DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

EEL-4921C – SENIOR DESIGN II

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PantherBot

TEAM NUMBER 1

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SENIOR DESIGN II PROPOSAL

Submitted to:

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ABSTRACT

Online orders are being used by more people every day. While the efficiency of these deliveries are still being improved from packaging to delivery. This project aims to improve the delivery efficiency of these online orders, by minimizing the time to deliver the package as the delivery driver and the effort needed to receive the package as the customer. The PantherBot complete this task by using a machine learning algorithm that allows it to discern the most optimal path to the customer with no user input. Its main feature will be its elevator friendly feature that allows it to navigate an elevator on its own. The project will go over the two main hardware components being incorporated: the chassis and the storage compartment. Finally, the project will provide helpful insight to project feasibility and other considerations that must be taken to ensure a safe, feasible, and efficient project is being done.

I. EXECUTIVE SUMMARY

The PantherBot	
Team Number: 1	Team Name: Team Locomotive
Mentor: Dr. Uluagac	Team Leader: David Langus
Team Member: Jeremy Yskes	Team Member: Ramon Johnson
Team Member: Andres Ferreira	Team Member: Ricardo Flores

A. *Summarized Problem Statement*

Online orders are a common commodity that most people use. These orders, while convenient, are still very inefficient. The package still requires extra effort from both the delivery person and the customer to finish the delivery in a multistory building. The PantherBot aims to solve this problem.

The PantherBot is an autonomous robot that can deliver the package directly to the customer regardless of the location of the customer.

B. *Objectives and Constraints*

1) *Safety*

a) The PantherBot implements a collision prevention protocol.

2) *Scalability*

a) The PantherBot efficiently delivers the package.

3) *Ease of Use*

a) The PantherBot will be user friendly.

4) *Marketability*

a) The PantherBot will be elevator friendly..

5) *Cost around $750*

6) *Rechargable Battery*

C. *Project Description*

The PantherBot is a self-operating robot capable delivering packages from one point to another with no user assistance. It will be capable of finding the most optimal path to the customer while being able to use any elevator. While maintaining a safe distance from other people and a safe speed.

D. *Feasibility Analysis*

The feasibility analysis is crucial in determining whether the project is viable, or if it can be done. To determine this, we split this analysis into seven factors as listed below and gave them a score according to how feasible they are.

1) *Technical*

The technical helps us determine if we have the available technology to for our products development. We assessed that our product as a score of 4.3 out of 5.0 on this factor.

2) *Resource*

The resource feasibility allows us to evaluate our own knowledge as well as the equipment we have. Currently we scaled our resources with a score of 4.0 out of 5.0.

3) *Economic*

The economic feasibility helps determine our product on an economic basis. This includes if we have the budget to complete the development, as well to see if the product can profit. We concluded that our product has a high chance of success in this section with a score of 4.5 out of 5.0.

4) *Scheduling*

Scheduling is one of the most important assessments to be evaluated for most project. Ours has a lot of development steps that could be delayed due to issues and errors with the software and hardware. If we keep to our schedule adequately, we can achieve the score of 3.7 out of 5.0. The lowest of all factors.

5) *Legal*

We must also determine if our product has any possible legal implications that could hinder our development. As such we gathered as much information to see how possible it is to complete this project. We came out with a score of 3.8 out of 5.0.

6) Marketing

Marketing asses the appeal of our product to the public. After doing some research we found that our product has a high appeal to most people. Respectively our score for this factor was also the highest of any other factor being a 4.8 out of 5.0.

7) Cultural

Cultural asses how socially accepted our product will be. We found that people were not just interested in the idea but wanting it to be completed and available. Our score for this section came out to be a 4.7 out of 5.0.

8) Project feasibility

To determine how feasible our project was, we took the previous factors scores and applied the following formulas to find their G.Mean and their weight.

$$G.Mean = \sqrt[n]{(A_1 * A_2 * A_3 * \ldots * A_n)}$$

$$Weight = \frac{G.Mean}{Total}$$

After finding their G.Mean and their weight we used the next set of formulas to determine the overall weight of each section and our feasibility score.

$$Weighted\ Score = Weight * Score$$

$$Weighted\ Average = \frac{\sum Weighted\ Score}{Weight}$$

To achieve success in our project the score we were aiming for was a 3.0. After completing the calculations above we came out with a score of 4.16, meaning that our project has a high chance of success.

E. End Product Description

While designing or developing a product, it is essential to establish a clear end-product description. To do we have our projects end-product divided into three level views.

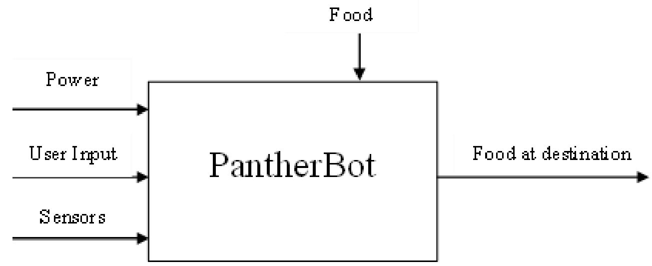


Fig. 1. Level 0 View of the PantherBot

Fig. 1 Shows the level 0 of the PantherBot, or also known as the black box diagram. Where you see the overall inputs that the design will be receiving and what output you are expected to have.

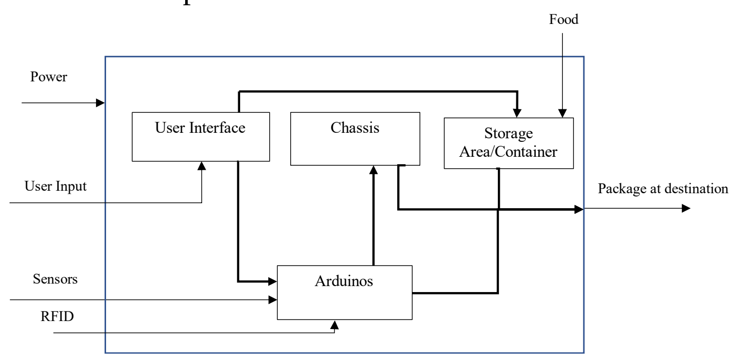


Fig. 2. Level 1 View of the PantherBot

Fig. 2 Shows the level 1 of the PantherBot. In this view you can see the overall components or sections of the product along with their inputs and outputs. It shows the direction the signal between each part.

Level 2 consist of diving deeper into each section of the build, such as the chassis. Where we show how the input for the power is directed throughout the microcontroller and sent to the drivers and other components.

F. Conclusion

As mentioned previously, the efficiency of delivering packages can still be improved. The PantherBots goal is to combat this inefficiency through its autonomous features. However, the development of this project heavily relies on the effectiveness of the team to maintain a strict schedule and complete tasks on a timely basis

II. PROBLEM STATEMENT

Online orders are a common commodity that most people use. These orders can range from food deliveries to household items. Currently, when these orders are being delivered to a multi-floor building, they would have to find the customer's floor or ask the customer to come to pick up the item. This is not just inefficient for the customer, but also the person delivering the online order. Our goal is to tackle this inefficiency for all parties involved.

The PantherBot is an autonomous robot that can collect and deliver two separate packages. Saving time for both the person delivering the order and the customer. The PantherBot can accurately and efficiently find the correct path to the customer. While maintaining a safe distance from other people and a safe speed. Additionally, the PantherBot is elevator friendly, sociable, and odor-free. The PantherBot costs around $750 and is easy to maintain.

A. ***Objectives***

1. *Safety*
   - 1.1. The PantherBot maintains an average speed of 3 mph.
   - 1.2. The PantherBot maintains an average of 2 feet distance from other people.
   - 1.3. The PantherBot implements a collision prevention protocol.
2. *Scalability*
   - 2.1. The PantherBot efficiently delivers the packages.
   - 2.2. The PantherBot is easily programmable for new code locks.
   - 2.3. The PantherBot should deliver the package accurately to desired locations.
3. *Ease of Use*
   - 3.1. The PantherBot is easy to set up.
   - 3.2. The PantherBot is self-Charging.
   - 3.3. The PantherBot needs to be user-friendly.
4. *Marketability*
   - 4.1. The PantherBot has a locking protocol to ensure theft prevention.
   - 4.2. The PantherBot displays when it is ready to carry a new package.
   - 4.3. The PantherBot displays when it has reached the customer and awaiting code confirmation.
   - 4.4. The PantherBot has an insurance protocol in case the package was never picked up.
   - 4.5. The PantherBot needs to be elevator friendly.
   - 4.6. The PantherBot should be able to transport two packages at once.

B. ***Constraints***

1. Cost around $750.
2. Rechargeable battery.

III. ASSUMPTIONS AND LIMITATIONS

In this section, we will detail some of the assumptions and limitations that will factor into the design and implementation phase of our project. These assumptions may be based on experience or from research. As for limitations, they can apply to the function of the product or to factors that the client has imposed or are the physical limit of the technology. In order to create an innovative device that can safely transport packages to the desired locations in a building, several assumptions and limitations must be stated. This section documents some of the primary assumptions and limitations of the PantherBot. Some features may be affected by the limitations. Through research and various brainstorming sessions, the team evaluated features based on viability. Some discarded features are app integration and GPS tracking.

Most of these assumptions and limitations have been set by both the client and the team. Some of these assumptions or limitations can be either changed or more may be added as the production of the end-product is being constructed. These changes are to ensure that the end-product can result in the best possible outcome for all parties involved.

We will now state the known assumptions and limitations that have been provided to us by our client and from internal discussions with the group members. They are as follows.

A. ***Assumptions***

The assumptions for our project are:

- Be able to dock at a charging station.
- Maintain a safe 2 feet distance from others.
- Maintain a safe 3 mph speed.

B. ***Limitations***

The limitations for our product are:

- Will have a maximum capacity of two parcels.
- Cannot operate for more than 18 hours.

IV. Needs Feasibility Analysis

The needs analysis is a systematic way to review aspects of the product to clarify the end-product intent of the client. This will allow the designers to determine what is feasible in the desired client expectations. This will involve multiple client interviews to get an accurate description. Including market and industry research to form an ideal concept from multiple perspectives.

Once this analysis is completed, the next step of the engineering process will be the feasibility analysis. This is formed from the client's description of the ideal end-product. The feasibility analysis determines what can be used in the end product. This will also include what is viable to use from an economic, legal, ethical, and manufacturable perspective. This analysis is used for client verification of the decision-making behind the product.

*A. **Needs Analysis***

A needs analysis is a systematic process used to identify and evaluate the specific needs of a person or specific individual. This analysis helps the designer orchestrate a product that satisfies not just the client, but also the users and themselves. This must be completed by the group before starting on the product itself.

1) Client Interview

For the construction of a product, the client's ideas, wants, and needs for the end product are essential. For this reason, the first thing a designer needs to do is set up an interview with the client. The information we gather from the client allows us to clarify our objectives, user requirements, and constraints. From the survey, we will be listing all the attributes set by the client on TABLE I.

TABLE I. ATTRIBUTES OBTAINED FROM INTERVIEWS WITH CLIENT.

Source	**Attribute**
Interview	The PantherBot should deliver the package accurately to the desired location.
Interview	The PantherBot needs to be elevator friendly.
Interview	The PantherBot must be able to identify what floor it is on.
Interview	The PantherBot should be able to transport two packages at once.
Interview	The PantherBot needs to keep a safe distance from other people.
Interview	The PantherBot needs to keep a safe speed.
Interview	The PantherBot should have a collision prevention protocol.
Interview	The PantherBot should have a locking feature to prevent theft of the package.

To properly understand the design the client desires, the team must analyze each attribute from the client's interview. We can now proceed to create a survey for the intended users to gather their needs as well.

2) *User Survey*

The user survey is to determine the users' needs for our product and determine its marketability.

TABLE II. ATTRIBUTES OBTAINED FROM SURVEY WITH POTENTIAL CLIENTS.

Source	Attribute
Survey	The PantherBot should be reliable.
Survey	The PantherBot should have a convenient form-factor.
Survey	The PantherBot is spill resistant.
Survey	The PantherBot should notify the customer when it has arrived.
Survey	The PantherBot should be customizable for companies.

3) *Team Input*

Our team must be able to add on to the ideas previously mentioned or have our own feedback as to what we would like to have incorporated. This is important to take note of as we are the ones responsible in the production of the product. The results of our brainstorming are shown in TABLE III.

TABLE III. ATTRIBUTES OBTAINED FROM INTERNAL BRAINSTORMING BY GROUP MEMBERS.

Source	Attribute
Team	The PantherBot must have a default secret code in case of malfunction with lock.
Team	The PantherBot should be easy to set up.
Team	The PantherBot should be able to find its own path to the desired locations.
Team	The PantherBot should be self-charging.

4) *Project Attributes*

Now that we have gathered a survey from all parties that are involved in the product, the next step is to combine these attributes. We are going to be combining the attributes provided by all parties on a single table, as shown on TABLE IV. Do note that all repetitions are combined and to be used to construct the problem statement.

TABLE IV. THE COMBINED ATTRIBUTES FROM ALL OF OUR INFORMATION GATHERING METHODS.

#	Source	Attribute	Overlap
1	Interview	The PantherBot should deliver the package accurately to the desired location.	16
2	Interview	The PantherBot needs to be elevator friendly.	2
3	Interview	The PantherBot must be able to identify what floor it is on.	3
4	Interview	The PantherBot should be able to transport two packages at once.	
5	Interview	The PantherBot needs to keep a safe distance from other people.	
6	Interview	The PantherBot needs to keep a safe speed.	
7	Interview	The PantherBot should have a collision prevention protocol.	
8	Interview	The PantherBot should have a locking feature to prevent theft of the package.	14
9	Survey	The PantherBot should be reliable.	11,10
10	Survey	The PantherBot should have a convenient form factor.	9
11	Survey	The PantherBot is spill-resistant.	9
12	Survey	The PantherBot should notify the customer when it has arrived.	
13	Survey	The PantherBot should be customizable for companies.	
14	Team	The PantherBot must have a default secret code in case of a malfunction with lock.	8
15	Team	The PantherBot should be easy to set up.	
16	Team	The PantherBot should be able to find its path to the desired locations.	1
17	Team	The PantherBot should be self-charging.	

After all these attributes were collected, we omitted any repetitions and included only the important attributes for our project. TABLE V. shows the list of all the important, categorized attributes from the client interview, the survey, and the team brainstorming sessions.

TABLE V. GROUPS AND FILTERED OBJECTIVES LIST.

Source	Attribute	Type
Client	The PantherBot should deliver the package accurately to desired locations.	Scalability
Client	The PantherBot needs to be elevator friendly.	Marketability
Client	The PantherBot should be able to transport two packages at once.	Marketability
Client	The PantherBot needs to keep a safe distance from other people.	Safe
Client	The PantherBot needs to keep a safe speed.	Safe
Client	The PantherBot should have a collision prevention protocol.	Safe
Client	The PantherBot should have a theft prevention feature.	Marketability
Survey	The PantherBot should be reliable.	Marketability
Survey	The PantherBot should notify the customer when it has arrived.	Marketability
Survey	The PantherBot should be customizable for companies.	Marketability
Team	The PantherBot should be easy to set up.	Ease of use
Team	The PantherBot should be self-charging.	Ease of use

As a result, from having an internal group discussion alongside our client, we have TABLE V. This list gives us a structure as to what the needs and wants from all parties are looking for from the end-product. With this, we can now derive our problem statement and objectives for the project.

1) *Problem Statement*

The PantherBot is an autonomous robot that can collect and deliver two separate packages—saving time for both the person delivering the order and the customer. The PantherBot can accurately and efficiently find the correct path to the customer. At the same time, it is maintaining a safe distance from other people and a safe speed. Additionally, the PantherBot is elevator friendly, sociable, and odor-free. The PantherBot costs around $750 and is easy to maintain.

