Conceptual Design Report
by FELEREST

Contents

1 Executive Summary

As the human race began interacting with cats millenniums ago, the relationship between cat and human only got stronger. This led to the domestication of cats today known as Felis Catus. Because of this, cats have achieved world domination with a population of 600 million. With the vast growing population, the responsibility that humans have is to take care of them as much as possible whether outdoors, in sanctuaries or just in our homes. This project tackles this issue from the feeding point of view, with this technology workload of humans are eased and there is no single cat left that goes by with a hungry stomach.

2 Introduction

The growing cat population keeps making it more and more challenging for humans to take care of them. There are hundreds of cats living in large territories like campuses, sanctuaries and more so in the streets. Even if some cats are taken under our wings to look after at our homes it might be challenging to follow their dietary behaviours. In regards to the immensely fast developing technology, there seems to be very little improvement and innovation when it comes to cat feeding systems. The already existing systems are too costly and incapable of tracking cat diets even for a single cat. The state of the art, according to an article on most rated automatic cat feeding systems of 2019 [7], has several key features. These are large food storage capacity, portion control settings, kibble size options and pet-proofing. This system costs 150 dollars. The absence of advanced monitoring systems leaves cats unsupervised where survival of the weaker cats is less probable. Because of this, it is not possible to detect cats that are in need of an external assistance of food and intervene. Aside from this, the absence of smart, inexpensive systems cause risks for both the cat and human health due to the unsanitary living conditions it creates. Figure 1 shows some pictures taken recently at the campus of Middle East Technical University which illustrate the situation at hand effectively. In the era of everything smart and connected it is only logical to propose, design and implement a solution, using novel techniques, which fills the gap in the untapped market of automatic cat feeding systems. Making our, homo sapiens', lives easier while also caring for our companions, Felis Catus, Felerest aims to solve these issues by taking on the challenges at hand while also providing customer oriented additional features.

(a) (b)

Figure 1: Photos from METU's campus

The motivation behind Felerest's work is to solve the aforementioned problems and bring more to the table. The final product's budget is 200 dollars, the marketing price is foreseen to be less than this which will surely rattle the market in the positive sense. The system will be capable of feeding a large number of cats making it adoptable for usage in campuses and homes where cats are plentiful. The system's reservoir will be adequate to feed more than 20 cats for the duration of the battery lifetime.

The goal is to identify cats and feed them amounts inversely proportional to their weights. This feeding system is achieved automatically by implementing a camera to the box and processing the images obtained from the camera to detect the presence of cats. The food container inside the box releases cat food from a rotating mechanism. The system releases food proportional to the number of cats present with regard to each cats weight, thin cats get more food while thicker cats get less. This system's purpose is to monitor each cats dietary actions individually and feed them accordingly, therefore the optimal usage is defined for cases where cats approach the box one by one. Although not as efficiently, the system is capable of feeding more than a single cat at once. Moreover, the system has the ability to function for a minimum of 5 hours on charged battery life with the additional feature of working as plugged to a power supply. The user will have access to a web interface, which contains information on how much food is left in the container, how many times each individual cat has visited the box, how many new cats were recognized and added to the log, the remaining battery lifetime while also providing images of the cats taken from the camera which will be a way to remotely track the visual of the cats. An extra feature of this system which distinguishes it from all other existing solutions is the dog deterring module. This is the key factor which makes it possible for outside usage. This way cats can safely approach the box without dogs eating their food or scaring them away.

In this report the subsystems constituting the overall system are identified and explained in detail by investigating each module that forms the subsystem. There are 4 subsystems in total: computer vision, electronics, mechanics, and back-end. The technical and implementation details at a subsystems level constituting the parts of the overall system are fully explained with technical details and supporting visual content. Algorithm details are included for Computer vision and back end parts. Alongside these, the requirements for each subsystem, the proposed solutions, the effectiveness of the solutions and their evaluations, possible foreseen risks and difficulties, testing procedure, testing results and action taken in regard to these results, planned future work in each subsystem and future test plans as a measure of success are investigated in this report. The tests of these subsystems and their results are examined exclusively. To effectively transfer these to the reader, first a general description of the overall system will be provided with solutions that satisfy the necessary requirements. In this part, the expected weight, dimension and the total power consumption of the system will be stated. Afterwards, each subsystem will be explained with its modules as defined earlier. After the subsystems are clear, the integration process and the measure of success will be discussed. A cost analysis of the final product will be explored. The deliverables of the project will be considered. Finally, the analysis of the proposed solutions will be recapped alongside a review about the remarks made throughout the process.

3 Overall System

Overall system design consists of multiple subsystems which work in a black box manner. Abstraction is the key property used in the design of overall system as well as subsystems. Each part designed for a specific interface which is then used by other parts. This abstraction and interface structure are also used in software design and implementation.

The overall system is controlled by the Controller. Controller manages every subsystem and connects them to operate the system in a consistent manner. Controller requires various subsystems to be functional. The subsystems Controller directly communicates are Video Server, Command Server, User Interface, Image Processor, Decision Maker, Database. Figure 16 in appendix A demonstrates the overall organization of the system. In the rest of the report, the subsystems are analyzed and presented. More information about bringing the subsystems to form the overall system will be presented in the integration part. Furthermore, more information explaining the implementation of the modules that form the subsystem are given in detail in each subsystem's section.

4 Server and Client

The overall system implementation is based on server - client model. Server is mainly responsible for computations and decisions that the system is going to be take. Server - client model make it possible to use advanced techniques, use powerful computation models, create cost advantage, easy user interaction as well powerful product design that is open to a lot of further improvements. Server - client model provides very powerful features that would be impossible if there were no server. Server - client model provides extensibility, flexibility, and usability of the system. Database management, extra features addition capability, light structure of the system are all constituting the reasonable choice of the server - client model.

Server - client model can be thought as basically two different computers located on the same network, and communicating over TCP/IP layer. There are certain responsibilites assigned to each of these two. High computational requirements and user interactions are handled in server side, whereas; hardware drivers, peripheral management, and data collection are located on the client side. Based on this model, much cheaper products can be produced and their optimization and feature addition can be done remotely and whenever needed. Therefore, after support services can cost very little in addition to the life time value of the prouct thanks to the extensibility of feature addition over internet. For better understanding, some certain responsibilities and tasks assigned to the server and client are given below.

Responsibilities of the server :

- Handling the required computations
  - Neural network train
  - Neural network prediction
  - SIFT vector extraction
  - SIFT comparison algorithm
- Decision making of every action the client takes
  - Notifying user with on-board LEDs
  - Deciding whether to run food mechanism or not
  - Activating dog deterring system
  - Turn the product on or off
- Complex decisions and computations excluded above
  - The time cat needs to eat food

  - Measure of the food to give to cat
  - Multiple animal cases
  - Different situations where environment interruptions can arise
    * Holidays - no people to supply food
    * Physical damage
    * Overloading of internal system, specifically batteries

Responsibilities of the client :

- Taking measurements and sending to the server
- Taking photos and sending to the server
- Driving output devices and, such as motor for the food gate
- Handling extra ordinary emergency situations
  - Connection lost
  - Environmental risks under connection lost cases

Figure 2 shows the overall communication. Command Server, Video Server, and Controller are located on the server side, whereas Command Client, Video Client, GPIO, and Camera are located in the client side. Each module has a different job to do, and they communicate with each other with black box method.

In this section, the remaining structure is as follows, comparison of server - client model over regular compute on product model, risks related to this model, planned solutions, and cost analysis. Following sections present these to the full extent.

a) Comparison

Every decision comes with a cost. Trade-off between the proposed model and the regular old model is better explained in comparison table 1.

b) Risks

Risks related to the server - client model are mainly because of communication interruptions or bad pipes between server and client. Sometimes drop of packages over network, or wrong data transmitted causes system to fail, or temporarily become unavailable. It seems most of the problems can easily be solved with a proper

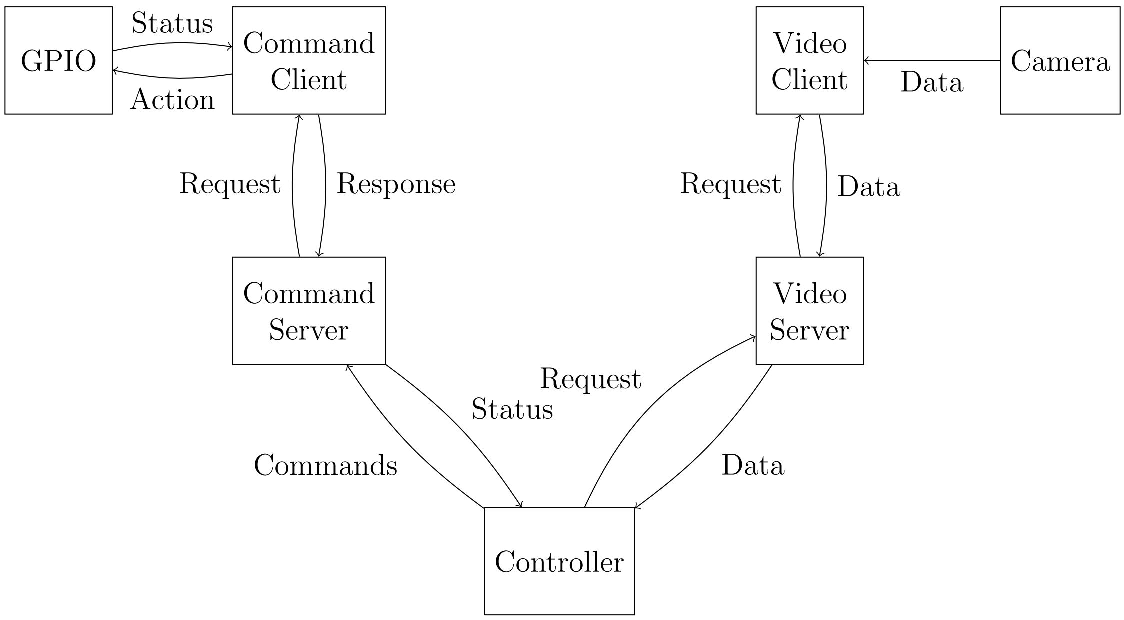


Figure 2: Server and Client Organization

programming practices and exception handling techniques. However, some more important problems may require decision making on client if there may be dangerous or destructive consequences. Finally, some risks related to the model includes :

- Connection lost
- Wrong data transmitted
- Unexpected data received
- Cyberattack

c) Planned Solutions

As mentioned, most of the risks can be eliminated using proper algorithms and coding practices. Exception handling and emergency behaviour are also the key solutions to the risks. Solution approaches to the risks mentioned above are given in table 2.

