the syntax and figuring out the correct way to make it work with our chosen microcontroller. In Table 9, you can see a full blown comparison between each language and their documentation, implementation, and learning curve.

Language	Documentation	Implementation	Learning Curve
C	Great. Since its release in 1972, many people have contributed to multiple packages and documentation	Medium. Although it includes extensive documentation, C is still considered a fairly complicated language, as it requires to also manage memory in a low memory environment	Shallow. Previous classes taken during the semester teach how to use C for embedded programming making it easier, even though it requires more boilerplate code
Rust	Good. Rust is a newer language, and even though it's gained popularity, it lacks some documentation	Medium. Rust is a fairly new language and its syntax can be quite confusing when coming from an object oriented programming background	Steep. Although it has a better performance than other languages, it would require for us to have to learn a completely new language that is not similar to

Python	Great. Python has been one of the most popular languages across many applications and provides multiple packages to control our application	Easy. Python has an easy to follow syntax that resembles plain english. It also provides its own garbage collector and is the languages of choice in the Raspberry Pi	Shallow. Most of our team members have some background making programs in Python and will not require for us to take the time to learn another language

Table 10: Programming languages comparison table

3.10.2 Mobile Application

Developing mobile applications that interface with other physical items has gained tremendous popularity in the last few years. Having a mobile application facilitates the use of certain devices and provides the users with more granular control of the services that interface with the application. These mobile applications also allow users to have more freedom and peace of mind due to the fact that in most cases, the applications allow them to interact with the devices remotely and have almost real time responses to their devices, controlling all sorts of devices in a seamless way.

With the rise of smartphones and our use of computers on a daily basis, many languages were adapted and frameworks were created that allowed for the development of mobile applications. There are currently two main operating systems that we have to account for when developing the mobile application, iOS for Apple devices and Android for almost any other smartphone device. These two operating systems have different native languages and frameworks, typically provided by the company developing the smartphones, that provide developers with all the tools necessary to design and build an application with all sorts of integration including network connectivity, bluetooth communication, notification services, amongst many other features. The drawback of these frameworks is that they are usually limited to be used only on that operating system, prompting the developers to lose half of the potential user base or to have to have two different applications each built with different softwares and having to manage different codebases.

Luckily, a couple tools and frameworks have been provided by several large organizations which allow the developers of the application to write the code once and distribute it on several platforms at the same time, making all the necessary functionality cross platform.

We will discuss the different languages and frameworks that are currently available to develop the mobile application that will serve as the method of communication between the pet parent and the automatic feeder. We observe the benefits and drawbacks of each of these frameworks and lastly, we highlight the choice we consider the best for the mobile application taking into consideration all the features that the application must have, including security and ease of use.

3.10.2.1 C# Language

C# is a multi-paradigm, general-purpose programming language. Static typing, strong typing, lexically scoped, imperative, declarative, functional, generic, object-oriented, and component-oriented programming disciplines are all covered by the C# programming language. Since C# is a C-based language, the two syntaxes are equivalent. Brackets are used to separate coding structures, and C-style object-oriented programming with dependencies and libraries is quite similar. If a developer is already familiar with Java or C++, the transfer to C# is straightforward.

Now considered a fairly popular programming language, C# provides developers with the ability to build structured web and mobile applications while providing an easy to use syntax. With its first release in 2000, and currently maintained by Microsoft, C# now includes many packages and libraries that make developing frontend applications very easy. Packages such as .NET for web applications and Xamarin for mobile applications are some of the most popular solutions for developing applications with C#.

Looking into Xamarin as a potential framework to build the mobile application that will interface with the pet feeder, we explore the pros and cons of building the application with this language. Xamarin allows full hardware support, including the access to the devices camera, GPS and bluetooth module, etc., it is open-source and free, and provides simplified maintenance. At the same time, the familiarity with platform-specific code might be needed, its developer community is considerably small, it can be not a great choice for applications with complex UI as the UI development is time-consuming and not mobile friendly.

Compared to other cross-platform solutions for the development of mobile application development, Xamarin does leave a lot to be desired. Since we aim to provide the best and easiest to use mobile interface, we decided that Xamarin was just not a good option for our design and vision for the final product.

3.10.2.2 Dart Language (Flutter Framework)

Dart is a client-side programming language for developing web and mobile applications. It was built by Google and may be used to build both server and desktop programs. Dart is a C-style garbage-collected, object-oriented, class-based language. Dart was developed 10 years ago and has rapidly gained popularity for its easy to learn syntax. Frameworks such as Flutter have helped the popularity of dart by providing an easy to use interface for developers to build great cross-platform applications.

Flutter is currently maintained by Google and has a very large community of open source contributors collaborating to make the framework feel as if the application was being developed using one of the native languages of the operating systems. Flutter accomplishes a cross-platform solution by only requesting a blank canvas from the operating system and drawing all of the components to this canvas and providing different callbacks that respond to different user inputs, such as tapping on a component or swiping across a list. In this framework there is a hierarchical structure based on parent and children objects referred to as widgets. These widgets make up almost every single aspect of the applications. They serve as visual components such as a button

or text, but also as for other aspects such as padding around components, the physical position of these other components and the aspect ratio that these components occupy.

Due to Flutter's way of laying out components and interacting with the device's operating system, and based on the design guidelines set by the team in charge of maintaining the framework, the components might not feel familiar to some users, as there is no way to tell the operating system to provide the developer with native visual components. In some cases, many developers have complained that due to the fact that Dart and Flutter run in only one thread, some simple aspects such as transitions and animations using this framework can feel janky and slow if another computation is required while performing UI updates.

Since our team is not familiar with Flutter to an extent where we could all collaborate and provide a mobile application that meets the requirements for our project and taking into account the possible drawbacks reported by other developers, we have decided that Flutter will not be a viable solution as it would probably cause us to take time away from other essential parts of the pet feeder and force us to learn a whole new framework in order to build a mobile application that will behave smoothly when being used by the pet parents.

3.10.2.3 JavaScript Language (React Native Framework)

JavaScript, sometimes known as JS, is a computer language that, together with HTML and CSS, is one of the essential technologies of the World Wide Web. On the client side, over 97 percent of websites employ JavaScript for web page behavior, with third-party libraries frequently incorporated.

Since JavaScript is one of the most popular languages for web and mobile development, many packages have been released that provide developers with the necessary tools to build their applications effectively. JavaScript provides many advantages when developing applications. It excels at delivering and rendering the contents of web and mobile applications at very fast times as it also includes a client-side script which speeds up the time of execution of a program and saves the time previously required to connect to the server and request the necessary content. JavaScript also has a very simple and rich interface, basing its design in interoperability, extendable functionality, versatility and lower overhead.

React Native, first released by Meta (formerly Facebook) in 2015, is an open-source UI software framework. It allows developers to leverage the React framework alongside native platform features to create apps for Android, Android TV, iOS, macOS, tvOS, Web, Windows, and UWP. It is based on React, a JavaScript framework also designed and maintained by Meta to build web applications which makes creating interactive UIs a breeze. Creating basic views for each state of the project, React can then automatically update and render the appropriate components as the data of the application changes.

The working concepts of React Native are nearly identical to those of React, with the exception that React Native does not use the Virtual DOM to alter the DOM. It operates in the background on the end-device and connects with the native platform through serialized data across an asynchronous and batched bridge (which understands the JavaScript written by the developers). The React Native framework is specially useful as it binds components to dynamic content while

also requesting native components from the operating system, making applications feel more familiar for users. It also provides access to almost every aspect of the operating system, settings that will be required in order to set up proper communication between the pet feeder and the mobile device and to provide the notification system that will alert pet parents of any manual interaction they need to perform regarding the pet feeder.

Some of the drawbacks of React Native is that the framework only includes the bare minimum out of the box. The framework can be very powerful and stable but almost every aspect of a basic mobile application, such as routing and navigating between screens, must be implemented from scratch by the user. There are many third-party packages out there provided by open source contributors and other organizations that aim to solve and make the implementation of some of these features easier but since these packages are not official and are provided in an open source setting, they tend to have several performance and security issues. In many cases, these packages also contain extra code or functionality that is not needed by the developers and tends to add an unnecessary overhead for application, reducing performance, increasing the intensity of the resource usage and decreasing the overall user experience.

As we examined the different alternatives for developing the mobile application for the pet feeder, and taking into account the drawbacks presented by the framework as well as the fact that most of our group members are currently working or have previously worked with React Native, we have decided to use the framework to allow us to dedicate more time to designing and building, instead of spending time trying to learn a framework that will, in most cases provide little to no performance advantage to other solutions available to us. We also aim to deliver an excellent mobile application interface that provides users with all the necessary tools, a familiar interface and an easy to follow user experience and React Native seems like the best solution.

3.11 Parts Selection

This part is a quick run through of all the parts that were chosen to use for the construction of the product. Initially, we were thinking of using only one microcontroller which would have been the Raspberry Pi, but after further review we decided we would use an extra one which we decided would be the Arduino. The Raspberry Pi would be in control of the sensors while the Arduino will control the motor and the pump. The MCP3008 is an 8-channel 10-bit Analog-to-Digital Converter that comes with an SPI interface. We went with this device, because it was agreed upon that this would be the best way to be able to read the inputs that would be incoming from the sensors so the microcontroller can understand the information it was reading.

The L293D is a motor driver device that will receive signals from the microcontroller and transmit that signal to the motor and pumps. Which means, once it receives the signal, it will send a current to the motor and pump which will then allow the components to function. This device has to be powered using 5V or else it will not work properly. This motor driver provides us with the capabilities to connect 2 components to it. It’s usually used to connect two motors, but we are going to use two different devices, because the required voltage for the motor and pump are not the same.

One of the features for our product is being able to detect whether the pet is in front of the pet feeder or not. Our final decision on what motion sensor should be used is the HC-SR04

UltraSonic sensor. The reason for this is because, everyone in the group has worked with this sensor before whether it would be from Junior Design or for personal reasons. Another reason would be because of the fact we have several. So just in case one is not working, then we could get another one without having to pay. We decided to go with a FlexiForce sensor, because it doesn't take up much space and it can still measure the weight quite comfortably, which is vital for our product to work.

We went with a regular DC motor, because it is the simplest one to work with. All we would need to do is provide a voltage to it, and connecting it to an ADC will allow us to easily control it from a microcontroller. The pump we decided to go with is the Gikfun 12V DC Dosing Peristaltic Pump. It requires 12 V and flows from 0-100 ml/min. This was the most convenient pump we saw, because of how simple it is to set up and it does everything we need it to do and it could be controlled by a microcontroller.

4. Design Constraints and Standards

Design constraints and requirements are important topics that must be considered when designing and building a new product. Constraints give a clear view of how the design might be affected by outside factors and what specifically needs to be taken into account when putting the pieces together. In the same hand, the constraints also serve as warning points and allow for identification of design issues even before the design has come into fruition. At the same time, we must consider current standards for the design, in order to provide a product that consumers are able to use with minimal to no friction and that is acceptable for the pertinent market. This section will take into account things we will need to consider in our journey through Senior Design and through completing a successful product.

4.1 Design Constraints

The whole world is currently going through a tough time. Due to the pandemic that has been prominent for the past two years, as well as war conflicts happening abroad, several items that had always been available to us are now scarce. This situation has caused a shortage of many materials and devices across multiple industries, causing an unbalance in supply and demand, and increasing delivery times, sometimes by months, of certain key products that we require in order to build the automatic pet feeder. This unprecedented situation is separate from regular shipping delays for components being ordered from and manufactured abroad. For this reason, one of our biggest constraints is the estimated time of arrival of each component. This is something that we are closely observing and adjusting to as we begin ordering these components and we continue to adjust the design and the design document to reflect the correct components and their expected time of arrival to be used in the project.

One of the most obvious constraints when building the automatic pet feeder is time. Having a product idea without having the time to actually work on it and build it will never allow the product to come into fruition. For this senior design project, we are given two semesters to fully complete a working product. The first semester of the senior design classes focuses on the initial steps of building the product, this include doing extensive research on current items in the market, designing the hardware and software that will be part of the pet feeder, writing the initial design document for the product, identifying and ordering the different parts and materials that are required to build the project successfully, building prototypes to showcase product behavior,

among many other research and design details that will be beneficial when building the final product. The second semester of the senior design classes focuses solely on actually putting all the pieces together to build a product that not only works but that meets the stipulated requirements highlighted across the design document and also provides value to the pet parents that will be using it. This stage requires a whole lot more hands-on work and collaboration in order to make sure that all the features are included and that the device can be completed in time. Having this in mind, since all of our team members are currently taking other classes that require constant attention, have full time jobs that take up a lot of time from them, or might have unexpected responsibilities arise throughout this semester, time and availability are a major constraint when planning and organizing tasks to complete the project.

As it occurs in many group projects and activities, when having to work together as a team, there will almost certainly be several different opinions and ideas on how certain aspects of the project or activity should be completed. Since we all have different upbringings, different skill sets and different interests, it can sometimes be difficult for all members of the group to agree on what the priorities for each part of the project are, what components to use, what language to write the code in, and virtually every other aspect of the project. This situation can in some cases cause a clashing of ideas and prompt the whole team to take some time to try and find the most effective way to arrive at a resolution. It is always good to take into account that each group member has a valuable opinion and these opinions and ideas should be listened to and considered carefully when deciding how to approach the project in a way that it doesn’t discourage some team members from speaking up or voicing their concerns. Even though all ideas presented by team members should be discussed, this dynamic could potentially delay the time of execution and thus should also be closely analyzed and considered as a constraint in order to complete the project in a timely and effective manner.

Materials and components required to complete the project might not be available during the time of the project's deadline. Another constraint to be considered is the availability of materials. As mentioned above, due to global issues in the supply chain, some materials tend to go out of stock very rapidly and could then not be available again for months. This could definitely pose a great threat to the work being done in the project and requires quite a lot of planning and organizing in order to ensure that all materials and components are actually available by the time they are needed in the building of the device. We are anticipating that some of the components that we chose for the project will not be available by the time they are needed therefore, are constrained by the availability of these components and will have to revise the design document in order to adjust the way the components we do have work together, to remove those not available and include alternatives to these.

Because we are dealing with a motor that will dispense dry pet food, which is usually several relatively small objects, there is a risk that the food will get stuck while dispensing it to the bowl. As it is described in the hardware design for the main body of the automatic pet feeder, we will be relying on a motor that will be in charge of dispensing the correct amount of dry pet food into the bowl of the pet. Since dry pet food is usually composed of several relatively small hard pieces, there exists the risk of some of the food getting stuck in the pouring container while dispensing bown into the bowl, preventing the motor to properly rotate and causing the automatic pet feeder to malfunction. For this, we are paying close attention to how the motor

interacts with the dry pet food and how to prevent it from getting stuck while serving the predefined amounts. In any case, we still consider this to be a constraint when building the feeder.

While continuing to design and build the automatic pet feeder, the price of the components as well as the time needed to invest into completing each of the features need to be taken into account when considering the feeder's final price. As with any product in the market, having its functionality be of use is, in some cases, not enough for it to be a viable product for consumers. The product's price tends to also be a big factor when deciding to make a purchase for a certain device, and consumers might consider other alternatives, maybe with less features, in order to avoid overpaying. In order to keep the overall final price of the automatic pet feeder at a reasonable amount for consumers, the components, materials and complexity of design all need to be taken into account. Not only are we constrained by the final price of the feeder but we are also constrained to our own budget for it. Since this project has no sponsor, all of the capital needed to build it has to come out of our pockets, which poses an upper bound on the amount we can spend to build it.

In the same manner, another factor that must be considered is the power consumption of the device. Since these automatic pet feeders will reside inside the pet parent's house, the device must not draw noticeably amounts of power, which will be reflected in the user's electricity bill. The device must stay within reasonable consumption at all times, whether that is in standby mode or when actively performing actions, such as sending and receiving messages from the mobile application, pouring the food, or making calculations.

4.2 Related Standards

Engineering standards are important guidelines for engineers and they promote safety, reliability, productivity, and efficiency. Even though they are not required by law, they are still worthy of consideration and implementing them into our process can be very beneficial in the long run. These standards are released by different entities and organizations and have been adopted by many companies, product designers and builders throughout the years, and guide and provide designers with roadmaps on how certain aspects of the design should be implemented. There are standards that cover several different aspects of the design. These standards can range from the ports that should be used when building a product in a certain country, to materials that are acceptable for use in products under certain conditions. This section focuses on these standards and how they are applicable to the automatic pet feeder that we will be completing for this project.

4.2.1 Power Standards

One of the most important things to consider when building any electronic device is how this device will be powered. Since the design of the automatic pet feeder is based around the fact that it will be permanently connected to a power outlet in order to perform all of the tasks that it needs to, we need to closely examine and determine which standard for power would be more effective for the pet feeder to properly work. In the United States, most household items are a standard and are all based on alternating current. Electric equipment is connected to the alternating current (AC) mains electrical power supply in buildings and other locations via AC power connectors and sockets. Voltage and current ratings, shape, size, and connection type all

change amongst electrical plugs and sockets. Plugs and sockets are utilized in a variety of ways across the world.

To replace light sockets with wall-mounted outlets, plugs and sockets for portable devices were created in the 1880s. For convenience and protection against electrical harm, a variety of devices have been devised. Today there are about 20 different types in regular use across the world, and several obsolete socket types may be found in older constructions. Because of the synchronization of technical standards, some types of plugs may now be utilized over broad territories to facilitate electrical appliance commerce and for the convenience of travelers and consumers of imported electrical things.

It is good to note that the power standards discussed below are primarily applicable for the United States, as this is the market that we are focused on and will be building the automatic pet feeder for, but this does not mean that these are the only standards available that could be used for a project of this scope. These are simply the best and most accepted standards for a common household in the US.

The standard voltage and frequency in the United States of America are 120V and 60Hz, respectively. If the normal voltage in your nation is between 110 and 127V, you can use your electric equipment in the United States of America (as in the US, Canada and most South American countries). It is not recommended to use your appliances if the frequency in the United States of America (60Hz) differs from that in your nation. However, if there is no voltage difference, you could try to use the appliance for a short period (at your own risk). Appliances that move, rotate, or have a timer, such as clocks, shavers, or electric fan heaters (in our case, the Automatic Pet Feeder), require extra caution.

These would have two types of sockets that are used throughout North and Central America, type A and type B. Type A only works with type A plug while type B socket can work with both type A and B plugs, otherwise it might require a converter. Check the appliance label for confirmation. Some appliances don’t require a converter at all. If the appliance label says “INPUT: 100-240V, 50/60 HZ” it can be used in any country. Table 11 will show the American National Standard for Electric Power & Equipment.

Nominal	Service	Utilization	Nameplate	NEMA
Standard	-5%, +%5	-13%, +6%	Motor	-10%, +10%
120	114 - 126	104.4 - 127.2	115	103.5 - 126.5
208	197.6 - 218.4	181 - 220.5	200	180 - 220
240	228 - 252	208.9 - 254.4	230	207 - 253
277	263.2 - 290.9	241 - 293.6		
480	456 - 504	417.6 - 508.8	460	414 - 506
	bandwidth 10%	bandwidth 19%		bandwidth 20%

Table 11: National Steady State Voltage Regulation Standards

4.2.1.1 NEMA Standard

The National Electrical Manufacturers Association, or NEMA, is a non-profit, ANSI-accredited Standards Developing Organization dedicated to developing technical standards for the manufacture of electrical and medical equipment. NEMA aims to establish industry standards in the areas of safety, innovation, interoperability, the environment, and market development. By extending market opportunities, collecting exclusive business intelligence, reducing market obstacles, creating supply chain links, and embracing innovation, NEMA provides designers a competitive advantage in today's quickly changing economy. NEMA developed and recorded one of the most common and popular standards for power cords. Despite the fact that it oversees a variety of activities in the electrical manufacturing industry, the NEMA organization is most known for the term "NEMA ratings" and the kind of enclosure used to produce electrical components.

NEMA has ratings from NEMA 1 to NEMA 13, each of which describes aspects of the electric device and how these should be interacted with. The ratings dictate options such as, the enclosure of the device being designed for indoors, whether it should be protected from rain or light and whether the enclosure meets other organization standards for health and safety. New NEMA ratings are issued every five years to protect electrical equipment against damage caused by liquids, dust, and/or corrosive chemicals. A NEMA enclosure is not required for all electrical components to be designed or built. NEMA ratings, on the other hand, are only used as a guideline in the industry and are completely optional.

As with most standards, NEMA has focused their attention on making sure these power cord standards meet the requirements for households across the United States and are compatible with regular power outlets across the country. Organizations may save costs, streamline processes, increase markets, and improve their bottom line by embracing NEMA standards.

The most common cables for Class II consumer devices are NEMA 1-15P power cords and cord sets (Standard 2-Conductor). Despite the lack of a ground pin, the 1-15P receptacle is upwardly compatible with NEMA 5-15R receptacles, which are frequently used in modern buildings in the United States. They are a low-cost option for devices rated at 10, 13, and 15 amps with a maximum voltage of 120 volts, and they may be molded in a variety of colors to meet the

demands of the customer. Kord King also offers the NEMA 1-15P with a polarized design and a cable grab style connection. The cable grip is molded into the plug, resulting in a single-piece, long-lasting construction. The polarized 1-15P plug has one broad and one narrow blade to prevent the intermixing of energized and neutral wires.