2) *Objectives*

5. *Safety*
   - 5.1. The PantherBot maintains an average speed of 3 mph.
   - 5.2. The PantherBot maintains an average of 2 feet from other people.
   - 5.3. The PantherBot implements a collision prevention protocol.
6. *Scalability*
   - 6.1. The PantherBot efficiently delivers the packages.
   - 6.2. The PantherBot is easily programmable for new code locks.
   - 6.3. The PantherBot should deliver the package accurately to desired locations.
7. *Ease of Use*
   - 7.1. The PantherBot is easy to set up.
   - 7.2. The PantherBot is self-Charging.
   - 7.3. The PantherBot needs to be user-friendly.
8. *Marketability*
   - 8.1. The PantherBot has a locking protocol to ensure theft prevention.
   - 8.2. The PantherBot displays when it is ready to carry a new package.
   - 8.3. The PantherBot displays when it has reached the customer and awaiting code confirmation.
   - 8.4. The PantherBot has an insurance protocol in case the package was never picked up.
   - 8.5. The PantherBot needs to be elevator friendly.

8.6. The PantherBot should be able to transport two packages at once.

3) Constraints

1. Cost around $750.
2. Rechargeable battery.

In conclusion, the objective of the Need Analysis section was to gather the needs of the client and users to construct a detailed list of objectives and constraints for our project. We were able to collect this information by having interviews with our client and potential users. This allowed us to refine the overall needs of our project. The PantherBot should receive the order from the person delivering it and only need a code that is provided by the customer. With this code, the PantherBot should be able to locate the customer, regardless of the floor, and wait for the code again to open. If the PantherBot does not receive the code, or is put incorrectly multiple times, it will go to a safe area with employees to have them open it with their code.

B. ***Need specification***

After meeting with our Mentor, and going through a team brainstorm, we gathered our project specifications. Every project has crucial parts for it to be as efficient as possible while meeting the require functionalities. After completing the need analysis our team reaches into conclusion that our robot must be safe and reliable. Therefore, we will be using a set of cameras and proximity sensors to create a redundant scan of the surroundings to avoid obstacles. Our robot will need wheels and motors big and strong enough to carry the drone and its content at a safe moving pace without getting stuck. The specification for our robot is listed as follows:

TABLE VI. PERPECTIVE ATRIBUTES

Objectives	Requirements	Justification
5.1, 6.1	4 DC motors with torque enough to achieve a maximum velocity of 3 miles per hour	The imcorporation of these 4 DC motors will allow PatherBot to efficiently arrive on time to its destination without delays
5.2, 5.3, 6.1, 6.3, 8.5	Proximity sensors, TOF cameras, and GPS	These componets will allow PantherBot to scan its environment and be able to manouver in order to avoid colissions.
6.2, 7.3, 8.2, 8.3	Screes, and numeric keypads	PatherBot will use screens to communicate with the users, and keypads to receive inputs from them as well.
8.1, 8.2, 8.4, 8.6	Aluminum chasis and electric lock	A strong chasis is required so PantherBot can not be forced open and an electric lock so it only opens once the correct code is inserted.
5.3, 6.2, 8.1,	Microcontroler	A microcontroler is used to program every function such as the insertion and verification of the code to open the lock.

Accordingly, the team has determined that to fulfill the project objectives, the product designed needs to comply with the specifications listed below:

Specification summary:

- At least 4 DC motors big enough to provide enough torque to be able to move the whole robot and its cargo to at least 3 miles per hour.
- A set of cameras to set a redundant perimeter around the robot embedded with motion and proximity software.
- A lock and keypad to be able to control the access to the food inside the container.
- A microcontroller to manage the insertion and verification of the code as well as all the software to control the robot.
- A screen to display messages to the users.

Since this is still a fresh idea for a prototype, we need to know the specification of all our components. For example, if the DC motors are too big in size, they either will not fit at all or will fit by taking away space from another piece of equipment. If one or more of the DC motors are too weak, the robot will not reach the places it is needed to reach. If the cameras are bad quality or they will either not cover the necessary area or will no longer be able to scan and detect the incoming obstacles. If the lock of the keypad does not work, the robot will either do not open when it needs to arrive or it will have issues on closing it and anyone would be able to get the package.

*C. **Feasibility Analysis***

The feasibility analysis is crucial in determining whether the project is viable, or if it can be done. The purpose of this analysis determines if the project is worth investing on and if it is feasible from a technological and legal standpoint. This analysis is going to be divided into seven separate factors. The first is the technological factors, in which the team must determine if the technology that is needed to complete the project exists or if they need new inventions. The second is the available resources, where the team will have to do a self-evaluation on their skills and accessible equipment. This will allow them to know if they will have to learn new skills such as operating special programs or buy new equipment. The third is economical factor, where the team will have to determine the economic risk, if they have sufficient funds, and if they can produce a profit. The fourth is scheduling, to see if the team can meet the preliminary and critical design requirements for their project. The fifth is cultural, which determines if the project will be accepted in the local area, they are planning on implementing it. The sixth is legal, where the project cannot violate any laws. Finally, the marketing, where the product needs to be attractive to the public

To produce an acceptable evaluation of all the factors mentioned for the project, we have taken each factor and assigned them a score. Each sub-section will be given a score of importance which will be compared to other parts in order to produce a feasibility score of the project. This final feasibility score will help determine how feasible the project is to produce, or if we will have to change our objectives to make the project feasible.

1) Technical Feasibility

This assessment focuses on the technological aspect of the project. It looks at the currently available technology to ensure it is adequate for the development process. TABLE VII. shows the feasibility score for this assessment. The score we were able to achieve from this assessment is 4.3.

TABLE VII. TECHNICAL FEASIBILITY WEIGHT SCALE AND COMPUTATION

Technical Feasibility			
Attribute	**Score**	**Why?**	**Solution**
Are all the components obtainable?	5.0	All hardware components are easy obtainable.	Purchased all components needed.
Are the needed components readily available?	4.0	Some components may take time to arrive.	If possible, order extra components. Keep our budget in mind.
Will new components need to be created?	4.0	Only existing components are needed.	Pick proper components to build said feature.
Total	13.0		
Average	4.3		

2) *Resource Feasibility*

The resource feasibility analysis focuses on the encompassing ability, knowledge, and skills of the team members. These attributes will determine if the team can create and developing the product. If the team is lacking on a skill or knowledge, they will have to learn this skill in order to develop the project.

In TABLE VIII. where we check for the abilities of the team. It is determined that the team's overall knowledge for the development of the project is more than adequate. This gave the team an average resource feasibility score of 4.0.

TABLE VIII. RESOURCE FEASIBILITY WEIGHT SCALE AND COMPUTATION

Resource Feasibility			
Attribute	**Score**	**Why?**	**Solution**
Will we have to improve our electronic skills?	3.0	We have limited knowledge in electronics as a whole.	Prototyping and reviewing basic electronics to improve our skills.
Will we have to learn more programming skills?	4.0	We have a sound foundation, but will be doing new types of programming.	Take time improve the programming skill we are lacking.
Is there any equipment that we are lacking?	4.0	The team as most, but not all items to complete product.	Buy the equipment.
Will we be needing more people to complete this project?	5.0	We have a full team of five. No more members needed.	No solution needed.
Total	16.0		
Average	4.0		

3) *Economic Feasibility*

The economic feasibility determines the viability of the project on an economical basis. This will help us determine the cost and the possible profit of the project. The importance of this analysis allows us to have a deep understanding of how viable this project is to create, and how much room we have for potential issues, if they arise. TABLE IX. Shows the results after analyzing the cost and resources needed to complete the project. The average economic feasibility to build this product is 4.5**.**

TABLE IX. ECONOMIC FEASIBILITY WEIGHT SCALE AND COMPUTATION

Economic Feasibility			
Attribute	***Score***	***Why?***	***Solution***
Is this project financially viable?	5.0	The total cost of the project is within our budget.	Ensure we don't get close to our budget.
Is there a possibility of going over your budget?	4.0	Some parts are fairly expensive to obtain.	Take proper care of all parts.
Total	9.0		
Average	4.5		

4) Scheduling feasibility

The scheduling feasibility is one of the most important assessments that must be determined. Due to the limited amount of time to complete the project, having an accurate understanding of the time each step of the process needs is crucial. This feasibility will allow us to meet the projects deadline. Being one of the more important factors, it is also one of the most difficult to determine, as there are unknown variables which could occur. In 0We have performed the schedule feasibility to the best of our ability to coordinate proper distribution of our time to complete each major task. The average score for the schedule feasibility is 3.7**.**

TABLE X. SCHEDULING FEASIBILITY WEIGHT SCALE AND COMPUTATION

Scheduling Feasibility			
Attribute	***Score***	***Why?***	***Solution***
Will the development of the project be completed in time?	3.0	We have a lot of development to complete in a short period of time.	Follow schedule, and ensure everyone is keeping up with their tasks. Helping others if needed with their task.
Can we meet the preliminary design review?	5.0	Completion of preliminary design does not require much time.	Follow schedule for proper completion.
Can we meet the critial design review?	3.0	Potential risk if team can complete on time critical design.	Schedule, communicate, and set obtainable intermediate goals to ensure proper management.
Total	11.0		
Average	3.7		

5) Legal Feasibility

The legal feasibility is to determine if the product has any legal implications that could hinder its development. This gives the team a good understanding of the risks that are involved for committing any regulation violations. 0Looks at the legal feasibility of the product and the laws and regulations involved in its development. One of the most important clauses of this analysis to ensure not just the safety of the development team, but also the safety of the consumer. The average score for the legal feasibility is 3.8.

TABLE XI. LEGAL FEASIBILITY WEIGHT SCALE AND COMPUTATION

Legal Feasibility			
Attribute	***Score***	***Why?***	***Solution***
Do we have a complete understanding of all laws and regulations for our project?	3.0	The team lacks complete knowledge of all regulations.	Research all regulations that are associated with our product.
Is there any conflict with our sponsor or mentor?	4.5	Our device has no mentor or sponsor conflicts.	Ensure we continue to have no conflicts.
Total	7.5		
Average	3.8		

6) Marketing Feasibility

The marketing feasibility will assess the appeal of the product to the general public. This will allow the team to determine if the products development will have a prolific acceptance. We will be considering viable markets for possible customers by understanding the existing products with similar functions and their acceptance by the public. 0Looks at the analysis of the marketing feasibility for the project. The average score for the marketing feasibility is 4.8.

TABLE XII. MARKETING FEASIBILITY WEIGHT SCALE AND COMPUTAION

Marketing Feasibility			
Attribute	***Score***	***Why?***	***Solution***
Has the public shown any interest in the product?	5.0	It has already started to generate interest.	Keep promoting our product to continue increasing interest.
What makes our product unique?	4.5	We will have a elevator friend feature that other similar products don’t have.	Highlight our products unique features.
Total	9.5		
Average	4.8		

7) Cultural Feasibility

The cultural feasibility will determine if it will be socially accepted by the public. Depending on the outcome of the cultural impact, it can determine how well the product is adopted. TABLE XIII. Looks at the targeted culture and assess its impact locally and globally. The average score for the cultural feasibility is 4.7.

TABLE XIII. CULTURAL FEASIBILITY WEIGHT SCALE AND COMPUTATION

Cultural Feasibility			
Attribute	***Score***	***Why?***	***Solution***
Will it be socially accepted locally?	5.0	The survey shows that the product is accepted highly locally.	Continue marketing product to ensure intertest is not lost.
Will it be socially accepted globally?	4.0	Although some countries have started to develop their own similar products, few have not started to accept them.	Market product on its benefical features to help positively affect the global cultures interest.
Does our management accept the product?	5.0	No manager resistance.	No solution needed.
Total	14		
Average	4.7		

8) Ranking of the Feasilibility Analysis

We decided to assign each attribute a numerical value which is shown in TABLE XIV. These values were determined based on the attributes level of importance. The table shows the calculated values of the geometric mean and the weight of each attribute along with its normalization. The total sum has been shifted and rescaled to equal one. If an attribute is compared to itself, the value given will be one. When an attribute is compared with another, the team will have to analyze the two to determine which is more critical and assign a value based on that decision. As such, we have determined the following scale of importance:

1 = Equal importance

3 = Moderately more important

5 = Strongly more important

7 = Extremely more important

The calculated geometrical mean value shown in TABLE XIV. is found using the formula:

$$G.Mean = \sqrt[n]{(A_1 * A_2 * A_3 * \ldots * A_n)}$$

Where A is the value of importance assigned to the attribute and n is the total number of attributes. The weight is found using the formula:

$$Weight = \frac{G.Mean}{Total}$$

TABLE XIV. OBTAINING WEIGHTS

	Technical	Resource	Economic	Schedule	Legal	Marketing	Cultural	G. Mean	Weight
Technical	1	1/5	3	1	1/3	1/3	1/5	0.54	0.06
Resource	5	1	5	1	1/3	5	1	1.70	0.19
Economic	1/3	1/5	1	1/7	1/5	3	1/3	0.41	0.05
Schedule	1	1	7	1	1	3	1/3	1.32	0.15
Legal	3	3	5	1	1	5	1	2.17	0.25
Marketing	3	1/5	1/3	1/3	1/5	1	1/5	0.43	0.05
Cultural	5	1	3	3	1	5	1	2.17	0.25
							Total	8.72	

9) Project Feasibility Assessment

0shows the weight value of each attribute and their respective score. These are then used to find the weighted score using the formula:

$$Weighted\ Score = Weight * Score$$

The weighted average is then found by adding all the weighted scores and dividing by the sum of the weights. The following formula is used:

$$Weighted\ Average = \frac{\sum Weighted\ Score}{Weight}$$

TABLE XV. WEIGHTED SCORE

	Weight	*Score*	*W. Score*
Technical	0.06	4.3	0.27
Resource	0.19	4.0	0.78
Economic	0.05	4.5	0.21
Schedule	0.15	3.7	0.56
Legal	0.25	3.8	0.94
Marketing	0.05	4.8	0.24
Cultural	0.25	4.7	1.17
Total	1	29.8	4.16
Weighted Average			4.16

From 0, it is shown that after assigning the values to each respective attribute, the overall score is 4.16. Since the maximum score our project can achieve is a 5, we are striving to pass a 3. This is because it would mean that we are at least 60% likely to have a successful project. The value 4.16 is greater than 3, and therefore, our project has a great probability of being completed.

While our score was reasonably high, being a 4.16, it still indicates that there is a high probability that the project succeeds. Despite this, there are potential setbacks that could delay the development of the project. We have shown that there could be scheduling and technological issues. While our team is strong with the programming department, we might struggle with the electronics as there is only one member that has subject matter expertise. To be able to meet the objectives set for our product, we will have to ensure that we properly manage our time developing the project, while also learning to do it effectively.

D. ***Marketability***

Marketability is a huge aspect of any successful product. Marketing is useful to promote products and services. A good way to put any type of product into the market is finding a need in the targeted market. Needs can also be created to later fulfil it with the desired product. Once a need is identified and targeted, the product's demand will grow rapidly.

Once the need in the market is set, we need to convince that our product is the best in the market so it can be bought by the clients. This is achieved by appealing to the client's logic and emotional side. Meaning that our product should have a simple and smart design. But also, it must connect with the emotional side of the client.

Since our product implements the idea of using autonomous robots to make food deliveries, we will be using two similar delivery robots. Both serve and function in an almost identical manner but are owned by two different companies. One is the six-wheeled ground drone from Starship technologies. The second is the autonomous delivery robot from Kiwi.

1) Starship Delivery Robot

The first project we begin with is the Starship delivery robot. The Starship Delivery Robot is an autonomous six-wheeled ground drone made by Starship Technologies. The product was first created back in August 2014, but the company who builds this robot started in July 2014 [1]. After a few years of testing and development, the company first deployed its first service launch at Milton

Keynes in October 2018. This product fits very good with the idea that we have in mind, as they use most of the features that we want in ours. Although this robot contains many similitudes with our project, we will pursuing a slightly different goal.

a) Project Summary

This robot was design to form partnerships with stores and restaurants to make deliveries faster, cleaner, smarter, and more cost-efficient. The robot can autonomously carry items over short distances. This robot will move at pedestrian speed and weight no more than 100 pounds. Also, can detect nearby objects so ensure safety. For security, it implements a mechanical lock that can only be opened by the recipient with their smartphone app. It is equipped with GPS so it can be tracked by the owners and the users.