Although the table is self-explanatory, some points are clarified. In case of a connection lost, the first procedure will try to reconnect. After some unsuccessful connection attempts, it generates some emergency codes on both server and client. Client computes some needed information such as battery voltages, etc. and sleeps for a while to try in a future step. If an important measurements taken, and dangerous

Regular Design (On-Board)	Server - Client Design
Narrower variety of tools	Much wider variety of tools
No further updates on product	Online and continuously evolving features and updates
Higher burden, higher product prices	Burden done on server, less product prices
Difficult fault detection	Easy and fast fault detection
Poor and limited data management	Very efficient and broader data capacity
Only on-product interface	Online, real-time interface
Limited after sale product support	Extensible after sale product support
Expensive product, no steal protection	Cheaper product, steak protection

Table 1: Comparison of Server Client and Regular design

Risks	Solutions
Connection lost	Reconnect, emergency codes, compute on client, sleep mode
Wrong data transmitted	Data checking, re-claiming data
Unexpected data received	Exception handling, ignore on some cases
Cyber attacks	4096-bit RSA encryption

Table 2: Comparison of Server Client and Regular design

situations possibility arises like overheating of batteries, then client decides to shut the system down completely. The server on the other hand both informs the user and support services for the fastest solution.

Wrong and unexpected data will be handled according to the rules python socket provides. try-catch blocks, and re-claim of data are core two concepts for the system. Server will simply re-claim the data, and handle the error with try-catch blocks.

Cyberattack is another vulnerability that can be exploited when the system connect to the internet. 4096 RSA encryption will be used to transfer both command data and video data. Also, public-key authentication, disabling password authentication, and SSH tunnels are going to eliminate big amount of vulnerabilities. Since any client is not vulnerable because of the completely closed firewall. Location of the only vulnerability target becomes the servers. Moreover, there are only a few number of servers, which makes it much easier to protect the system. Consequently, there is only a limited number of servers are investigated for security purposes.

d) Tests

Reliability and performance tests are done on the server - client model. System logs, debug mode outputs, router log information is used in the test process. The following results are obtained :

- Bandwidth : 121 KB/s on METU internet(depends on connection speed, fps rate)
- Classification Lag : 0.78 s on LAN, 1.7 s on METU internet, 12 s on DSL connection
- Number of program crashes, recovered : 1 crash per 16 minute
- Memory usage (server) : 624 MB
- CPU usage (server) : 13.3 % (i7-4770S)
- Memory usage (client) : 1.99 MB
- CPU usage (client) : 2.2 % (ARM1176)

Results show that, with a regular old computer, the server can handle 40 clients at a time. Increase in computational power and optimizations are going to produce better results. More discussion on the computation burden is investigated in the Computer Vision section of the report.

5 Computer Vision

Feeding cats, deterring dogs, and adjusting system behaviour based on the given cat identities, computer vision part carries the core responsibility and major development requirements in the overall project. Technologies that are going to be used in these processes, methods and optimization methods that are going to be used in these parts are presented in this section.

Computer vision is divided into two separate sub categories: finding object class and identifying the object. The details are explained in corresponding subsections of this section.

a) Classification

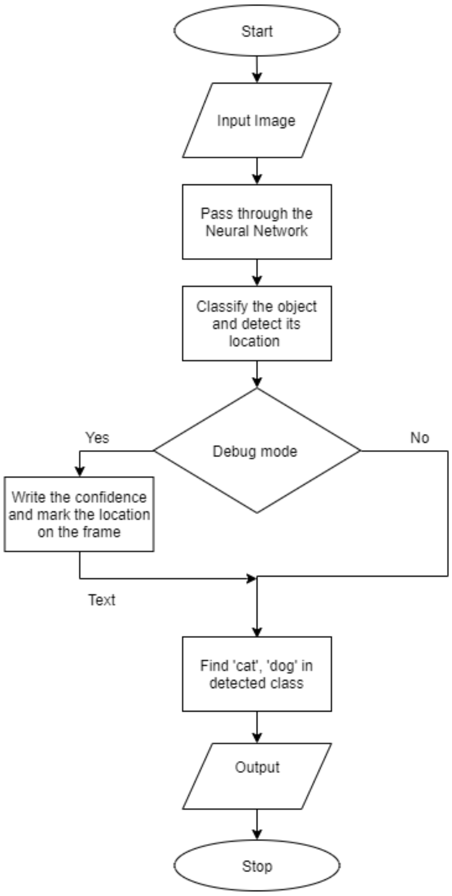


Figure 3: Algorithm Flowchart of the Classification Subsystem

As depicted in figure 3 the algorithm is somewhat straight forward. In the initialization procedure first the weights of the system are obtained, later the frame is passed through the neural network to classify where there are any objects that belong to the 80 different classes or not. However, not all of these classes are important to us. Therefore, the list containing the detected classes are compared with the desired classes which are cats and dogs. If there is a dog present, the system returns the string 'dog' no matter the presence of a cat. If there are cats present, the system returns the string 'cat'. If the debug mode is activated, the algorithm puts every classified object in a box with the confidence rate written on top. It also writes the time that has passed to do this procedure to every frame. This way, it can easily be defined what the network is doing wrong so the problem is easily detected, fixed and improved. In addition to this, the algorithms contain logging info lines which log what the system is currently doing to a separate file at all times. This was when an error is encountered it can be easily avoided.

1. Requirements

- Differentiate between cats and dogs.
- Clearly recognize scenes without any dogs.
- Detect how many cats are present.
- Have reliable confidence for the classifications.

2. Solution

Neural network based solution is utilized in order to detect cats and dogs. There are other methods that are considered and eliminated. The methods are mainly :

- Histogram based
  - Not capable of extracting complex features.
  - Very variant to the ambient noise.
  - No ability to understand the object properties, just color.
  - Very bad response to illumination, rotation, color variations in cats.
- Feature descriptor
  - Very hard to find appropriate data.
  - Not accurate compared to neural networks.
  - Difficult to develop algorithms for mass data set.

After different alternatives were evaluated and discussed, neural networks, especially Convolutional Neural Networks are chosen for classification purposes. Neural networks are universal approximators according to the universal approximation theorem [6]. Therefore, it is clear that, any feature can be taken into account with neural networks. Also, powerful results obtained from the CNNs in recent years [13] make it a better choice for our application. Moreover, it is easy to find a lot of different resources, not only document and articles but also the codes and ready to use trained networks. With the adoption of CNNs as the classifying method, the disadvantages of inaccuracy and complexity that exist in other methods were avoided.

A basic NN architecture can be seen in figure 4. Inputs are not only images, but also the environmental features such as food case weight and animal weight. All of them are not going to be implemented, and most of them will be model dependent, for different applications of the product, different model features will be included. Figure shows all possible features that will be included in the neural network prediction model. More basic and simpler network architecture is given in figure 5, the networks we are going to be using are more complex and more layered structures which are basically the same in principle but requires more work in practice.

The neural network architecture os trained, validated, and tested before it gets ready to be used. There are a lot of ready to use open source repositories which provide very powerful trained networks. Such repositories include YOLO, tensorfow pre-trained models. There are very different implementation details which are not going to be explained in this report.

3. Risks

Possible risks include computation burden and false positives in the neural networks. Computation burden is the major factor in selecting and maintaining the correct hardware, consequently the cost. On the other hand, false positives play a crucial role in performance of the product. Therefore, both of these risks are going to be inspected seriously.

Computational burden is an important issue in choosing correct hardware. Since more power is demanded as computational burden increases, more weight and more complex electronic components would have been required if computations were to be done in the product. On the other hand, computational power requirement is not a big issue in servers that can do massive works in parallel. This is the actual motivation behind the server - client model exploited in this product. With the advancing product number and models, servers can provide very powerful computational capability for a very little operating cost. In Digital Ocean, 10 $ per month can provide required computations for 30 products at the same time with the early

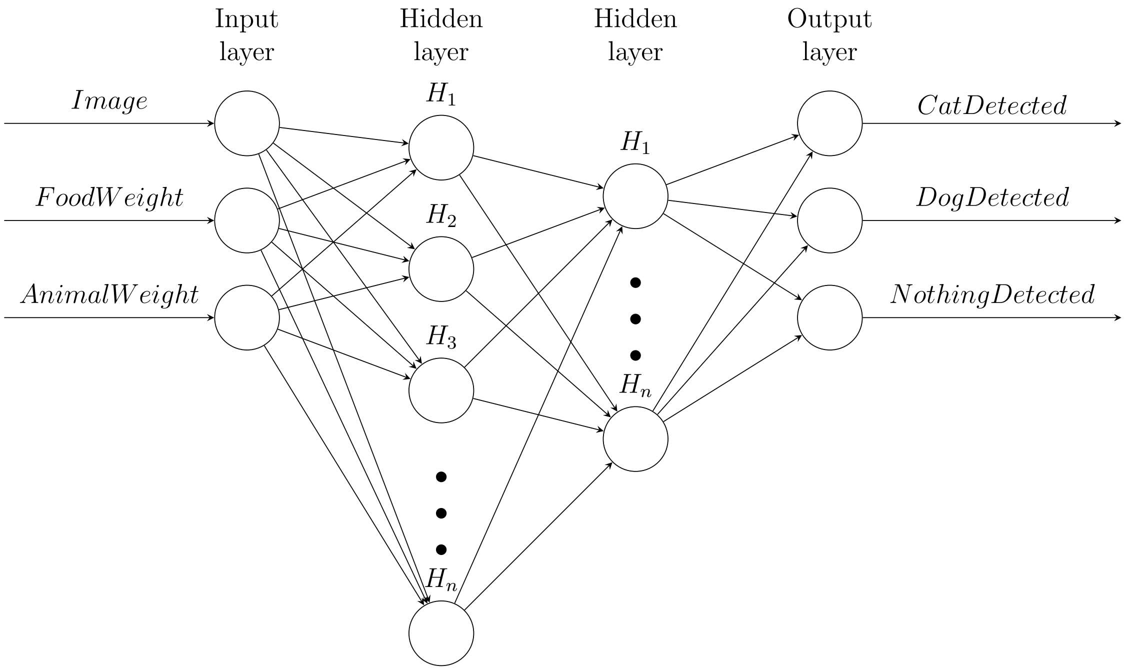


Figure 4: Proposed Neural Network Architecture

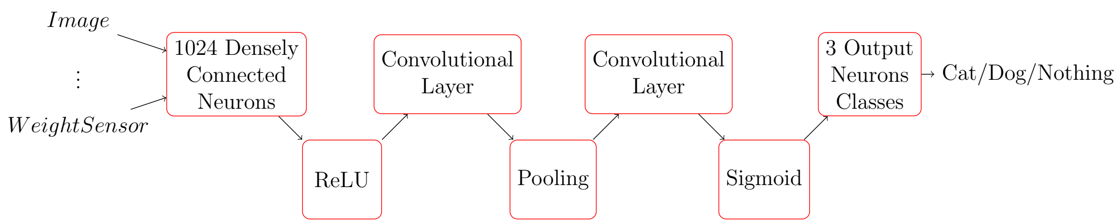


Figure 5: Simple Neural Network Architecture Design

prototype configuration requirements. In addition, improvements in the algorithm and parallel processing capabilities provided by major cloud computing platforms can increase the efficiency of the computation. Moreover, by adjusting the system properties, network - algorithm - data optimizations, 200 product computations are expected to be done on a 10 $ machine, which makes 0.05 $ of operating cost per month.