4.2.1.2 IEC Standard

The International Electrotechnical Commission (IEC) is a global non-profit membership organization aimed at promoting international trade in high quality infrastructure and electrical and electronic equipment. Their work goals are innovation, cost-effective infrastructure development, efficient and sustainable access to energy, intelligent urbanization and transportation systems, climate protection and people and environmental safety. The IEC brings together more than 170 countries and provides more than 20,000 specialists worldwide with a global, neutral and independent platform for standards. It oversees four conformity assessment systems where members verify the proper functioning of devices, systems, equipment, services, and people.

The IEC publishes approximately 10,000 international IEC standards that, combined with the conformance assessments, allow governments and enterprises of all sizes to build national quality infrastructure, ensuring safety and reliability in almost every country in the world. The IEC provides a technical framework that enables designers and builders to consistently purchase and sell high-quality products. International IEC standards are used for testing and certification to ensure that manufacturer's commitments are met and serve as the basis for risk and quality control. As previously mentioned, these standards serve as a guiding point for developing new products, and similarly to the NEMA standards, they provide a roadmap for designers to ensure their products will work properly in every household in the country that they are based on and evaluating their standards for.

The IEC connector standards are mostly concerned with the side of the plugs that connects to the devices such as computers or TVs and in our case, the automatic pet feeder. These standards on connectors are a great way to visualize how the design will operate, as well allow us to provide a concrete plan, with correct measurements as to where and how all parts fit together. The standard also provides a competitive advantage for certain markets as it does not require any type of adapter in order to make it work with existing power outlets. In the same manner, the IEC standards are, in most cases, totally compatible with NEMA standards, providing an easier solution and integration.

In the industrialized world, the IEC 60320 is the standard connection interface. It makes it easier to choose a connection for a cord set as well as a country-specific plug. In addition, the IEC 60320 offers a standard framework for product design and testing. Accessory power, power cables and cord sets, jumper cord sets, modules and Accessory Power Strips are just a few of the interpower product lines that use IEC components. This gives us a sense of security for building the automatic pet feeder with this connector as the connector is widely used and performs excellent with NEMA extensions and with the voltage levels that are available in the United States.

The most common way to connect a removable cord set to an electrical or electronic device is to use the IEC60320AC power inlet. Manufactures can install an IEC 60320 power inlet into their equipment to install a cord set (for example, a country-specific plug on one end and an IEC plug on the other) just before shipment. This allows device manufacturers to manufacture a single device for distribution worldwide.

4.2.2 Water Quality Standards

Standards not only apply to physical components that form part of the product's main body design but they also apply to objects that interact with it and the quality of these items. Since the automatic pet feeder will hold drinking water for the pet, the water container itself also needs to meet and be based on a certain standard that is acceptable by the pet parent, and specially by government organizations, and won't cause any harm to the pet drinking water from it.

Over 90 pollutants in drinking water are subject to EPA legal regulations. Pollutant regulatory limits indicate the level of human and pet health protection that water systems can achieve with the highest technology available. The water system must also follow the EP revision schedule and method of water quality inspection. Inside of the United States, individual states may establish their own drinking water standards under the Safe Drinking Water Act if the regulations are at least as strict as the EPA's national standards.

As water will be held inside the pet feeder, potentially for a long period of time, the water container must not allow for external contaminants to enter the water. The container must be sealed with a good material that allows for the container to be close to a vacuum seal and must be of a material that will not contaminate the water. For this, several types of containers should be evaluated to ensure they will not leak any chemicals to the water if they come in contact for a long time. In order to make the container as safe as possible, if made with plastic, the enclosure material must be made of at least BPA-free plastic. Products that do not contain BPA are products manufactured without the use of the compound bisphenol A. BPA has historically been used in many plastic products such as baby bottles, plastic tableware and cutlery, storage containers and water bottles. BPA-free plastic is totally acceptable for humans and thus is properly accepted for pets.

We can also consider the possibility of not utilizing plastic in the container. For this we could consider other alternative containers that could be made out of glass canning jars, glass storage containers, silicone containers, or even some metals such as stainless steel. These materials would also be great for keeping the water safe but they will increase the overall price of the automatic pet feeder and will also affect some design aspects of the feeder such as the weight.

4.2.3 FDA Food Standards

Since the automatic pet feeder will be in charge of holding the dry pet food that will be dispensed to the pet, the food container, along with the food bowl where the pet will eat, must meet certain standards of health and safety. These standards ensure that the dry pet food remains preserved for the pet and attempt to extend the shelf life of the food. This is especially important when considering the fact that the pet parent will be pouring the food from its original container into the food container that the automatic pet feeder has.

The Food and Drug Administration (FDA) regulates the production of cat food, dog food and dog treats. Pet food is regulated by the FDA in the same manner that other animal feeds are. According to the Federal Food, Drug, and Cosmetic Act, all animal meals must be safe to eat, made under sanitary conditions, contain no harmful chemicals, and be accurately labeled. In the same manner, almost all dry pet food packages indicate that the pet food must be stored in a dry cool place in order to maintain its healthy and sanitary conditions. The FDA stipulates that dry pet food and unopened canned food should be kept in a cool, dry location. The temperature should not exceed 80 degrees Fahrenheit. This is due to the fact that nutrients may be broken down if exposed to too much heat or moisture. At the same time, if the pet is too curious and might venture into the food, the package should also be stored in a safe place where the pet can't reach and potentially make a mess.

Taking into account the FDA standards for pet food, in order to design and build a safe container that can properly store the food, we need to consider the same conditions outlined in the Water Quality Standards section. That is, the container must be made of a non-toxic plastic, glass or stainless steel, in order not to contaminate the food or allow outside bacteria to access the food. Even though the food container is right next to the water container, the food container must stay dry at all times, allowing the food to stay fresh and prolong its time inside the container. In the same manner, the container must have a lid that allows it to be fully sealed and prevents the pet from opening the container and accessing the food outside of their scheduled meal times.

Since the pet will be eating out of a food bowl, this food bowl will get dirty over time as more food is poured in it, combined with the dog's own bacteria. If left for too long, the bowl could become filled with bacteria and contaminate any food that is poured into it, and at the same time, it could cause even the food inside of the food container to be affected. In order to address this, the food bowl should be removable and replaceable, allowing the pet parent to separate them from the machine and take them to wash. The bowl should be made out of the same material of the food container or preferably out of stainless steel, which is a very durable material that can be easily cleaned.

4.2.4 Pet Safety Standards

Safety should at all times be the priority for all pet parents. Since we can't unfortunately teach pets the safe way a person learns and we can't talk reason into them in regards to what could be dangerous or how to handle certain items, ensuring our four-legged friends are safe and sound even when they are not in sight has been a problem that all pet parents must deal with. We are especially concerned with looking after our pets when they are interacting with new items such as toys, another pet or even an automatic pet feeder. In all situations, we ensure that pets are out of any harm and are not causing any harm to others either.

Having this in mind, we need to consider all the aspects of the automatic pet feeder to ensure that it will bring value to the pet parent and the pet, but that is also a safe item for them to interact with. Safety measures include from ensuring that the device does not have an electrical failure that can hurt the pet to having a design that prevents the device from being tipped by the pet in a random attack of the zoomies. Among the aspects to consider, the device must have a lid that keeps the container closed, also ensuring that the pet can't begin chewing on it or use the as a handle to move the machine around. The pet feeder should also be durable enough that, in the

case the pet trips on it or someone inside the household tips it, it won't break, or even open and spill the food or water all over the place.

In the same manner, the pet feeder must have all wiring concealed and out of reach of the pet at all times. This will reduce any chances for the pet to get shocked or for the pet to start chewing on the wiring and causing the automatic pet feeder to malfunction or even completely break. At the same time, the pet feeder must also properly work a high percentage of the time. If the pet feeder is not working at the optimal conditions it was designed, its behavior might be compromised and could put the pet at risk.

Since the automatic pet feeder will most likely come in contact with the pet on a daily basis, it must also be made of a material that is not toxic. This not only includes the material of the enclosure itself, but it also includes making sure that if painted, the paint should also be made of components that will cause no harm to the pet.

4.2.5 Communications Standards

The automatic pet feeder will feature communication between the main body and the mobile application. The device must be capable of sending notifications to the mobile application whenever any manual action is required from the user such as, refilling the food and water containers, restarting the feeder, and viewing the camera feed. At the same time, the feeder must be able to receive messages from the mobile application in order to control settings such as the amount of food, scheduling and setting pet information. In order to be controlled remotely, the device must be able to support both bluetooth and wifi connectivity, the former for pairing to the device, initial setup and close proximity communication, and the latter in order to allow for external and long range communication. Both of these protocols of communication are standards set by IEEE.

The Institute of Electrical and Electronics Engineers (IEEE SA) is a division of the IEEE, including power and energy, artificial intelligence systems, the Internet of Things, consumer and consumer technology, biomedical, healthcare, learning technology, and information. Technology and robotics, telecom and home automation, automobiles, transportation, home automation. The IEEE has established SA standards for almost a century through programs that emphasize balance, transparency, due process, and consensus. The IEEE standard is developed by a group of technical experts around the world. IEEE SA is an autonomous non-profit organization that brings the community together to create standards and innovation. IEEE SA produces consensus-based standards and provides two types of participation mechanisms for creating standards.

4.2.5.1 Bluetooth

The Bluetooth wireless communication technology is based on the IEEE 802.15.1 standard. Bluetooth is a low-tier, terrestrial wireless short-range communication technology. It is intended for compact, low-cost devices that consume little electricity. This standard radio protocol powers many everyday devices such as headphones and wireless speakers, but is limited to short distances. The technology works with three different classes of devices, ranging from 100, 10 and 1 meters. Bluetooth was previously standardized as IEEE 802.15.1, but now differs from Wi-Fi in many ways, including continuing under the Bluetooth Special Interest Group (SIG). In

addition, Bluetooth operates at much shorter distance than Wi-Fi, emphasizing direct communication between packet-based protocols using master and slave architectures. The Bluetooth standard will be implemented in the feeder in order to allow close range communication and pairing to the device.

4.2.5.2 Wi-Fi

Wireless LAN (WLAN, often referred to as WiFi) is a collection of inexpensive terrestrial network technologies for data transmission. The 2.4GHz and 5GHz industrial, scientific, and medical (ISM) frequency bands are used in wireless LAN standards. This family of wireless network protocols is based on the IEEE 802.11 standard that defines protocols that enable communication with Wi-Fi enabled wireless devices such as mobile smartphones that support our mobile app. Almost all smartphones support Wi-Fi to connect because the internet has become an important wireless communication standard supported by communication mode common to many electronic devices. Wi-Fi is the most popular in the consumer space, and most portable laptops support at least one version. The Wi-Fi standard will be implemented in the feeded in order to allow long range and remote communication from and to the application. Not only do you need to configure your Raspberry Pi as an access point, but you also need to be able to connect to the internet. The integrated network card is configured to act as an access point. This access point can now be used by embedded systems to communicate with the database and update the fields corresponding to the configuration file. That said, you may need to give some hints that an intruder could gain access to your network and exploit the development board of the Automatic Pet Feeder. This network invasion could happen due to various reasons such as a weak Wi-Fi password or no password whatsoever. Wi-Fi vulnerabilities are a concern and should be taken seriously by everyone, but they aren't important to the hacker's eyes, since it's likely that the thought of an Automatic Pet Feeder isn't a big deal for them to attack and leave it at bay. Thus, this method provides the best way to communicate with the app in a smooth and secured fashion. Table 12 will show a brief explanation of the wireless connection discussed earlier in Wi-Fi and Bluetooth.

	Bluetooth	Wi-Fi
Authority	Bluetooth SIG (it used to be IEEE 802.15.1)	IEEE 802.11, WECA
Bandwidth	Low (~800Kbps)	High (~11Mbps)
Hardware Requirement	Bluetooth adaptor on all the devices connecting with each other	Wireless adaptors on all the devices of the network, a wireless router and/or an access point
Cost	$	$ - $$$
Power Consumption	Low	High
Frequency	2.4 GHZ	2.4 GHz

Level of Security	Low	Low-High Depending on the complexity of password assigned
Range	10 meter	100 meters
Ease of Use	Very simple to use. Can connect up to seven devices	More complex due to configuration of HW and SW

Table 12: Comparison of Bluetooth and Wi-Fi

4.2.6 IPC PCB Standards

Considering that a huge part of the Automatic Pet Feeder is designing our own Printed Circuit Board, it is crucial to investigate the association which produces PCB related standards. This organization, previously known as the IPC (Institute of Printed Circuits) and now known as the Association Connecting Electronics Industries, works to secure the standardization of electronic equipment and assembly requirements. Members from practically every facet of the electronics business, including design, printed board manufacturing, electronics assembly, and test, are represented in the non-profit, member-driven organization. This means that the IPC's standards apply to all types of printed circuit boards, including single-sided, double-sided, and multilayer. The idea is that by regulating most of the requirements that commercial PCBs must meet, the organization will be able to assist ensure product reliability and lifetime. When it comes to printed board design standards, IPS (Investment Policy Statement) classifies IPC-2220-FAM as a family of specifications for board design that includes IPC-221, IPC-2222, IPC-2223, and IPC-2225. With that in mind, the IPC-221B is a generic printed board design standard that specifies broad standards for the design of single-layer, double-layer, and multilayer printed boards as well as other forms of components mounting/interconnecting architectures.

Among those, IPC-2222B is the next standard in the family of printed board standards, and it specifies the explicit requirements for designing stiff organic printed boards while also supporting the general IPC-2221 standard. IPC-2223, which is responsible for Sections Design, works in tandem with IPC-2221 to define precise standards for the design of flexible printed boards, as well as the forms of component mounting and interconnecting structures. Flexible Printed Boards Standard IPC-2225, in addition to the list of standards, aids in the establishment of criteria for the Sectional Design Standard for Organic Multichip Modules (MCM-L) and MCM-L Assemblies by considering thermal, electrical, electromechanical, and mechanical concerns. As can be seen, IPC provides a wealth of standards, ranging from general requirements to specific requirements for printed materials. Using software, create circuit boards that meet the specifications for traces, thickness, tolerance, and material qualities.

Producing PCB products that are safe, dependable, and high performing necessitates ongoing attention to detail and a dedication to quality throughout the manufacturing process. Companies can achieve this by adhering to IPC guidelines throughout the process. The IPC standards all grow upon one another, just as PCB fabrication methods do. For practically every stage of production, an IPC standard can be implemented. Companies involved in the products that use them must commit to quality through IPC standards for printed circuit boards in order to create high-quality, reliable products that match consumer expectations. IPC compliance can help a

company enhance its operations and products in a variety of ways. To remain competitive in the industry, PCB producers must integrate quality throughout the manufacturing process.

The IPC standard for PCB helps you develop high-quality, reliable products that satisfy customer expectations by including more than 225 active standards ranging from design and purchasing through assembly and acceptance. As a result, if a PCB manufacturer says that its methods are IPC compliant, we can be confident that we will receive superior PCB and electrical assembly services that will exceed our expectations. The IPC standards are optional, but following them improves a product's robustness, reliability, and durability.

In addition, when combined with other standards, they can help reduce electromagnetic pollution and pass the tests and certifications that electronics products must pass before being sold in international markets (IEC, ISO, ITU standards and tests may be mandatory to access other markets). They are used to setting themselves apart in their own country. It also aids us in designing and manufacturing faster and at a lower cost by allowing us to learn from the experiences of others.

Following the analysis of IPC Printed Circuit Board standards, the IPC standards should be followed, as they assist in ensuring that the desired results are achieved by the design. With the standards in place, it is easier to assure that the final product will be reliable and of sufficient quality to compete in the marketplace. This means that adhering to these criteria throughout the manufacturing process is critical to ensuring performance and longevity. As IPC establishes the language for the worldwide electronic sector, this also enables for seamless collaboration. Furthermore, these standards assist designers in removing ambiguity and ensuring that electrical assembly manufacturing fulfills appropriate quality testing, avoiding delays and ensuring that production runs smoothly.

5. Hardware and Software Design

The following section outlines the design of the automatic pet feeder, taking into account both its software and hardware counterparts. Here we discuss how each of the components communicates with each other, what different parts are needed in order to perform the outlined tasks and how each feature is designed to meet the given requirements. Included in the design, we can find how the software side will be structured and how it is able to set the correct actions for the main body of the feeder to perform. We also describe how the flow of communication is established between the hardware and the software.

5.1 Hardware Design

One of the most important parts of this product is to make sure that each of the components is getting the amount of power it needs to function while at the same time not providing too much power to the point they break. It is vital that we get this right, because this could delay the process in getting the final product if components break or certain parts just don't work. In Table 13 we can see all the voltage and current requirements of our electronics and plan accordingly.

	Voltage Requirement	Current Requirement
MCU	5 V	2 A
Pump	3 V	100 mA
Motion Sensor	5 V	15 mA
Weight Sensor	3-5 V	1.6 mA
Water Sensor	3-5 V	none

Table 13: The voltage and current requirements for each components

Using the requirements of the parts we have decided, we need to build the schematic and designate the connection for the Raspberry Pi. This prototype will be absolutely necessary to complete so we are able to build a functional unit. After spending some time to figure out where we were going to build our schematic, we decided to go with Eagle, because not only does it give us the option to build a schematic but we are also able to convert it into a Printed Circuit Board (PCB) and it would provide us with a Bill-of-Materials (BOM) so we can order the parts we need. It will allow us to build the circuit exactly how we want it.

The automatic pet feeder can exist in several states depending on what action is currently happening. When the device first powers on, it enters the idle state, that means that it is currently getting all the processes ready and ensuring that it has access and can connect to all of the components that are part of the body and necessary for performing the different feeding tasks. The feeder also includes a pairing, ready, error and dispensing state, each which has its own values and can be identified and addressed as it needs to. In order to differentiate the different states, the light indicator will be on different colors or be blinking depending on the action. Figure 35 gives a high level overview of the different states and how they interact with each other depending on external factors

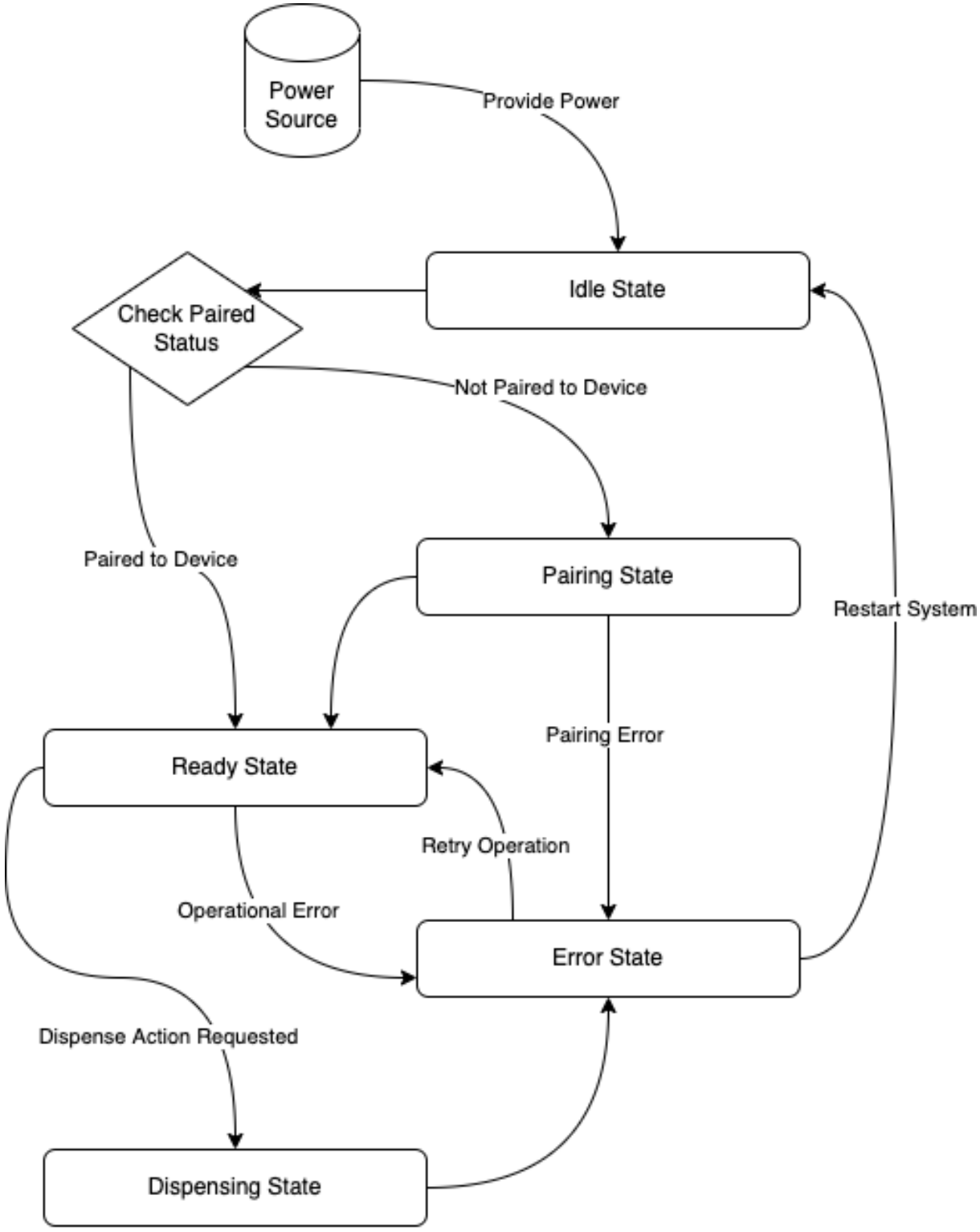

Figure 35: Pet Feeder States

Table 14 highlights the difference between the light indicator colors that appear on the body of the automatic pet feeder. These colors indicate what each state is, that way the user can determine how to interpret and address each state depending on their light indicator color. Notice how some states do not require any user interaction or intervention, the light will turn to the corresponding color only on notify of the current state.