Fig. 3. Starship Robot

b) Fundraising Strategy (Rewards)

Starship Technologies first announced a $17.2 million in founding in January 2017. Over the years this company was able to grow in a rapid manner. Every year since Starship Technologies got founded it has managed to collect more than $17 million in funding for the development of the robot. But, in January 2022, Starship Technologies announced a €50 million founding partnership with the European Investment Bank.

c) Technology overview

We separated it into a table and paired each technology name with its function inside the Starship Technologies for the technology used in the Autonomous Delivery Robot. We can see all the information technology in TABLE XVI.

TABLE XVI. STARSHIP ROBOT TECHNOLOGY

Technology	Function
Maximum Speed	6 kilometers per hour
Delivery Radius	4 miles
Operating Time	1260 Watt Hour battery for over 12 hours of driving
Robot Dimensions	697 mm (L) x 569 mm (W) x 571 mm (H) (without flag)
Total Weight	23 Kilograms
Cargo Box Dimensions	400 mm (L) x 320 mm (W) x 340 mm (H)
Maximum load	10 Kilograms
Sensors & Cameras	Ultrasonic sensors, 12 cameras, TOF cameras
Tracking system	Radar, GPS
Safety Feature	Alarm System, Reflectors, Signal flag

d) Description

Starship is a delivery robot is an advanced autonomous device that can carry items over short distances. Starship would partner with nearby restaurants or grocery stores, giving them and their customers the ability to get their deliveries shipped. Both the customer and the store are charge usage fees.

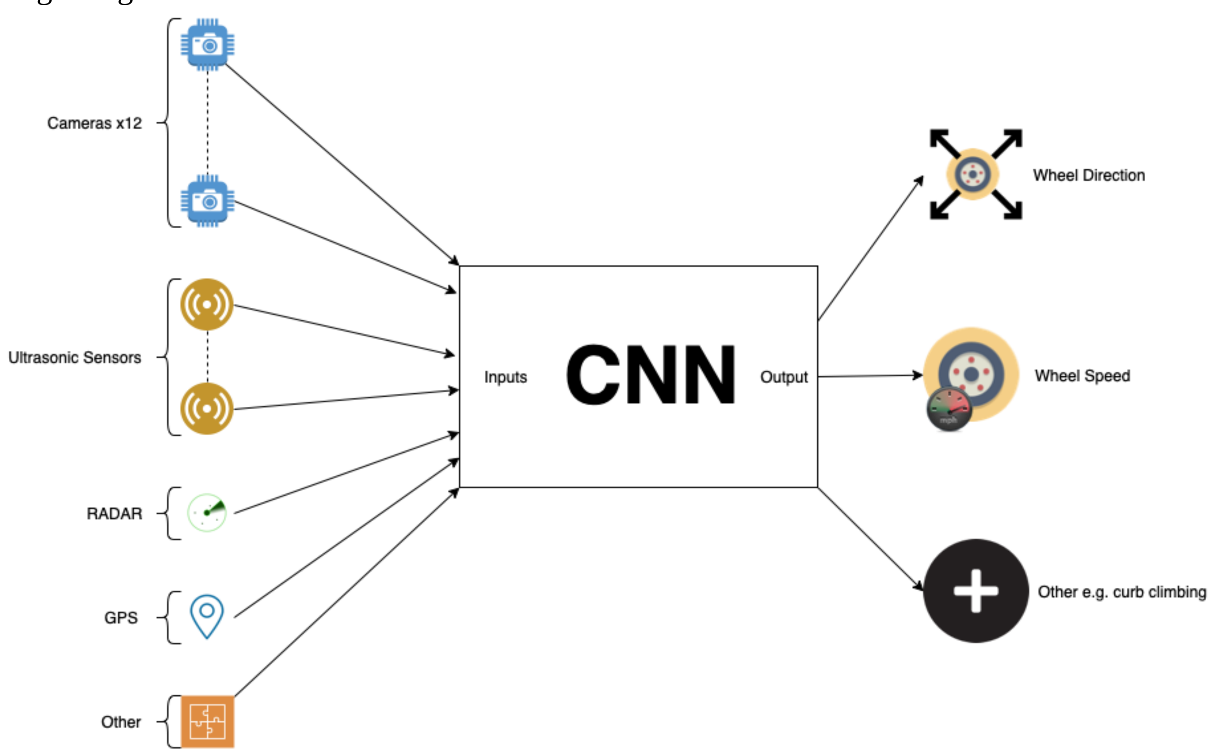


Fig. 4. Block Diagram for Starship Robot

These land drones are equipped with 12 precise cameras and a Time of Flight or ToF camera. These cameras are used to keep the drone in its intended path while avoiding obstacles in its way. It is also equipped with high precision Global Positioning System or GPS to been able to reach from the store to the customer faster than a human delivery. The use of DC motors and servo motors to control velocity and direction of each wheel.

2) Roxo

Roxo is a FedEx delivery robot intended to deliver small packages to nearby locations. Roxo was developed in collaboration with inventor Dean Kamen from Deka Research and Development Corp. Roxo's idea originated from the chassis and working models of iBot wheelchairs by Dean Kamen. His idea was to replace the chair with a compartment big enough to carry small packages to the user's location. Roxo was first unveil doing test in United States of America in February 2019. Then it was first deployed at Dubai, United Arab Emirates in October 2019. [2]

a) Project Summary

The Roxo delivery robot is a ground drone made to deliver within three-to-five miles from the retailer's location. Roxo is equipped with a redundant sensor system to ensure a 360-degree safe and autonomous behavior. Roxo is design to travel through sidewalks, bike lanes and rode sides. This ground robot is also design with 4 powerful wheels and 2 support wheels to assist climbing into sidewalks, stairs, and ramps. The combination of wheels also increases the stability of the robot in difficult inclinations while also setting the center of mass in a more manageable position. [3]

Fig. 5. Roxo

b) Fundraising Strategy (rewards)

FedEx to reach out for future technology invested in this new project in conjunction with Deka Research Development Corp. This investment intents to revolve issues caused by delivery drivers in crowded cities. Delivery drives usually slow down nearby traffic and are related to several parking infractions and car accidents, making the delivery reliable for all the damages. The cost of such damages in a city like New York could be as twenty-seven-million dollars in fines alone.

c) Technology Overview

We separated it into a table and paired each technology name with its function inside the Roxo robot. We can see all the information technology in TABLE XVII.

TABLE XVII. ROBOX TECHNOLOGY

Technology	Function
Maximum Speed	10 kilometers per hour
Delivery Radius	3 to 5 miles
Robot Dimensions	914 mm (L) x 737 mm (W) x 1473 mm (H)
Total Weight	91 Kilograms
Cargo Box Dimensions	914 mm (L) x 737 mm (W) x 1308 mm (H)
Maximum load	45 Kilograms
Sensors & Cameras	LiDAR and redundant cameras
Tracking system	Radar, GPS
Safety Features	Alarm System, Reflectors

d) Description

With a reachability of three-to-five miles this robot can reach a maximum of ten kilometers per hour. Roxo weights ninety-one kilograms and can carry a maximum load of forty-five kilograms in its compartment. In contrast to many other delivery robots, Roxo is a tall vehicle with a maximum height of 1.4 meters tall. Roxo is capable of carrying objects with a volume of approximately one cubic meter in its inner compartment that only open once it arrives, and it is confirm through an app.

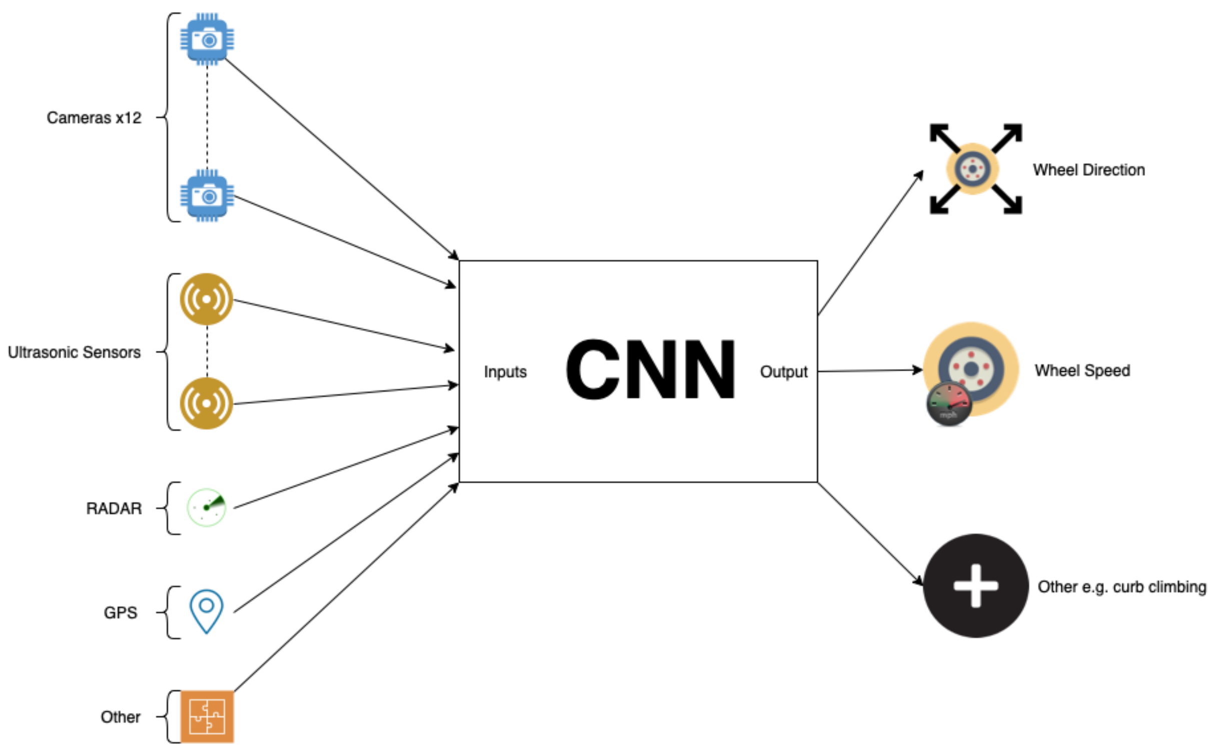


Fig. 6. Roxo Block Diagram

The FedEx Roxo is a delivery ground drone made for same day deliveries. Roxo is equipped with two small wheels and four medium size wheels to help the robot maintain a better balance and to help the robot climb small obstacles. With a system of redundant cameras this robot is able to follow its path while avoiding obstacles in the road. Equipped with radars, GPS, and sensors this robot is made autonomous, but in the need of help it can be overtaken by a human. Roxo also uses DC motor and servo motors to control the velocity and direction of the wheels.

V. Risk Analysis

The Risk Analysis is a crucial step in building a project. When we start considering different risk factors, we start to notice that even the smallest choices can highly affect the integrity of the product. Like Need Feasibility Assessment, we must divide the risk into the same categories. By analyzing the risk our team will be able to find solutions to most problems by either preventing them or finding a standardized solution depending on the cause of the risk.

To properly display the risk, we must create a fishbone diagram made from the risks, the risk exposure matrix, and the actions that must be taken in the case of a risk happening. Depending on the severity of the risk, some actions must be taken immediately but others could be implemented later.

A fishbone diagram, as its name suggests, mimics the structure of a fish skeleton. The main problem is placing the fish's head. Then each branch will represent each of the major causes of the problem. Similarly, each sub-branch would represent a more specified cause. Fishbone diagrams are mainly used to find plausible causes on a project to prevent or react in the case of one of these problems happens.

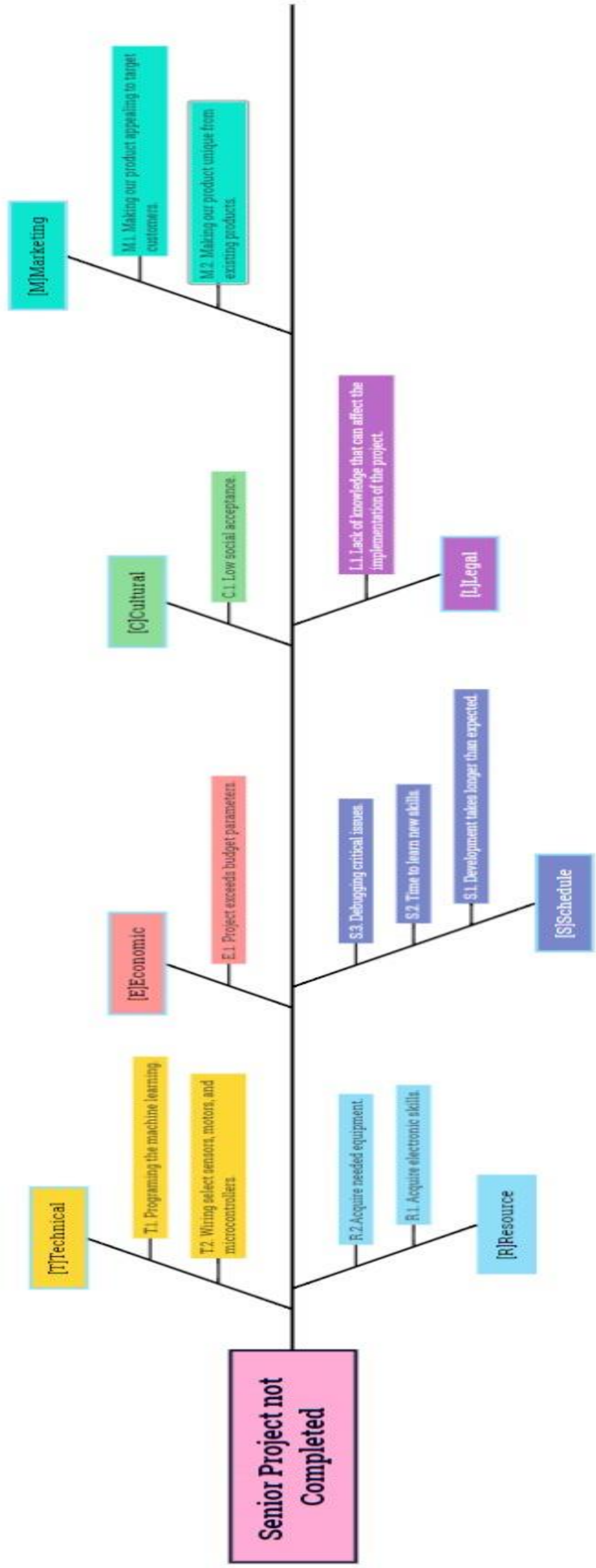


Fig. 7. Fishbone Diagam

Fig. 7. shows the fishbone diagram, which presents the risks the project can have in a fishbone diagram. All these risks, if not handled properly, can lead to not completing the development of the project. In technical we will have to design, program, and debug a machine learning algorithm that will be time-consuming even with no issues. In resources, we run the risk of having to learn new skills for both electronics and programming. In economics, if we run into too many issues during development, we can exceed our limited funds. In schedule, we can run into the time available for development. In cultural, we have a major risk that the product will not be as socially accepted as we expect. In legal, if we are not properly informed with the state or city regulations, we can fact legal risk with public safety in an elevator. Finally with marketing, we run the risk that tour product isn't as accepted as other products with similar functions.

Furthermore, with the fishbone diagram, we were able to create a list with all the plausible causes and their sub-causes.

1) Technical

T.1 Programming machine learning.

T.2 Wiring select sensors, motors, and microcontrollers.

2) Resources

R.1 Acquire electronic skills.

R.2 Acquire needed equipment.

3) Economic

E.1 Project exceeds budget parameters.

4) Schedule

S.1 Development takes longer than expected.

S.2 Time to learn new skills.

S.3 Debugging Critical issues.

5) Cultural

C.1 Low social acceptance.

6) Legal

L.1 Lack of knowledge that can affect the implementation of the project.