The other major risk of false positives, or more generally, poor performance situations encountered in regular operation risks are planned to be solved in a number of steps. Fine tuning, time dependency of consecutive frames, probabilistic models such as confidence intervals are supposed to be used in this process. These processes mainly relate to dogs classified as cats since false positives are the worst cases, and possibly they damage or misuse the system. Some methods are explained below.

The first method to be considered is to make the preprocessing stage as effective as possible. This way, the inputs to the classifier are adjusted according to the neural network's data set which reduces the error rate. This also increases the system speed and accuracy.

The second method is fine tuning, it is the most basic and important process in the improvement of the classification performance. Since the models used are trained on online data sets and mainly in good ambient conditions, their adaptation to the Felerest product domain requires some samples, their editions, and re-training of the network [9]. During this procedure, it is crucial not to disrupt the already existing structure of the network and the weights. To prevent this, the network's trained data set should be taken into account. The images that are to be trained with fine tuning should not be vastly different from the data set. Moreover, the quantity of the fine tuning set should not be too small and should contain some images from the actual data set. In this project 150-200 frames were seen as an optimal quantity to achieve fine tuning. Noise factors should also be taken into account when doing this. For these reasons, more research is to be conducted on the fine tuning topic.

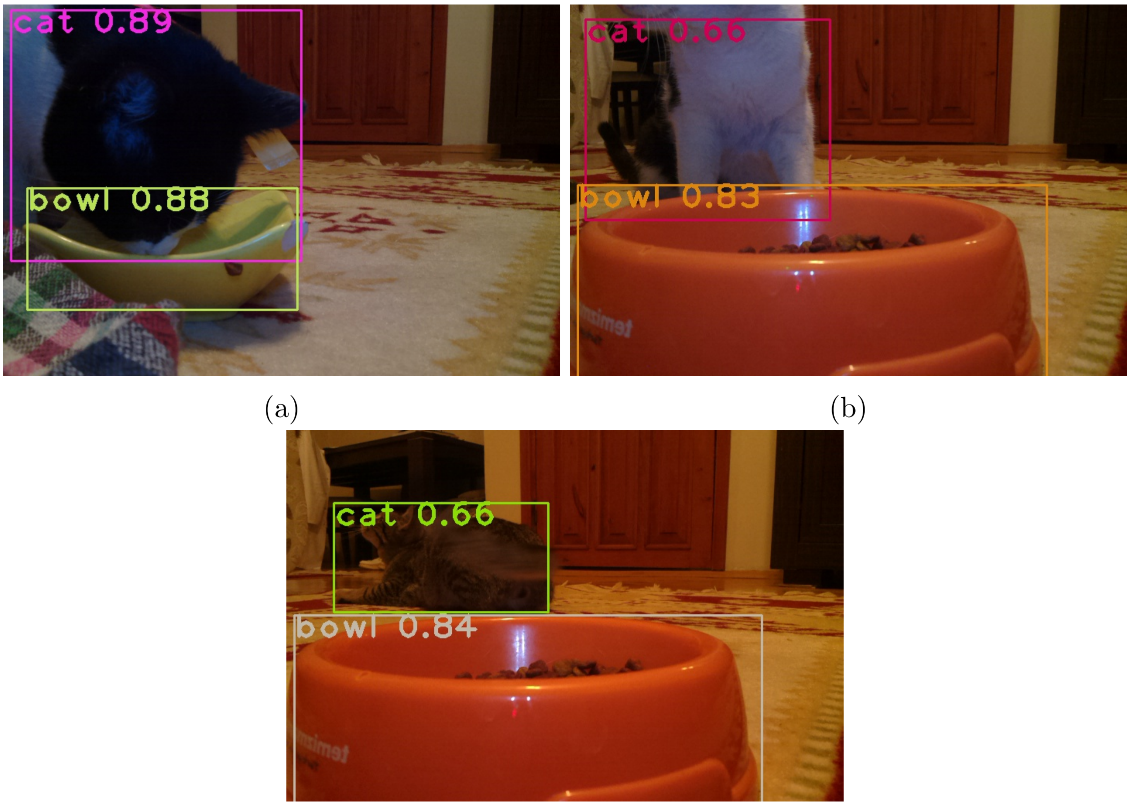
4. Tests

Some test results are given as in figure 6. Tests are done in extreme conditions where light is very little, and view angle is narrowed by intent. With this configuration, worst case situations are investigated. Tests are done on 3 different real cats and 20 cat, 10 dog photos. The results are astonishing, for 50 samples taken from pictures of animals, only 3 pictures which is the same cat picture with a lot of effects. Overall the performance was unexpectedly high with a whooping accuracy of more than 90 percent.

The data set is given in this link.The test was done on images obtained from google randomly. These images were printed on A4 paper in large scale and held in front of the camera at various angles from various distances. Because of the enlarged photos, low quality of the printer and the images itself there were some uncompensated noise factors. However the results are promising. Note that this accuracy results are only for raw images, other sensors, decision maker and other probabilistic models are not taken into account. The expected accuracy for the system to work are going to be higher than 99 %, with very little false positives.

5. Plans

- Conduct extensive research on fine tuning.



(a) (b)

(c)

Figure 6: Images of real life test results

- Conduct extensive research on pre-processing.
- Examine the training data set of the original network for better implementation of fine tuning.
- Detect how many cats are present in a single frame.
- Implement fine-tuning and preprocessing into classification module.
- Improve speed, optimize the code further.

6. Anticipated Difficulties

In the following parts of the classification system, it is expected to encounter further difficulties regarding the speed of the system. This is because the classification module rely on the computation power strongly. After it has been implemented to the rest of the system the time for the camera to open, the time for the frame to pass through the preprocessing module, the image complexity, the constant stream of data the will surely slow down the system. Another issue that was already encountered was after the implementation of the whole system, the camera was driving too much power that the PWM signals going to other parts of the overall system were disrupted. This caused the sensors and the motor to malfunction. To avoid this in the future an Arduino is to be used for better PWM signals with less noise. This is crucial since back-end and identification rely strongly on the speed of the classification part. More information on this is presented in the electonics subsystem section.Another anticipated difficulty is the weights to be more inaccurate after fine tuning. This is due to the unfamiliarity to this technique and somewhat complexity of it. Therefore, the plan is to approach it cautiously after extensive research.

7. Test Plans

- Compare the confidences, speed, accuracy between the fine tuned data and the original network.
- Test with real cats.
- Test with multiple cats by putting a picture.
- Test the system's confidence, speed and accuracy before preprocessing and after preprocessing.

b) Identification

This subsystem takes an image classified as 'cat' by the classification subsystem and recognizes or identifies the cat in the image. This is necessary for profiling the cats and tracking their feeding logs.

1. Requirements

The requirements for this subsystem follow:

- The subsystem should be able to identify new cats.
- The subsystem should be able to recognize identified cats.

2. Solution

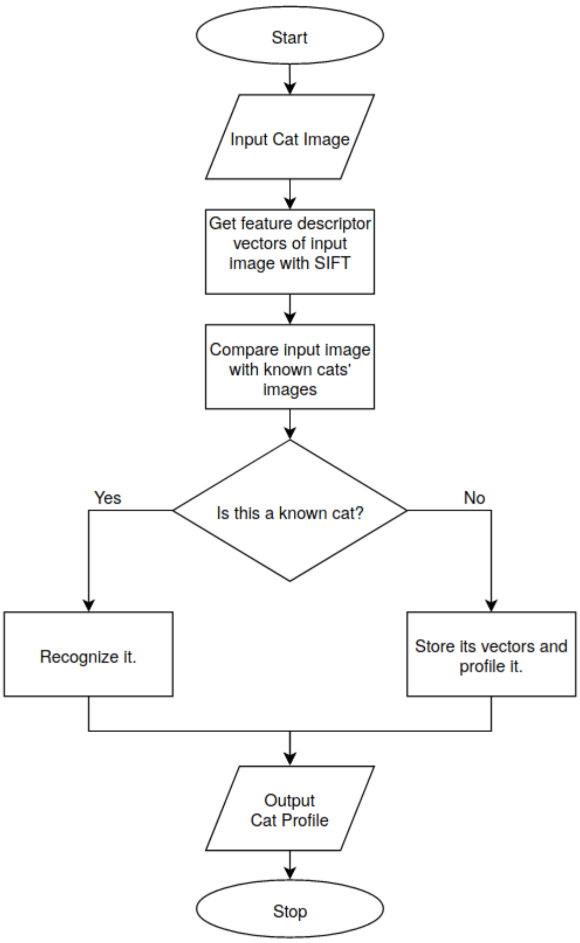


Figure 7: Algorithm Flowchart of the Identification subsystem

For identification purposes, one of the most powerful feature detection algorithms, SIFT (Scale-Invariant Feature Transform), is used on the initial tests.

The algorithm flowchart of this subsystem is in Figure 7. The subsystem starts with an image input. Since this image is fed from the classification subsystem, it is certainly an image of a cat. Later, this image's feature descriptor vectors are obtained by SIFT and compared to the stored vectors of images of known cats. This comparison is the most crucial part of the entire process; most of the past and future tests of this subsystem will have been done on various methods of comparing these vectors. After this vector comparison, if any known cat's features are similar enough, it is decided that the input cat image belongs to that cat. Otherwise, the cat is identified as a new cat, and a new profile for it is set up. Lastly, the cat's profile is returned as the output of the subsystem, and the process ends.

Figure 8 is an example of the SIFT key feature extraction. The image on the right is a mapping of the features on the original image of our beloved friend Ponçik on the left.

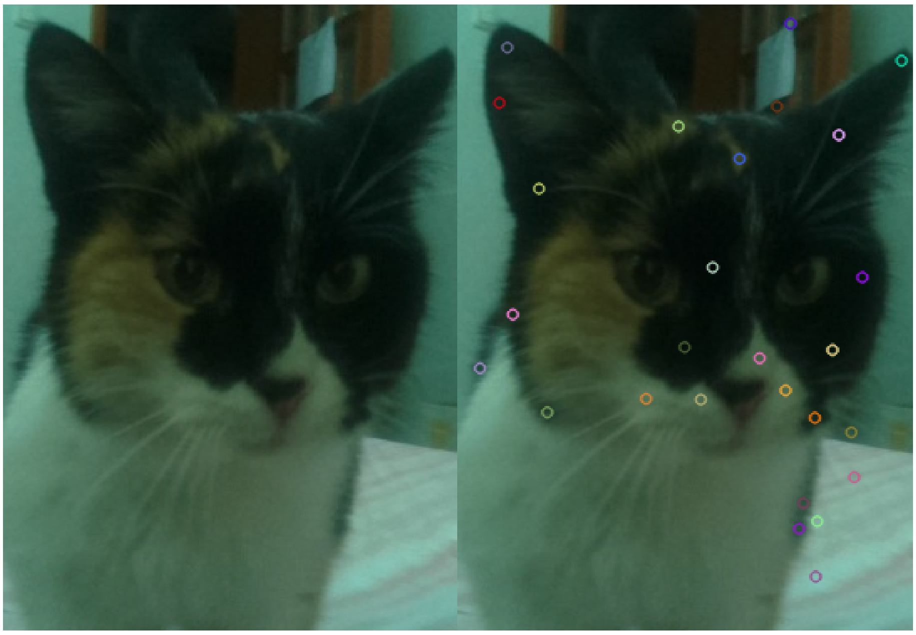


Figure 8: SIFT feature mapping

Current implementation of vector comparison computes a loss between two vectors. This loss is simply the euclidean distance between the two vectors:

For vectors x and y with n elements each:

$$d = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + (x_3 - y_3)^2 + ... + (x_n - y_n)^2} \tag{1}$$

During a comparison of the input image with one of the stored images, each input vector is compared with all vectors of the stored image, then the smallest euclidean distance is saved as that vector's loss. Then all input vectors' losses are summed together to yield the loss between those two images. When this loss falls below the defined threshold, the input image is matched with the compared stored image. This is the case of recognition of known cats. When the loss of the input image against any stored image is larger than the threshold, the vectors of the input image are saved, and a new profile is set up for the unrecognized cat.