State	**Light Indicator**
OFF	OFF
Idle	Solid Yellow
Pairing	Blinking Yellow
Ready	Solid Green
Dispensing	Blinking Green
Error	Solid Red

Table 14: Light Indicator Color For States

5.2 Software Design

Our software for this project is what will tie everything together and it consists of two parts. The first part is our mobile application which is for the user experience. This is where we'll be able to display information and let users adjust things to their liking. The mobile application will be the main point of communication between the pet parent and the automatic pet feeder. Almost every interaction with the feeder will occur through the app, except for powering on and off the device. The mobile application will also receive messages from the device. The second part is our embedded systems, which will be what connects our mobile application to our hardware. The software running inside of the microcontroller will also serve as the brains for the whole feeder. The firmware facilitates the initial setup of the device, connects and controls how each event posted from the mobile application will be processed. It will also control how the motors rotate to dispense the food by calculating the number of rotations depending on the amount of food set by the user through the mobile application. It will control the water pump to pour water once the bowl is low enough. The firmware also facilitates access to the camera feed and any other sensors from the feeder.

5.2.1 Mobile Application

When first launched, the mobile application will prompt the user to either sign in to an existing account or create an account (Figure 36). This is to ensure each user has their settings stored in our database for the next time they login. After login, the user will be prompted to pair the feeder to the app. After pairing, if they are a first time user, a guide will be displayed to walk the user through the initial set up.

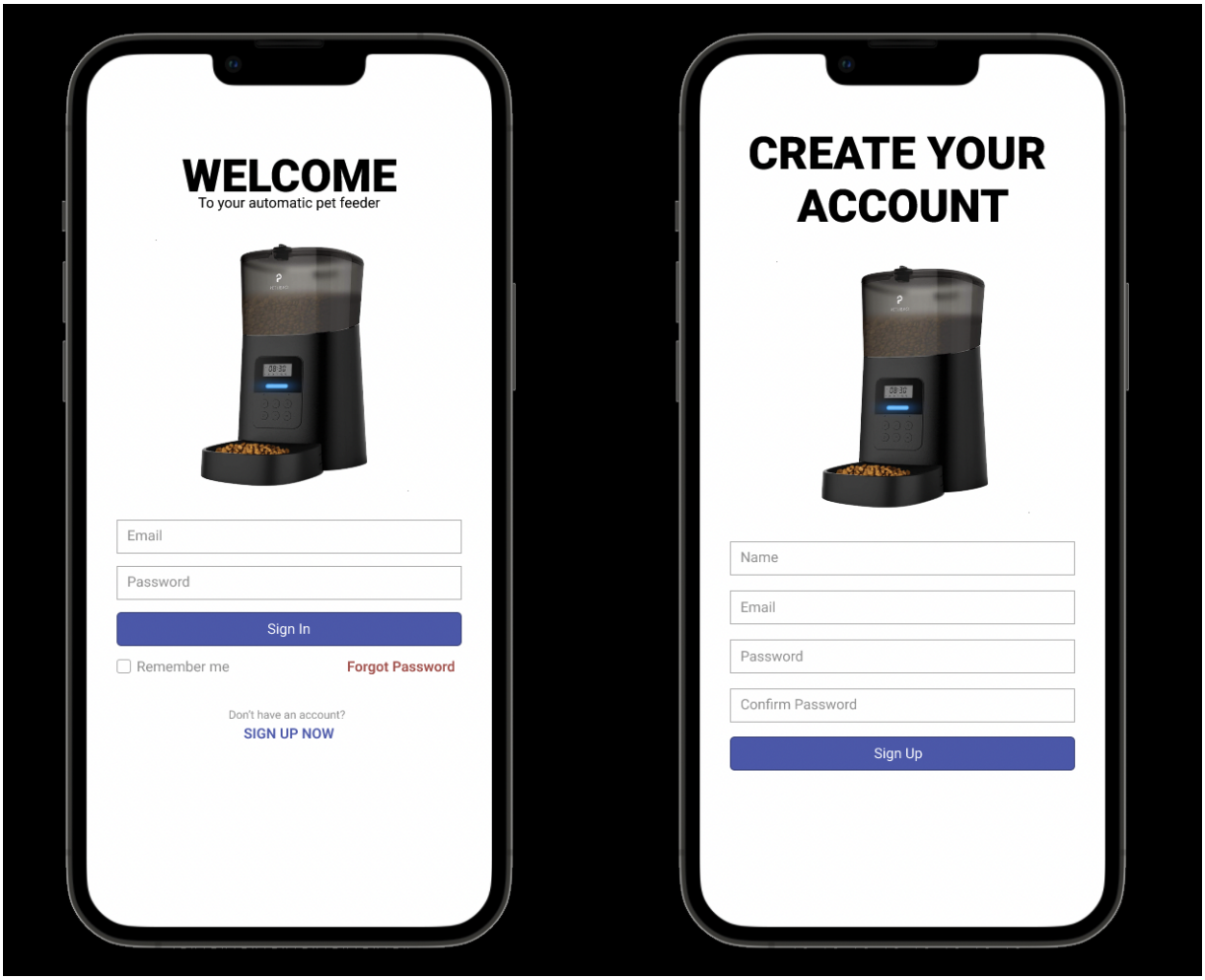

Figure 36: Prototype of the login and create account screen of our application

Once the device has been paired, the mobile application will allow the user to register all the pet information, including their name, age and weight. The user will then be able to set the different settings and scheduling that will be present in the feeder. On any other subsequent launch, considering the device has been previously paired, the mobile application will just launch to the main three tabs seen in Figure 37.

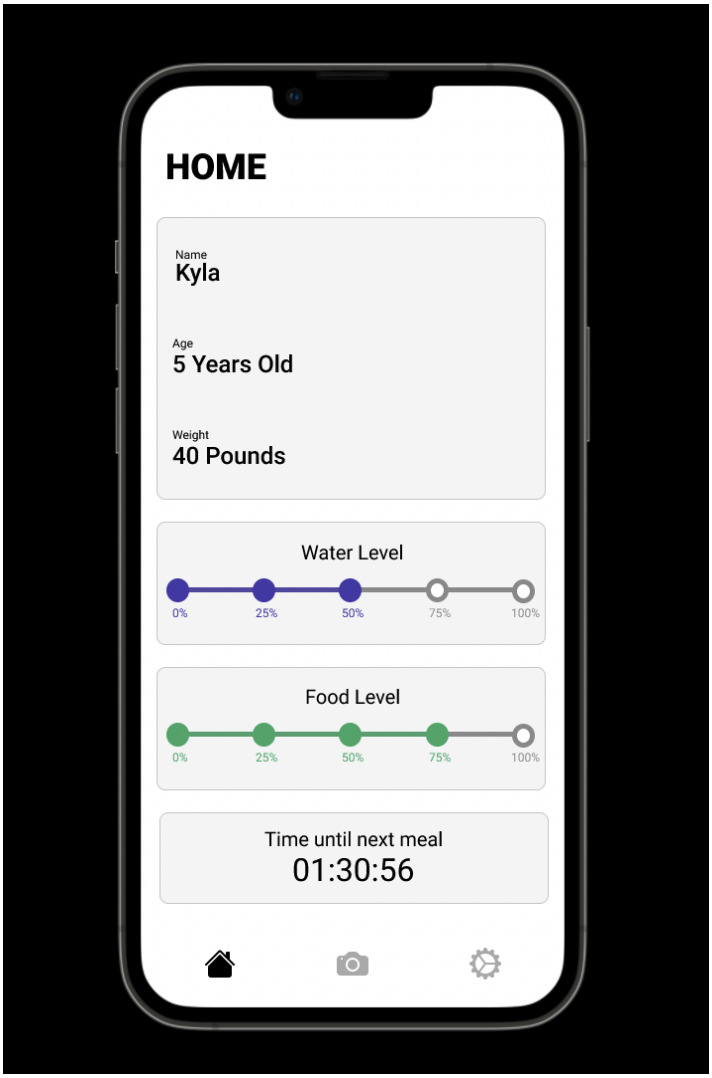

Figure 37: Prototype of the home screen of our application

The mobile application also includes a backend service. This backend service is the one in charge of processing all communication from and to the device. It receives messages from the pet feeder, determines what action must occur, performs any calculation and saves the settings or changes in the database. This backend service is also required in order to send notification to the mobile application. It constantly keeps the state of the device while listening for new notifications or commands. Once the mobile application launches, it makes a call to the backend service in order to retrieve the settings and current state of the feeder.

Besides the backend, the mobile application will feature three main tabs as the user interface, the first one will host the home screen, which contains all the information regarding the pet such as their name, age and weight, as well as general information including the food and water levels of the automatic pet feeder and the remaining time until the next meal. The home screen will also host any other relevant information and alerts that might require the pet parent's attention or, although rare, any manual interaction with the feeder.

The second screen will include the camera feed (Figure 38). Here the pet parent will be able to activate the camera feed from the automatic pet feeder in order to ensure that the pet has eaten all their food or simply to ensure that the pet is okay. Behind the scenes, this screen will make calls to the main body of the feeder and request the raw data from the camera feed. The mobile application will then decode the content, ensure that it is a proper format of a video and lastly, properly display it in the page. Since connectivity errors may arise, the page will also display an error message alerting the user when the camera feed could not be retrieved, along with a button in order to retry the operation.

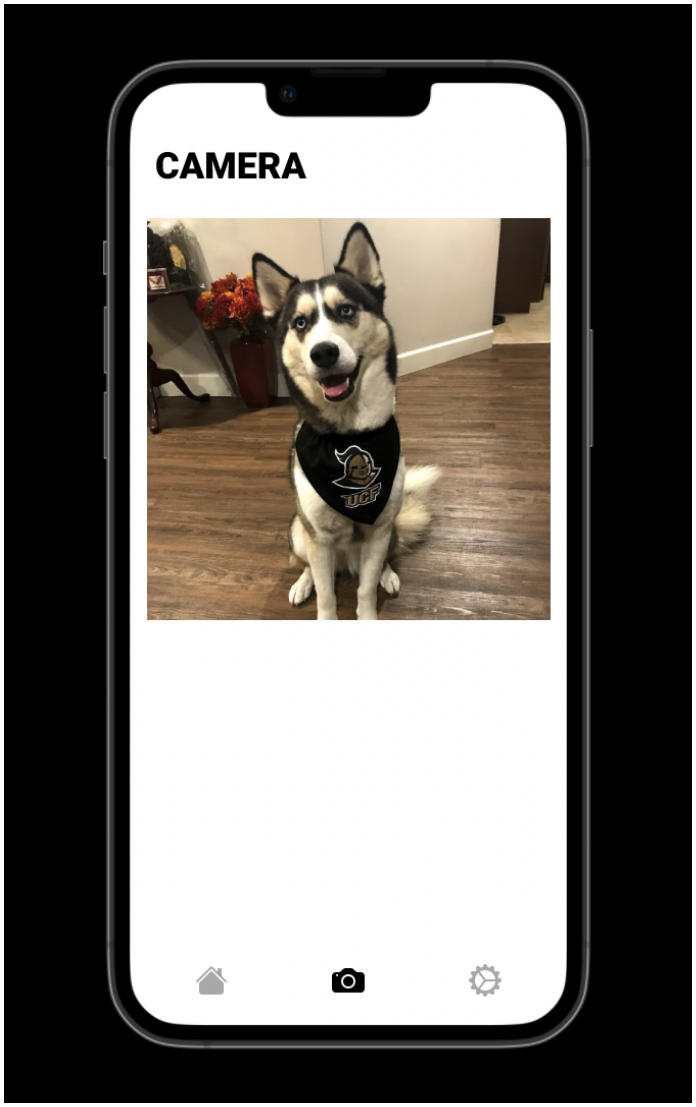

Figure 38: Prototype of the camera screen of our application

The third screen is where the pet parent can manage all the settings of the feeder as shown in Figure 39. Here the users can modify all the pet's information, as well as set the predefined amount of food to be served, the frequency and time for the meal cycles. Behind the scenes, this screen posts events to the backend service with the new settings that need to be applied to the feeder.

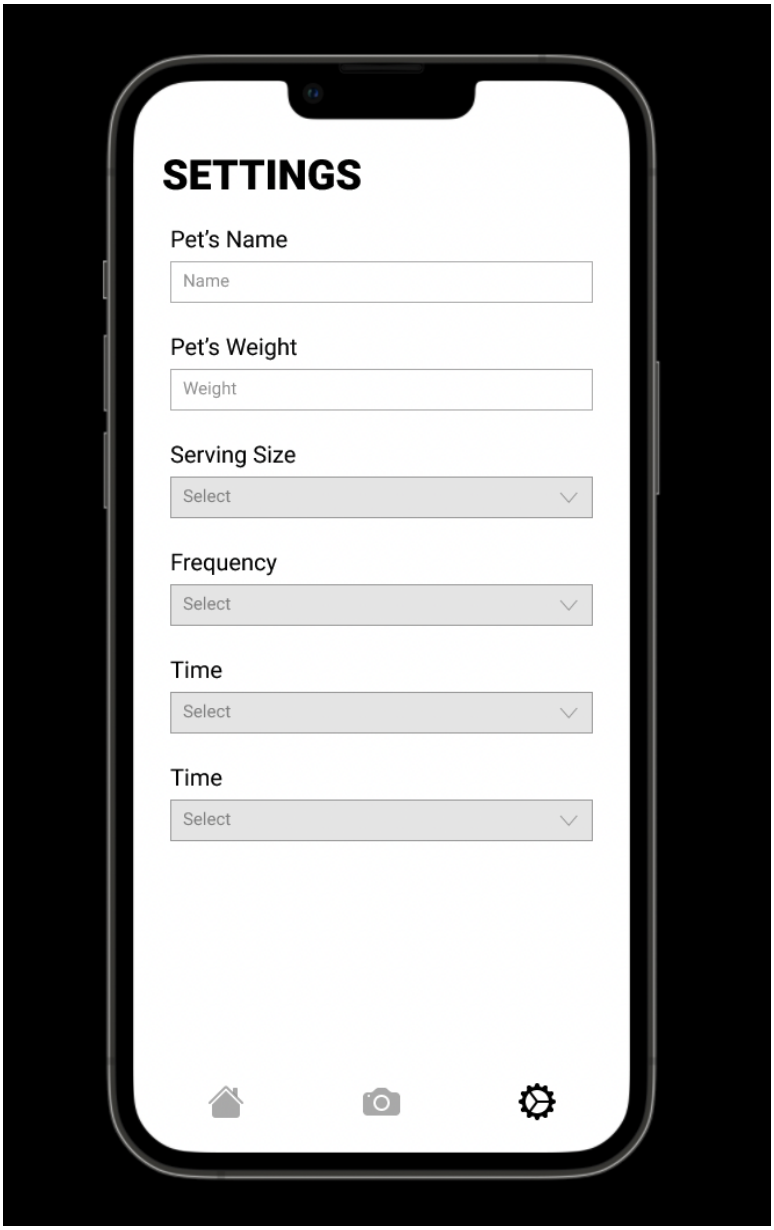

Figure 39: Prototype of the settings screen of our application

This entire mobile application will be created using React Native. React Native is a framework for developing mobile applications that our members doing the software have experience in. It is a great modern day framework that will help us accomplish all our goals while being compatible with iOS, Android, and web. A big picture view of the flow of the mobile application can be observed in (Figure 40) below.

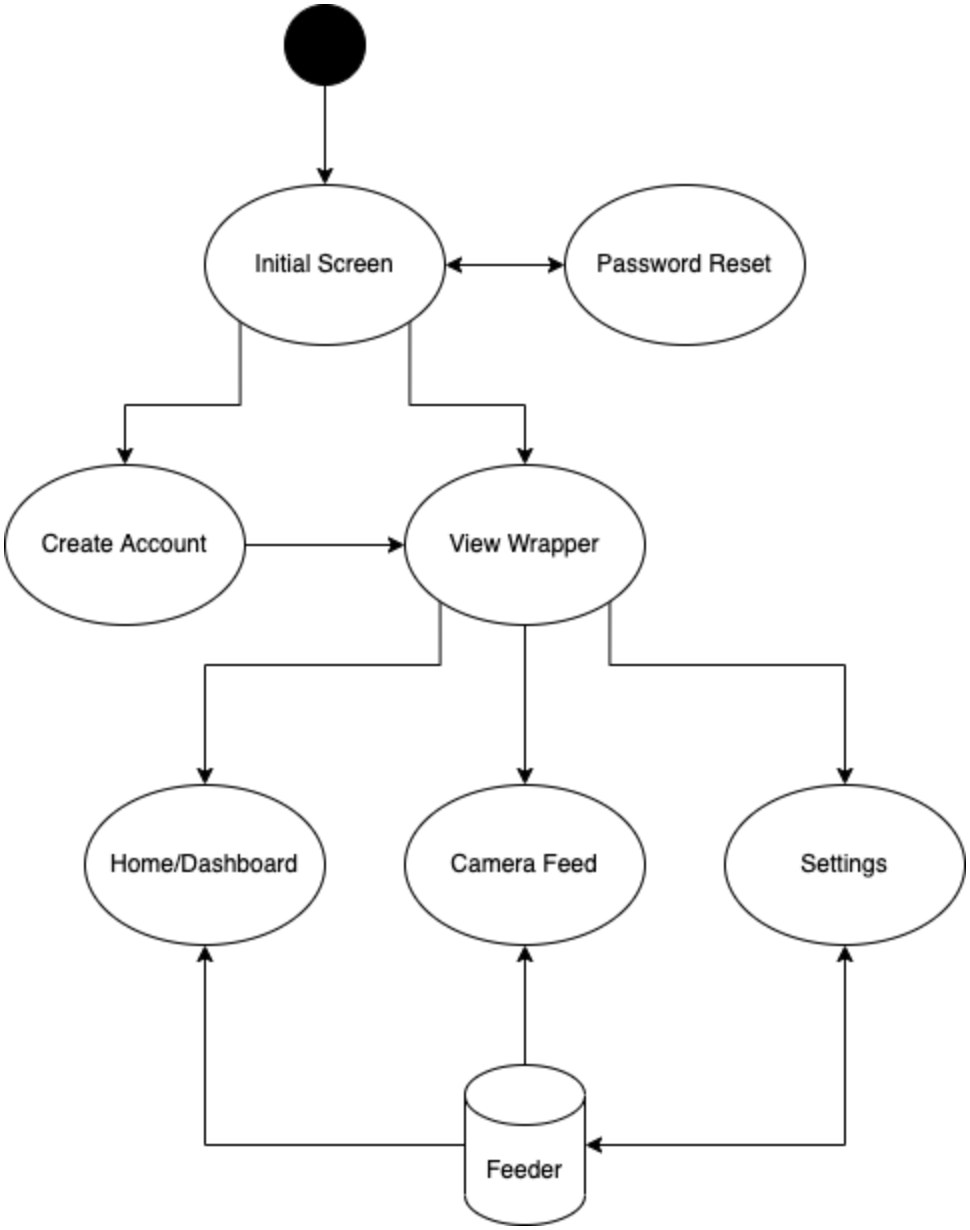

Figure 40: Mobile application flow

5.2.2 Microcontroller Programming

The mobile application is not the only piece of software that needs to be designed and programmed. As we will be working with a microcontroller, which will serve as the brain of the pet feeder, this also needs to be programmed in a way that ensures that all functionality is properly accounted for.

Since the microcontroller inside of the automatic pet feeder will be the one controlling the behavior of the pet feeder, it needs to have good firmware which is kept up to date with its latest version. In computing, firmware refers to a type of computer software that gives low-level control over the device's hardware. This is particularly important as the firmware is what allows

us to program specifics of how the microcontroller interacts with each of the components inside of the pet feeder. Below (Figure 41) can be observed as a high level overview of the main flow of the microcontroller software.