7) Marketing

M.1 Making our product appealing to target customers.

M.2 Making our product unique from existing products.

With the information, we have collected from the list of plausible cause and their sub-clauses, the team can conduct a risk assessment by creating a Risk Exposure Matrix TABLE XVIII. shows the Risk Exposure Matrix, where the previously defined risks are categorized into importance and likelihood of occurrence. The risks that are classified under Class I risks do not require active management. The risks that are classified under Class II risks require active management. The risks that are classified under Class III require pro-active management. The risks that are classified under Class IV requires urgent and immediate attention.

TABLE XVIII. RISK EXPOSURE MATRIX

Likelihood of Happening				
	Very Likely	**Possible**	**Unlikely**	**Severity**
Class IV	•	•	• [L.1]	• Catastrophic
Class III	•	• [T.1][S.1]	•	• Severe
Class II	• [S.3]	• [M.2][C.1]	• [R.1]	• Moderate
Class I	• [S.2][M.1]	• [T.2]	• [R.2][E.1]	• Low

From TABLE XVIII. . the primary factors and risks revolve around the legal, technological, and scheduling problems. The main aspect of technological risk is associated with schedule risk. If we are unable to create the machine learning algorithm in an appropriate amount of time, it could delay other steps in the development of our products. As for our legal risk, if we do not follow all regulations that are demanded, we could be forced to delay development until we resolve the legal dispute. It is unlikely that we will run into risks regarding resources, our economic support, marketing our product, and appeasing our local culture.

To combat these risks TABLE XIX. shows actions to minimize the risks in our Risk Exposure Matrix. In this table, we show solutions to the more pressing issues such as our technological completion of the machine learning algorithm. It also shows solutions to smaller issues such as having to find any extra equipment we might be missing.

TABLE XIX. ACTIONS TO MINIMIZE RISK

Actions	
[E.1]	• Create an emergency found for extra resources
[R.1]	
[T.2]	• Double-check every connection
[R.2]	
[C.1]	• Understand the targeted market
[M.1]	
[M.2]	• Find a unique feature to incorporate
[S.2]	• Dedicate time to learn the needed skills
[L.1]	• Research about local rules and laws
[T.1]	• Check on every stage on the building process
[S.1]	
[S.3]	

In conclusion, we have found potential risks in the development of our product. These risks need to be monitored and if arise, need to be dealt with immediately. The most important being L.1, T.1, S.1, S.3. Aside the ones mentioned, all other potential risks will need t be considered to have a smooth development process

VI. OPERATING ENVIRONMENT

An autonomous food delivery robot has to move on streets and within societies to deliver the orders, which means it must face different environmental conditions and climatic changes. The top concern is the safety, security, and efficient delivery of food which can be affected by mechanical disabilities or environmental changes. Luyao et al. discussed in their recent paper that autonomous delivery robots or vehicles are consuming either gas or electricity, which causes greenhouse gases emission to some extent [1]. Most of the robots are environment friendly, as the autonomous food delivery robot uses less energy and produces less waste in terms of pollution. But harsh environmental conditions like wet or muddy terrain, radiations, dust, temperature (cold or hot), humidity, corrosion, shocks, vibrations, etc., can significantly impact the robot [2]. The sensors installed in the robot are affected mainly by the climatic changes, like some sensors do not work in cold temperatures, some not in dust, etc., which results in not false observations and wrong data collection. This interruption in robots' work due to the environment can cause inefficient and wrong results.

Matthias et al. presented an intelligent execution monitoring system for robots based on the known structured environment. However, still, they face precision issues in robot results due to unexpected operating environment changes [3]. Using Artificial Intelligence (AI), the sensory interpretation model was designed and implemented, taking into account temporal environment changes, and proposing and implementing a suitable, realistic solution. In the case of the panther bot, environmental conditions have many impacts as it has to move on streets where there can be high or low temperature, dust, and noise pollution, wet or muddy terrain, and many other possible conditions [2]. The sensors within the robot should handle the environmental changes and tackle them without affecting the results. As the main concern is the safety of the food, thus the robot body should provide security to the food and the sensors installed in it.

VII. INTENDED USERS

The accurate specification of the intended users and uses is an important part of a project's design. We must first determine who the target consumers and uses are in order to make informed and clear product design selections. This data is then collated and used in the product development decision-making process to help reduce the number of potential factors to evaluate.

A. ***Intended Users***

The intended users for the PantherBot are the faculty and staff on campus. With more companies exploring the option of food delivery via robots, the chances are that there will be a reduction in human contact or interaction within the food delivery industry. The introduction of the PantherBot will improve delivery productivity by accurately calculating the route based on the location and satellite imagery, which can improve the delivery time and aid contactless delivery.

B. ***Intended Uses***

The PantherBot is designed to navigate around campus, reduce greenhouse gas emissions when delivering food, and provide more inexpensive delivery choices than traditional options. The storage compartment will be insulated to ensure that the food remains at a constant temperature while being able to carry multiple packages. A lock-in mechanism will be in place so that the food can only be accessed by the intended user.

VIII. BACKGROUND

The background section will provide readers the necessary knowledge about other options in the market, it will explain their technology, capabilities, and functionality. Finally, it will contrast these options that represent the best of the delivery systems in the market to PantherBot the best solution to the delivery problem.

Today automation is taking over the world. Everything people interact with has a computer inside it, each day this computer becomes more powerful and more efficient at the task it is trying to achieve. This phenomenon is occurring in all industries, from your lights turning on as you walk into your house, to a full self-driving car that can manage traveling point to point with little to no human interaction at all. Even though these technological advances are improving the lives of people, it is not clear how it will impact the lives of those working in industries being taken by these automated systems. According to [9] 400,000 jobs were lost to automation in U.S. factories from 1997 and 2007. However, this number keeps growing and accelerated as industries were trying to social distance workers during the COVID-19 pandemic. In this same article it is stated that a group of economists estimated 42% of jobs lost during the pandemic will not come back. During this pandemic many of the people who lost their jobs due to the acceleration of this change started working for the delivery industry mainly Uber and DoorDash [10]. There are over one million workers in the delivery industry as of 2022 [11] and this number is expected to grow at a rate of 5.8% during this year. Therefore, it is inevitable to ask: Is this change happening too abruptly? What would have happened if the delivery industry was taken over by delivery robots? How can automation be integrated in society? In this section, three projects that are avoiding these questions will be discussed and a solution to these questions will be provided in the concluding part of this section.

A. ***Starship – Delivery Robot***

Starship launched in 2014 by the cofounders of Skype Ahti Heinla and Janus Friis [12]. Their main project is the Starship Delivery Robot.

1) Project Summary

This robot uses a mixture of computer vision and Global Positioning System (GPS) to go from point to point within a 4-mile radius and deliver any package that can fit in its compartment and is about 20lb without human interaction. This system is currently being used in many university campuses and is being tested in cities completing over 2-million autonomous deliveries.

2) Technology Overview

The computer visions is performed by using and array of twelve camaras, ultrasonic sensors, radar, and neural networks. It is able to perform obstacle detection and avoidance and able to recognize animals, pedestrians/cyclists, and other delivery robots. It goes at about 4mph, can go up curbs and is able to operate in rain and snow. It uses a mobile application to request deliveries which allows only the owner of the package to monitor the journey of the robot and open the lid to access its content. In Fig. 3 the Starship Delivery Robot is depicted along with its dimensions [13].

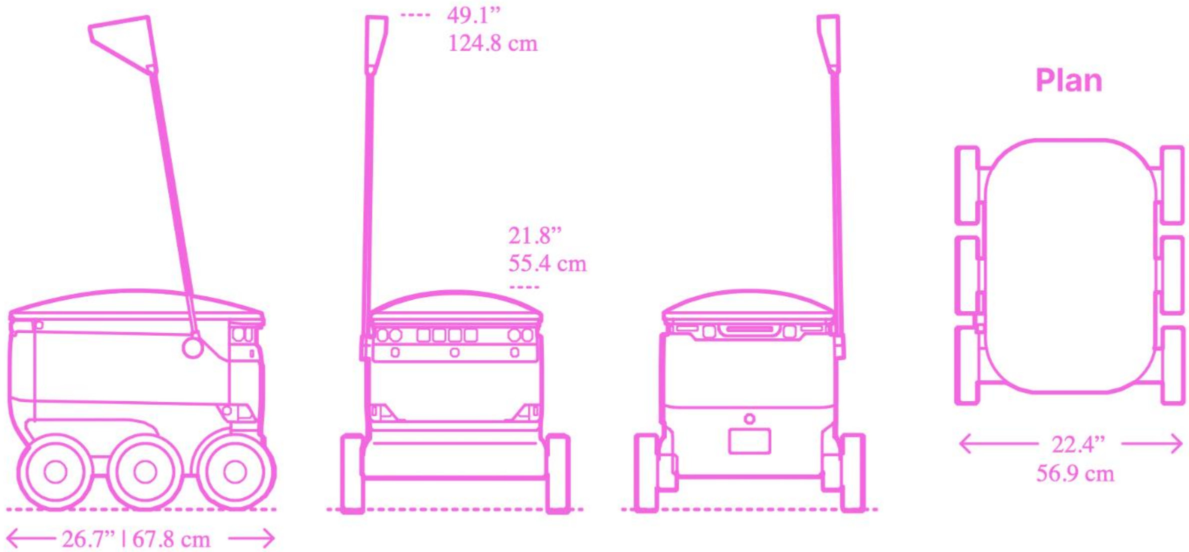


Fig. 8. Delivery Robot with Dimensions

3) System Description

Since most of this project is closed source, it is difficult to find specific details about this project in their website it is specified that proprietary mapping techniques are used to ensure the accuracy when navigating through spaces. However, an understanding of neural networks can help figure out the inner working of this system.

Every neural network (NN) like many systems consist of inputs, these inputs are called features and are provided by sensors to the system. In this case it is possible that the features include GPS, vision data captures by the twelve camaras, distance measurements calculated by the ultrasonic sensors, speed information derived by RADAR, and many other combinations of those main features, such as combining vision and distance to have a ground level feature that allows the robot to go up and down curbs. The most common of these NN used for navigation are convoluted neural networks (CNN) which can take image data and transform it into navigation commands such as direction and velocity. For this to happen successfully the CNN has to be trained, meaning that the system has to adjust how much speed and in which direction to go in for every different scenario. It is possible to do this in three ways supervised and unsupervised or a combination of the two. We suspect that for this project the developers used a combination of the two. First, by having employees that would monitor these systems and flag when they did something wrong (supervised) and later once the system was more stable use system reports such as crashes or malfunctions to flag and adjust the CNN. This is depicted in Fig. 4.

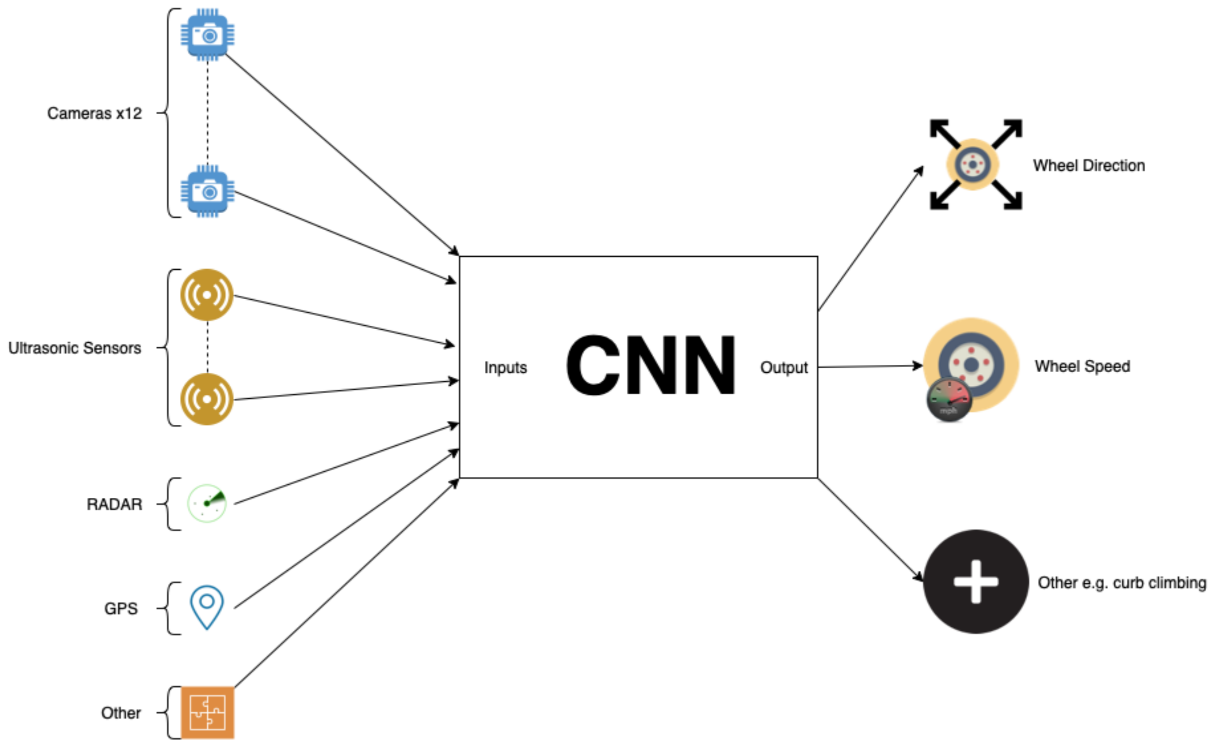


Fig. 9. Starship Delivery Robot Neural Network

This is the workings of the CNN when its fully trained. For example, during training if the wheel speed indicates that the robot malfunctioned this would be flagged, and it would be used to adjust the relevance of the sensor inputs. This process happens over and over until the weight, relevance of the inputs is optimized.

*B. **Kiwibot 4.0***

Kiwibot launched in 2017 and introduced their first version of the Kiwibot a robot that would deliver food with the help of a human controlling it remotely. In 2021 they announced Kiwibot 4.0 an all-new semi-automatic food delivery robot that can perform the same tasks with little to none human intervention.

1) Project Summary

This Colombian company started at the University of California, Berkley has put major emphasis on the robot social skills giving it speakers and an expressive face that react to humans around it. Currently they swarm various university campuses in California as well as some areas in the streets of Miami, Los Angeles, Washington, and other cities [14].

2) Technological Overview

The Kiwibot 4.0 navigates its environment using a similar method to the Starship Delivery Robot. However, it uses a more diverse suite of sensors, like the previous delivery robot it makes use of GPS and cameras, in this case three frontal cameras and a rear wide angle 180-degree camera, it also takes advantage of a full range LIDAR sensor alongside proximity and cliff sensors. It is capable of delivering 2 food orders at a time over short distances. In Fig. 5 the Kiwibot 4.0 is depicted along with its dimensions [15]

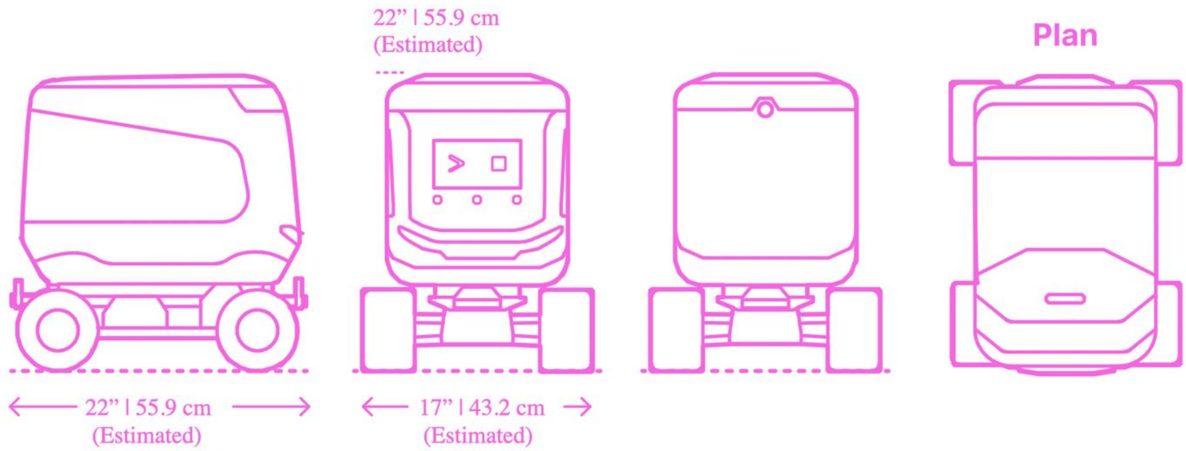


Fig. 10. Kiwibot with Dimensions

3) System Description

Since this project is closed source as well information about its inner workings are difficult to find. However, we suspect that the model for the overall navigation continues to be the same but now having more features added such as the LIDAR sensor this is all powered by NVIDIA. Furthermore, we hypothesized that a different system is used for the user interaction that is hardcoded based on the input of some sensors, if a person is detected in front the robot might say “Hello”, events, if the lid is opened it might say “Get your food”, or time, it might say “Good morning”, or “Good afternoon” based on its internal time tracking system. A diagram of the updated system as well as the new system are presented in Fig. 6 and Fig. 7 respectively.