3. Risks

The problem with comparing images using euclidean distances of vectors is that the loss values are not self normalized. One alternative is to use the cosine of the angle between said vectors. This method ensures that the loss values are always between 0 and 1, which results in a more coherent identification module. Nonetheless, using the euclidean distance of the vectors is preferred over using their angles with respect to each other. The reason for this is that vectors consist of both magnitudes and angles, and magnitude is anticipated to play a larger role in the case of SIFT vectors.

Aside from SIFT, there are some other feature detection algorithms that are being considered by the Computer Vision team. These include, but are not limited to, SURF (Speeded-Up Robust Features), Harris Corner Detector, FAST (Features from Accelerated Segment Test) and ORB (Oriented FAST and Rotated BRIEF).

4. Tests

This subsystem is currently ahead of schedule. Hence, it is not the priority of the team; consequently, there has not been considerable amounts of tests.

5. Plans

Future plans of this subsystem follow.

- Decide on a feature detection algorithm. Some possible choices are SIFT, SURF, FAST, ORB, and Harris Corner Detector.
- Decide on an image comparison method that detects whether the input image belongs to a known cat.

From the Computer Vision team, Furkan is responsible for the future work regarding this subsystem.

6. Anticipated Difficulties

Since interfering with the way SIFT extracts the feature vectors is not an option, there is no guarantee that the extracted vectors will always be helpful. If this turns out to be an issue for the overall system, the team will consider doing background research to use another feature extraction algorithm that is more customizable.

7. Test Plans

Future plans on how this subsystem will be tested are listed below:

- Images of various cats will be stored.
- These will be labeled either as 'known' or 'unknown', arbitrarily.
- Cats with the label of 'known' will be fed into the algorithm.
- Cats with the label of 'unknown' will separately be fed into the algorithm.
- Input image of any label will be compared with 'known' cat images.

There are two criteria for a successful test result:

1. When a 'known' cat's image is fed into the algorithm, the algorithm recognizes that cat.
2. When an 'unknown' cat's image is fed into the algorithm, the algorithm identifies it as a new cat and sets up a new profile for it.

6 Electronics

a) Requirements

The requirements for the electronics subsystem are listed below.

- The subsystem should be rechargeable and the charging time should be less than 5 hours.
- Rechargeable batteries should be non-removable.
- Battery duration should be at least 5 hours.
- The subsystem should be wired correctly and properly.
- The subsystem should be able to operate during charging.
- The subsystem should be able to operate Raspberry Pi.
- The subsystem should be able to drive the servo motor.
- Power consumption of the subsystem should be minimum.
- Status of the food supply should be observable.
- Battery level for both charging and operation modes should be observable.
- The subsystem should be able to measure the weight of a cat.
- The subsystem should be able to deter dogs from the area without causing any harm.

b) Solution

1. Computer

The system runs on a computer. Raspberry pi zero wh is selected as the computer since it provides the required operations, which are listed below.

- Getting images from the camera module.
- Connecting to the server for fast classification.
- Controlling the rotation of the motor by generating PWM signals.
- Measuring the distance coming from the ultrasonic sonar sensor.
- Measuring the weight of the animal coming from load sensor.

- Receiving the analog battery voltages to indicate battery level in the web interface.
- Controlling the LEDs which indicate detection of cats/dogs.
- Controlling the LEDs which indicate the battery level.
- Controlling the dog deterring system.

Getting the images from the camera and connecting with the server are explained in the 'Integration of the Subsystems' section. All other operations will be explained in detail in the following modules.

2. Camera

A high quality camera is required in order to obtain successful classification results. Two different cameras can be used.

Part A Raspberry Pi Camera Module

Raspberry pi has an input socket for its camera module. The camera is run by the GPU without CPU assistance. A 5 Megapixels sensor is used in this camera. A 15-pin Camera serial interface (CSI) is used to attach the camera to the device, and this interface is capable of high data transmission rates. Hence, the communication with the device to extract frame data is fast. With this camera, high-quality images can be obtained in a very small time interval. This camera, with dimensions of 20x25x9mm, will be placed in an apparatus for protection.

Properties of the camera module are listed below [5]:

- Horizontal field of view 53.50 degrees.
- Vertical field of view 41.41 degrees.
- Focal length 3.60mm.

Part B Webcam A webcam can be connected to the USB input of the Raspberry Pi. Raspberry Pi USB input is run by CPU. Since there will be different operations on the CPU, the extraction of frame data will be slower. Also, even if % 100 of the CPU is used for frame data transmission, the frame rate is still much lower than using the camera on the GPU. In order to obtain faster results, the image resolution should be decreased. However, if the image quality decreases significantly, classification operation might not work as accurately.

3. Motor

In the mechanics part, the gate mechanism is explained in detail. Two different positions of the gate are required. These two positions can be adjusted by two different ways.

Part A Servo Motor

The positions can be adjusted by changing the duty cycle of the PWM signal of the servo motor.

There are 3 connection wires to the servo motor. The power and ground inputs are connected to the outputs of separate voltage regulators, and the control wire is connected to the PWM GPIO port of the raspberry pi.

A PWM signal is generated with a python script implemented in the raspberry pi. Maximum and minimum positions of the motor are selected as the operating positions. When the gate is to be opened, duty cycle is switched to %2.5, and when the gate is to be closed, duty cycle is switched to %12.5.

The motor can operate between 4.8 and 7.2 Volts. The selected operation voltage is 6.6V which is close to the maximum voltage, but a safety margin is set. The output torque of the motor is around 12 kgF-cm, which is more than enough to rotate the gate under full load. [8]

Part B DC Motor

A DC Motor can be used to rotate the gate. A DC motor is a two wire continuous rotation motor, where the wires are power and ground wires. DC motor is also controlled by PWM signals. However, the power wire is controlled by turning it on and off. The motor should be on until it reaches to the required position and then turned off. This opening and closing operation might not be precise since the motor rotates very fast.

Also, more power will be dissipated in the DC motor than the servo motor.

4. Measuring the Food Level

The users will be informed about the remaining food level in the reservoir. The food level can be measured by two different methods indicated below.

Part A Ultrasonic Sonar Sensor

An HC-SR04 ultrasonic sonar distance sensor can be used to measure the distance between the food and sensor. The sensor generates an ultrasonic sound around 40kHz. However, the amplitude of this sound is very low in order not to disturb the animals. The sensor contains two different transducers. The first transducer generates the sound wave, and the second transducer receives the echo of the transmitted wave. The distance is calculated by the following formula:

$$\text{distance} = \text{time} \times \text{speed of sound} \; / \; 2 \tag{2}$$

The generated sound is transmitted from the transducer, then the wave bounces back from the object; the returned wave is received from the second transducer. The distance is divided by 2 since the sound makes a round trip between the sensor and the food.

Sound speed is taken as 340 meters per second.

The sensor has 4 pins: VCC, GND, ECHO, and TRIGGER [2]. VCC pin is connected to one of the power outputs of the raspberry pi, and ground is connected to the common ground. Trigger pin is the digital output pin of the sensor; it can be considered as the transmitter transducer, and it is connected to the PWM output pin of the raspberry pi. Echo pin is the digital input pin of the sensor. A trigger signal is applied and the time is measured until the echo pin returns high value.

Part B Infrared Distance Sensor

An infrared distance sensor such as GP2Y0A710K0F can be used in order to measure distance. The infrared sensor returns more accurate results than the ultrasonic sonar sensor. However, it is much more expensive than the ultrasonic sonar sensor.

The operation principle is similar to the ultrasonic sonar sensor. An IR distance sensor uses a beam of infrared light and the reflected light from the object is received in the light detector position sensing part. When the position of the object changes, the angle of the reflected beam changes, and the distance is calculated from the angle change. A built-in signal processing circuit is included in the sensor to measure distance. The sensor returns analog voltage values as output with respect to the distance between sensor and object. [11]

5. Measuring the Weight

A weight sensor is used in order to obtain additional information about the cats.

The sensor has three input wires. Power will be supplied from the raspberry pi, and ground will be connected to the common ground. The output wire returns analog voltage values with respect to the applied force on sensor. The analog voltage should be converted into digital data. An analog to digital converter HX711 integrated circuit will be used, and the digital data will be read though a port in the raspberry pi and scaled according to the measured weights.[10]

6. Battery

The battery is one of the most important components of the project, since the system will not operate without a power supply. Two different power supply units will be used to supply raspberry pi and motor units separately in order to decrease motor noise.

In order to satisfy battery requirements, three different solution plans are considered.

Part A 18650 Lithium-Ion Batteries are selected as power supply since they are rechargeable and portable. Capacity of the battery will be determined from the current values when all subsystems are integrated. Increasing the capacity can be done with shunt connected batteries.

Part B As an alternative, lithium-polymer batteries can be used. They are also rechargeable and portable. Furthermore, their capacity is higher compared to Li-Ion batteries. However, Li-Ion batteries are both cheaper and safer.

Part C A power bank can be used. The capacity of a power bank is higher than the other 2 solutions, but the cost is also higher. This solution might be the most stable power supply. However, it is not cost efficient.

2600 mAh 18650 Li-Ion batteries are selected after the current measurements. 2 batteries are shunt connected for the raspberry pi unit and 2 batteries are shunt connected for the servo motor unit. By this way, 5200 mAh capacity is obtained for each unit. These values are calculated with respect to the maximum drawn currents. However, the required operations consume much less current than these values. Hence, the overall system is able to operate at least 5 hours on this battery setup.

7. Battery Charger

The charging operation is done by using TP4056 1A lithium battery charger circuits. Since two different power supplies are used, two different charger circuits are connected. One of the charger circuits is connected to an electric socket from its micro-USB input. Input of the other charger circuit is connected in parallel to the first charger circuit. By this connection, when adapter is connected to the box, both charger modules will operate. Outputs of the charger circuits are connected to the inputs of shunt connected batteries. By this way, while the batteries are being charged, other subsystems can operate.