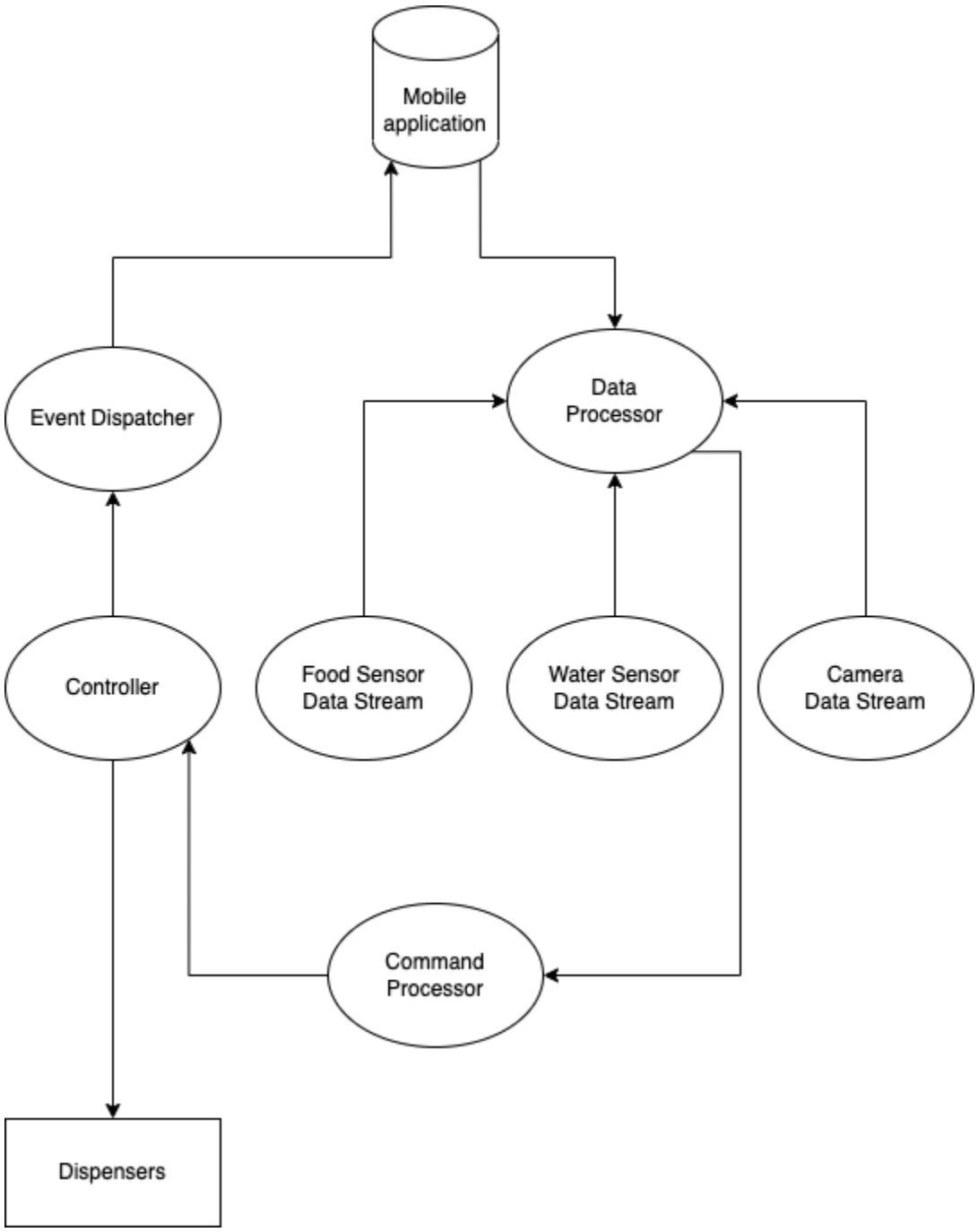

Figure 41: Microcontroller Flow Overview

The software inside the microcontroller must deal with several aspects at the same time. It must, first, ensure that the microcontroller has a way of constantly communicating with the mobile application in order to send messages when an action is required from the user and also to

receive, decode and interpret message events coming in, in order to determine what instruction should be performed. The microcontroller software will keep the state of the feeder, including its predefined settings, the last time the feeder poured a meal into the pet's bowl and how much food was poured. In the same manner, the microcontroller software must keep track of all the sensors that form part of the feeder, this include the weight sensors for the food and water bowls, as well as the sensors for proximity of the pet and the amount of food and water left in the containers.

In order to keep accurate meal time cycles, we must leverage the microcontroller's internal clock, which will provide us with the necessary values that will be included in the calculations for the time between the previous meal and the next scheduled meal. The software must also take into account that, at any point, the pet parent may change the predefined meal time and it must adjust accordingly to ensure that the pet does not go hungry for longer than it should. Since many processes will be happening at the same time within the microcontroller, we must ensure we make use of proper concurrency methods. That is, so that the microcontroller does not miss performing a task because it is being used to watch the camera feed or check the state of the pet feeder's sensors.

Similarly, the microcontroller software will be responsible for reading the raw data coming from the camera module, encode it in a secure and effective way and send it to the client requesting the feed, in this case that would be the mobile application.

5.3 Schematic

We needed to create a schematic and designate the necessary connections for our Arduino Uno and Raspberry Pi before we could assemble our parts to form a prototype and test our concept. After spending time online looking at a variety of schematic construction applications, we decided on EasyEDA because it is free to use and included a PCB design option that we could acquire once we were through. Since we are using two microcontrollers, there are two schematics for each. One of the questions we had was whether we would use two power sources or try to have both microcontrollers share a power source. After doing plenty of research and a few bits or trial error, we discovered that we were able to power the arduino with the raspberry pi using the USB part of both boards. The arduino was able to function properly and the raspberry pi was able to handle giving the power to the arduino. As a result, we came to the conclusion that the schematics for both the arduino and raspberry pi can be completed separately at first and then merged after completion, since the only connection between the two would be the USB connection that would power the arduino.

The first schematic is using the Raspberry Pi microcontroller and it is powering the sensors that are a part of our product. The Raspberry Pi will be used to power the HC-SR04 UltraSonic Sensor that will be detecting motion and the Pressure Pad that will be measuring the weight. The ultrasonic sensor is more of a simple connection, because we were able to use an example connection that we did in Junior Design. The ultrasonic sensor has four pins that need to be connected. The first pin is the VCC and with this sensor, it requires 5V for it to work properly. So, thh VCC pin is connected to the 5V pin (pin 2) on the raspberry pi. The second pin to be looked at is the Trigger pin and this pin should be connected to the GPIO pin (pin 7). The echo pin is the third that connects and this one would be connected to a voltage divider. The last pin to be connected is ground. For the MCP3008, that is the ADC that the weight sensor would be

connected to. The VDD and VREF are the same voltage and the rest of the pins would be connected as it shows in Figure 42. Since there is only one sensor being used, it is connected to channel 0.

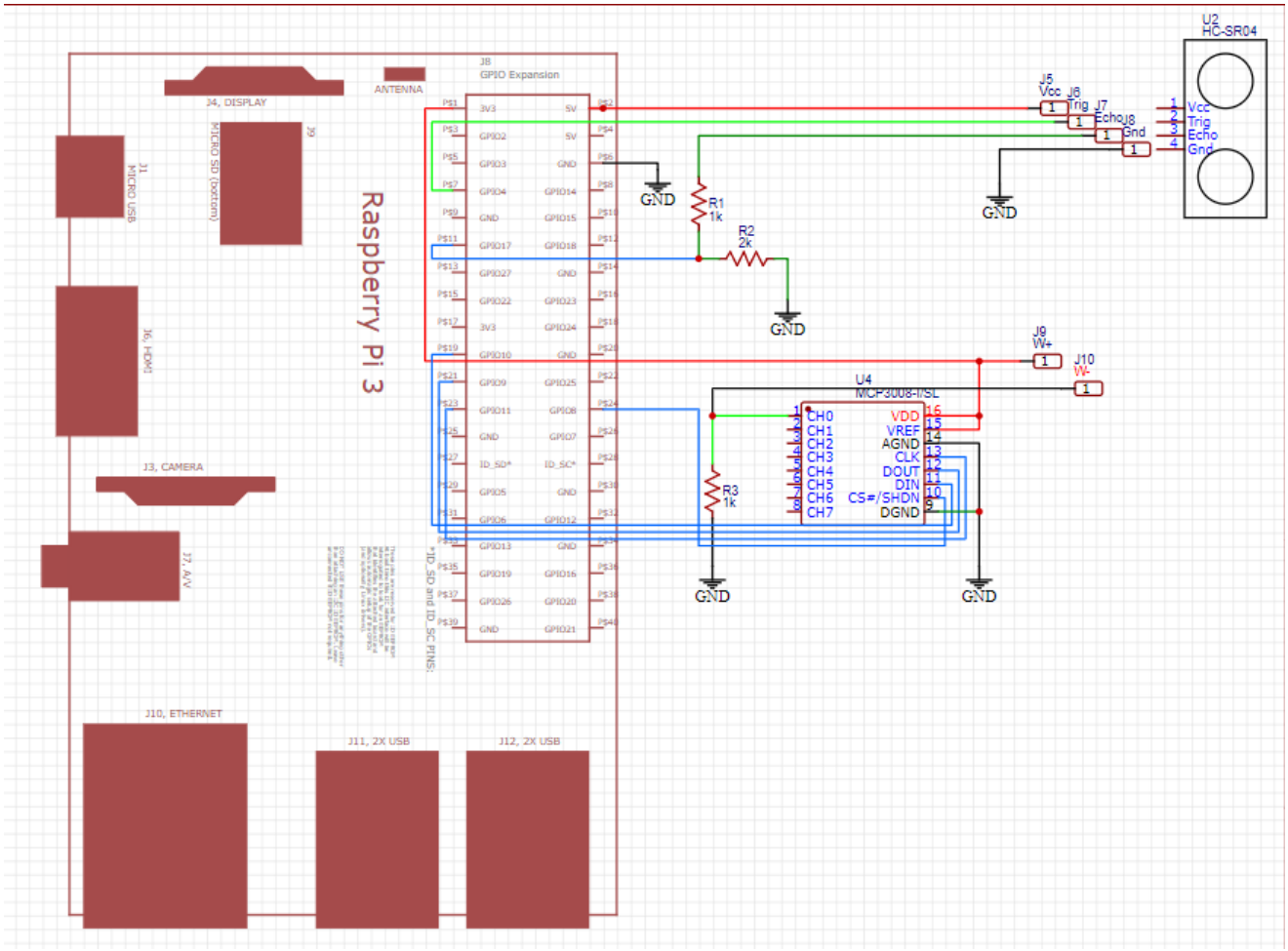

Figure 42: Schematic for sensors

The second schematic in Figure 43, shows the Arduino microcontroller and this one is used to be connected to the components that are going to be a part of the product. The two components that are going to be used are the motor and the pump. There will be one motor in use and it requires around 5V and the pump will require 12V. All of the components used are connected to a separate L293D since both require a different Vin. however, they will be connected the same way. The 12V will go into the pump, then a voltage divider will be used to reduce the voltage that goes into the motor.

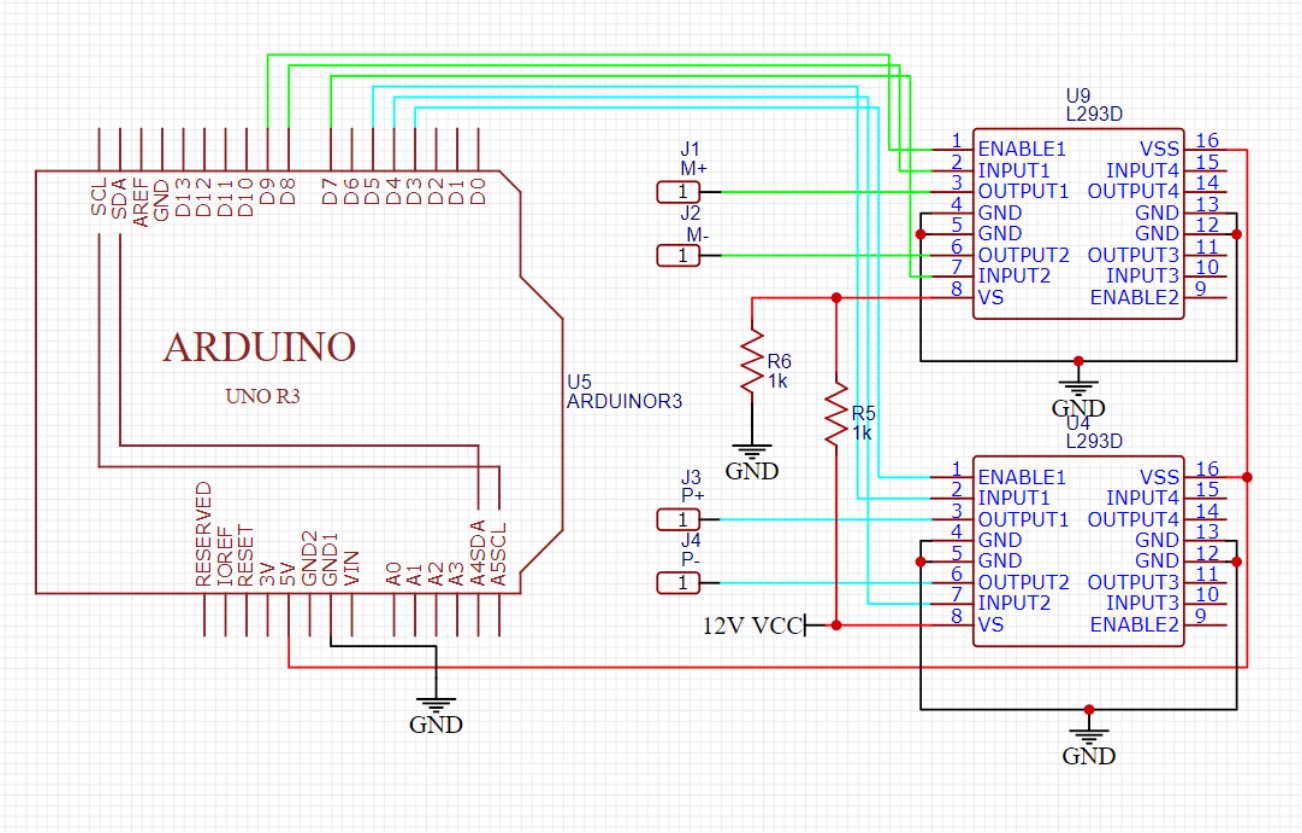

Figure 43: Schematic for Motor and Pump

6. Prototype

Before building our project, it is important to test our hardware and software. Testing allows us to make mistakes without affecting the integrity of the project. We can also solve these mistakes quickly and make sure that they aren't made in the final product.

6.1 Construction

The construction involved for the prototype will consist of different parts. First, we will have to plan out how we are going to execute the testing. This can be done by reading documentation as well as creating schematics for each individual part we are hooking up to the microcontroller. So, for both the construction and testing phase of our prototype, we need to test all of our components individually. Once that is done, we can start combining the components and creating some of the logic that our app and end product will require. The final prototype should have all of the components working together and be ready to solidify our circuits with PCBs.

6.1.1 Water sensor construction

Constructing the water sensor circuit was relatively straight forward. The sensor only consists of three pins including a VCC pin, a ground pin, and a signal pin. The microcontroller we used with this sensor ended up being the Arduino Uno. This is because the signal coming from the water sensor is analog and an Arduino Uno handles analog signals by converting them to digital signals (PWM). If we wanted to use a Raspberry Pi, we would have to use an analog to digital converter (ADC) chip like the MCP3008. Because we plan on using a Raspberry Pi to interface with our

app, we need to either get an ADC chip or send the signal from the Arduino to the Raspberry Pi. The easier option and the more likely option is to just use the Arduino as a secondary microcontroller to read in values of the sensors. This allows us to keep the logic for the sensors on the Arduino and to just send a HIGH signal to the Raspberry Pi when we need to. To replicate this we ended up using LED's to represent the HIGH signals we would be sending from the arduino to the Raspberry Pi. We used two LEDs (red and green) to represent when the water level was near full and near empty. Both of these LEDs were connected to ground and anode was connected to the digital signals coming from the raspberry pi. On both LEDs, a 220 ohm resistor was used in series with the 5V signal coming from the Arduino Uno.

6.1.2 Motor construction

The construction of the motor circuit was quite simple to set up in an isolated environment. We are using the 28BYJ-48 Stepper Motor. When the 28BYJ-48 motor is in full step mode, each step translates to a rotation of 11.25 degrees, according to the data sheet. That means each revolution has 32 stages (360°/11.25° = 32). A 1/64 reduction gear set is also included with the motor. (Actually, it's 1/63.68395, but 1/64 is a decent enough approximation for most uses.) This indicates that each rotation consists of 32*63.68395 steps, or 2037.8864 2038 steps! The motor's current usage is roughly 240mA. Because the motor consumes so much power, it is preferable to power it directly from an external 5V power source rather than from the Arduino. We ended up using a 9 V battery as this connects very easily to the driver of the stepper motor.

The driver that we used is the ULN2003 Driver Board. ULN2003-based driver boards are commonly included with the motor. The ULN2003 is a motor driver IC that consists of an array of seven Darlington transistor pairs, each of which can drive loads up to 500mA and 50V. This board makes use of four of the seven pairings. The board features a connection that properly matches the motor wires, making it very simple to attach the motor to the board. Four control inputs, as well as power supply connectors, are also available. Four LEDs on the PCB indicate activity on the four control input lines (to indicate stepping state). When stepping, they offer a lovely image. An ON/OFF jumper is also included on the PCB to isolate power to the stepper Motor.

In order to fully make the sensor work, we need to configure it using an Arduino Uno board. The 28BYJ-48 Step Motor is fully compatible with this board and the Arduino packages already come with the functions necessary to make the stepper move. We connect the pins from the driver to the arduino in ports 8, 9, 10 and 11. These pins are then specified in the code as the step pins that the stepper takes in the controller. Once all is set up, we can upload the code to the controller and enabling the power to the motor, we see the motor starting to work with the speed and steps we specified. A schematic of how the motor connects to the controller can be observed below in Figure 44.

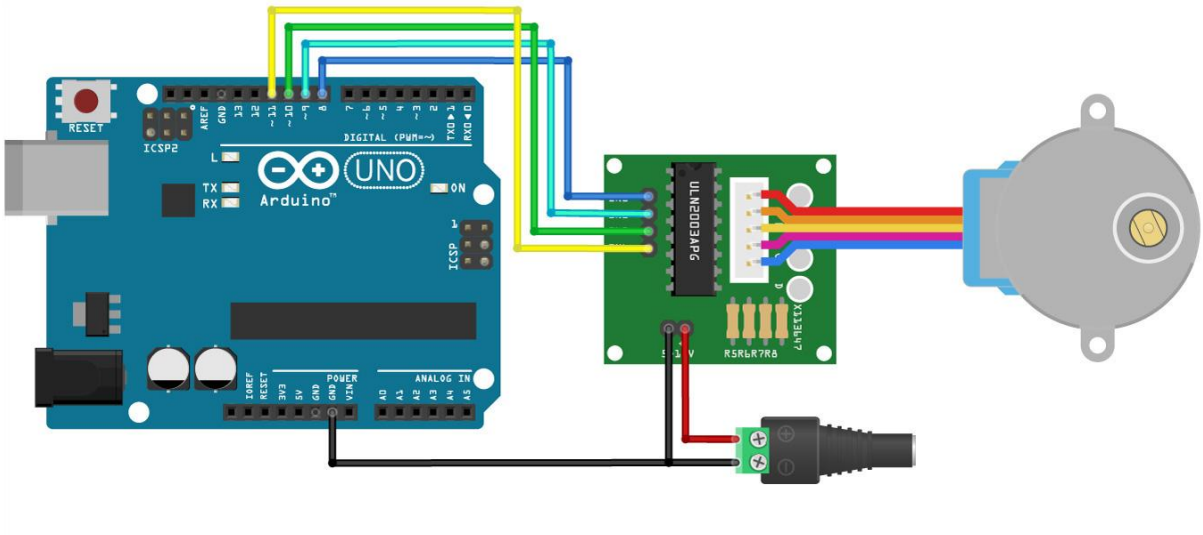

Figure 44: Stepper Motor Construction

6.1.3 Water pump construction

Constructing the water pump circuit for prototyping proved to be much more involved than the other components. This was because in order to get the pump working with an arduino, a L293D Motor Driver IC needs to be interfaced with it. Additionally, a 12V 1A power supply needs to be used to power the peristaltic pump. To use this, we attached an adapter that allowed us to screw wires in for the positive and the negative terminals. We then took those wires and used an alligator clip to attach them to breadboard wires. This allowed us to use the 12V 1A on the breadboard and hook it up to the motor driver. The motor driver is a dual-channel H-Bridge driver which means it has the ability to power and control two motors at once. When we combine everything, this will allow us to drive both the water pump and the motor for releasing the food off of the same driver. H-Bridge also means that we are able to control the rotation of the dc motors. For the pump this means that we can pump in both directions. An example of how this works is shown below in Figure 45. It's basically just switching polarities with switches to turn the motor one way or the other.

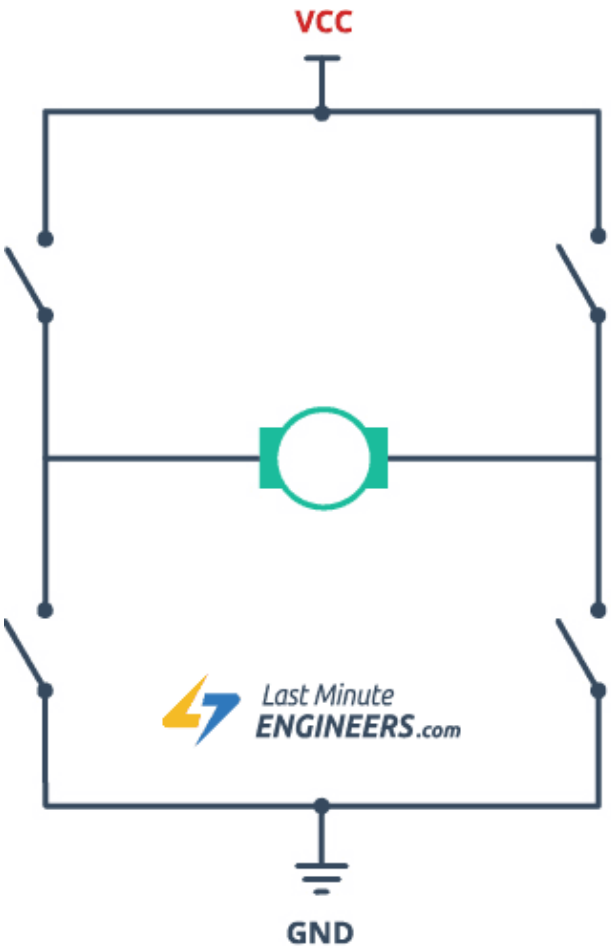

Figure 45: Working of H-Bridge

With the driver we can also control the speed of the motors. This is done by varying its input voltage and PWM (Pulse Width Modulation) is the technique used for this. PWM is a method of adjusting the average value of an input voltage by transmitting a series of ON-OFF pulses. Duty Cycle, which is proportional to the width of the pulses, determines the average voltage. The average voltage applied to the DC motor (High Speed) increases as the duty cycle increases, while the average voltage applied to the DC motor decreases as the duty cycle decreases (Low Speed). The PWM approach is shown in Figure 46 below, with various duty cycles and average voltages.