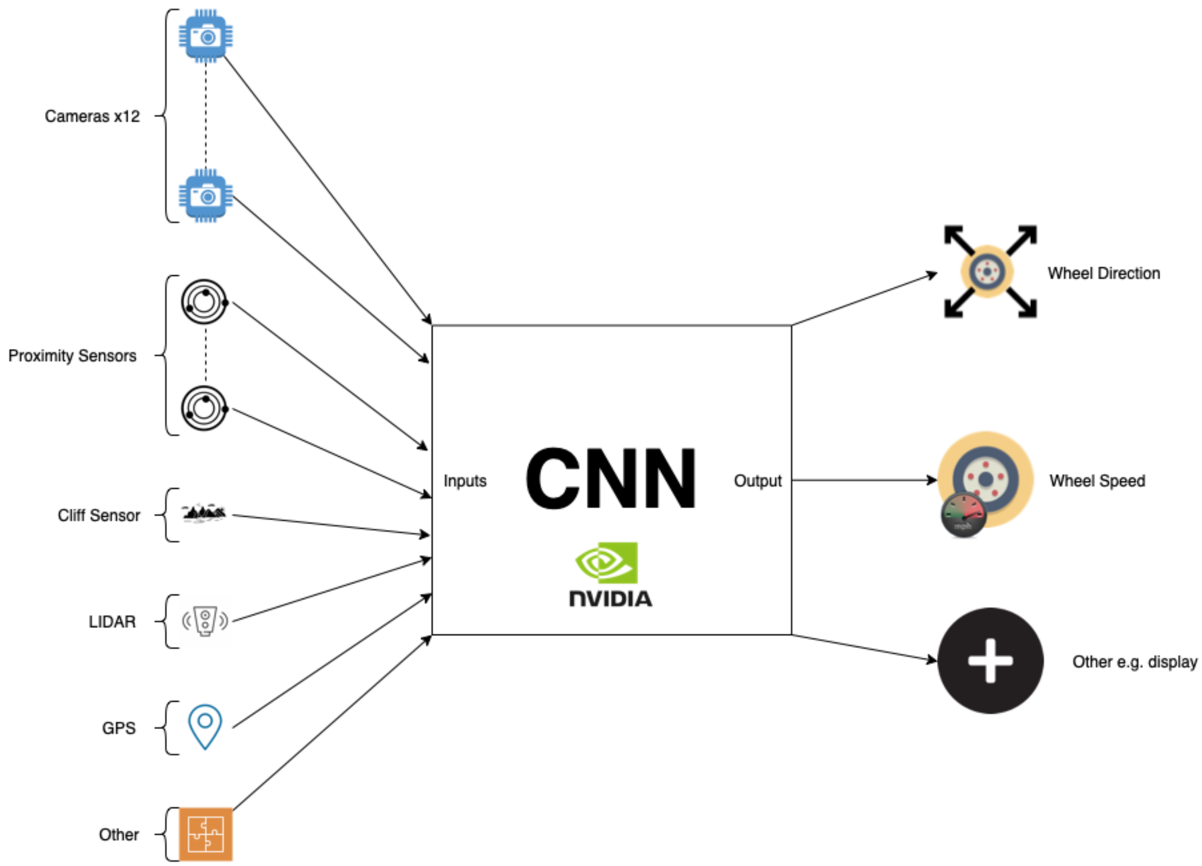


Fig. 11. Kiwibot Neural Network

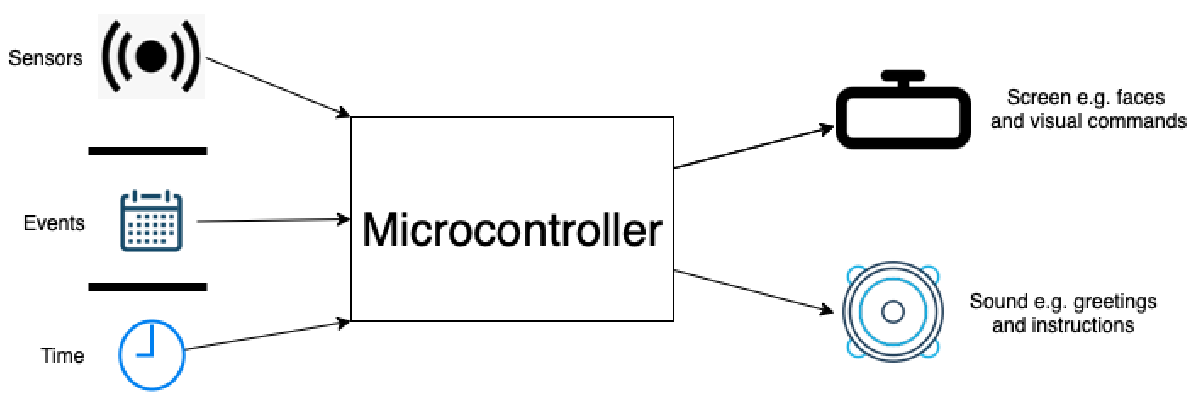


Fig. 12. Kiwibot Social Interactions Controller

These diagrams (Fig. 6 and Fig. 7) depict how the full system works only using two main processing units that could communicate over any protocol such as UART, I2C or SPI. All of the specifics of this systems are hidden, and this is the best model that might represent the complete system.

C. *Savioke – Relay Botlr*

Savioke was launched in 2013 by Steve Cousins, who back in the day was the CEO of Willow Garage the inventors of Robot Operating System (ROS) [16].

1) Project Summary

Ten months after the company was founded, they presented their delivery robot as a room service alternative for hotels. Relay uses ROS an open-source operating system for robots and is currently operating in over 100 hotels which completed over 1-million deliveries [17]. It is able to carry things like toothbrushes, towels, or even small orders of food such as coffee cups.

2) Technological Overview

Relay is approximately 3ft. tall, weighs less thank 100lb has a carrying capacity of 2 cubic feet and travels at a human walking pace [18]. It uses 3D depth cameras, LIDAR, and sonar for navigation and collision avoidance. Currently it is able to access elevators that are connected to the network and can navigate and entire hotel with just one training session. It also has a touch screen that can be accessed to send the robot to a particular room number and retrieve the contents from inside. In Fig. 8 one Relay robot is depicted with the name of A.L.O.

Fig. 13. Relay Robot (A.L.O)

3) System Description

Even though ROS the operating system of this robot is open-source the working specifications are closed-source. Therefore, even though it is running of open-source software we need to assume the inner workings of the full system. Since this robot needs a one-time training session it should not be using neural networks to map and navigate its environment, instead it is mapping and saving its traces in order to make them again at a later time. Relay might be using machine learning for object recognition and avoidance. For example, go slower when it detects people. However, it should not be relaying on it to know where it has to go. In Fig. 9 this training step is shown.

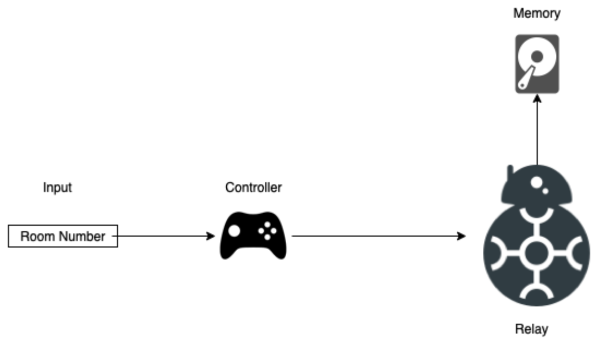


Fig. 14. Relay Training

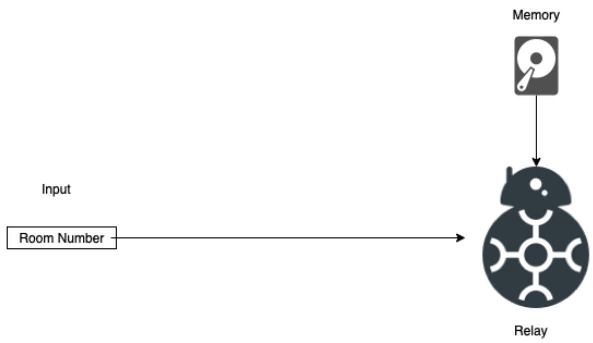


Fig. 15. Relay Operation

The input, room number goes to the controller and a human using the controller takes the robot to that room. The robot saves this trajectory along with the different decisions the human performed, such as which elevator button to press, in memory. After Relay is trained for all the room numbers the controller is removed, Fig. 8 and the information of where the room is located is retrieved from memory and navigated to it by the robot.

IX. INTELLECTUAL PROPERTY

Intellectual property is of great significance to research before a designer embarks on a particular invention. Patent infringement causes several difficulties during designing and inventing a model. It is always preferred to work on intellectual property before concluding some results. This helps in avoiding lawsuits that are helpful for the investors too. Patent protections are of great importance as they help upcoming designers and engineers grow and develop while limiting the rouge competitors from copying the designs. With patent protection, investors invest in or fund the projects more at a superficial level of risk. Thus, learning about the patents before inventions is more beneficial in the long run and to become successful in the future.

The relationship between a robot and intellectual property is dual. It can qualify for patent protection based on its appearance and designed structure. Generally, the robot may be regarded as an object of intellectual property. This section discusses the patents related to the project 'Autonomous Food Delivery Robot,' filed in the United States (US). This section discusses three patents: *Autonomous delivery platform, a Mobile robot having a collision-avoidance system for crossing a road from a pedestrian pathway, and a system and method for securely delivering packages to different delivery recipients with a single vehicle*. These patents are from Google's Patent search engine with settings configured to US patents offices. The main objective was to search for recent designed, developed, and published work on autonomous delivery robots. These patents are discussed as follows:

*A. **Autonomous delivery platform (Patent # US9256852B1)***

The inventor of this patent was Jussi Myllymaki. The patent was granted on July 01, 2013, described below [19].

1) Summary

The patent involves computer programming products and a system for autonomous packages delivery-based road vehicles having secured and access subsystems. It receives the destination and the compartment access information about the receiver and the package; thus, drives to the destination while securing the package. The compartment access information is primarily the Personal Identification Number (PIN). The access subsystem involves the PIN pad for the receiver to receive the package after entering the same PIN into the access subsystem. Some embodiments have positioning systems installed for the destination location. Several embodiments include the payment information into compartment access information/subsystem for payout at delivery service. Mainly have the payment card reader for receiving the payment information.

Several other embodiments have dynamically updatable destination information capability, which allows updating location dynamically, at least in part on the reported location of a mobile communication device associated with the access information. Various other embodiments have Near Field Communication (NFC) based information communication service through NFC initiator and target (receiver). This patent involves all these embodiments'-based delivery platforms. An illustration of the overall system is presented in Fig. 11, which depicts the autonomous delivery platform design.

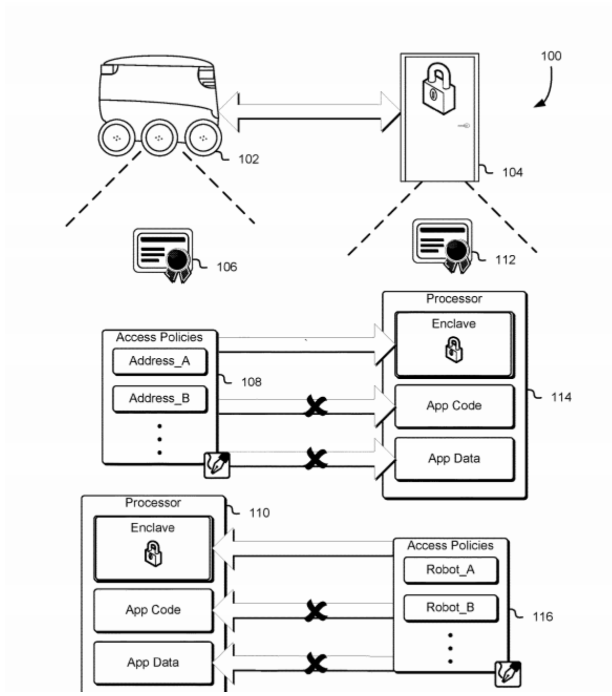


Fig. 16. Autonomous Package Delivery Platform [19]

The patent overview can be briefed from Fig. 11, and it can be observed that different embodiments are combined, using a digital key to gain access to the package drop off destination. These embodiments have three essential parts: adding capabilities to the access subsystem for PIN identification, positioning system, payment card, etc.

2) Claims Summary

The patent has a total of eighteen (18) claims, but the ones that are directly related to our project include:

An autonomous road vehicle operative to receive the first destination and to drive toward the first destination. A positioning system operative to determine the location of the package delivery platform. Securing a package, associated with the first destination and a first compartment access information, in a first securable compartment of the securing package system

Non-Infringement

The project is not similar to this patent as the panther bot will be programmed and instructed to enter the elevator, too, and it will be able to select the floor on its own according to the provided location. This is more advanced as building delivery can also be delivered with efficiency through the panther bot. Moreover, there is no payment setup; the payment will be through UberEats however the delivery man will enter the code (PIN) to provide the robot with the correct delivery zone.

B. *Mobile robot having collision avoidance system for crossing a road from a pedestrian pathway*

The inventors of this patent were Ahti Heinia, Risto Reinpold, and Kristjan Korjus. The patent was granted on September 05, 2017, described below [20].

1) Summary

The patent introduces a mobile robot-based system for collision avoidance near or on the road. The system senses the road conditions and initiates crossing the road if the conditions are suitable for crossing. The sensors continuously keep sensing the road while crossing the road to avoid accidents. In the case of hazardous, the sensor and ultimately the system/robot will initiate the collision avoidance maneuver. The invention is for the package delivery robots operating on pedestrian walkways. They can be configured to navigate surroundings outdoors at least partially autonomously. For localization, computer vision techniques can be used. Some embodiments involve reverse braking and reverse acceleration in collision avoidance maneuvers. Other embodiments generate audio and one video signal in case of collision, whereas some involve cameras that examine the traffic status and indicate accordingly.

Several other embodiments include a stereo camera, radar, and ultrasonic sensors to identify worse conditions. However, several embodiments involve examining the traffic light indicator's status through sensors and visual cameras. Few embodiments include sensing the moving objects using sensors like a pyroelectric sensor. These objects include not only all vehicles but also all living beings. Some embodiments include the adjusted threshold (distance) value and initiate the alarm if any object bypasses the threshold value. An illustration of the patent is presented in Fig. 12.