For Li-Po batteries, same charging mechanism can be used.

If power bank is used, there will be no charging mechanism. The micro-USB adapter will be directly connected to the power bank.

8. Voltage Regulators

Stable voltage is required to operate the raspberry pi and the motor. The raspberry pi requires a 5V 1.2A power supply. 1.2A is the maximum stall current. This requirement is satisfied by using a 5V 1.2A DC to DC boost voltage regulator. Two parallel connected batteries give 3.7V and the total capacity is 5200 mAh. The shunt connected battery is directly connected to a 5V 1A regulator. The output of the regulator is not ideal, but nonidealities do not affect the operation of the raspberry pi. The USB port of the regulator is used and the raspberry pi is powered from its micro-USB input.

The selected operation voltage of the servo motor is 6.6V. An XL6009 adjustable DC to DC boost converter is used. The regulator can supply output current up to 4A and the stall current of the servo motor is 2.5A. Hence, both voltage and current requirements are satisfied. However, cooling of this regulator is insufficient. It might be switched with a better regulator.

Input voltages for both regulators are between the range of Li-Ion Battery voltages. The overall system can operate when the batteries are empty and charging, as well as when they are full.

9. Dog Deterring

Dog deterring module is explained in the 'Mechanics' section of this report.

c) Risks

Possible risks for the electronics subsection are listed below.

- Voltage difference between shunt connected batteries.
- Low output torque from servo motor.
- Unstable PWM signal generation.
- Unstable voltage regulator outputs.

- Wiring faults.
- Grounding faults.

d) Tests

1. Tests Procedure

- Measure the voltage of batteries.
- Charge the batteries with charger circuits until the voltages are balanced.
- Connect batteries to regulators.
- Measure the output voltage of regulators for different voltages inside the voltage range of battery.
- Power up the raspberry pi and the motor.
- Connect the GPIO pins, camera, sonar sensor.
- Measure the distance with sonar sensor.
- Drive the motor.
- Obtain images from the camera.
- Measure the maximum and minimum camera view distance.
- Drive the motor while camera is active.
- Measure the distance while motor and camera are active.

2. Tests Results

- Li-Ion batteries operates properly. Output voltage is between 3.7V and 4.2V.
- Parallel charging for two different power supply units operates correctly.
- Batteries work while charging.
- 5V 1.2A regulators return 5.35Volts when the input is 3.7V and 5.45 Volts when the input is 4.2V.
- Adjustable regulator operates correctly, however its cooling system is not sufficient.
- Measured distances can be seen in Figure 9.

```
('Distance:', 3.69, 'cm')
('Distance:', 4.41, 'cm')
('Distance:', 6.07, 'cm')
('Distance:', 7.53, 'cm')
('Distance:', 8.57, 'cm')
('Distance:', 9.48, 'cm')
('Distance:', 10.5, 'cm')
('Distance:', 11.75, 'cm')
('Distance:', 12.48, 'cm')
('Distance:', 13.07, 'cm')
('Distance:', 14.82, 'cm')
('Distance:', 15.61, 'cm')
('Distance:', 16.94, 'cm')
('Distance:', 18.35, 'cm')
('Distance:', 18.62, 'cm')
('Distance:', 21.57, 'cm')
('Distance:', 22.89, 'cm')
('Distance:', 24.93, 'cm')
```

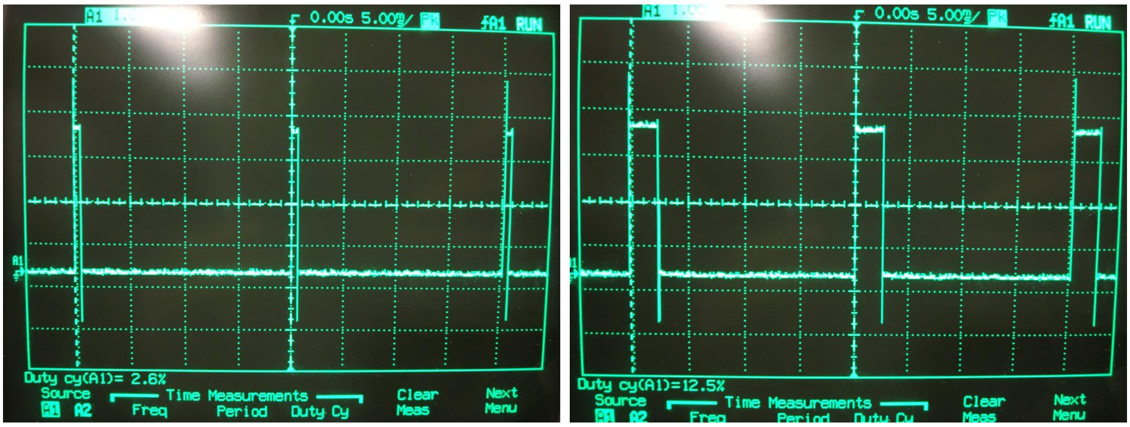
```
('Distance:', 25.33, 'cm')
('Distance:', 25.09, 'cm')
('Distance:', 21.51, 'cm')
('Distance:', 19.14, 'cm')
('Distance:', 15.5, 'cm')
('Distance:', 11.75, 'cm')
('Distance:', 9.9, 'cm')
('Distance:', 8.47, 'cm')
('Distance:', 5.92, 'cm')
('Distance:', 4.61, 'cm')
('Distance:', 4.15, 'cm')
('Distance:', 2.96, 'cm')
('Distance:', 3.22, 'cm')
('Distance:', 3.17, 'cm')
('Distance:', 3.41, 'cm')
('Distance:', 3.91, 'cm')
('Distance:', 2217.56, 'cm')
('Distance:', 2215.8, 'cm')
```

Figure 9: Measured Distances From Ultrasonic Sonar Sensor

- Motor is rotated according to the entered duty cycle values. For %2.5 and %12.5 duty cycles which are the on and off positions for the mechanical gate, generated PWM signals can be seen in Figure 10.
- Generated PWM signals are disturbed while camera is working. Jittering and motor noise occurs.
- Obtained images from webcam and raspberry pi camera module can be seen in Figure 11.
- A dog can be detected from the taken image from the camera with a distance range of 10 cm to 180 cm away from the box. Average detection distance is 110cm.
- A cat can be detected from the taken image from the camera with a distance range of 15 cm to 153 cm away from the box.
- The system draws 0.8 A during the charging operation after the batteries are connected for 4 hours.

3. Evaluation of Test Results

- Batteries are able to operate more than 5 hours. Also, system operates properly with power bank. Since Li-Ion batteries are cheaper, in the design of



(a) PWM Signal Duty Cycle = 2.5 (b) PWM Signal Duty Cycle = 12.5

Figure 10: Generated PWM signals from the Raspberry Pi

system Li-Ion batteries will be used. Li-Po batteries will not be tested since first solution operates as required. The subsystem requirement for the battery duration is satisfied.

- Parallel charging operates as required. The subsystem requirement for rechargeability is satisfied.
- Batteries are placed in a small case that is screwed into the box. The subsystem requirement for non-removable batteries is satisfied.
- 5 V regulator outputs voltages between 5.35 V and 5.45 V for the battery input voltage levels. This is undesired, however does not cause any faults for the raspberry pi.
- Solders and connectors are used in wiring. The subsystem requirement for proper wiring is satisfied.
- The raspberry pi operates with the battery connections. The subsystem requirement for operating the raspberry pi is satisfied.
- The subsystem operates properly during charging. The subsystem requirement is satisfied.
- The images are obtained successfully from the webcam and raspberry pi camera. The output images can be seen in Figure 11. When the images taken from the same position are compared, the quality of the image taken with the webcam is very low. Raspberry pi camera module, though more expensive than the webcam, will be used in the final design, since the image quality is vital for every module of the 'Computer Vision' subsystem.

(a) Webcam (b) Raspberry Pi Camera

Figure 11: Comparison of Images Taken on Raspberry Pi Zero

- The cat should be 15 cm away from the camera in order to obtain successful classification results.
- The maximum distance between the cat and camera for an accurate classification is 153 cm. This distance is a positive result, the foods will be served before the cat arrives at the box.
- Noise generated by the camera module propagates through the system finally affecting PWM generation and motor drive. Possible solutions are listed in the anticipated difficulties subsection of electronics subsection.
- The drawn currents are low, but the overall system current is not measured. The subsystem requirement for minimum power consumption is partially satisfied.
- The total charging time will be around 12 hours, which can be considered a long time. However, the system will be able to operate for much more than 5 hours. The subsystem requirement for charging time is not satisfied, but the charging time can be decreased by using lower capacity batteries.
- The distance between the top of the reservoir and the food level can be measured from the ultrasonic sonar sensor. However, when this distance is shorter than 2 cm, it returns false output. This problem can be solved easily by putting the sensor 2.5 cm above the maximum level of reservoir and rescaling the code in order to obtain correct volume percentage. Since ultrasonic sonar sensor operates properly, infrared sensor will not be tested.

e) Plans

- Fuses will be added in order to obtain a safe system.
- Motor noise will be eliminated/minimized.
- Weight sensor will be tested and integrated to the subsystem.
- Analog voltage level of the batteries will be taken from one of the GPIO pins of the raspberry pi and percentage value will be observable in the web interface.
- Voltage level indicator will be added to the box.
- Dog deterring system will be integrated to the subsystem.

f) Anticipated Difficulties

1. PWM signal is disturbed while the camera is working. Possible solutions are listed below.
    - Using capacitors at the input of servo motor and output of batteries. By this way, motor noise can be suppressed since the noise will be filtered. [3]
    - Using ferrite choke in order to eliminate high frequency noise. [1]
    - Applying more complex high pass filters.
    - Using twisted cables to reduce the magnetic field noise. [4]
    - Using motor drivers.

    These solutions will be tested in the listed order until a satisfactory result is achieved.
2. Adjustable regulator heats up while driving the servo motor. Possible solutions are listed below.
    - Using a regulator with a better cooling system.
    - Directly connecting separate batteries to the power inputs of the motor, with the help of relays.

g) Test Plans

- PWM signal will be tested while all other subsystems are working step by step applying the solution methods listed in the anticipated difficulties section of the electronics subsystem.

- New regulator connected to the servo motor will be tested.
- Weight sensor will be tested.
- Voltage level indicator will be tested.
- Dog deterring system will be tested.
- Overall system power consumption will be measured.
- Overall system will be tested after the fuses are added.

1. Test Procedure

- Test the battery duration after all of them are fully charged while all subsystems are operating.
- Test the motor for 200 rotation cycles to see how well it behaves.
- Test the voltage level indicator during charging and non charging periods.
- Test the volume level indicator with the motor rotation.