When it came to hooking up the L293D motor driver, we had to look at a pinout diagram. We started with hooking up the power supply. We used 5V from the Arduino Uno to power the logic circuitry in the motor driver through Vcc1 and then we used the 12V 1A power supply to power the motor through Vcc2. This brings us to the output pins, which we hooked up to each end of the peristaltic pump. Once again, polarity did not matter and all that happens when you switch around the polarity is the motor spins in a different direction. The last pins we need to connect on the motor driver are the control pins. These control the speed and spinning direction of the DC motors with the Arduino Uno's digital PWM pin for the speed and a regular pin that alternates between 5V and 0V depending on whether it's set to HIGH or LOW in the code.

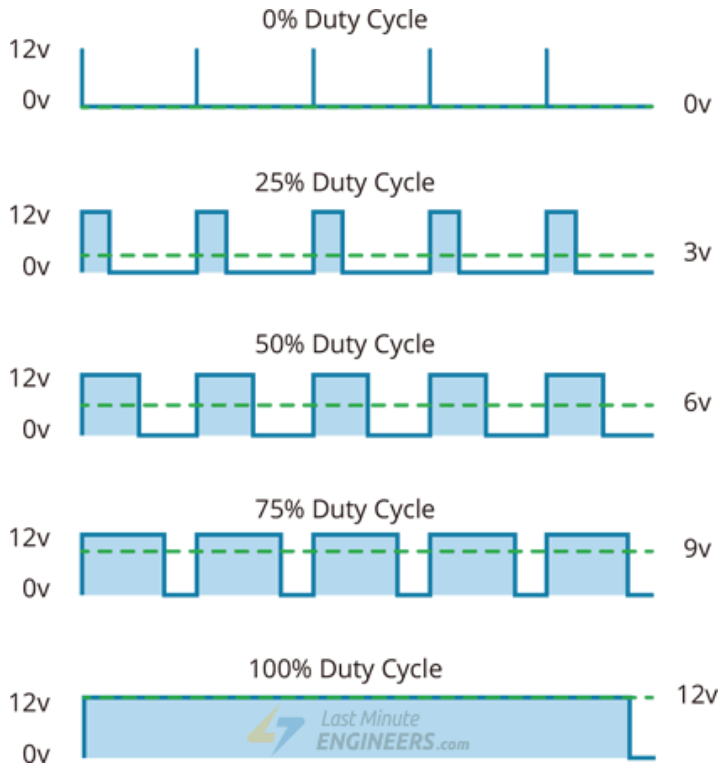

Figure 46: Pulse Width Modulation (PMW) Technique

6.1.4 Motion sensor construction

Setting up the motion sensor was a very manageable process. The sensor that was used is the HC-SR04 Ultrasonic Sensor, and it consists of four pins: VCC, Trigger, Echo, and Ground. It will be hooked up to the Raspberry Pi microcontroller so we will be able to read the distance. The VCC pin is used to power the motion sensor which will then allow us to detect the range of the closest object to it and it will be hooked up to pin 2 on the Raspberry Pi which is the 5V GPIO and the ground pin was hooked up to pin 6 on the raspberry pi. The next pin on the motion sensor is the trigger pin which triggers the ultrasonic sound pulses that will determine whether there is something in front of it or not and it would be connected to pin 7 which would be GPIO4. The third pin to mention is the echo pin. The echo pin is the part to receive a signal that is reflected back to the sensor after the trigger pin sends a pulse that determines whether there's an object in front of it or not. Unlike the other pins, the echo pin will be connected not only just to pin 11 which is GPIO17 on the raspberry pi, but also to a voltage divider to limit the amount of current and voltage that is coming from the echo pin. The calculations for the voltage divider can be seen below in Figure 47. The input voltage is 5V and the required output voltage was 3.3V. So plugging this into the voltage divider and assuming we know R1 to be 1K Ohm, we get 1941 Ohms for R2 which we ended up rounding up to 2K Ohms.

$$Vout = Vin * \frac{R2}{R1 + R2}$$

$$\frac{Vout}{Vin} = \frac{R2}{R1 + R2}$$

$$\frac{3.3}{5} = \frac{R2}{1000 + R2}$$

$$0.66 = \frac{R2}{1000 + R2}$$

$$0.66(1000 + R2) = R2$$

$$660 + 0.66R2 = R2$$

$$660 = 0.34R2$$

$$1941 = R2$$

Figure 47: Voltage divider to obtain R2 in the motion sensor circuit

6.1.5 Force-sensitive resistor construction

The construction for the force sensitive resistor was by far the easiest out of all the sensors. All that was required was, first, connecting one side of the sensor to 5V. Then, connect the other side to an analog input with a pull down resistor connected to ground in between. The way it works is that when the force-sensitive resistor drops in resistance, the total resistance of the sensor plus the pulldown resistor drops from around 100 KΩ to roughly 10 KΩ. That means the current running through both resistors rises, causing the voltage across the fixed 10K resistor to rise as well. This can be seen in Table 15 below.

Force (lbs)	Force (N)	FSR Resistance	(FSR + R) ohms	Current through FSR + R	Voltage across R
None	None	Infinite	Infinite	0 mA	0V
0.04 lbs	0.2 N	30 KΩ	40 KΩ	0.13 mA	1.3 V
0.22 lbs	1 N	6 KΩ	16 KΩ	0.31 mA	3.1 V
2.2 lbs	10 N	1 KΩ	11 KΩ	0.45 mA	4.5 V
22 lbs	100 N	250 KΩ	10.25 KΩ	0.49 mA	4.9 V

Table 15: The approx analog voltage based on the sensor force and resistance with a 5V power supply and a 10 KΩ pulldown resistor.

6.1.6 Camera construction

Getting the camera set up was more of a challenge than expected. Connecting it to the board itself was easy because there is a dedicated connector for the ribbon cable. But, setting it up for testing on the raspberry pi proved to be an annoyance. It ended up not being as plug in play as advertised. First, the Raspberry Pi wasn't able to pick up the camera due to settings not being enabled. The only way to run a test with the camera is through the command line but trying to run the command was throwing the error: "the system should be configured for the legacy camera stack." This meant that we needed to go into the Raspberry Pi's configuration menu to enable legacy mode. Once that was resolved we were able to properly test the camera which we will dive more into in section 6.2.

6.2 Testing

This section explains how we put our automatic pet feeder's hardware and software to the test. There are several aspects of the pet feeder that absolutely needs to be tested to make sure our product is functioning properly. To reduce the risk of failure during system deployment, make sure that each component of the system is working properly before delivering the overall system. The pet feeder absolutely needs to be tested to make sure our product is functioning properly. We must guarantee that each component of it functions as intended. For each part, we will try to make sure that we can test these and not breach the limit of what each part can handle. As a result, testing is one of the most important aspects of laying the groundwork for this product. As a result of the testing, we are able to check the prototype's functionality using a variety of hardware and software tests. For example, we began to evaluate the operation of each of the components before moving on to other components of the device like the microcontrollers. We've broken down each part of the pet feeder into several sections like the motor, pump, or sensors in the testing and prototyping. By dividing the testing into sections like this, it provides us with more flexibility especially when it comes to things such as hardware testing and prototyping and software testing. It's important that the components can work as expected before

we complete the final build of the pet feeder, because if just one of these parts stops working, then we would have to revise a chunk of our product.

6.2.1 Water sensor testing

Before getting to the circuit we described in the construction section, we first needed to test that our sensor was working. We downloaded Arduino's dedicated IDE and hooked up the Arduino via USB. The code we had to write had to dedicate a pin to power the sensor via the digital pwm signal pins and then dedicate another pin to read in the analog signal coming from the water sensor. The Arduino IDE with its dedicated library makes this process very simple versus a microcontroller like the MSP430. All we needed to do was use the setup function to inform our arduino that we plan on using the serial monitor by setting the data rate to 9600 bits per second (known as a baud rate). Then, we just needed to set up all of our pins as OUTPUT and initialize the power pin to LOW. After we've initialized everything, we can move into the loop function where our logic will be executed. First, we need to turn on the sensor by setting it to HIGH. After that, we need to trigger a short delay before reading the value the sensor is outputting. Lastly, turn off the sensor and do what we want with that value. First, what we did with that value was simply print it out to a serial monitor shown in Figure 48, to confirm that the sensor is working.

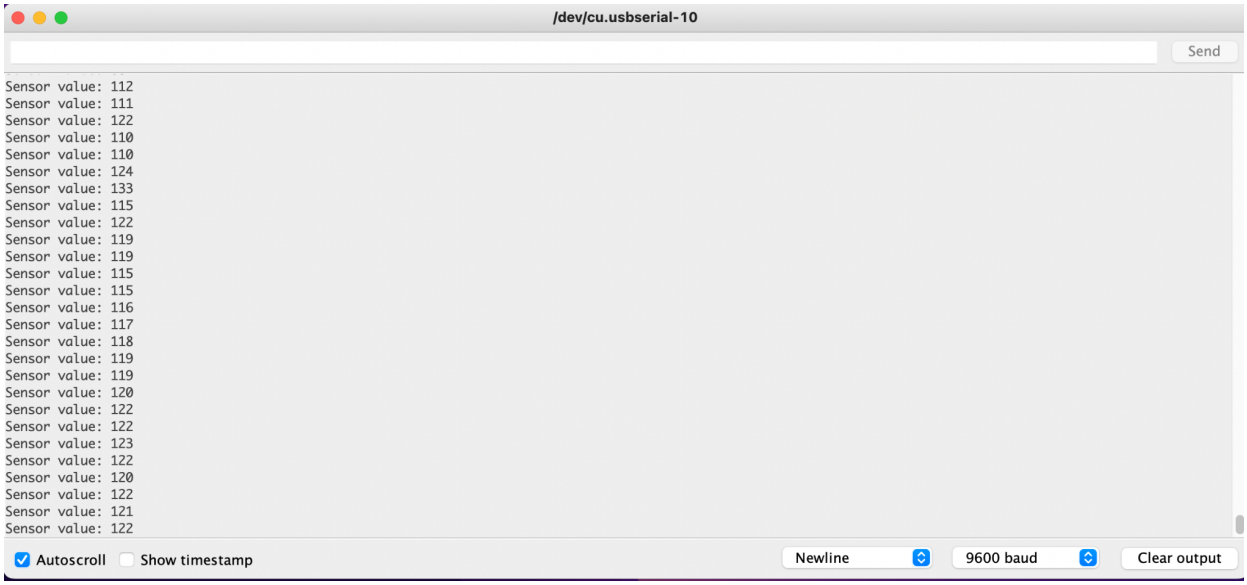

Figure 48: Printing the water sensor's value to a serial monitor

The serial monitor prints out a value based on how far the sensor is in the water. This is because the sensor acts as an open circuit and is basically measuring the resistance of the water. So, the value the sensor outputs is directly correlated with how conductive the water is. Once we were able to verify that the sensor was outputting values, we could set up some logic to deal with specific values. This is called the calibration phase and we basically tested to see what values we got when the sensor was out of the water, what values we got when the sensor was barely in the water, and what values we got when the sensor was fully submerged. Then, we could send a HIGH signal on two different wires on the digital pins side of the arduino when they are in a certain range. So, if the values were less than or equal to 20, then that meant the water was low and to set the signal to HIGH on the wire connected to the red LED. If the value was more than

110, then we would do the same but for the green LED. This circuit can be seen set up in Figure 49. This would be easily translatable and could be applied to the water pump. Instead of turning on the red LED, we would turn on the pump and then turn off the pump when the green LED turned on.

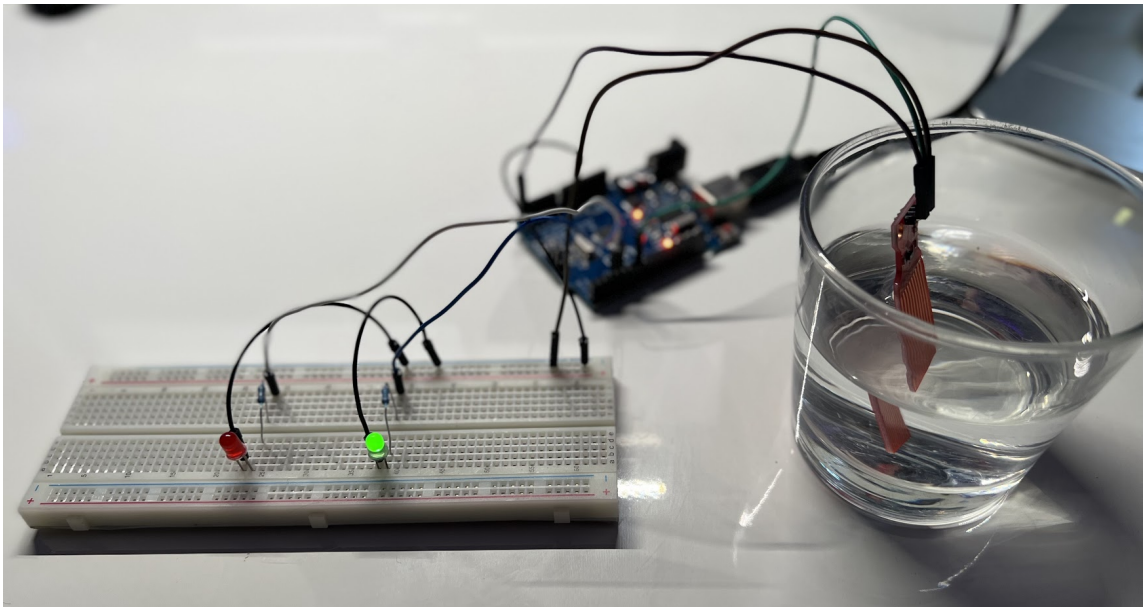

Figure 49: Testing the water sensor on a breadboard

6.2.1.1 Test Results

After running through many tests using this water sensor to simply detect water levels and trigger LEDs, we came to the conclusion that this sensor will not work for us. This is due to inaccuracy and the fluctuation of values while testing. At times, the sensor would give readings of values in the range of 0 to 85 for low water level and full water level. But, as testing continued, the range would dramatically change and sometimes it would read the value of 20 for the low levels of water and sometimes it would read 90 for the low level. When the sensor was covered with water it had the same results. Sometimes the sensor would read a value of 150 when it was full and other times it would read 180. This makes the water sensor pretty unreliable and we will have to find another solution for measuring the water more accurately.

6.2.2 Motor Testing

There are multiple aspects that need to be considered when working with, installing and testing the food dispenser of the automatic pet feeder. The mechanism in charge of dispensing the food will be installed at the bottom of the food container and will be composed of a motor that rotates a certain amount of times depending on how much food has been configured to dispense and a measuring cup that will hold rations of the food. The combination of both the rotation of the motor and the amount that the measuring cup holds, will allow the automatic pet feeder to dispense the correct amount of food by dispensing the food in different intervals and stopping once the necessary amount has been dispensed.

The motor that will be inside of the dispensing mechanism must not be active at all times. That is, even though the automatic pet feeder will be connected to power throughout its whole operation, the motor itself should not only be active when a command to dispense is received by the pet feeder's controller. While the motor is not currently dispensing food, whether due to its schedule or by the user triggering a meal dispensing, the motor should stay in an idle state, not drawing power and only waiting until the controller tells it that it needs to dispense. The voltage sent to the motor should be kept within the motor's allowed range and should not be exceeded. If the motor requires a different voltage level than the one outputted by the circuit or by the controller, we must be able to add a voltage regulator before the motor to ensure it stays within those levels at all times.

In order to test the correct functionality of the motor, we will be conducting a series of tests to ensure that the motor rotates only on command, to calculate the correct rotation angle and to ensure it can do this multiple times if the dispense command requires it. For this, we will be setting up the motor in a controlled and isolated environment in which we will set up all the connections necessary, along with the circuit that the motor requires to function properly. Before we even connected to the controller, we must ensure that the motor itself works as expected, that it rotates at a reasonable speed and that we can configure it to only rotate a certain amount of times and then stop at the right position, which will allow the measuring cup to hold more food and be ready for the next meal schedule. The motor's functionality should not be affected by other components or sensors that are included in the pet feeder and should also perform its tasks correctly even when other components are added. For this we will have to ensure that power given to the automatic pet feeder is distributed correctly amongst the components and that the power each of these components does not fall short or does not exceed the power that each of the components supports, so that the motor does not get damaged over time and ceases to work and dispense the food.

Besides testing the correct functionality of the motor, we will need to do extensive stress testing. In order to achieve this, we will need to have the motor running on intervals for a significant amount of time. These stress tests will be done in order to simulate the workload that the motor will be receiving on a constant basis when performing its intended meal dispensing tasks on a daily basis while pouring food to the pet bowl. The stress tests will be performed by running the motor by itself consistently for extended periods of time, and by running it together with the measuring cup, since this will add extra weight to the motor and might affect the speed and power that will be required to dispense the food.

Once the motor has been tested in its own isolated environment, we will be connecting it together with the controller and ensuring we can set the correct amount of full turns the motor must perform. Since the motor will need to wait for the measuring cup to be filled in between turns, that is, if the dispensing requires more than one turn, during our testing, we must ensure that the motor can wait in place and begin rotating only when the measuring cup has the required amount to be dispensed. This testing together with the controller will require a bit more involvement, since we will need to program it to send the information correctly to the motor, have it wait in between turns and dispense the correct amount of food and not a significant amount more or less than the expected. In this case, the controller must also output the correct signals that will let the motor know what its current state is and how to approach the rotating.

The controller will be the brains of the motor and will be in charge of all the tasks the motor must perform. An environment with an Aurdino as a controller can be observed in Figure 50.

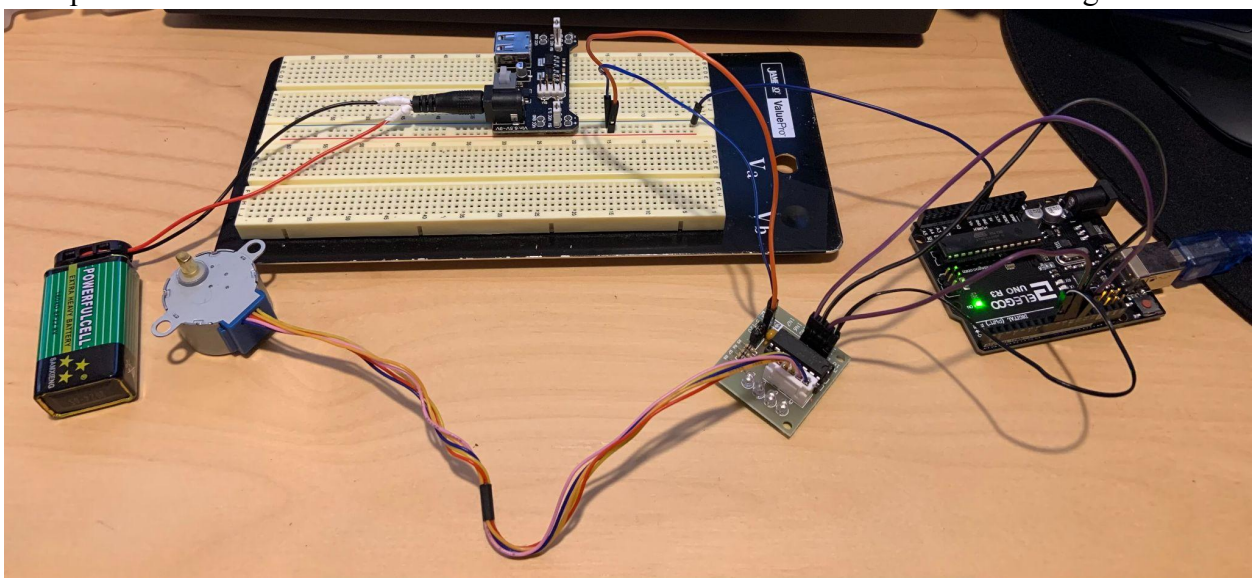

Figure 50: Stepper Motor Testing With Arduino

For the environment to properly work with the Arduino, we had to add the necessary code that drives the motor. The code was implemented using the Arduino IDE and uploaded via USB to the controller. Following the stepper motor instructions, we were not able to use the 5 V that the Arduino outputs to power the step motor. The step motor requires a driver which controls all of its functions and an external voltage source as we can not use the voltage from the Arduino. The external voltage source needs to be between 5 and 12 V in order to properly power the stepper motor. We decided to test it out with a 9 V battery as it performs very well and was available to us. The stepper method above consists of 32 steps per revolution but it also has a 64 gear reduction, thus, in order to make it rotate appropriately, we have to multiply the number of revolutions by the gear reduction. This configuration allows us to set the motor in motion. The motor also conveniently provides some

After the motor has been successfully tested by itself and together with the controller and potential voltage regulators, we will need to ensure that settings set by the pet parent through the mobile application are translated and communicated properly to the controller and this in turn provides the correct values and commands that the motor will need. Once this step has been done, the testing of the motor will be considered complete.