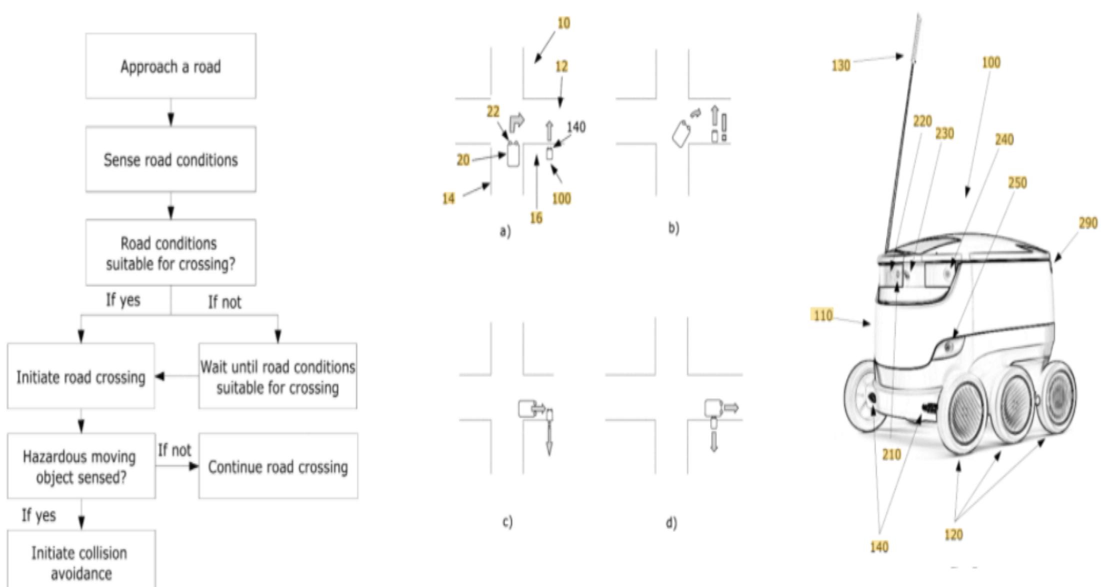


Fig. 17. Mobile Robot with Collision Avoidance System [20]

Fig. 12 shows the flow chart of the system through which different embodiments work. Along with this, a visualized delivery system and its working on the road can also be observed. The working of the mobile robot will be according to the flow chart. It will take actions based on the sensed readings.

2) Claims Summary

The patent has a total of twenty-six (26) claims, among which the relevance to our project are listed below:

The mobile robot avoids collisions while approaching the road from the pedestrian pathway. The mobile robot also senses the road conditions via its sensors. The mobile robot then initiates a collision avoidance maneuver to determine a hazardous moving object.

3) Non-Infringement

The project design concept is similar but not the same as the patent. The robot includes ultrasonic sensors and several other sensors, cameras, and an alarming system to avoid collisions. They will work in almost a similar format but with advanced and improved features.

C. System and method for securely delivering packages to different delivery recipients with a single vehicle

The inventor of this patent was Ahti Helnla. The patent was granted on September 16, 2021, described below [21].

1) Summary

The patent discusses the mobile robot's ability to deliver two packages at a time to multiple recipients (receivers). The robot will approach the first recipient through its location and then the other. The sensors installed within the robot verify and confirm the delivery of the first package to the first recipient and the others. This is more related to the secure delivery of multiple packages to multiple recipients for time-saving. Some embodiments remove the first package details after and the second after its delivery. Several embodiments measure first data reflective of the presence or absence of each package along with their ID that is either a barcode or a QR code. They also take in the package size, dimensions, weight, visual characteristics, Radiofrequency (RF) tags, etc., to easily communicate with the component and deliver it properly.

Some embodiments communicate with the servers continuously about the package details and update the server with the package status after delivery. Several other embodiments include the robot's processing component to process sensor data (package-related data) to determine the subsequent course of action for the robot. This helps in navigating to the delivery location of that package through the GSM modules and ultrasonic and Lidar sensors. Sometimes, a stereo camera is also involved for a better view and up-to-date package information. An illustration of the patent is presented in Fig. 13.

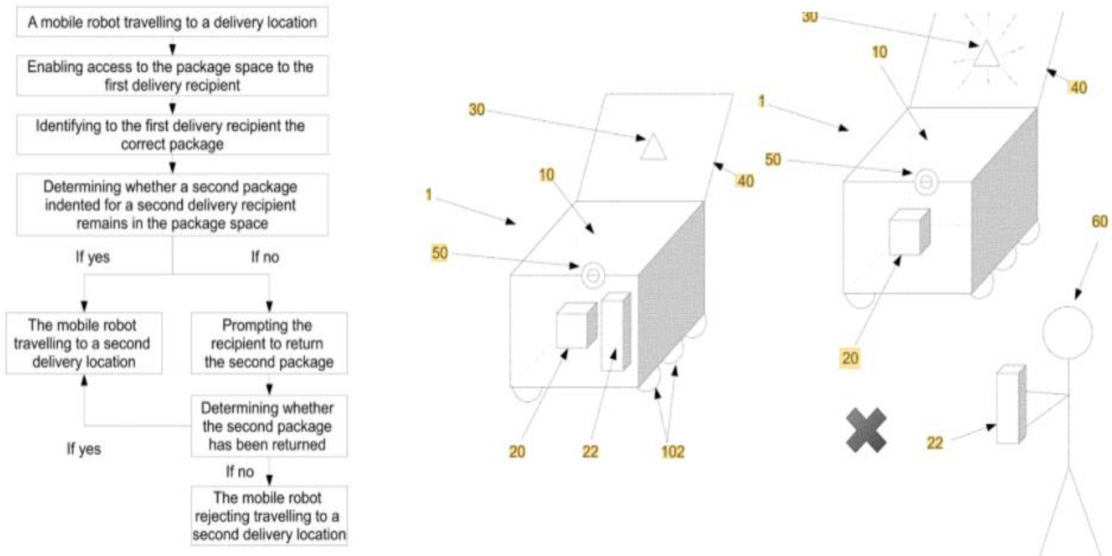


Fig. 18. Multiple Package Delivering Robot [21]

Fig. 13 depicts a mobile robot that can deliver multiple packages simultaneously. The flow chart depicts the robot's working to deliver the first package and later to the other.

2) Claims Summary

The patent includes 22 claims, among which the ones relevant to our project are:

A mobile robot with at least one package space. A mobile robot that enables package delivery and verification from the recipient to the server.

3) Non-Infringement

The patent includes several claims, but the one relevant and somewhat similar to our project is the concept of delivering more than one package in one route. This feature is helpful as it is time-saving and has more minor concerns. The robot does not have to be exposed to the environment every time. It can save time by delivering multiple packages to multiple recipients in just one go. This feature of the panther bot enhances efficiency and feasibility.

In conclusion, the four patents discussed above are relevant to the project. Moreover, there will be no patent issues by distinguishing our design from the patents. The real world and the simulation within the PantherBot should be closely matched, by measuring the precise location of the operating environment and modeling it in the software.

X. Globalization

PantherBot is a project that will be used in a lot of big buildings around the world. Big buildings may usually be complex and hard to traverse, which can be an issue for people that are not familiar with the structure of the building. PantherBot needs to be able to go through the building without any difficulty. The robot itself will be programmed with different routes to move in the building. The robot will also have sensors to make sure it can move through each hallway without getting stuck by obstaclescle on its way. Starting at Florida International University Engineering Campus we have hopes to expand to more buildings in the area of Miami and, at a point, globally. The global expansion would spread throughout many places, like Canada, England, and China. More specifically, we are looking into cities with big hospitals and university campuses. Our main concern in terms of globalization is the acceptance of this new robot to substitute for the old human delivery process. Taking this into consideration, we must be sure that the PantherBot is as human-friendly as possible.

As mentioned before, the current delivery system is becoming obsolete. Initially, these robots were fully controlled by humans, but as technology advances, there are becoming more autonomous with time **Error! Reference source not found.**. Therefore, now more places globally are implementing similar autonomous and semi-autonomous robots to perform this task. The goal of this project is to increase the efficiency of the delivery process made by humans and other robots. PantherBot will serve as a revolutionary steppingstone for autonomous delivery robots. PantherBot would aid humans to get their deliveries with a higher level of time efficiency for the delivery person and the user.

Considering this project from a global perspective, PantherBot will challenge many cultures. Our project will introduce its own way of making deliveries using technology. Many places have started to implement similar drones to operate in streets but almost none of them work inside of buildings. Therefore, places, where PantherBot gets implemented, would have to culturally adapt to have a robot roaming around their work or study areas. Even though PantherBot will collide with some cultures, it will overall improve systems wherever it gets implemented.

*A. **World Trade Organization (WTO)***

The World Trade Organization (WTO) is an international organization that deals with global rules of trading between countries. Trading has one of the most important characteristics that shape the globe. Therefore, many nations throughout the years have opted for treaties that would ensure a more secure and predictable way. This is the foundation of many organizations to set a more standardized mechanism of trading across the world.

Founded in 1995, integrated 160 representatives all from different countries to conduct various sets of standards regarding trading in a diplomatic manner. Which itself accounts for approximately 98% of all international transactions **Error! Reference source not found.**. The WTO serves as a median to solve or prevent conflicts over international trading.

Our project intends to use all WTO regulations as a guide for international trading. These regulations include agreements like Most-favored-nation (MFN), which states that any country or trading entity should be treated as equal. National treaty states that foreign and local trading entities should be treated as equal. Predictability indicates that there must be transparency in every trade. Free trade will be achieved gradually through negotiation.

*B. **Trading Barriers***

As with anything trying to globally spread, our project will encounter many difficulties. One of these difficulties would be trading barriers. Trading barriers limit trades from being done all over the world. These barriers will make any product very hard to be traded across the entire world. Such barriers are made by regulations in each country. Depending on the country, each regulation would somewhat differ or be completely different. PantherBot might collide into one or more of the trading barriers because of the battery needed to work, or maybe even the software or wireless connections.

Over the past few years, one of the main limiting factors was the Covid-19 pandemic. This event caused trade to be reduced almost entirely when the pandemic was at its global peak **Error! Reference source not found.**. Also, with the current situation in Europe between Russia and Ukraine, new fees could be imposed to trade in different countries. Another barrier could be norms made from climate change to minimize pollution and ozone damage.

Without WTO and ISO, trading could be very inefficient or even not functional at all. This organization works closely with all the countries to ensure that trades are done following the laws of both countries, the sender, and the receiver.

*C. **Collaboration Tools***

Out PantherBot team is composed of five aspirants of computer and electrical engineering. Utilizing various collaboration tools, our team was able to maintain active communication throughout the entire project. Among the tools we used, WhatsApp Messaging was the top mechanism our team used to communicate with each other. Another huge resource our team used was the Florida International University Engineering campus. At FIU we were able to do regular team meetings as well as work hands-on with the robot. Another great tool that needs to use to meet and communicate with each other was through Zoom meetings. Zoom allowed us to remotely work on a project while sharing the screen live, share files, and speak in real-time.

The Combination of all these collaboration tools will lead our team to a successful path in designing and building this project. With the material thought in class by our professor and our mentor during we were able to successfully come up with the idea of the PantherBot, as well as analyze its progress at any time.

*D. **International Success***

The use of autonomous delivery drones is increasing over the last few days. As humans, we try to improve existing ways to do things. Many buildings around the globe have started to become more technological as time passes. Therefore, a huge number of buildings in popular cities have opted to implement drones to make the deliveries inside of such huge buildings. We have collected information on successful similar delivery drones in different places to assure a good design.

We decided to find an interview with an autonomous delivery robot company. This company is the Ottonomy Inc. with Deepak Gupta, their Chief Revenue Officer. During this interview, he spoke about the benefits of implementing these autonomous robots for everyday consumers. He explained with an example of a person in an airport not wanting to lose their seat to wait in line to order their food. With this problem in mind, he continued to explain how it will increase efficiency for companies and the cost for consumers. He spoke on how this continuous wave of development in autonomous technology will only continue to grow as its popularity grows **Error! Reference source not found.**.

We did a second interview with the manager with Dadeland Mall regarding the autonomous robot they use, Cartken's autonomous robot. We asked him if these robots had made a positive or a negative contribution to the mall. He replied by explaining how customer satisfaction had increased, and food court sales have as well. He was unable to go into the numbers with us but he assured us it was a good amount. He followed by telling us some issues with the robot such as it getting stuck when it goes off certain edges, but the company development is aware and is working on improving it.

International success is achieved by hitting the necessary demographics in international markets. For any project to succeed internationally must adhere to the international rules. Once the project can overcome every barrier, the project could be very easily implemented wherever it might be needed. Whenever this happens the project becomes successful internationally.

XI. Standard Considerations

The standard considerations of any product are key to that product's success in both the national and international markets. These considerations carefully define what a product is allowed to do and what it isn't allowed to do, under what conditions it will operate safely, and confirm the correct design of materials, methods, and products that will uniformly be associated across production for all items. There are three types of standards that are usually important when following their conventions De facto, De jure, and voluntary consensus standards.

In the industry, there are organizations that set most standards which can be very useful to follow for your product to have a successful market experience. A few of the most important organizations for standards are: The Institute of Electrical and Electronics Engineers (IEEE), The National Institute of Standard and Technology (NSIT), the American National Standards Institute (ANSI), and some other international organizations that develop standards suited for their countries. These organizations are valuable worldwide, and people prefer buying devices that have their marks on them. Not only do people prefer buying those devices that follow international standards but also to import and export to and from certain countries those standards have to be part of the product, else the import might cost a lot of money, or it could be completely prohibited.

For this project, we have considered a few standards from very prestigious organizations both international and national for success in both markets.

A. ***IEEE 1823-2015***

This standard is extremely useful when designing a device that has one or many Universal Serial Busses (USB) communications given that it specifies the appropriate power connection for any device that uses more than 10W and up to 240W. This standard mention that any power connection must include and communication link, a link allows the device to be referenced to and referred. Said link is used to regulate power consumption and to give the correct identification process between the adapter and the device that consumes the power. This standard is commonly used for portable computing such as smartphones, entertainment devices such as gaming consoles, and more simple devices that may not have a way to communicate. The PantherBot is a portable device that will require power through the connections of the Raspberry Pi or the Arduino Mega. The method to successfully provide enough power to the system for these devices to operate successfully will have to be completely designed from scratch and therefore must adhere to this standard for it to perform at peak efficiency while constraining the amount of harm it can do to an unexperienced user.

B. ***ISO 14001:2015 (Environmental Management System)***

This standard assures that the industry follows all of the processes in order to reduce the danger to the environment. The design process for a device might result in risks such as health dangers, pollution, and performance problems. The standard permits the planned product to operate with minimal environmental impact. The standard considers changing environmental conditions as well as social and economic demands.

C. ***ISO 9001 Certification (Quality Management System)***

In the electronic industrial industry, this accreditation is highly regarded. It improves client happiness with a certain product. The certification authority is primarily looking for the procedure document, process approach, proof of procedure, process sequence, related health risk, and industry quality requirements. The certification is issued after the auditing agencies conduct a thorough examination of all procedures.

Microcontroller programming is necessary for the proposed device, as well as some software development and maintenance standards. Software development, maintenance, testing, validation, and change control are all covered by ISO 9000. It also includes techniques for making changes to existing code.

D. ***IEEE 802.11***

Since the PantherBot will be able to communicate over the internet it is imperative that we follow the most popular and commonly used standard in the industry today. From IoT devices using this standard to communicate to huge servers' networks, this standard has proven to be one of the best and most recognized both nationally and internationally. IEEE 802.11 specifies the speed and frequency of the WiFi signal. This standard specifically addresses how the PantherBot will standardize the following:

1) *The signal strength, how far can it reach.*
2) *The signal frequency, how much data will the device send back.*
3) *Is this standard compatible with legacy systems.*

This standard will particularly be beneficial in order to comply with over-the-air interfaces between a client and the station.

In conclusion, after reviewing many industry standards the team has decided to go with the previously described. This will ensure overseas success for our product without limiting the intended use of this product. Given that all standards are from renowned organizations it is proof that these standards will not interfere with each other. Software, hardware, sensors, mechanical fittings, and electrical accessories are all included in the proposed "PantherBot" design. In addition to the components, the employees' safety and health must be maintained. It is necessary to gain certification for numerous standards after considering all of the aforementioned considerations.