7 Mechanics

a) Requirements

The mechanical part should be constructed such that:

- There must be enough space for electronic components to fit in.
- Camera unit should be adjusted properly so that it should be protected from animal attacks.
- There must be no obstacle in front of the camera unit, so that it can capture accurate photographs.
- Angle and the position of the camera must be adjusted properly in order to identify cats and dogs from 1.5 meter.
- Integration of the food mechanism should be such that it must waste minimum amount of food, and the food given to the cats must be controllable in terms of the quantity.
- Capacity of the reservoir should be 4 kg (in full capacity) in order to provide 150 meals for a standard cat.
- Unwanted dogs must be deterred without giving harm.
- Amount of food remaining, battery chargers while loading and in operation should be visible by the user easily.
- Overall system must be resistant to heat and cold. It must be waterproof, and sturdy. Most importantly the weight of the overall system should be around 10 kg so that it can be carried by a single person.

Mechanical design is composed of two parts:

- The interior design
- The exterior design

In the interior design there exit several parts like:

- Inner cable connections is done.
- Food mechanism is placed.
- Reservoir and the electronic components are fitted into the box.
- Integration of the dog deterring system will be done.

Connections will be done properly since every extra cable creates a clutter inside the system. The electronic components will be placed as close as possible in order to shorten the cables length. There will be minimum number of cable between the flowing food in order not to block the food flow and to protect the hygiene of the food.

Food mechanism will be stable and sturdy. It will be fixed between the food reservoir and the path that food will flow. The details of the food mechanism will be discussed in the below for the mechanical part of this report.

Dog deterring system must annoy dogs and deter them from the area without causing them harm. The details about the system can be found in the subsystems and risks part.

The exterior design is mostly composed of the durability of the case. Its sub-parts can be observed below.

- Camera will be mounted properly.
- Material for outer design should be selected such that it must be economic, durable and must not exceed 6 kg for all outer design.

The expected size of the box is 40X26X50 cm^3 with maximum 10 kg weight.

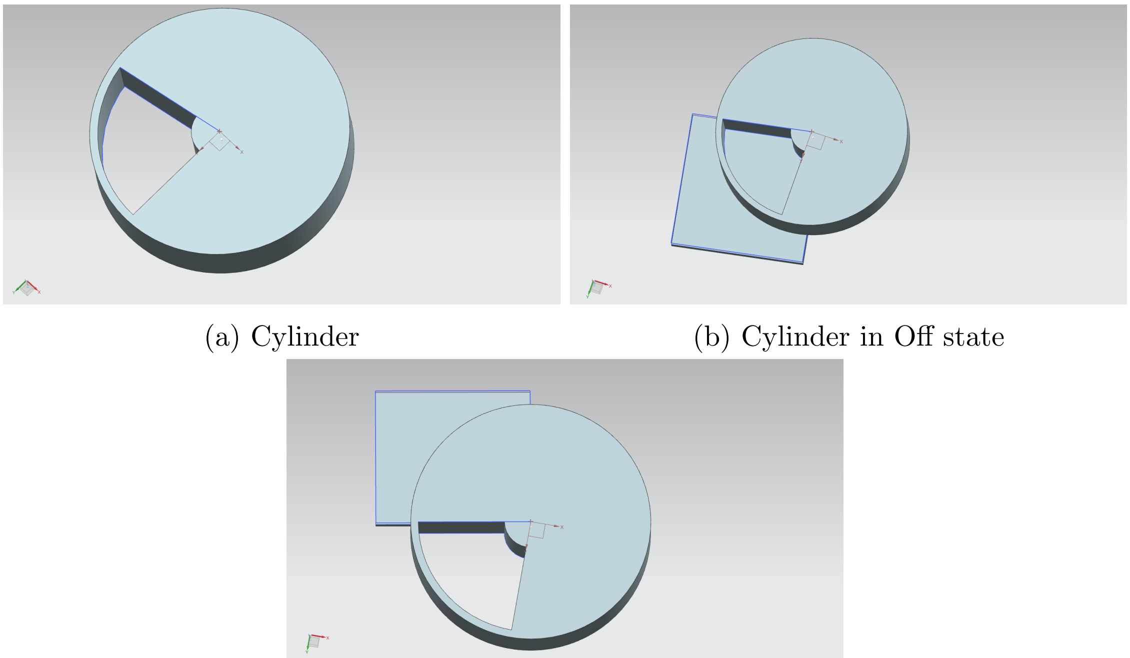
1. Food Mechanism

Food mechanism should contain four important features:

- The food flow must be controllable.
- Power consumption should be low in order to sustain 5 hours of non-stop working.
- Minimum amount of food should be wasted.
- Weight of the overall food mechanism (reservoir and motor together) should not exceed 5 kg.

In order to satisfy these four conditions, two different solution plans are considered.

Part A In order to control the flow amount, it is considered that first storing nearly 30 gr of food in an empty area, then by pouring this stored food, we planned to control the quantity of the food given. To do so a 45mm radius cylinder (4.5 mm depth) shaped apparatus will be used. %25 of the cylinder is empty and free to store food. The cylinder is between the reservoir and the obstacle that cuts the food flow. The food will be first poured to the empty region of the cylinder due to the gravity, then it will be stored there until a cat arrives. When a cat arrives the servo motor (MG99R which has 9.4 kg-cm torque) rotates the cylinder. The stored food in the empty region of the cylinder rotates through the pour free region of the obstacle and will be poured down when it reaches an opening. By this way in every two rotation of the cylinder 15 gr of food is supplied to the cat. The technical drawing of the cylinder can be seen from the figure 12.



(a) Cylinder

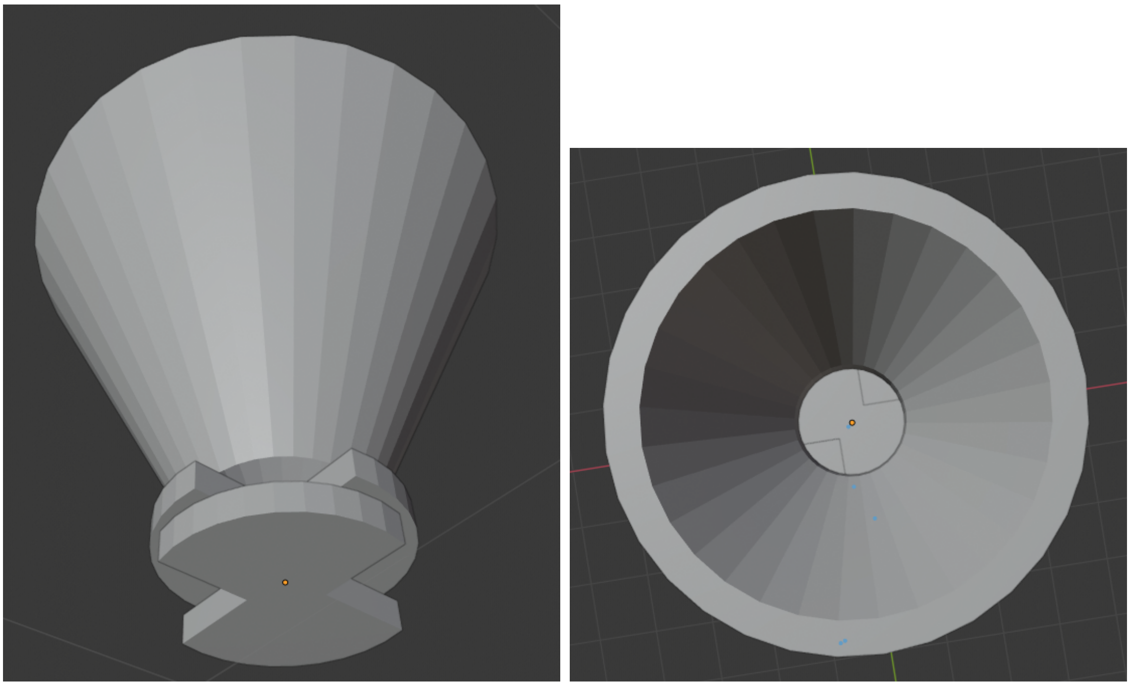
(b) Cylinder in Off state

(c) Cylinder in On state

Figure 12: The representation of the disk

When food is pouring from the cylinder also the food in the reservoir will also flow on to the cylinder due to the gravity, however, they will be stopped by the solid part of the cylinder and by this way the food flow from the reservoir will be stopped. There are still considerations if this design will properly stop the food, therefore there exist a plan B

Plan B This plan mainly considers stopping the food flow. There will be two identical disks which their radius is 45mm. One-third of these disks are empty. One of them can rotate and other can't. The stable disk is connected to the end of the reservoir and the other one is placed right under the stable disk. Servo motor is connected to the rotating free disk and the motor provides the necessary torque (12 kg-cm) to rotate it. When two open sides are matched, the food stars to flow through the empty region, and when one opens and one closed side is matched the food flow stops. This solution is a practical way to stop the food flow when there is no cat however, it is problematic in terms of the controlling the quantity of the food. Moreover there exist some other problems like what will happen when a food is jammed between the reservoir and disk. one can see the representation of the disks from the Figure 13.



(a) Disks and Reservoir (b) Disks and Reservoir in Off state

Figure 13: The representation of the states of the cylinder

Both of these solutions require test which will be mentioned on the Test and Test Plans part.

2. Dog Deterring System

Unwanted dogs must be removed from the area without giving harm to them. In order to solve this problem two different solution are considered.

Plan A Dogs can be removed from the area via using dazer. Dazers aim is to repel the dogs using 25.000 Hz signal[12]. This frequency is far beyond a human to hear however dogs can hear this signal and leave the area. The problem of this device is that cats can also hear this frequency range and react to it. Therefore they can also leave. Moreover, dogs can get use to this voice and as time passes, dazer might not be an effective way to deter them.

Plan B Dogs can be deterred by squeezing water on them. The water must have a high pressure so that it will hurt the dog bot not harm it. However there exist several drawback of this plan since one will need an extra place in the box to store the water, which also will have a weight. Moreover, the user will be responsible for supplying water to the system. Most importantly for this system to be effective the box and dog should be close to each other so that dog can fear from pressure and leave.

The planned test can be seen under Test Plans.

3. Exterior Design

The outer box should be reliable since it might be exposed to an attack of an aggressive animal and it has to resist the outdoor conditions such as heat and cold. Therefore in order to observe and select the right material, the above tests will be conducted which can be seen under test plans section of this report.

b) Tests

1. Food Mechanism

Description of the Test for Plan A Test was conducted in order to observe the behaviour of the food flow when we use Plan A.

The purpose of this test is:

- Determine the quantity of the average amount of the food poured.
- Determine if there any food is jammed between reservoir and the cylinder. If there exist some, determine if they will harm to rotation or not.
- Determine if motor is capable of rotating without difficulty.

Procedure can be followed below.

- Fully fill the reservoir with food.
- Observe the food flow in reservoir in off condition.
- Rotate the cylinder and observe the amount of food flow.
- While rotating observe the food flow from reservoir to the solid part of the cylinder.
- Observe if there exist any food jammed between the solid part of the cylinder and the reservoir.
- Return the cylinder to its old position.
- Observe if the flow of the food is completely stopped.