6.2.3 Water pump testing

The testing for the water pump is very similar to the motor. This is because the peristaltic pump is basically just a DC motor. The difference is this motor squeezes the tubing to pump water. So, what we are testing is that we can successfully hook up the pump with an arduino and trigger the pump to turn on with specific conditions. Those conditions plan to be when a force-sensitive resistor reads a low or high value from a pet's water bowl. The low value will be when the water bowl is empty, so we will turn the pump on. The high value will be when the water reaches a decent height without overflowing to turn the pump off. In Figure 51, you can see the setup we

had for the water pump circuit. The goal was to write some code on the arduino uno and watch the pump simply transfer water from one cup to another. The goal of testing is to know that we can use it in the final product. And after testing, it's pretty clear that this pump is a winner. It transferred water between cups flawlessly and could easily be controlled with some simple code.

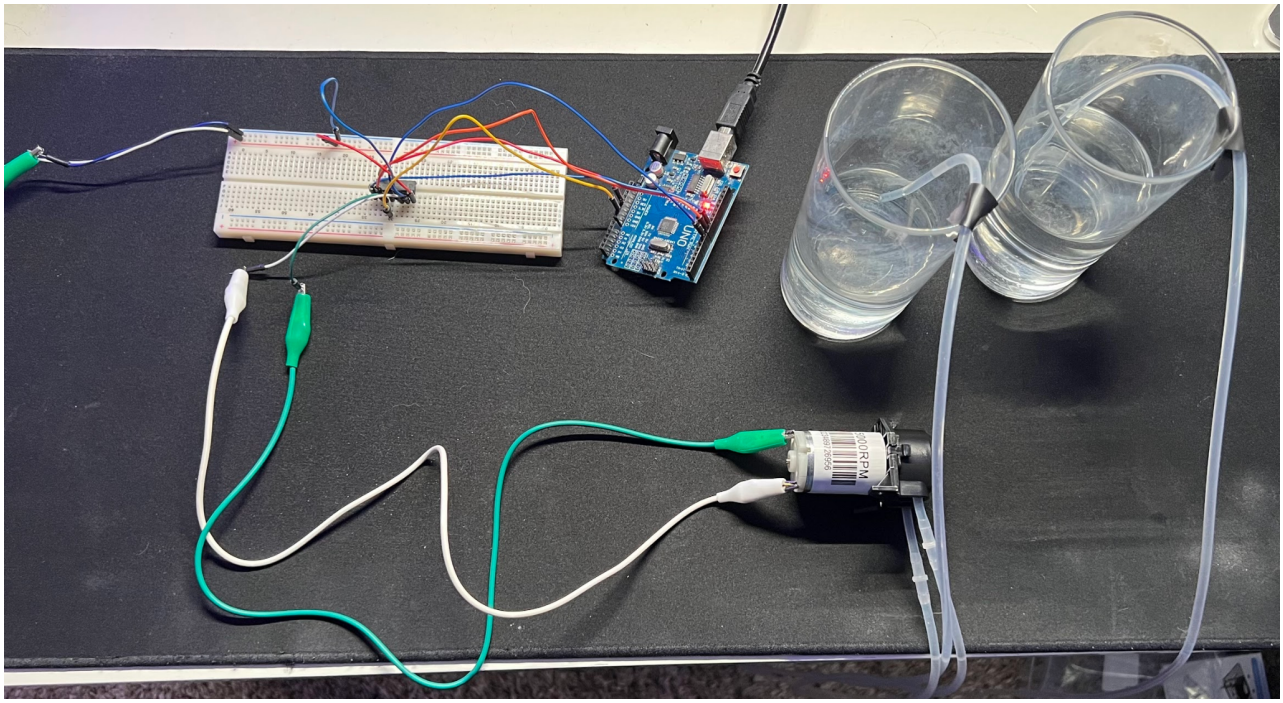

Figure 51: Water Pump Testing

As far as the final product goes, it doesn't need to be on the whole time the pet feeder is on. We know that it just needs to get power from the circuit for it to become active which means that we just need to get the app to tell the microcontroller what to do. So, it needs to be activated by the app that will be connected to the microcontroller. The microcontroller will receive a signal from the app, and send power to the pump which will make it active. Once the pump is active, it will then pump water into the bowl that is meant for the water. Similar to the motor, we will make sure that there is a sufficient amount of power being sent to the pump, but not too much. We know that we are done testing the pump once we are able to successfully control the pump from the app and that it pumps out the exact amount of water we command it to. Once we finish that stage of testing, then we can move on to connecting it to the microcontroller and have it only pour water once the microcontroller tells it to and the microcontroller would know to tell it when the person using the apps instructs it to do so.

6.2.4 Motion sensor testing

The motion sensor is a component that will be active for the entire duration the pet feeder is on. It will be used to detect whether a pet is in front of the pet feeder or not, which means that once the pet is in a certain range, the user will be notified on the app. Figure 52 shows an overview of the flow for detecting the pet.

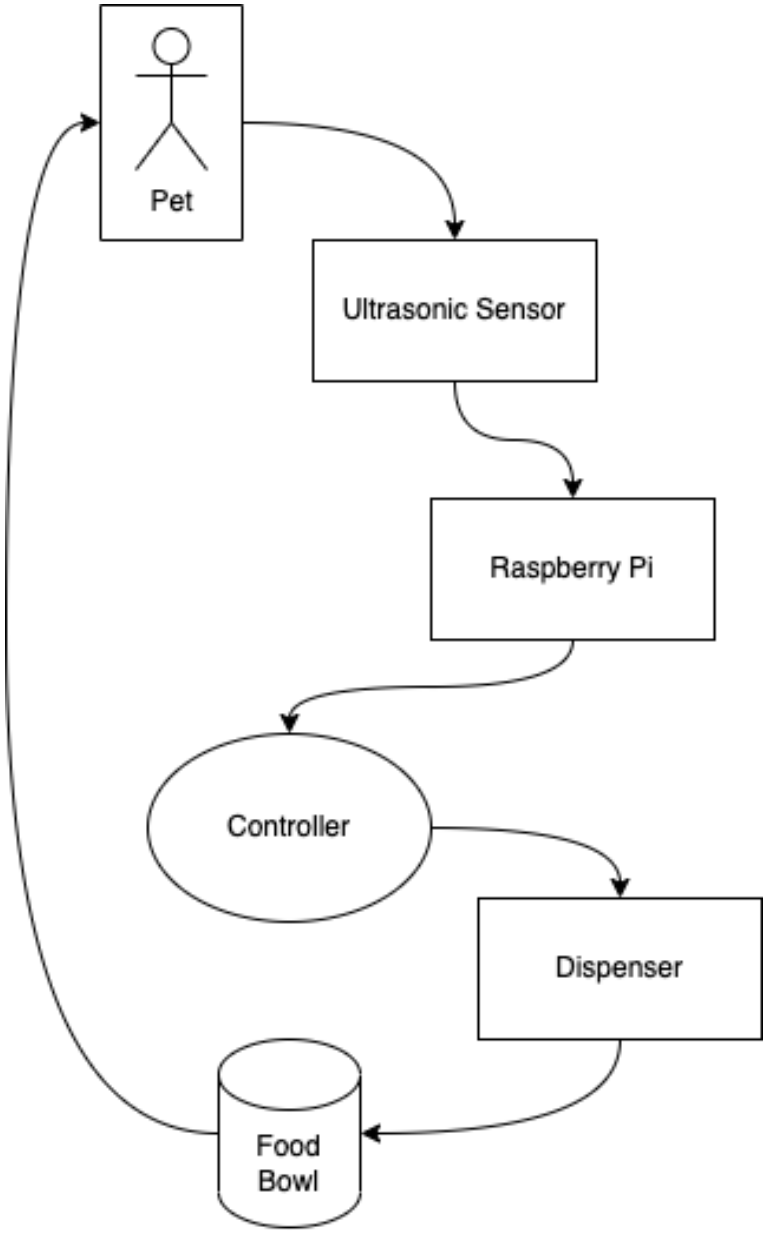

Figure 52: Flow for Detecting Pet

Since this device will be active the entire time, we must absolutely make sure that the amount of voltage being sent to it is not too much so it can continue to work efficiently without any problems. So the first part of testing for this part will consist of simply making sure that it's able to read the distance between it and the object in front of it. Once that part is out of the way, the motion sensor will be connected to the microcontroller, and the controller will be programmed to notify the user that the pet is there once the value of the distance reaches below a certain value. It can also detect when our food container is low to notify the owner to refill the reservoir.

To begin the testing, we first needed to make sure we were getting values from the sensor. This took some trial and error because we were coding on the Raspberry Pi this time which is written in python instead of C. To begin, we needed to set up our pins on the Raspberry Pi before entering a try except statement. This process of setting up the pins was similar to the arduino where we needed to dedicate pins to outputs and inputs as well as initialize them to LOW. So, we set the trigger pin on the sensor to be an output because that is how we will trigger the sensor to send an ultrasonic pulse. The pulse will then bounce off any nearby objects and reflect back to the sensor to be read. The time it takes to bounce off an object and return back to the sensor is measured with time to determine how far it is. We get this reading from the ECHO pin which is why we initialize its pin on the Raspberry Pi as an input. Now that we set up the pins, we initialize the trigger to low and enter the try statement. In the try statement we have an infinite while loop with all of our logic. To begin our logic, we need to send a pulse to the trigger pin on the sensor. We can do this by setting the pin to HIGH for ten microseconds and then setting it to LOW. This starts our 8 ultrasound bursts at 40kHz to get a response from the echo pin. To read the response from the echo pin we need to create a variable for time and measure how long the echo pin is LOW and how long the echo pin is HIGH. Subtracting these tells us how long the pulse duration was. Then we use the formula in Figure 53 to calculate the distance.

$$Speed = \frac{Distance}{Time}$$

$$34300 = \frac{Distance}{Time/2}$$

$$17150 * Time = Distance$$

Figure 53: Formula used to calculate an object's distance from the ultrasonic sensor

We use the speed of sound at sea level which is around 343 m/s and then we divide it by 2 because it goes to the object and back to the sensor. Then, we plug in our pulse duration into time to get the distance from the sensor in centimeters. Now that we are at the end of our loop we can print out the distance to the terminal and then sleep for two seconds to give the sensor time to rest so that we get more accurate readings. After we set this up, we saw that we were getting what we expected. When nothing was in front of the sensor, the terminal would print out a high distance and then when we moved an object in front of the sensor it would output a low distance. Finally, to test what we would actually use this for, we once again set up a simple circuit involving some LEDs (seen in Figure 54) which in the future would be notifications sent from our app.

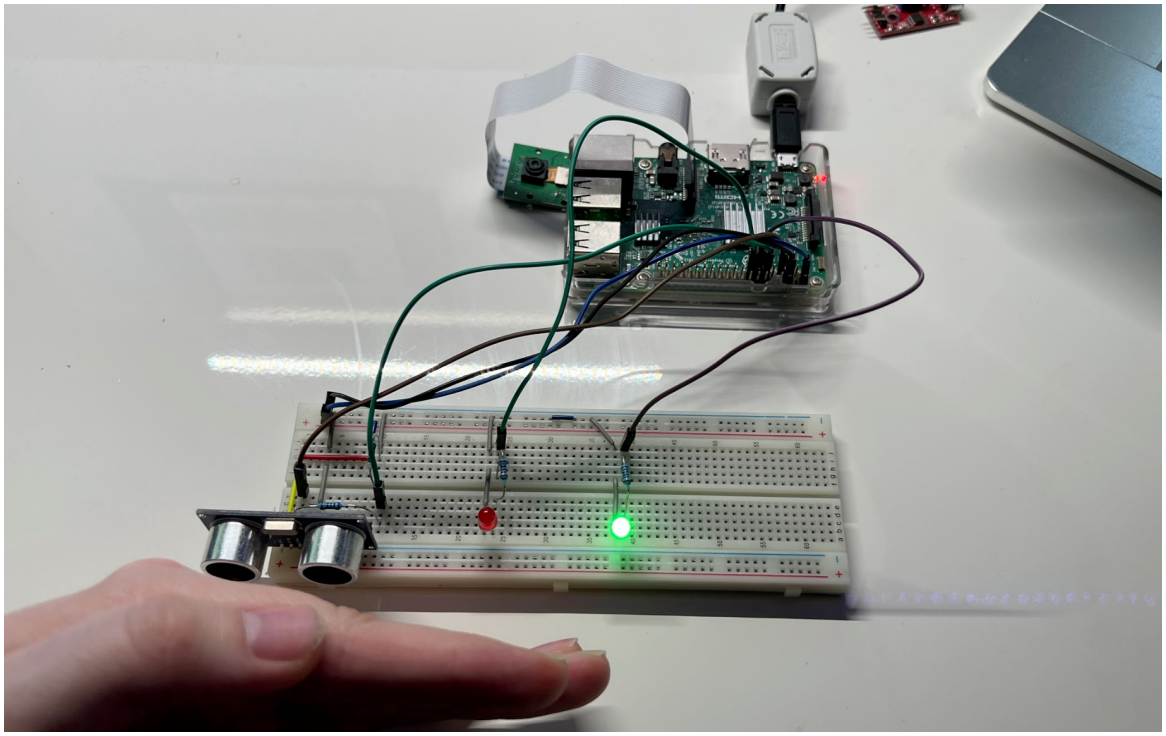

Figure 54: Testing the motion sensor on a breadboard

When the green LED is lit up, the sensor is detecting a distance of less than or equal to 10cm. In Figure 54, you can see my hand is the object that is less than 10 cm away from the sensor. This shows how we could have the sensor pointed at our pet food in a reservoir and detect the levels based on how far the pet food is from the sensor. Having the ultrasonic sensor at the top of the reservoir pointed down at the food will let us fulfill our design for the mobile application which involves showing when the food is at 100% full, 75% full, 50% full, 25% full, and 0% full. This goes the same for the water but we would have to change the formula calculated in Figure 53 to use the speed of sound through water.

6.2.5 Weight sensor testing

There are times where pets do not eat all of the food that was poured in the bowl during the previous meal cycle. This could be due to the pet not being hungry or getting distracted by something else happening around the household. Since the automatic pet feeder will be working on a schedule, in order to not keep pouring into the bowl until a point where it overflows or begins to overfeed the pet, it is of utmost importance that we can detect the amount of food left in the bowl at the time that the scheduled meal is due and we need to pour more food for the pet. Before pouring the food, the automatic pet feeder will check for the amount of food left in the bowl and will determine whether we should pour more food or hold out on the amount until the next meal period.

In order to achieve this behavior and keep track of the amount of food in the bowl, we will be relying on the use of weight sensors located at the bottom of the pet food bowl. These sensors will sense the weight difference between an empty bowl and a bowl with some food in order to determine whether the bowl is empty or not. In order to ensure correct behavior at all times, this

will require extensive testing as we need to identify the weight threshold where we consider skipping the meal cycle. Since different pet food might have different weight, we will be needing to perform tests with different types of food and come up with an average weight that makes sense across multiple types.

We will be performing multiple tests in a controlled isolated environment at first, that is, we will be connecting the weight sensors to a breadboard along with a microcontroller and will try to test that the behavior stays consistent when not combining the circuit with any other major components at the same time. Just connecting the weight sensor to the controller through the breadboard is not enough to make it work, we also have to program the microcontroller with the necessary code based on the weight sensor's datasheet and drivers in order to properly read the values coming in from the weight sensor. The software we use to program the controller should continuously return value depending on how hard we press down on the weight sensor. A figure of what a potential isolated environment could look like with the weight sensor and an Arduino Uno as a controller can be observed in Figure 55 below.

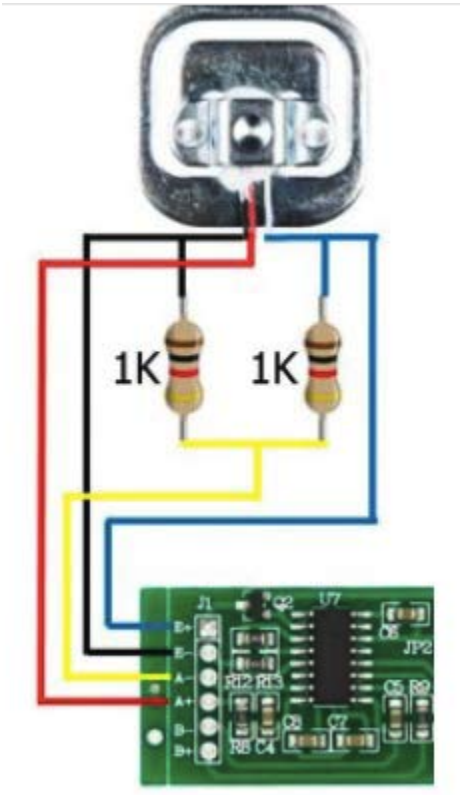

Figure 55: Weight Sensor in Isolated Environment

Since the job of these weight sensors is to alert when the value falls too low, meaning that the food needs to be refilled, we will perform stress tests and push pressure on the weight sensor by placing a test food bowl on top of it and pushing down with our hands, we will then just read the value from the sensor and send it to the software so that it alerts the user that the food is running low through the software, all while comparing the current value of the sensor the previously determined threshold.

Once we have been able to successfully read the values from the sensor and perform the necessary calculations with the threshold in the software, we will then write the write the necessary code in order to send notifications to the mobile application, letting the user know about the current condition of the food bowl so that they are aware of meal cycles skipped and are up to date with their pet's meal.

Once these tests for the main parts are up and running properly in their isolated environment, we will combine the weight sensor circuit with other components and other sensors and ensure that it behaves the same way and its behavior is not affected by these other components. After we have validated that the weight sensor works properly by itself and together with other components, and we validate that the messages are being sent to the mobile application, we can conclude that the weight sensor works as intended and we can say that the testing is complete

6.2.6 Camera testing

Testing the camera took some time to get working due to difficulty with Raspberry Pi OS. Some configuration files had to be adjusted as well as some operating system settings had to be changed. This was due to an error that was occurring when trying to run the test to see that the camera works. First we went with trying to get libcamera to work as we discussed in the research section of our report. Once we got that running we realized that we wanted to use a different library known as picamera because it was easily interfaceable with python. This caused more errors to occur that we needed to resolve, one of them being to enable legacy camera support.

Once these headaches were past us, we were able to run a simple python script with picamera to test that the camera was working. All that had to be done was to create a camera object, set its resolution, and then start a preview. From here, we can see that our camera is working and that we can now move on to some more advanced features of the picamera library. One of these features is demonstrated in Figure 56. Using web sockets we were able to stream a video feed from the raspberry pi onto the local ip. We were also able to import the socket library to grab the ip automatically so that the python program would run no matter what network you were connected to.

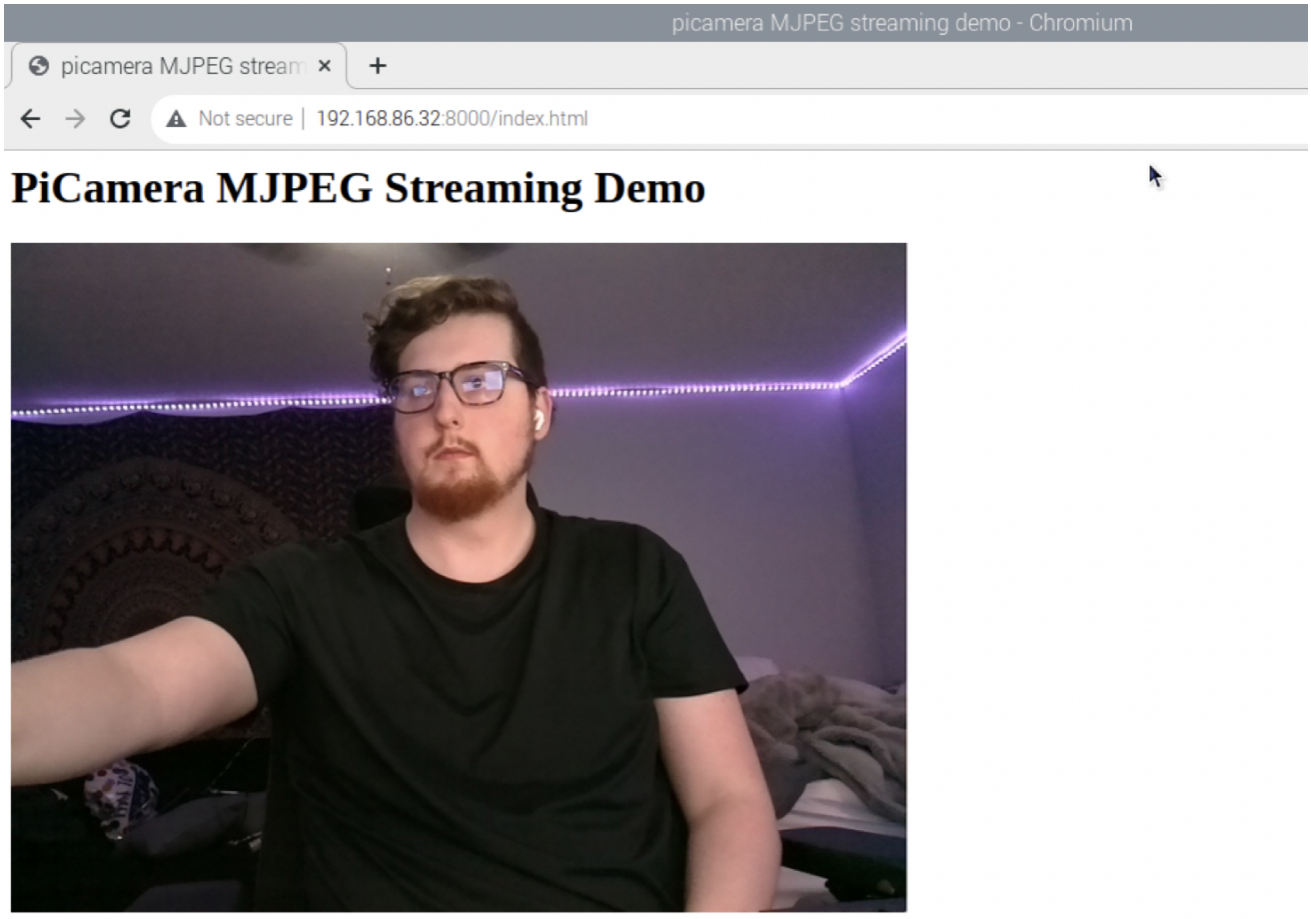

Figure 56: Web streaming with the picamera library

6.2.7 Force-sensitive resistor testing

The testing for the force-sensitive resistor was pretty straight forward. Our goal was to make sure that we could easily read values on the arduino and trigger something after putting pressure on the sensor. So, we connected an LED to light up when a certain amount of pressure was applied. This was easily implemented in code. We read in the values from the senor through an Analog pin and then we lit up the LED with a digital output pin on the arduino. This can be seen in Figure 57 below. The plan for the project is to place this sensor underneath the water bowl to measure the amount of water in the bowl more accurately. This was due to the poor test results from the water sensor in section 6.2.1. The sensor will then be calibrated to sense when to turn the water pump on and off. When the water bowl is near empty, the sensor will trigger the water pump to turn on and start filling the bowl. When the water bowl is nearly full, the sensor will turn off the pump. Finding out the values for this will take some trial and error.