XII. Health and Safety

In the global market, the health and safety consideration of the customer is the most vital when determining the success of a product. To establish the needed health and safety elements, the products design must revolve around avoiding any harmful effects to those that could use it. According to the World Health Organization (WHO), health is described as a form of physical, mental, and social well-being. While safety is defined as having the ability to live without the detrimental fear of harm, danger, or threat. For the success of The PantherBot following these descriptions is a must.

Alongside the safety of our customers, the safety and health of our employees must be considered. Our product carries an electrical and physical risk to our employees that we must keep in mind. As we follow the Electrical Code Table 310.16 and the National Electrical Code 250.20(B0). As our product will be suing a 120-V AC power we need to ensure that no harm will come to those that use it.

*A. **Health Safety and E-Waste***

Every product that is designed must abide by the proper health and safety regulations. It is the engineer’s job to ensure that the product is not just safe to use but will not harm the health of the user. The PantherBot is designed with the utmost quality that does not put the safety of any user in harm’s way. As such the materials used in the development of this product adheres to the restrictions of hazardous substances (RoHS) guidelines. This includes, but not limited to banned substances that are known to be dangerous such as lead, mercury, cadmium, and more. Each of these substances can cause harm to the user’s health in various ways.

The materials used are not the only consideration that has to be made. The physical safety of our user and employee must kept in mind. As our product is meant to carry and deliver packages from various points to another, it is detrimental that we ensure that no physical harm comes to any user. The PatherBot will have in place ultrasonic sensors that will constantly be checking its surroundings to ensure that it maintains a safe distance from others and other objects. This anti-collision protocol will take the top priority for all processes. While the stabilization of the robot and the opening of the door will be maintained using proper resistance hinges and having a proper center of gravity.

The last consideration is the E-waste, which includes electronics that are reaching the end of their useful life and are discarded. Since our product relies on hardware components, we must keep in mind how much e-waste we are producing. As such we have limited the number of possible components that cannot be easily recycled or reused in other electronics. These electronics include using two microcontrollers, a Raspberry Pi, and an Arduino to control the systems of the product.

*B. **Liabilities***

Liability is defined as the state of being responsible for something, especially by law. As the designers of The PantherBot, if something were to occur, we would be held responsible. As such, the engineering team behind the development of The PantherBot is responsible for any defects that may harm any user or their property. Ensuring that the proper liability is in place in case of any situation that might occur. Every unit’s software and hardware components will follow all guidelines and restrictions of the law itself. All units be designed to minimize all form of harms and risks that could fall on the user or those handling the product. A set of strict liability rules will need to be followed based on the American Law Institute. The following strict tort liability concepts will be addressed, followed, and adhered to.

“(1) One who sells any product in a defective condition unreasonably dangerous to the user or consumer or his property is subject to liability for physical harm thereby caused to the ultimate user or consumer, or his property, if

the seller is engaged in the business of selling such a product and

it is expected to and does reach the user or consumer without substantial change in the condition in which it is sold.

(2) The rule states in Subsection (1) applies although

The seller has exercised all possible care in the preparation and sale of his product, and

The user or consumer has not bought the product from or entered into any contractual relation with the seller.”

As dictated above, the course of action and the liability concerns follow any product. This includes products that are purchased directly, but also indirectly. As such creating a contract with the user is a must to assure that no harm will come to them under any circumstance. The engineering team hopes to demonstrate the use of this ethical principle to guarantee the success of our product. The PantherBot’s design and development will ensure the safety and health of any user by anticipating any possible defect or issues it might have.

The PantherBot is an autonomous delivery robot that can be used by anyone regardless of technological competence. The goal of the product is to design a robot that ensures the safety and health of any user. The final product we strive to achieve will be composed of toxic free materials and risk-free components. The amount of e-waste that is being produced will be at a minimal. All the ensure that our product follows the principle of creating a harmless robot that the consumer can use.

XIII. ENVIRONMENTAL CONSIDERATIONS

Another huge aspect when creating any type of project are the environmental considerations. Some might think that these considerations should just be considered for projects that will be use outside, just like a gasoline car. This believe is nowhere near the truth. Environmental considerations affect us all.

The environment is conformed from everything that surround us, natural or man-made. Therefore, both nature ad humans must maintain a good relationship to care about each other. If humans do not take the conscious decisions about their actions impacting the environment, it can lead to a variety of catastrophic global events. Such as an increase and intensity of wildfires, extreme storms, and hurricanes.

The PantherBot will be following Florida Electronic Hazardous Waste Regulations, The Restriction of Hazardous Substances Directive, and the Hannover Principle. A common regulation between the three is the restriction of lead. Even though PantherBot will very little lead, out project will not be compromised by it. Lead will only be used when soldering different components together. Since microcontroller like the Arduino UNO and microcomputers like Raspberry Pi are widely used in the global market, they must be following all the regulations. Therefore, our microcontroller and microcomputer will not pose a problem when designing the PantherBot.

The PantherBot team will have to take the necessary measurements to ensure the safe disposal of the project after its life cycle has been completed. Even though our project will have most of its components soldered to each other, we will implement some interchangeable pieces. This will reduce the net waste being thrown into the environment. Out sensors and battery will be connected using jumper wires in such a way that if they ever get damage or they simply wear out, we can replace them with new parts. This method will greatly benefit the environment since this modular approach will reduce the amount of wasted material because only the piece that needs to be change will be replace and not a whole section nor the whole robot. This would ensure that that all the proper consideration are being considered. If we avoid the use of solder whenever we can, it will help in a more friendly environmental disposal at the same time as an easier and more accessible user integration and modification. In the future this can lead to greater improvements to our project.

As already mentioned, the PantherBot's design will be done following the Florida Electronic Hazardous Waste Regulations. This means that PantherBot should adapt to the Florida Electronic Hazardous Waste Regulations the same way as the place PantherBot will be implemented at, in this case Miami. Since it would be highly beneficial for the environment the Recycling of Electronics in Businesses must be considered. This regulation, it is recommended to recycle only to those with a third-party certification [26]. In the case that this recommendation could not be pursued. There are some steps to follow to ensure that the non-third-party certified entity is a valid recycler. Due to this, the Florida Electronic Hazardous Waste Regulations provided a questionnaire to help users:

- Does the recycling facility have a DEP/EPA identification number?
- What kind of insurance does the recycling facility have?
- Where exactly does your electronic scrap end up?
- How does the recycler ensure that the data on your electronic scrap is destroyed?

Utilizing this questionnaire, we can ensure we have taken the proper steps to validate our recycler for the proper consideration.

The Life Cycle Assessment is vital when considering all the projects that after use go completely into the environment as harmful waste. When using the Life Cycle Assessment, it is critical to consider the database of materials that will be use in the project. Such database includes materials like plastic, paper, metals, chemicals. Processes such as electricity, transport, heat, processing of materials, and surface treatment may also be considered from the database. While taking into account the environmental considerations we chose the best materials to fit our PantherBot. In the PantherBot Life Cycle Assessment, some factors remained the same when analyzing for materials and processes, as we notice that those were the best options, such as polyethylene which will be used to build the container and other structural parts. We decided to go with solder Sn63Pb37 due to its benefit to the circuit and because it will be used in very little portions its effect will be negligible to the environment. Electricity low power as the process for both the microcontroller and the microcomputer to both control the moving system and the locking system. These components in each assessment remain the same. There were impacts on Human Health, Resources, and in the Ecosystem in both Life Cycle Assessments. We compared to different PantherBot designs. In the first design, we used Steel as the metal for the robot's chassis. Then on the second design, we use an Aluminum Alloy as the metal for the robot's chassis.

Environmental considerations and the Life Cycle Assessment out team was able to have a deeper look at the environmental impacts that the project will have in its future life spam. With these considerations met, our understanding of the Economic Feasibility is now greater. And by PantherBot acknowledging the Hannover Principle, it will focus on a more sustainable future. As we already know mentioned, PantherBot will use steel as the material for its chassis since it is the more environmentally friendly option. Also, we studied the impact on the materials that are being used in the design and construction of the Pantherbot. Furthermore, PantherBot will comply with the regulations, directives and principles set by the Restriction of Hazardous Substances Directive, Florida Electronic Hazardous Waste Regulations, and the Hannover Principles.

On the following bar graphs, we can see that both options have very similar score but overall having a steel frame over an aluminum frame is more environmentally friendly.

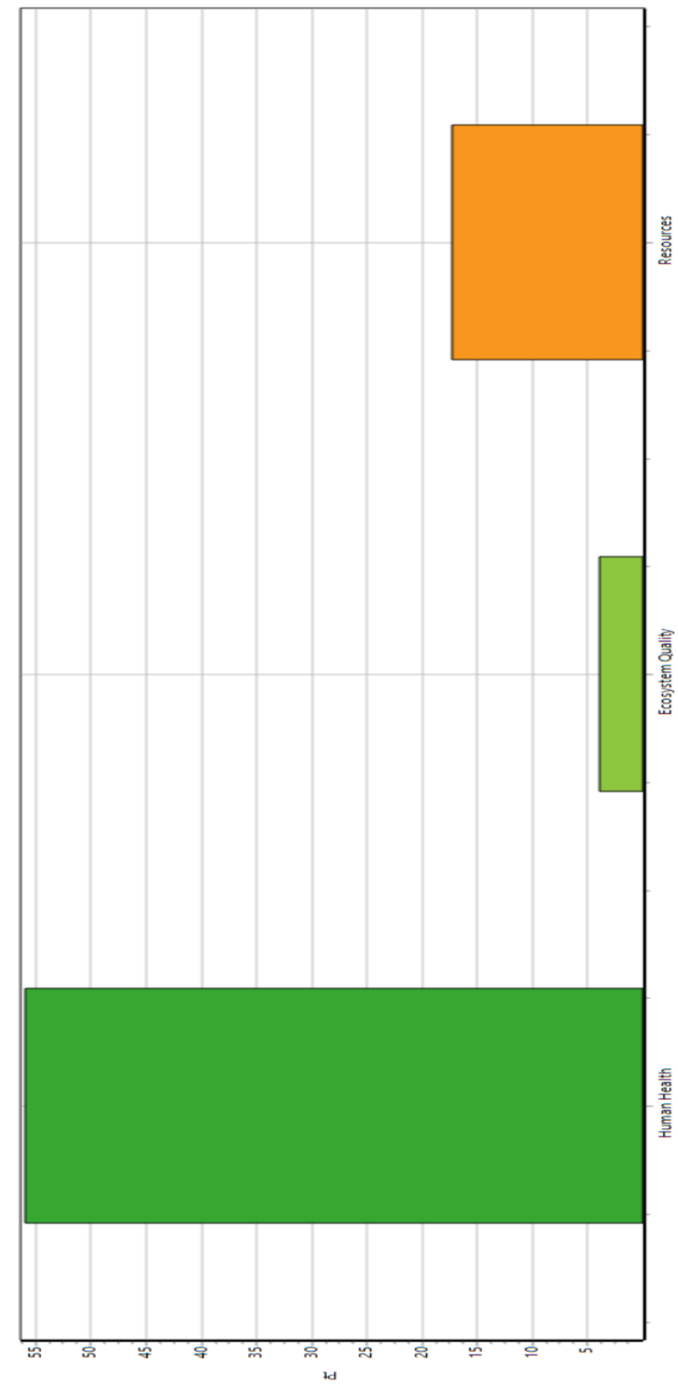


Fig. 19. PantherBot wih Steel Chassis

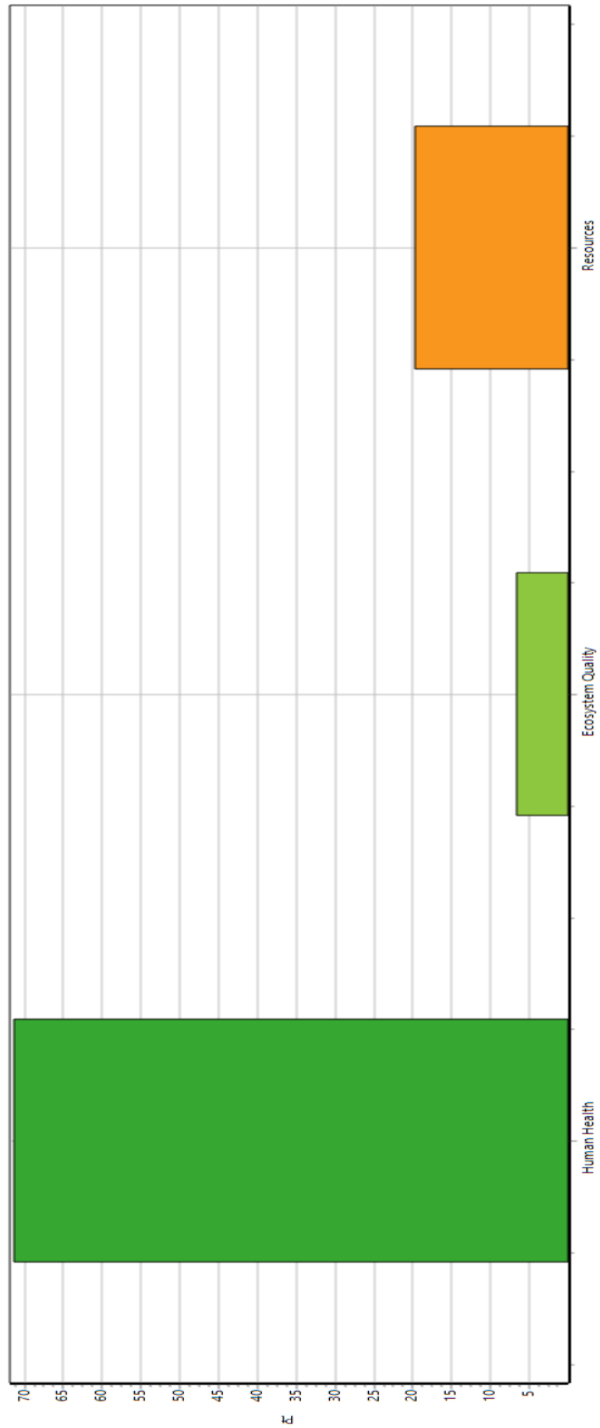


Fig. 20. PantherBot with Aliminum Chassis

XIV. SUSTAINABILITY CONSIDERATIONS

A product must be created in such a way that it will satisfy the demands of the end-user for an extended period. Before placing a product on the market, client expectations must be projected for a long time. It is critical in the design process to create a sustainable product that will have a beneficial influence on the future; for a product to be sustainable, it must be feasible to make and use without harming or destroying it. It is unlikely that a product can be called sustainable if it uses nonrenewable resources, harms the environment, or causes harm to humans or society. This section goes through all of the steps that must be taken to keep the planned product on the market for a long time; this will not only boost the client base but will also have a low environmental effect. The basis of what this notion symbolizes is the concept of sustainability. As a result, three pillars signify sustainability: the economy, society, and the environment. Informally, these concepts are referred to as profit, people, and the planet.

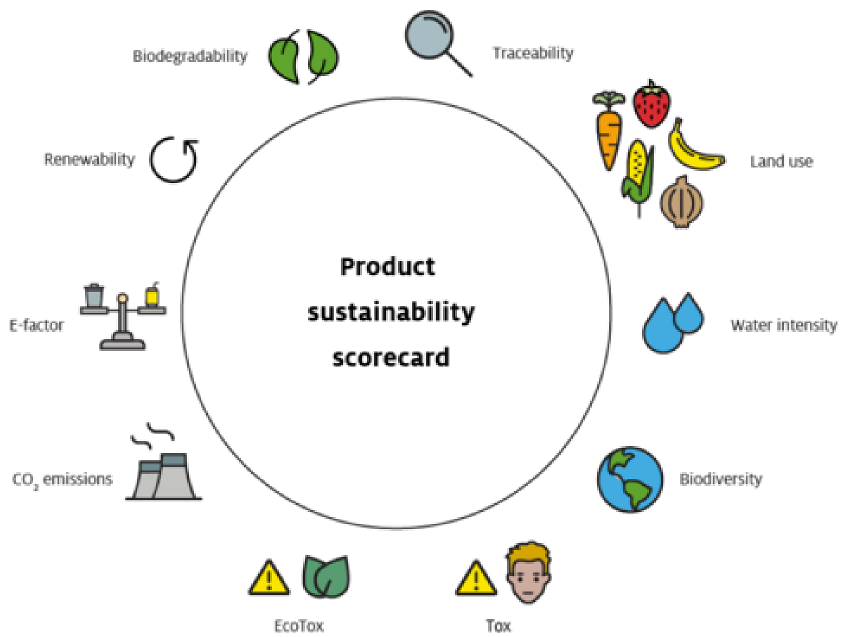


Fig. 21. Product Sustainability

Figure 38 indicates a product's overall sustainability scorecard. The product must meet particular requirements in order to be sustainable, as listed below:

• All of the components in the design must be traceable, including the details of the manufacturer and international part number.