- Turn the cylinder again and observe the food flow again. Compare with the previous amount of food flowed.
- Repeat this process 10 times.

Results of the Experiment It is observed that food flow is not fully controllable in every rotation. It sometimes pours more food than cat needs in one cycle. In 4 trials food flowed more than expected (40 gr on average). Only in 4 trials 10 gr of food is flowed on average, which is an acceptable weight and in 2 trials food flow is not stopped. The results for the first test is not good however with some improvements on the current placement of the reservoir and the cylinder situation can become a lot greater. In the test for Plan A, these improvements will be done and the results will be checked if it now satisfies the necessary conditions.

The food is jammed between the reservoir and the cylinder however it is observed that it contains no danger to the rotation of the cylinder since the motor has enough torque in order to rotate the disk.

It is observed that when the camera and motor are connected to the same raspberry-pi, the motor starts to falter although when the motor is not rotating. This is due to the soft pwm that raspberry-pi provides. In order to overcome this problem, the motor driver will be used since it provides a hard pwm.

c) Plans

There exist several test plans in order to check the systems reliability and considering the different plans for different subsystems. The responsible person and the working schedule can be seen from the figure 14..

TASK NAME	START DATE	DAY OF MONTH*	END DATE	DURATION* (WORK DAYS)	DAYS COMPLETE*	DAYS REMAINING*	TEAM MEMBER	PERCENT COMPLETE
Mechanics								
Food Mechanism Test for Plan A	12/22	22	1/30	40	0	40	Doğa - Utku	0%
Food Mechanism Test for Plan B	12/22	22	1/30	40	0	40	Doğa - Utku - Fatih	0%
Dog Deterring System Plan A	12/30	30	1/30	32	0	32	Doğa - Utku - Fatih	0%
Dog Deterring System Plan B	1/5	5	2/29	56	0	56	Doğa - Utku - Fatih	0%
Exterior Design	12/22	22	2/15	56	0	56	Doğa - Utku - Fatih	0%

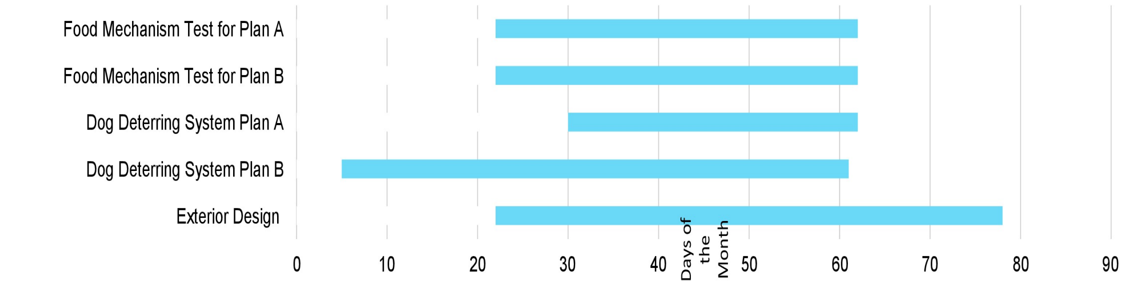


Figure 14: Gantt Chart for Mechanical Part

d) Anticipated Difficulties

1. Food Mechanism

It is expected that the food mechanism will create problems in terms of controlling the amount of food flowed. In order to get over with lots of tests will be conducted until it satisfies the necessary conditions mentioned on the food mechanism part. The balance of the cylinder and disk also might create an if a large amount of weight applies pressure on them but the first trials showed that, encountering this problem is a low probable one.

2. Dog Deterring System

Dogs are quite clever animals, therefore deterring them from the area by using the same method will create problems since they will understand that the precautions that taken will not harm them.

e) Test Plans

1. Food Mechanism

Plan A The same test procedure will be done, but only repeating 100 times via using a motor driver. The falter on the motor will be observed and the quantity of the food flow will be determined. The measure of success for this experiment is to drive to the motor without being faltering. The successful stop rate for food flow is %4 and the amount of food flow in every cycle should now vary %10 in weight.

Plan B Purpose of this test is:

- Determine the amount of the food flow according to the selected angled rotations.
- Observe if there will be any jammed food between the disks, if there any observe if this will create a danger for controlling the quantity of the food.
- Checking the reaction of the motor to an unstable load.

Procedure can be found below.

- Fully fill the reservoir with food.
- Observe the food flow in reservoir in off condition.
- Rotate the disk to an certain angle and observe the amount of food flow.
- While rotating observe the food flow when one open and one solid parts of the disks match.
- Observe if there exist any food jammed between two disks.
- Return lower to its old position.
- Observe if the flow of the food is completely stopped.
- Turn the disk again with a different angle and observe the food flow again. Compare with the previous amount of food flowed.
- Repeat this process for 4 different angle.

- Determine the most efficient angle.
- Observe the quantity of the food flow for this efficient angle for 100 trials.

The expected main problem is the reaction of the motor to an unstable load since, the load will be on one side of the disk, therefore it may create a shaking behaviour. The solution for this behavior can be cutting two sides which having the same axis. In this way one can solve the shaking problem, however, on the other hand, it might create a problem and controlling the amount of food flowing through. The measure of success of this experiment is stopping the food flow at least 95 times, moreover, it is desired that the quantity of the food is also controllable. In each trial, one has to get a similar amount of food flow.

2. Dog Deterring System

There exist tow different tests for two different plans. Purpose of this tests are observing the response of dogs to the deterring system.

Plan A The procedure is:

- Active the dazer system.
- Observe the behaviour of dogs when dazer is first applied.
- Observe the behaviour of cats.
- Repeat this process for 10 times.
- Observe the behaviour of the dogs after they get use to the sound of the dazer.

Measure of success of is achieving %80 of deterring the dogs at first trial and %60 of deterring when they get used to it.

Plan B The procedure is:

- Active the pressured water system.
- Observe the behaviour of the dog after it gets wet.
- Repeat this process 10 times with different dogs.
- Repeat same process 15 times with the same dog.

Measure of success of is achieving %100 of deterring the dogs when they first encountered with the pressured water and %80 when they used to it.

3. Exterior Design

The purpose of test is to determine the reliability of the box.

- Check the weight of the box.
- Apply force on the box and check if there exist any considerable damage on it. If not continue.
- Place electronic devices and the food mechanism inside the box and apply for on the box. Check if electronic devices, camera and food mechanism works properly. Check the angle of the camera. Observe if it works functional.
- Repeat this process 5 times.

The measure of success for this experiment is having non-considerable damage on the box and it is desired that all electronic devices and the food mechanism work as it was before applying force. Moreover, the camera can move a little but it is expected to capture photographs that can useful for identifying cats and dogs.

8 Integration of the Subsystems

After the tests are conducted for subsystems and the optimal solutions are determined, the subsystems will be integrated.

Integration plan for subsystems is scheduled as below:

- Integration of mechanical parts.
- Integration of exterior design with electronic equipments.
- Integration of camera and microprocessor.
- Algorithm related integration on microprocessor.
- Integration of microprocessor and mechanical part.

Being satisfied the subsystem requirements, integration between the subsystems will be done. The integration procedure can be seen below:

- Integration of the box with the camera and microprocessor unit.
- Integration of the dog deterring systems with the box.
- Integration of the exterior design with the food mechanism.
- Integration of the box with the computer vision submodule.

Measure of success can be seen below:

- %90 of successfully identifying cats.
- %90 of successfully identifying dogs.
- %70 of successfully deterring dogs from the area.
- Giving right amount of food to cats at %80.
- At least 5 hours working system without being charged.

In figure 15 one can observe the subsystems and their related works, in a Flow Chart. Firstly all of the subsystems will finalize their products according to the desired specifications. The jobs for every single subsystem can be seen in above. After every subsystem finalizes their product, the integration of the subsystems will be done. Since everything is nested and parts rely on other parts to function properly, the implementation process should be approached with caution. The malfunctioning of a single block can disrupt the whole system. The main idea to avoid such a case is to write test codes for each module, write info logging to a separate file to detect where the system goes wrong. Another important aspect is to test the whole system after each module's implementation to the existing system. This way it will be easier

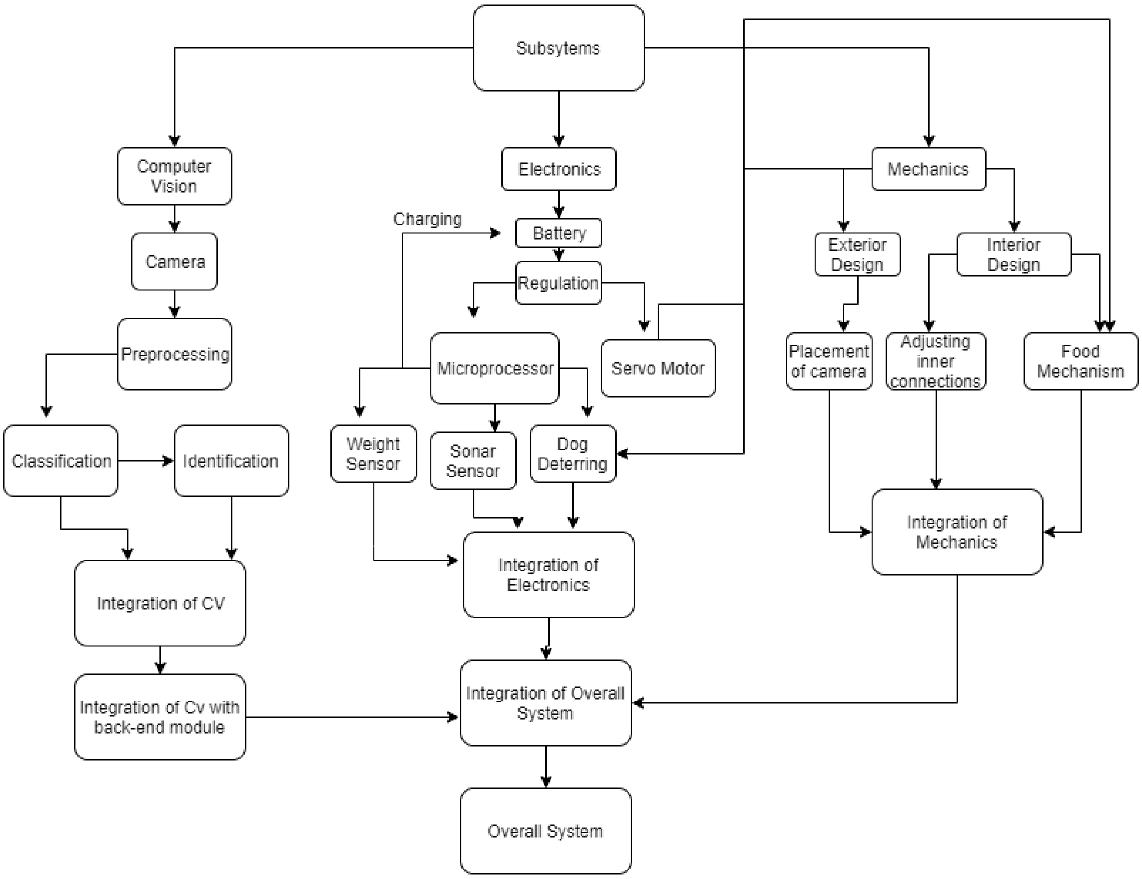


Figure 15: Flow Chart for Overall System

to make sure the functioning is proper and the new arriving module doesn't cause any problems.