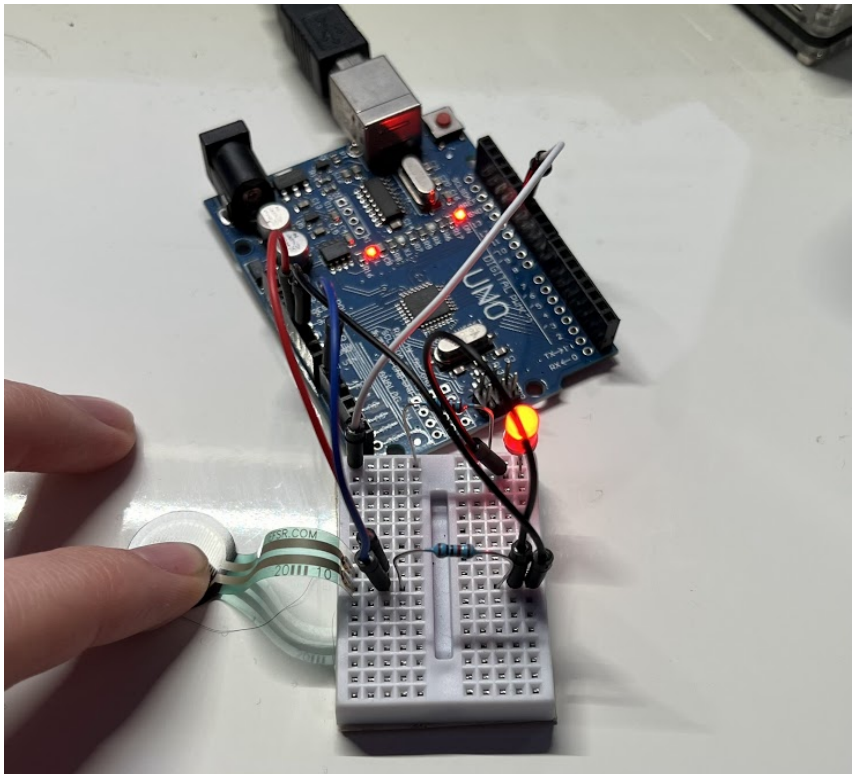

Figure 57: Testing the force-sensitive resistor on a breadboard

7. Pet Feeder Operation

Even though the pet feeding process is one most pet parents are familiar with, in order to ensure the safety of the pet that will be using the feeder, the household where the device will be residing, and the integrity of the device itself, interacting with the automatic pet feeder requires that the user read the complete operation as to familiarize themselves with the appropriate operation of the feeder.

The following section serves as the Owner's Manual for the automatic pet feeder. In here we outline and describe all the different modes of operation, what each of the different settings, what buttons are present and how these work in conjunction with the other operations in the device, what the different light indicators mean, how the pet feeder will interact with different external devices, how to identify different error codes and how to resolve any issues that may arise while learning the use and maintenance of the automatic pet feeder. Below can also be found all the different settings of the device, what buttons and light indicators throughout the machine and what all of these do. In order for the automatic pet feeder to work properly, the device must be interacted with in a way that respects the guidelines and procedures discussed below as this will guide any pet parent interacting with the machine through the different paths that the device could take in order to perform the proper task it is programmed to do. It also highlights how the machine is controlled and how to ensure that it is always performing under optimal conditions.

All the steps outlined in the section below are the recommended modes of operation of the automatic pet feeder. Interacting with the feeder in a different way or through a different flow than the one that is explained could result in the pet feeder malfunctioning or not performing at

its full potential. If an error arises when interacting with the automatic pet feeder's main body or with the mobile application, please refer to the Error Codes and Troubleshooting section to learn about different methods that could resolve the issues. Although not in the current workflow, these steps and guidelines are subject to change and can be simplified as the final version of the pet feeder is completed.

7.1 Power

The automatic pet feeder is a wall-powered device. It works by being connected to most conventional standard American power outlets and requires that it be connected at all times once it's been set up in order to perform all of its functions.

Once the device has been connected to power, a light indicator should light up on the device indicating that the device is ready to be powered on. Even though the device is connected to power, it will remain in an idle state, disconnected from communications until it is powered on. On its main body surface, the automatic pet feeder includes a button labeled 'power' which can be used in order to boot up the device. Pressing the button once and letting go will start the device, which will enter its booting mode. While the device is booting up, it begins getting all the components enabled, gathering and reading all the necessary data in order to manage the different pumps and sensors, and determining whether a pairing has successfully happened before and if it should automatically connect to the external device.

If the device is able to properly enter pairing mode and it finds a successful previous pairing, it will automatically connect and go into its 'ready' mode, which is indicated with a green solid light in its light indicator. In the ready mode, the automatic pet feeder is fully functional, has access to all the reading and different metrics from the sensors and has a two way communication with the external device running the mobile application. It is good to keep in mind that if the device is paired but the mobile application is not installed in the mobile device, the device will not be able to communicate with the mobile device and vice versa. In order to get the two way communication established again, the user must perform another pairing to the machine and restart the flow. Please refer to the 'pairing' section for more information on how to enter pairing mode.

If the light indicator does not keep a solid green light, or if the light indicator is blinking red, please refer to the 'error codes and troubleshooting' section, which provides information and describes any potential issues that may arise during the booting process, as well as a guide on how on how to resolve the failures and what actions to take when the device is not in a stable condition.

7.2 Pairing

The automatic pet feeder performs almost every single action by receiving messages from an external device running the mobile application and processing the commands in order to set its schedule, dispense water or food, or view the camera feed. Thus, in order to control every aspect of the feeder, the user must first download the mobile application to the mobile device and pair it to the automatic pet feeder.

Once the mobile application has been downloaded and installed in the mobile device, the pet parent needs to perform the pairing with the main body of the pet feeder. The pairing establishes a two way communication between the main body and the mobile application which serves as a bridge from the mobile application to send instructions to the main body and for the main body to send alerts, notifications and other important communications related to the flow of the pet feeding process.

For a better user experience, the pet parent should allow notifications from the automatic pet feeder's mobile application. In most mobile devices operating systems, once the mobile application has loaded, a pop up dialog will appear prompting the user if they want to allow notifications to be received from the pet feeder's application. If the user pressed on the `Do not allow` button, notifications will not be received. It is of utmost importance that this is enabled so that the feeder can communicate properly with the mobile application and alert the user when action from them is required. If denied permission to send notifications when the pop up alert appeared and they would like to have notifications sent to them now, the user can go into the settings page in their mobile device, look for the automatic pet feeder's application icon and enable the notification and any other alerts that they choose to receive from the feeder. An image reference on how to enable notification in iOS can be observed below in Figure 58.

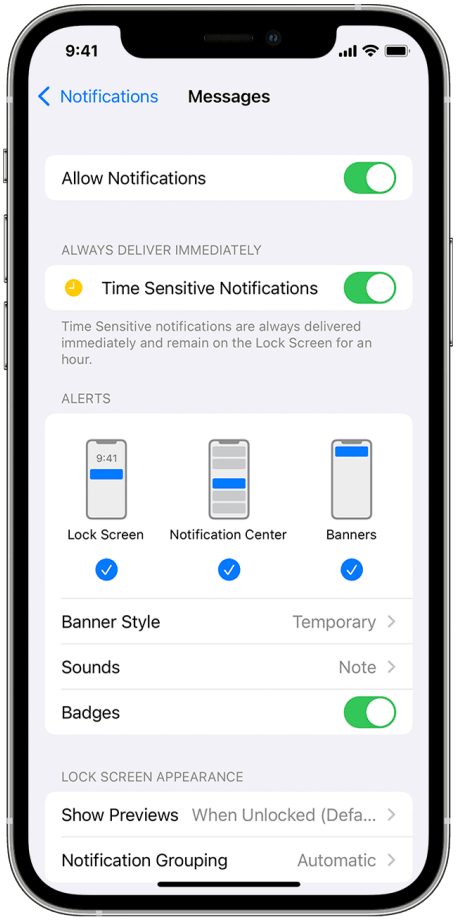

Figure 58: Enable Notification in iOS

The first step to be taken in order to begin pairing is to enable pairing mode in the main body of the automatic pet feeder. Even though there is no dedicated button to enter pairing mode, we can actually begin pairing by holding down the power button for five seconds before letting go. After the button has been released, the light indicator should begin flashing indicating that the pet feeder is in pairing mode and letting the user know that it is ready to begin the pairing flow with the mobile application.

On the mobile device running the application, we must ensure that it has bluetooth enabled. Bluetooth is used for the pairing flow and thus it is required to be enabled in order to pair to the main body. Bluetooth can be enabled by going into the mobile devices settings page, and looking for the communications tab. If bluetooth is active, a toggle button will appear active or the bluetooth icon will be colored in. Assuming that bluetooth is enabled, the mobile application will display a ‘pair to feeder’ button. Tapping on the pair button will begin looking for bluetooth signals around the vicinity, and if the automatic pet feeder has been set to pairing mode, the name of the feeder should appear in the available devices list on screen. Tapping on the pet feeder’s name will begin the pairing process, enabling the two way communication with the main body and establishing the initial or default settings of the automatic pet feeder.

If the pairing to the mobile application has completed successfully, a message will be displayed in the application, letting the user know that the pairing has completed, and will contain a button to redirect to the settings manager page. At the same time, the main body’s indicator light will turn to solid green, indicating that it has entered the ‘ready’ state and is fully functional.

7.3 Food Dispensing

The main feature of the automatic pet feeder is its automatic, scheduled, frictionless pet dry food dispensing. On the outsides of the pet feeder’s main body, there are two containers. One of the containers serves as storage for clean drinking water for the pet, and the other container is where the dry pet food is stored to be used in the dispensing of the food. The food dispensing flow is handled internally by the pet feeder but can be configured via the mobile application. In order for the feeder to successfully begin dispensing food it must first be configured and adjusted to match the schedules of the pet that will be interacting with the feeder.

The configuration page for the different settings that are supported by the pet feeder can be found under the third tab in the mobile application depicted with a gear icon. Here, the pet parent can verify and adjust the settings for different items such as the weight of the pet, serving size and frequency of food dispensing. The food dispensing has two modes of operation, weight based serving sizes and recommended frequency, and fixed value serving size. If the pet parent chooses to use the weight and information of the pet, the application will automatically calculate the amount of food that needs to be dispensed into the pet bowl and will give recommendations for the frequency of the meals that the pet feeder should dispense. At all times, the pet parent can verify and adjust all different settings that the pet feeder will be basing its operation on, even after the application has calculated the recommended settings and assigned them to their respective fields. This is primarily important in scenarios whether the pet has dietary restrictions and the pet parent needs to set a different schedule.

On the other hand, if the pet parent chooses to set a fixed value for the amount of food, frequency and times for the meals that will be dispensed, the automatic pet feeder will remember and respect the settings that the user has set. The changes and settings would then be propagated to the feeder once the pet parent has saved the form and all the details have been confirmed. There is no limit to how often the feeding settings can be adjusted and should propagate to the automatic pet feeder as long as the mobile device running the application has been successfully paired with the device and there is an active connection, whether through bluetooth or Wi-Fi.

It is important to be aware that the pet feeder will not be able to dispense any food and will remain in the ‘ready’ state until the settings for the feeder schedule have been adjusted and confirmed. This is due to the fact that the pet feeder can neither deduct, nor assume the schedules for the dispensing. That way, no food needs to be wasted and provides more granular control for the user to adjust their settings to what can better fit their needs.

Once the settings have been confirmed by the pet parent, the pet feeder will begin its meal cycles. Under the pet food bowl we can find a weight sensor that is in charge of measuring the amount of food left in the bowl in order to determine if the pet feeder should dispense more food so that the pet can have enough. The weight sensor ensures that the amount of food dispensed and currently in the bowl does not exceed that of the settings set by the pet parent. This is done in order to keep a consistent diet for the pet at all times while providing users with data points on how often and how much their pet has been eating, without them needing to confirm by looking at the bowl on a daily basis.

We encourage pet parents to ensure the bowl does not contain any other items besides the pet’s dry food. This includes items such as pet toys, common small and large household items and any other item the pet might have brought as a toy. Since the measuring of the food is based on a weight sensor mechanism, by ensuring that the bowl only contains the pet food, the automatic pet feeder can guarantee a more accurate reading and provide a better feeding schedule.

The mechanism that provides the food from the main food container into the pet bowl contains a measuring cup like compartment that holds half a cup of pet dry food and dispenses the correct amount based on half-cup intervals. If the amount of food to be dispensed exceeds the half a cup measure, it is expected that the mechanism will dispense food multiple times until it has met the preconfigured value. That is, if the value that the user has set in the mobile application is two cups of dry food, the feeder will dispense food a total of 4 times before stopping. Once the correct amount has been poured, the feeder will halt its operations in the feeder until the next meal cycle or until the user has triggered a new, out of schedule dispensing. The pet feeder will also blink green while it is dispensing food and will return to a solid green once the feeding action has completed, letting the user know when it is ready for the pet to eat. Figure 59 showcases a high level overview of the food dispensing flow

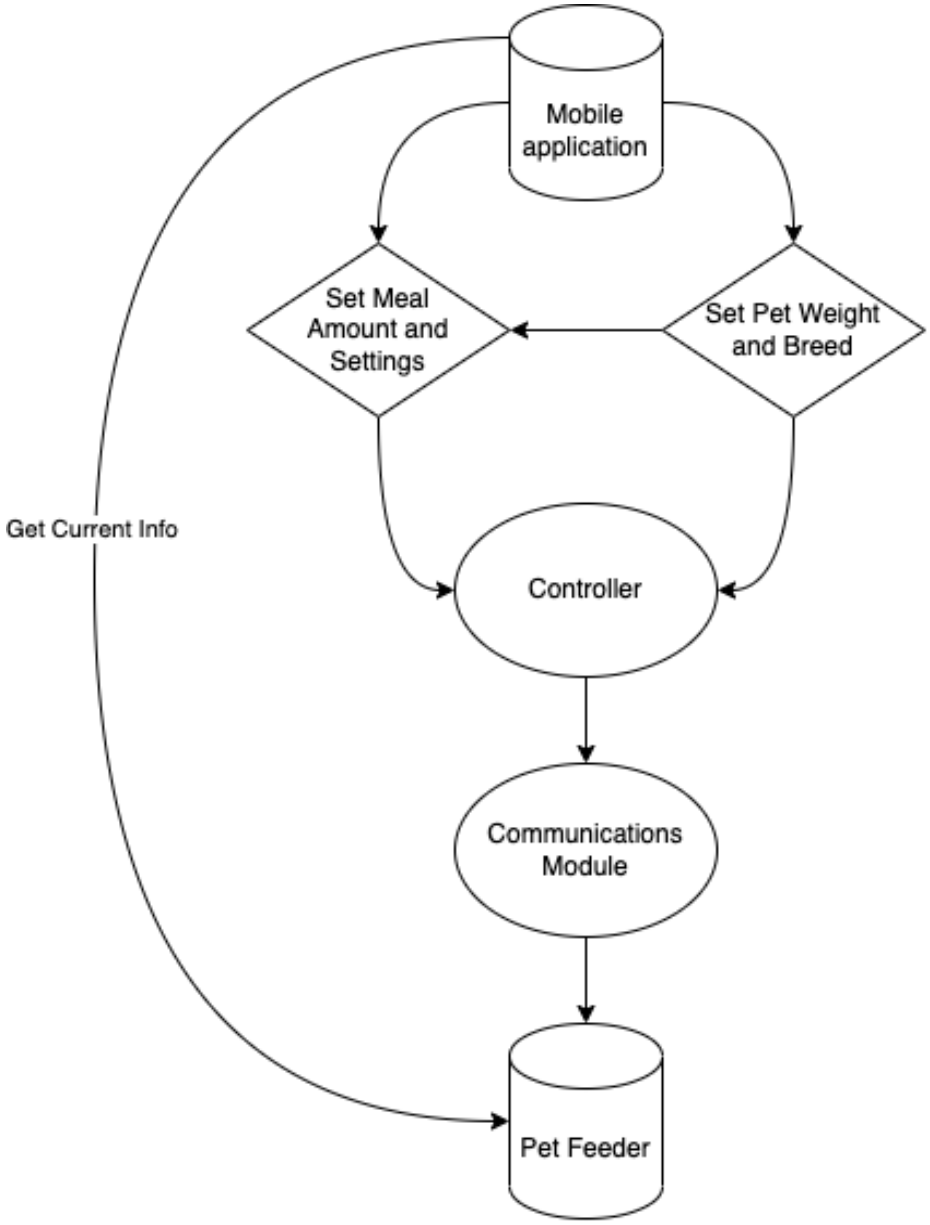

Figure 59: User Food Dispensing Flow

7.4 Water Dispensing

The automatic pet feeder also includes a water dispensing mechanism. On one of the sides of the pet feeder's main body, there is a container that serves a storage for clean drinking water that will be used to fill the water bowl. The pet feeder will send a notification to the mobile device paired to the device when the water in the container is running low so that the pet parent can be aware and ensure to refill it so that the pet can have enough water at all times. If the water container does not have any water, the pump will not activate and no water would be dispensed. In this scenario, the low light indicator on the feeder will light up, letting the user know that the bowl could become empty or will eventually be empty if the water container is not refilled, potentially causing the pet to run out of water. This can be dangerous in situations where the pet parent is not at the house with the pet to be able to refill the water container. In a similar way as the pet

food dispenser, the water pump uses a water sensor together with a weight sensor to continuously check the amount of water that the bowl currently has. The pet feeder ensures that the water dispensed will never overflow the bowl and splash the water all over the floor. The water mechanism is not controlled by settings from the application and its values can not be modified. The feeder instead ensures that at all times the pet has enough water to drink in the bowl, as long as the main water container has water. It is recommended to activate the water container alerts in the mobile application in order to be up to date with the latest status of the container. More information can be found in the mobile application section with steps on how to enable the notification settings of the mobile application. More information on the refill containers alerts can be found in the section below.

The light indicator on the automatic pet feeder will begin to flash green while the water is being dispensed. There might exist the case where other actions such as, the food dispensing, will not happen while water is being poured into the bowl. When this interruption happens, the action will try to after the water has been poured. If at any point water does not come out, the feeder's container is most likely empty, and checking on the indicator light should display either empty or low levels of water. Since the water is being monitored by the sensors continuously, there is no need for the pet parent to manually trigger the action or to have to set a specific schedule. This simplifies tremendously the constant checking that the user needs to do to ensure that the pet has sufficient water throughout the day. If the water container does have water but it still isn't dispensing water, please refer to the troubleshooting section to explore possible causes and solutions and to get the pet feeder up and running as soon as possible.

We encourage users to remove the water bowl at least once a week to ensure it is clean and does not have any items that could affect the drinking experience of the pet. In a similar way as the pet food dispenser, the water bowl should regularly be inspected to ensure that there are no toys or other objects that could interfere with the measurements of the sensors, yielding in turn an erroneous response.

7.5 Refill Containers Alerts

The main body of the automatic pet feeder has attached to it two containers, one for water and another one for food. These containers are the source of the food and water that will be dispensed into the bowls. If the water runs out in the container, the pet feeder will turn on the light to the container that needs to be rebuilt. At the same time, the dispensers should not engage as there is no action to be performed.