9 Cost Analysis

Item	Quantity	Price ($)	Total ($)
Raspberry Pi Zero WH	1	20	20
Raspberry Pi Camera	1	16	16
Raspberry Pi Camera Cable	1	3.5	3.5
Raspberry Pi Camera Case	1	4.5	4.5
16 gb MicroSD Card	1	5	5
Li-Ion Battery	4	5	20
Lithium Battery Charger	2	1	2
Micro USB Adapter	1	4	4
Voltage Regulator	3	2	6
Ultrasonic Sonar Sensor	1	1	1
Weight Sensor	1	1.5	1.5
Ultrasonic Sonar Sensor	1	1	1
Servo Motor	1	1	5
Mechanical Components	-	-	60
Additional Payments	-	-	30
		Total Cost	179.5

Table 3: Estimated Cost Analysis for the Project

10 Deliverables

There will be five deliverable that Felerest will provide to users.

The products and services that will be offered are listed below.

- The box that only feeds cats,
- A mobile/web application that will show food, water and battery level.
- Customer oriented additional features to the mobile/web applications.
- A thorough user manual for the system setup, reservoir refilling process, and the mobile/web application,
- 3-year warranty that excludes user faults,
- Charger for the battery.

11 Conclusion

Looking at the environment one can see the food leftovers that cause visual pollution which also leads to health and hygiene problems. Felerest are determined to solve this problems while protecting our beloved friends. To do so, Felerest engineers are determined to create novel ideas which will lead be pioneering in the field of automatic cat feeding systems. Our goal is to improve the life standard of the cats and humans by using the blessings of technology.

The purpose of this project is to feed cats at the required amount while also determining their eating behaviours, without any human interaction. This project is useful for the owners which cannot leave home due to their cats and for those cats who lives in the streets or in sanctuaries who are in need of human care.

The problems were indicated from different viewpoints and our engineers developed different strategies to solve them. The details of these strategies were mentioned above exclusively. Felerest always has a backup plan just in case if plan A is not enough, these plans were also mentioned. Alongside these, every module's test results, planned future test ideas, the foreseen risks and disadvantages were discussed thoroughly. Furthermore, each engineer's following responsibilities and the role division was displayed out. This report includes flow charts that explain the algorithms implemented in the computer vision part, 3D designs of the mechanical structures, and pictures of test results for each subsystem. This report was written in order to show a clear picture of the project for customers and members of the company. We believe that customers should always have the chance to personalize their products. This is why we provided customer oriented additional features to the mobile/web applications.

Our vision for the future is to market these feeding systems commercially available to everyone around the world. This way our furry little companions are never hungry and are always well taken care of. This will surely be an important step for the pet society, making it the first ever connected, smart, cat feeder.

12 Appendix

a) Appendix A

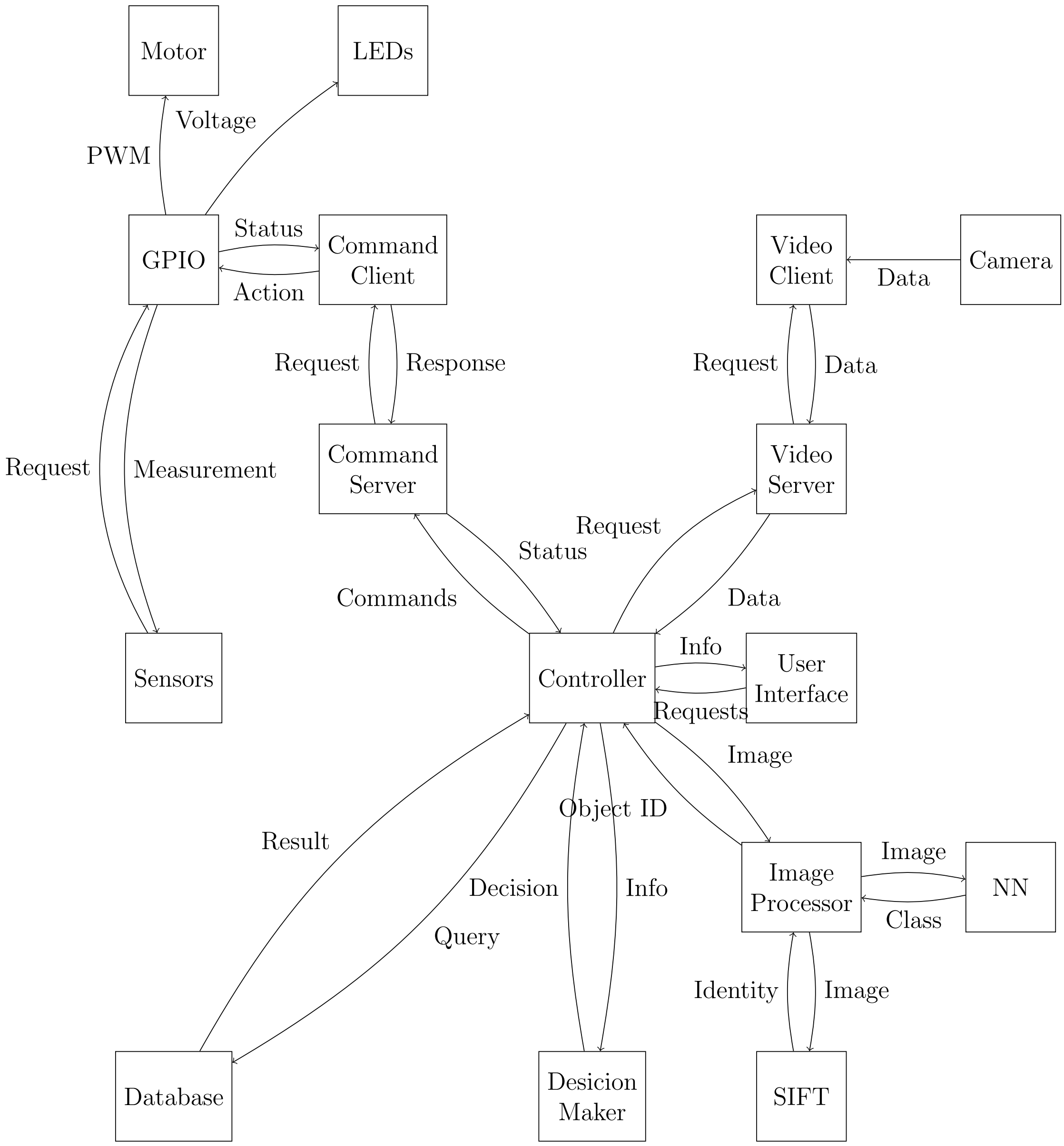


Figure 16: Overall System Organization

b) Appendix B

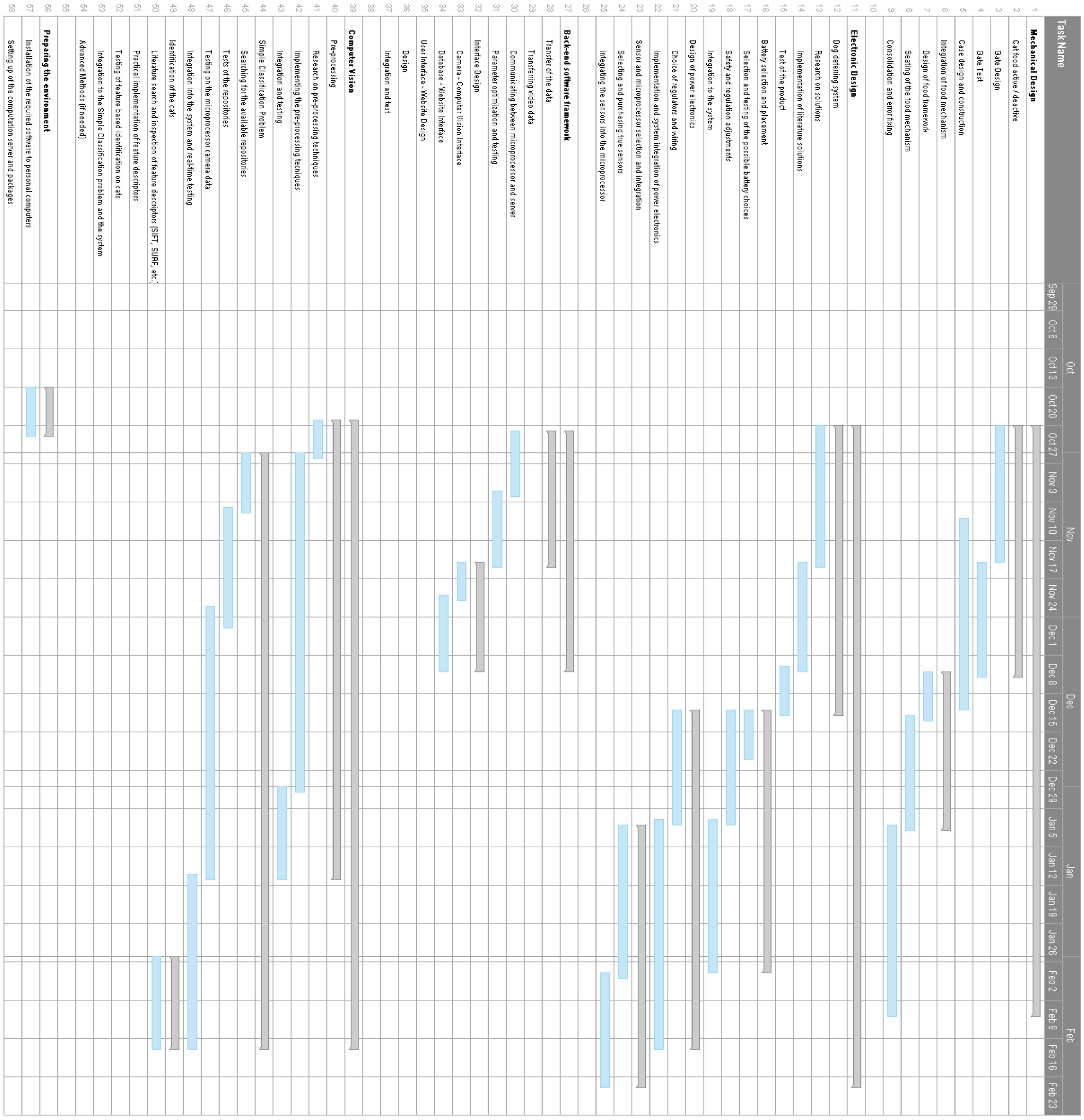


Figure 17: Gantt Chart

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