In the mobile application, we can turn on the water and food container alerts in order to receive communications from the main body of the pet feeder. While the feeder is reading all the data on the sensors for the container levels, if it reaches a certain threshold where there will not be enough to fill up the request to either pour water or dispense the pet food, the pet feeder will gather all the information regarding the container that is running low and save it as an alert, and shortly after, it will propagate that alert to the mobile application paired to the device. Icons similar to the one shown in Figure 60 will appear in the UI of the mobile application somewhere in the home screen, alerting the user that the containers need a refill.

Figure 60: Water Refill Needed Icon

The notification settings from the device running the mobile application need to be enabled in order for the mobile application to properly receive alerts from the feeder. The notifications for the mobile application can be enabled by going to the settings on the device running the application, looking for the notification settings under the application tab and enabling notifications for it. This might already be enabled if the access was granted when the application was first launched. We encourage you to have the notifications on at all times to not miss an important alert about the pet's meal cycles.

Once the water runs out, there will be an alert sent to the user to notify them that there is no more water in the bowl. This is important because it will allow the user to make sure that they can provide water to their pet. As soon as they get that notification they will be given the option to dispense water into the bowl. However, if there is no more water in the container, the user will still be notified that the bowl is empty. They will have the option to add more water, but they will see that the water level in the bowl is still too low. They will be able to realize that if they told the device to add more water and the water levels are still too low, then the water level in the container must be low as well.

7.6 Mobile Application

The mobile application is the main point and sometimes only point of contact with the automatic pet feeder's main body. The application allows the user to have a two way communication with the feeder, sending commands for the feeder to perform and receiving alerts or important messages from the feeder.

The first time the application is launched, it will display the sign in page. If an account has been created in the past, the credentials can be entered in the text fields, otherwise, we can create a new account. Creating an account ensures that we can have a more secure and personalized experience when interacting with the pet feeder. While creating the account, there are several aspects to consider adding to the account, including a good password and an email that the user has access to and can be used as an alternative destination for the pet feeder to send alerts to. By providing the email, in cases where the notifications are not enabled in the device or if the flow of sending it over push notification fails, we can default to sending it through an easier and relatively faster way.

In the login screen, there is a button to reset or recover the password for an account, assuming the password has been compromised or forgotten. By clicking on it, the instruction will guide the user through the steps on how to properly reset their password in order to regain access to their account. Once the reset button has been pressed, a message confirming the sending of an email with the complete instructions on how to reset the password along with a link that redirects to the change password page with the information of the account. Here the user can type in a new secure password to access their account back.

Once signed in, if the automatic pet feeder has not been paired, the application will redirect to the pairing mode page. Here it will provide a button to begin scanning for automatic pet feeders around the area. Keep in mind that bluetooth has to be turned on in order for this integration to work properly. If the pet feeder has successfully been paired, in the home screen, there should be a connection icon highlighted, indicating that the feeder has been paired and the notification should be coming. Only when the icon is visible should the user expect to perform actions that propagate to the automatic pet feeder. Keep in mind that the home screen will in many cases not even load unless the feeder has been paired.

Once a connection has been established and the pairing has completed, the user can observe the home page with general data on the automatic pet feeder's status, the status of the containers of food and water or any alerts or notifications that the user might need to be made aware of. Here the user will be able to get a high level overview of all the action items, ensure the pet feeder is working as it should and confirm that the statuses are all correct. This is a great page when needing to take a quick look at how things are going with the pet feeder even in occasions where the user is not in the same place as the pet feeder is. An image reference of the bottom navigation bar can be observed in Figure 61. The bottom navigation bar is what allows the pet parent to navigate throughout the different pages of the mobile application and is the only way to access certain features such as the camera feed and the settings for the automatic pet feeder.

Figure 61: Mobile Application Bottom Navigation Bar

Under the second tab of the bottom navigation bar we can find the camera feed. Tapping on the camera icon will begin loading the camera feed. There might be a delay of a couple seconds while all the background tasks for getting the camera feed ready finish. Even if it seems like no feed is coming in, waiting a couple seconds could ensure that it is not simply a bad connection rather than the feed not loading. The feed's quality will depend on the quality and speed of the internet of the person visiting the application. We recommend you continue to wait while the processes are done. If there are any action errors, rather than the feed just taking too long to load, an error message with me displayed on the screen with some information on what could have happened along with instructions on how to proceed or where to look if the error persists.

The camera feed is a great way to interact with the pet and also keep an eye on how things are going while the pet parent is not in the house, and it becomes easier to know and keep track of what the pups are doing and to keep an eye on everything.

Under the third tab, depicted with a gear-like icon, which contains several fields that can be set in order to configure the automatic pet feeder. This should be done before trying to get the pet to start using the machine. If this is the first time signing in, most of the fields will be empty, allowing the user to input the values they decide to have for the scheduling feature. This step is required during first launch or the pet feeder will not dispense any food or water until the values are set. This is mainly because the automatic pet feeder does not want to assume how much food it should pour, as it has no context whatsoever on what type of pet it would be and whether it should eat half or three cups. A message will also be displayed in the home page when the pet feeder is paired but no scheduling has been defined.

On the settings page, we can confirm all the configuration that is required for the pet feeder to dispense the food and water. These settings can be changed at any point and should propagate to the automatic pet feeder as soon as they are changed, assuming that all the fields are filled correctly. As stated in the food dispensing section, here we can define how much food will be served on each interval, how many intervals will happen and at what time the intervals will be. If the weight of the pet is added, the application will populate the serving size with the amount it considers it should be dispensing for the type of pet that has been defined. In the settings, the user can also trigger out-of-schedule food or water dispensings. This is particularly important in scenarios where the pet can't eat at another time and needs to be served right at that moment. This gives more control to the user so that they are not tied to the schedule at all times.

The application should be monitored often as it will include all the information regarding the automatic pet feeder. Here the user can find all the alerts, notifications, issues that might arrive with the pet feeder as well as have all the communication with the pet feeder for the different actions.

7.7 Handling and Maintenance

As we like to eat our food on clean plates, it is important to be considerate of pets. They are part of the family, so they should be able to eat their food in clean bowls. So, in our build, we will make it possible to remove the bowls so that they are able to be cleaned. The bowls will be placed in a space at the bottom of the device where they could just simply pick up the bowl they wish to clean and once they are done cleaning, they can drop it back in the spot that it was in before.

There are two containers that will be included in the autonomous pet feeder. The two containers include the one for food and the other for water. The container that is used to hold the water would not be removed, because there is nothing inside it that would require the container to be removed. Plus, it would be difficult to properly place the container and have it be capable of connecting and disconnecting to the pump without making a mess or having to go through a difficult process to maintain the integrity of the structure. However, considering that water generally does not leave a smell and that there are many other containers that are filled with water and are reusable, there would not be a reason to have to constantly remove the container

and wash it so frequently. As a result of this process, this container will not be able to be removed.

The food container will have the capabilities to be removed, because when the food is placed in the container, it will drop into a wheel that will spin the dispense the food. This means when the container is empty, the pet owner would not have to worry about any food spilling out, because there is nothing in the tank to spill. The motor is not directly connected to the tank, which gives us options on how to place the container. Plus, the food that is being poured into the container is more likely to leave a lingering smell after a while unlike the water tank is only being filled with water and water is much less likely to leave a smell. Not only would it leave a smell, but since the food that will be poured in this container is dry food, it would also leave crumbs all over the place giving the pet owners more of a reason to keep it clean so they would not be pouring new food in the crumbs of the old crumbs that may have been there for however long.

Overall, the pet owner would definitely be able to clean both bowls and those can be easily moved. Someone could make a claim that the bowl that is used for water does not need to be cleaned because this would be similar to our water container that we made to not be removed. However, for the pet owners that do not have a designated bowl for water and food, they do not pay attention to which bowl they use for either food or water. So, allowing both bowls to be removed so they can be washed allows the pet owners some flexibility where they would not have to pay direct attention to what bowl is used for what.

7.8 Safety and Interactions

The automatic pet feeder will include a switch that will turn it on and off even when plugged in or being connected to batteries. When plugging the pet feeder into the wall, it should be off to absolutely make sure that there is no power being absorbed by the device so the user would decrease the chance of being shocked. Once the device is plugged, then the user would be in a safe position to safely turn the device on. In a similar case with the batteries, it is best that the device is off before putting any batteries in. This would be the same case when unplugging the device. It is best to make sure the device itself is turned off before unplugging to prevent any chance of someone being shocked.

Once the device is unplugged, the user will be notified that the connection with the pet feeder has been lost. This would be the case, because the microcontroller inside would also be off, which means there is no way for the signal from the phone to reach the device itself unless it is on. In general, if the device is off, the user would be notified and when they look on their phone to see what is going on, they will see that they are disconnected from the pet feeder, and this would let them know that device is off in some way.

The pet feeder will be built to be able to withstand a little bit of roughness, however it is best to place it where it will be safe for most of the time. Since the device is made to feed pets, the expectation is that whoever is placing it would put it where most people would put their pet's bowls. This would include places like the living room or kitchen simply because these places are usually at room temperature which would prevent the water from getting too hot and also because it is a comfortable place for a pet to eat and drink. It is possible for it to be placed outside, because the food and water containers will be covered preventing anything from the

outside from invading and contaminating the food or water for the pets to eat. However, something to consider when placing the device outside, is that the temperature of the food will be at the mercy of the weather outside. So, if it is very hot outside, then the water that is in the pet feeder will also be hot and the same for when it is cold.

7.9 Error Codes and Troubleshoot

The automatic pet feeder is designed with optimal conditions in mind, but we have to also consider the possibility of it running into errors when trying to process certain actions or within the system itself. In these situations, the main light indicator in the feeder could turn either red or yellow depending on the error or alert that has occurred. If the user is working with or has access to the mobile application, there should be visible an alert with the error code that the feeder was able to gather before failure, if any. An icon such as the one displayed in Figure 62 will be visible at the top of the mobile application when an error has occurred. If no message is displayed, tapping on the icon should guide the user through the different steps they can take to resolve the issue.

Figure 62: Error Icon In Mobile Application

Some actions can be fixed by simply retrying the operation, which could occur in cases where the error happens during communication and is not a functional error with the feeder. By retrying the operation, the old request gets ignored and instead, the pet feeder proceeds to process the new request. If the error indicator persists after retrying the operation, the user can proceed to utilize the switch to reset the pet feeder. This case is rare and should not occur often. Having the mobile application and reviewing the error alert in there, could reveal more information as to what could be affecting the machine at the moment.

If retrying the operation does not fix the issues presented in the automatic pet feeder, as a last resort, we can cause a force reset on the device. In order to do a forced reset, we can press and hold the power button located in the automatic pet feeder for more than 5 seconds. This will let the microcontroller in charge of all the functions in the pet feeder know that the device must be restarted. By doing this, the controller will reset all operations, kill all processes and restart the device as if it was being booted up from scratch again. In most cases the device will keep all the scheduling and information previously set by the pet parent but there might be odd cases where the data is corrupted and we will need to do a clean start, deleting all the data.

Although we do not recommend it, the pet parent can also restart the automatic pet feeder by unplugging it and plugging it back in. Unplugging the pet feeder like this should only be done in excruciating circumstances where the errors can not be resolved by retrying the operation, following instructions in the mobile application or by forcing a restart by pressing and holding the power button. Please keep in mind that the device should be protected from getting damaged if it is unplugged like this but the controller might need to do a fresh start to ensure no orphan processes are left behind and that the flow of operation does not get damaged.

Errors with the automatic pet feeder's main body are not the only errors that could arise. Although it should not happen often, the mobile application might run into an error when trying to process data or to display content received from the feeder. In most cases, and in the same manner as errors with the actual pet feeder, an error message will be displayed in the mobile application, guiding the pet parent to an easy resolution of the problem. In the same manner, most errors should be fixed by just retrying the operation. In cases where retrying the operation through the mobile application does not work, we recommend that the pet parent closes the mobile application, quits the application completely and then reopens it and tries again. In the majority of cases, by closing and opening the application again, all local settings are reset and the functionalities and commands that are sent to the pet feeder restarted. This restart should only apply to settings that are saved within the mobile application itself but should not affect settings that have been set by the pet parent. All settings for food amount, scheduling and pet information should be kept intact and should persist across restarts of the mobile application.

8. Administrative Content

In this section, you will find the project details. These include its deadlines, goals, costs and milestones as well as an overview of the team which worked on it. You will see how these elements fit together to make up our design for the automatic pet feeder. It includes all necessary logistics needed to create this device while also containing insight into how we were able to budget for it so effectively given these particular constraints - by estimating average materials costs and developing benchmarks based on what other parts manufacturers charge for similar products.

8.1 Budget and Financing

The first item on our list in Table 13 has to do with the casing that will contain everything. For this we will be going with a pre-existing design to avoid having to deal with any mechanical engineering. So, for the food dispensing portion, we'll have to find an already working dispensing mechanism that we can gut and override. For the water dispensing portion we will only need something to contain the water and a water bowl for the pet to drink out of. The water dispensing will be done with a pump and tubing that goes from the container to the water bowl. The type of pump we will be purchasing will be an aquarium pump because of low cost, low power consumption, and the fact that we don't need a high flow rate. For the microcontroller, we can go with an arduino or a raspberry pi which will come at no cost due to group members already owning them. Both of these microcontrollers come with the benefit of ease of use. Arduino has their own IDE with the primary coding language being C/C++. A Raspberry Pi's primary programming language is Python which is a higher level language. Both have their pros and cons and we'll have to decide which one better fits our needs. Next, in Table 16, is the PCBs

we'll have to print. The cost of this comes down to how many PCBs we need for the project and how many work when we get them. For the power supply, we plan on going with an AC-DC wall power adapter. These are cheap and supply a constant voltage for our device. They also eliminate having to deal with high voltages. Lastly, we will be using a small DC motor to open and close a door and some sensors that should be inexpensive and power efficient.

Item	**Price**
Casing	$50
Pump with Tubing	$25
Microcontrollers	$0
PCBs	$10 - $50
Power Supply	$20
Motor	$5-$20
Motion Sensor	$0
Water level sensor	$0
IR sensor	$16
Pressure Sensor	$10
Total	**$150-$200**

Table 16: Estimated Budget

Towards the end of the semester, we started with the construction and prototyping. We were able to start mapping out our actual budget seen in Table 17. Our estimates proved to be decently accurate with most of our purchases landing in our estimated window. But, our total will most likely end up above our estimated total range. We did end up having to buy additional parts that we didn't think about when we originally estimated our budget. We also made cuts to some of the parts that we originally thought we would buy. The casing is going to be the bulk of our purchases because we plan on doing a mix of building our own housing as well as using an existing pet feeder. This will definitely land us over our estimated price of fifty dollars for casing and push us into the two hundred dollar range.

Item	Price
Casing	N/A
12V DC Peristaltic Pump	$12.78
10ft Food Grade Silicone Tubing	$8.59
Microcontrollers	$0
Arducam 5MP Camera	$10.69
Raspberry Pi Cooling Fan	$17.11
PCBs	N/A
12V 1A Power Supply	$6.99
Motors	$0
Motor Drivers	$9.62
Ultrasonic Sensors	$14.54
Force Sensitive Resistor	$10.87
18AWG wire	$15.99
Total	**$107.18**

Table 17: Actual Budget

8.2 Milestones

At the start of Senior Design I, our class was tasked to start planning for a timeline of how to accomplish this project through thorough research and detailed analysis of the components chosen. These tasks are called milestones by the Senior Design Advisors. In the Goal section, we discussed what we want to accomplish week by week. The report's time table is approximately 15 weeks, in which we will go over different resources that will help build our project. Also list several active products in the market as a form of research and comparison to further achieve the goal that we have in mind to pursue a unique Autonomous Pet Feeder by adding some small yet very effective features that will separate our product from the rest. This list (Table 18) will display the week in which we are working on, the deadline when the milestone is due, and description of our project based on the milestone we are trying to accomplish.

Week #1	Due Dates	Milestones
1	1/14/22	- Form a group and brainstorm ideas
2	1/21/22	- Choose an Idea
3	1/28/22	- Complete ABET Attendance Quizzes 1 and 2 - Attend Bootcamp - Complete Bootcamp Quiz
4	2/4/22	- Complete ABET Attendance Quiz 4 - Finish Initial Project Document - Divide and Conquer
5	2/11/22	- Complete ABET Attendance Quizzes 5 and 6 - Work on D&C V2
6	2/18/22	- Complete ABET Attendance Quizzes 7 and 8 - Finish Updated Divide and Conquer D&C V2
7	2/25/22	- Start Required Quizzes
8	3/4/22	- Do Table of Contents Assignment - Work on 60 Page Draft
9	3/11/22	- Work on 60 Page Draft
10	3/18/22	- Finish Required Quizzes - Work on 60 Page Draft
11	3/25/22	- Finish 60 Page Report
12	4/1/22	- Work on 100 Page Draft
13	4/8/22	- Finish 100 Page Report
14	4/15/22	- Critique 100 Page Report
15	4/22/22	- Critique 100 Page Report
16	4/29/22	- Complete the Final Document by Tuesday 4/26/22

Table 18: Senior Design 1

8.3 About the Team

This section is meant to pull back the curtain and give a brief description of each team member. This includes what we are majoring in and why, our current employment status, what we do in our free time, our goals after graduation, and the skills each of us bring to the table on this project.

8.3.1 Devin Besaw

I am an undergraduate student at UCF pursuing a B.S. in Computer Engineering. Currently, I intern as a Client Engineer for the startup company SightPlan. In high school my favorite subjects were math and web design which led me to choose this degree and the position on the SightPlan team as a Client Engineering Intern (Front-end web development). In my free time, I enjoy playing softball, video games, and escape rooms. After graduation I plan to stay in web or app development to further develop my skills. For this project, the skills I bring to the table mainly have to do with software development but also include some hardware skills. I believe my strongest skills are as an app developer and embedded systems developer. I've developed personal apps and messed with microcontrollers on my own time. As for my hardware skills, they mostly come from personal experience with soldering and tinkering with electronic components.

8.3.2 Fernando Oviedo

I am an undergraduate senior at UCF pursuing a B.S. in Computer Engineering. I was born in Washington Heights New York to Dominican parents. I moved to the Dominican Republic when I was 8 years old in which I picked up baseball as a passion. I later on moved to Florida from high school to this day. In high school, I developed interest in computers in terms of fixing them and making them better by swapping parts and changing Operating Systems. I originally was interested in Information Technology but then I wanted to know exactly how a computer works and what makes it function, when does it fail and why is it happening. That pushed me to pursue a career in Computer Engineering and want to focus on Artificial Intelligence. Currently I'm working full time at Home Depot as a Sales Specialist for the Flooring/Blinds department. My hobbies include video games, working out, sports, and outdoor activities. After graduation, I plan on getting a job as a Systems Engineer and then pursuing my masters degree in a new program that UCF is considering opening in Robotics and Autonomous Systems.

8.3.3 Gershon Prospere

I am an undergraduate senior at UCF pursuing a B.S. in Electrical Engineering and will graduate in August of 2022. My hobbies include watching anime, reading manga, playing games, and listening to/playing music. I started my passion for electrical engineering when I was kid, discovering all of the circuitry inside phones and TV's and ever since then, I have kept going to how these devices work and they keep improving as time continues to go on. In high school, I definitely knew electrical engineering was exactly what I wanted to do, because mixing my early passion of electronics with math and physics being my favorite and best subjects, electrical was definitely the way for me. After graduating, I plan to move out of Florida and work at Texas Instruments.

8.3.4 Jose Tapizquent

I am an undergraduate student at the University of Central Florida pursuing a Bachelor of Science degree in Computer Engineering. I was born in Venezuela and came to the United States in high school. Since I got to the country, I have been very interested in software and computers and decided to start learning web development through different online courses and started learning how to code and how to work around designing software. By learning to code through online courses and school, I was able to obtain a position as a Software Engineer at UKG, a Saas company based out of Weston, FL. I spend my free time developing mobile applications while continuing to learn about software design and lately about decentralized applications and web3. I also enjoy building home automations and gadgets with a Raspberry Pi or an Arduino and several sensors I've bought off the internet.

8.4 Conclusion

As we have continuously worked on this project, we have come across many obstacles that obstructed our path to completion, but we were able to overcome almost every single one of them. Even though the pet feeder is not a product that has come out recently, we wanted to do something that was a big improvement compared to the rest of the competition which would not be too difficult for us but enough of a challenge to really get us thinking about what to do and really work together to make sure we completed the project and learned a lot from it.

Through all the research we conducted, we were able to create different ideas that would help us achieve our goal of making something better. We considered that most pet feeders don't really use sensors, so we made to come up with many ways to incorporate sensors into our device, which how we thought of using a water, motion, and weight sensor which would take our product to the next level because with these sensors, we were able to make a pet feeder more autonomous than any other pet feeder before. What pushed us was our motivation to make a pet feeder that was fully functional so we all could finish our last semester with a bang. Considering several of us own pets, one of us could also be the ones to own the device and to use it making our lives more convenient.

The reason we went with a pet feeder is because we all understand how important pets are to families around the world. We know how much people care about pets so we wanted to do something that was challenging for us but had a great end goal, because we knew that once we accomplished the goal for this project, we made something that expanded our knowledge in the field of engineering and trained us to work efficiently as a group.

This project is an essential part of our learning experience as engineers. After all the years learning about different topics related to our degree, this is where we get to do some hands-on work and develop some experience with engineering. This project has also shown us the benefits of working in a team to accomplish a goal. Having different people with different backgrounds coming together to combine our skills is something we will experience in the field.

Appendix A

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