• During operation and after disposal, the component must not release any dangerous substances or poisons.

• The E-waste created by the device must be under the specified limit; the gadget must not endanger human life or any other form of life if it is used for an extended period, and the device must be universally usable across the world.

A. ***Software***

The software that generates the control signals of the PantherBot is designed to run at a very high speed and make complex computations. The PantherBot will be programmed for the interaction between the simulated environment and the robot itself. Its dynamic system is in constant flux; with the condition of the robot, sensor readings, and control signal effects all shifting. There are several techniques for achieving product sustainability; that depends on the importance of the program, the resources available, and the level of sophistication of the software in use. Technical preservation is one way to create long-lasting software. The preservation of the precise hardware utilized in the design is known as technical preservation. This is avoided by utilizing software that is compatible with a variety of hardware. The program will not be able to separate itself, our objective with the code we've created is to make it as basic and straightforward to upgrade as possible in the future by:

- Applying physical laws to the robot's motions, taking into account obstacle impacts, and supplying updated values for the robot's sensors.
- Designed to find out how to attain its purpose and survive in its environments on its own.
- The target's coordinates are sent into the control system via a separate Python application that monitors the robot's progress.

B. ***Hardware***

A new product must start with the right materials and production procedures to be sustainable. To examine the environmental consequences of our design's process, services, and materials, our team used the Life Cycle Assessment (LCA) approach. We looked at how the various pieces of gear we use may affect the environment. We will also detect inputs and ecological discharges and ensure that they do not have an adverse impact on the environment or society. The objective of the PantherBot is to deliver services that fulfill the highest sustainability requirements while working at their best; our team went through the process of securing long-term software and hardware. It is critical to consider sustainability issues when designing any product to ensure that it has a positive impact on society and the environment. Our team adopted the Life Cycle Assessment approach to assess possible environmental consequences caused by the hardware and software employed:

- To ensure that the control application code is bug-free, it must be tested under a variety of scenarios.
- The modular structural design also enables the designer to make changes as and when needed.
- All of the chosen components must have adequate time before they become outdated.
- The chosen components must not emit any hazardous substances, harming the environment.
- Provisions must be created for a more comfortable component replacement.
- Adequate gaps between components should be given to avoid heat dissipation-related deterioration.
- Thorough quality tests at the component level are required to reduce the risk of product failure.

The capability of a product to last is a critical requirement for its creation. The design process, component selection, and marketing methods all have an important impact on the product's long-term viability. Customers will trust a long-lasting product, and it will gain market appeal. Basic considerations are being taken to improve the PantherBot long-term viability. Our objective is to create an autonomous delivery robot that adheres to sustainable standards, prioritizes durability, and is a low-cost solution, enabling delivery robots to be more practical in the real world.

XV. MANUFACTURABILITY CONSIDERATIONS

Manufacturing techniques are critical to the success of any product. The use of the incorrect production technique will result in higher costs and worse product quality. Manufacturability is one of the most important factors to consider when designing and developing a product. One of the most important elements to consider when designing a product is its ability to be manufactured. The mechanical and electrical features of the PantherBot unit design are linked to manufacturability. The electrical and mechanical components of manufacturability are discussed in depth in this section.

*A. **Mechanical Design***

The mechanical design focuses on the entire structure and considers elements like durability, compactness, appearance, ease of integration, and other similar considerations. The following mechanical elements are taken into account by the PantherBot:

• The design will be kept as simple as feasible to decrease the number of parts and hence the cost.

• For simplicity of production, the mechanical design shall incorporate all standard components and adhere to standard specifications.

• The design is modular, allowing different components to be easily combined.

- Standard interfaces such as Arduino and Raspberry Pi will be used to design the PantherBot; along with electronic components, sensors, and a camera. These mechanisms will be accessible in the market, and assembling will be easier.

• By all means, the mechanical design will ensure that the PantherBot is built most efficiently and productively possible.

*B. **Electronics Design***

The installation of components on a circuit board (PCB), the wiring between the parts, the spacing between the elements, selection, and other similar aspects are all part of electronic design. The following are the electronic factors taken into account by PantherBot.

- The distance between the components is kept a bit wider than typical.
- Component spacing was chosen to reduce the wiring distance to a minimum.
- Electrical lines are designed to prevent wires from interfering with other equipment and to protect them from wear and damage.
- For the PantherBot, standard components will be chosen.

*C. **Simple Design***

If one followed the simple design protocol when creating a product or device, the design would be as basic as feasible without sacrificing the gadget's or product's quality. The goal is to limit the number of points of failure as low as possible. This also allows the item to be produced and manufactured at a lower cost.

- The use of common parts for designing a device is important to the budget as well as the time frame of the project. The parts used are accessible in the market, being premade and off-the-shelf components.
- Easy assembly is important considering cutting down the cost of most parts and products.
- Easy assembly of the robot means that it is easy to disassemble; for troubleshooting or repairing the system, which is very critical.

In conclusion, in the production phase of any device, manufacturability is the most important factor to consider. Manufacturability factors are incorporated early in the design process, resulting in fewer design modifications throughout the manufacturing phase. The PantherBot's manufacturability concerns include mechanical, software, and electrical factors, with all minute details taken into account.

XVI. Ethical Considerations and Social Impact

When creating or designing a new product or working on a new project, it is essential to consider the ethical considerations and significant social impact that that product or project can have. This section will review the ethical considerations and social impact our project could have and show how we will deal with these potential issues using the IEEE Code Model. All products or projects have to comply with the IEEE Code of Ethics, and if it does not, it is considered an ethical dilemma. Products or projects might have ethical dilemmas, and the engineers or designers have to make sure that the products or projects do not infringe on people's rights. Ethical dilemmas can be addressed using the Ethical Model Theory by finding the best way to deal with the dilemma while making the product or project as appealing as possible.

*A. **Ethical considerations***

There are not only legal consequences for violating the code of ethics, but there are also moral consequences for any team that does not comply with the code of ethics. Ethics should be taken into account and addressed appropriately by the entire team. The team should always be aware of the problems and provide solutions using the IEEE Code of Ethics. The following codes are the IEEE Code of Ethics from the IEEE website:

1. To hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, to protect the privacy of others, and to disclose promptly factors that might endanger the public or the environment;
2. To improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems;
3. To avoid real or perceived conflicts of interest whenever possible, and to disclose them to affected parties when they do exist;
4. To avoid unlawful conduct in professional activities, and to reject bribery in all its forms;
5. To seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, to be honest and realistic in stating claims or estimates based on available data, and to credit properly the contributions of others;
6. To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclosure of pertinent limitations;
7. To treat all persons fairly and with respect, and to not engage in discrimination based on characteristics such as race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression;
8. To not engage in harassment of any kind, including sexual harassment or bullying behavior;
9. To avoid injuring others, their property, reputation, or employment by false or malicious actions, rumors or any other verbal or physical abuses;
10. To support colleagues and co-workers in following this code of ethics, to strive to ensure the code is upheld, and to not retaliate against individuals reporting a violation.

Our project is designed with the Code of Ethics in mind and our team is fully committed to complying with the IEEE Code of Ethics. We will accept responsibility for any decisions we made regarding our project design and any conflict that may arise. Our team will always prioritize the health and safety of the public and consider all of the societal and ethical implications that are a direct result of our project.

After the team's analysis of our project for any ethical dilemmas that could potentially violate the IEEE Code of Ethics, our team found the following:

People could assume that the food would always arrive without issues. This assumption can lead to them thinking that the food has been stolen by the delivery driver or from the robot if it doesn't arrive. This assumption would break the code of ethics to protect the privacy of others since food is private and could be tampered with.

The following table offers solutions to the potential problem the robot could face while making deliveries. We will go through 4 different theories to see the best solution for the dilemma. The different theories are:

- Utilitarianism: The morally right action is the one that has the greatest benefit (or least harm) for the largest number of individuals.
- Ethical Egoism: The morally right action is the one that promotes and protects your own best interest.
- Kantian Ethics: The morally right action is the one based on rules that are obtained by rationality and will also be followed in similar situations.
- Rights Ethics: The morally right action is the one that respects the rights of all individuals and society.

TABLE XX. POSSIBLE OUTCOMES FOR ETHICAL DILEMMA

Options	***Description***
1	Ignore the problem
2	Users are informed that there could be malfunctions in the robot's locking system and that the delivery driver might not use the robot.
3	Users are alerted when the robot has been opened during delivery.
4	Users are reimbursed for the value of the food.

TABLE XXI. WEIGHT OF ETHICAL THEORIES

Option	***Utilitarian***	***Egoism***	***Kantian***	***Rights***	***Score***
1	0.00	1.00	0.00	0.00	1.00
2	0.25	0.5	1.00	0.25	2.00
3	0.50	0.25	0.75	0.00	1.50
4	1.00	0.00	0.25	0.50	1.75

The table above shows the weight of each option, when compared using the previously mentioned four different ethical theories. While option 4 would benefit most people, it is less practical and would be very expensive for the developers. Option 2 will solve the ethical dilemma and is the best balance between all four ethical considerations.

B. ***Social Impact***

This section shows how the PantherBot will contribute to society either locally or globally. The PantherBot's primary intended users are students and faculty from the Florida International University Engineering Campus. However, we hope that PantherBot can be used in many other Florida International University buildings and even in many campuses around Florida and across the United States. Our goal is to increase the efficiency of online food delivery orders. From our surveys, our intended users believe that PantherBot will increase their food delivery options inside of the campus.

The PantherBot will contribute to our local society by helping students and faculty obtain food deliveries more efficiently. Especially on Florida International University Engineering Campus, there are few options to obtain food. Hence, many people would opt to order deliveries instead. Food deliveries in universities can be complicated to achieve. Therefore, our goal is to achieve a more effective way of making these deliveries. Then, PantherBot could help many campuses and buildings across the United States on a bigger scale.

Based on Sebastian Deterding’s Talk: What your design says about you, our design intends to improve the efficiency of the deliveries on Florida International University’s Engineering Campus using PantherBot. We believe that our invention will improve the acquisition of food on the campus. On a large scale, PantherBot will attempt to improve how people receive their deliveries in buildings that are hard to access or too complex on the inside for a delivery driver. An unintended effect that our product could have is that it could damage food places already placed on the campus. This is because people would prefer their favorite food places over the only options that they have set on the campus. And lastly, our concept of the good life would be a life where our project makes other people their lives easier, more efficient, and possibly provides businesses a more effective way to deliver on campus.

Analyzing a new product is paramount for ethical considerations and social impacts. If there is an ethical dilemma, the team must ensure it does not violate any of the IEEE code of ethics. If so, the best course of action is to use the Ethical Theory Model. Our team has the responsibility to maintain high standards and make products that will contribute to making the world a better place. The PantherBot may have ethical dilemmas since it is a new implementation that has not changed since the university was founded, but the team must be ready to overcome them.

XVII. CONCEPT DEVELOPMENT

Concept development is key to the success of any project since it allows for a comparison of the best possible options for implementation, rather than just deciding on the first idea, which could have disadvantages. We will rank different combinations of features in a concept development section using the project objectives. This section will discuss various features that the design can incorporate to meet specific goals, and we will assess the strengths and weaknesses of each combination presented. After evaluation, the best combination of features will determine the design.

For our project, we need to evaluate these four main topics: the robot its navigation or sensor system, the charging system, how the robot will be accessed and used, and how the robot will interact with elevators. The options for the navigation and sensor system we considered Lidar, Ultrasonic, and or Camera. We intend users to access and use our robot through a simple code entered by the delivery driver, a website, or an app. Lastly, the options for how the robot enters and exits the elevator in a multistory building are with a self-made arm and barometer sensors to press the buttons, or with a SwitchBot and barometer sensors. These features will be combined to create different options, each with advantages and disadvantages. The Figure below shows the concept fan, representing all of the features and options we can use when developing our project. Each arrow down represents a subset.

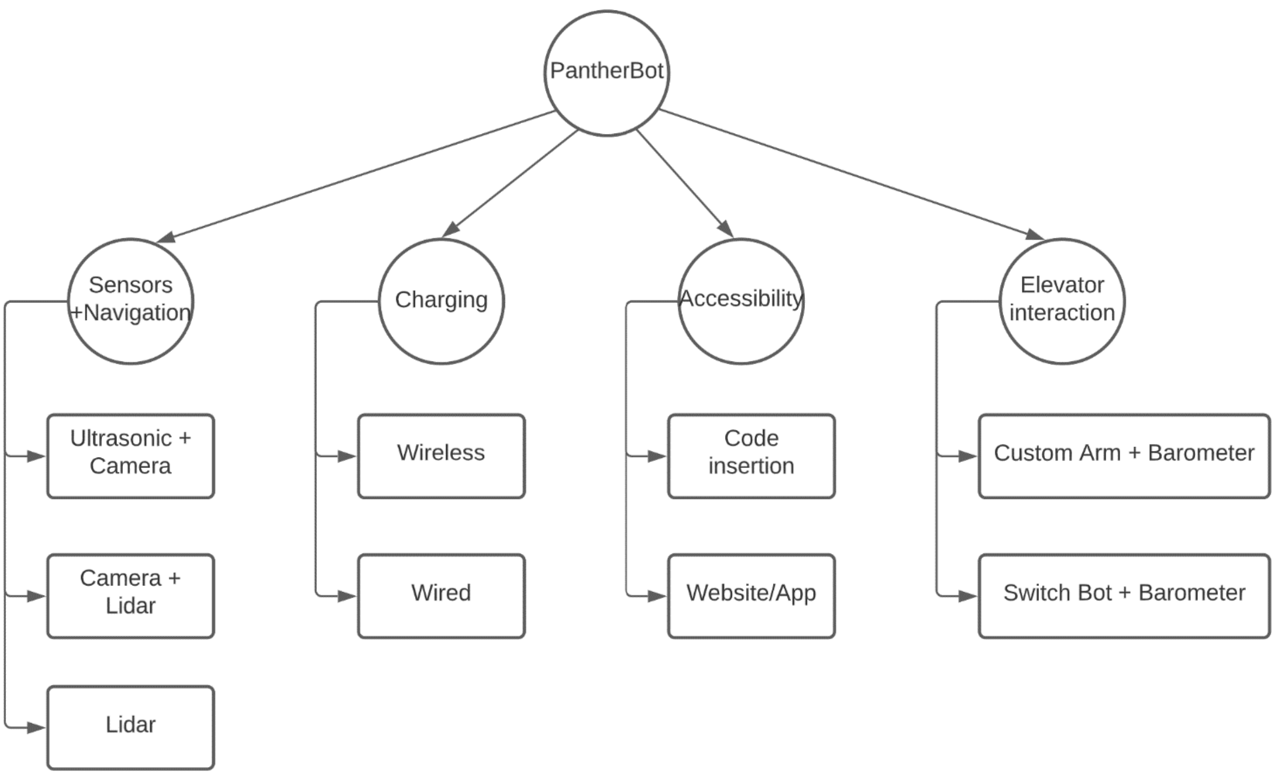


Fig. 22. Concept fan

A. ***Alternative options***

1) Option 1: Camera + Lidar, Wireless, Code insertion, Self-made arm

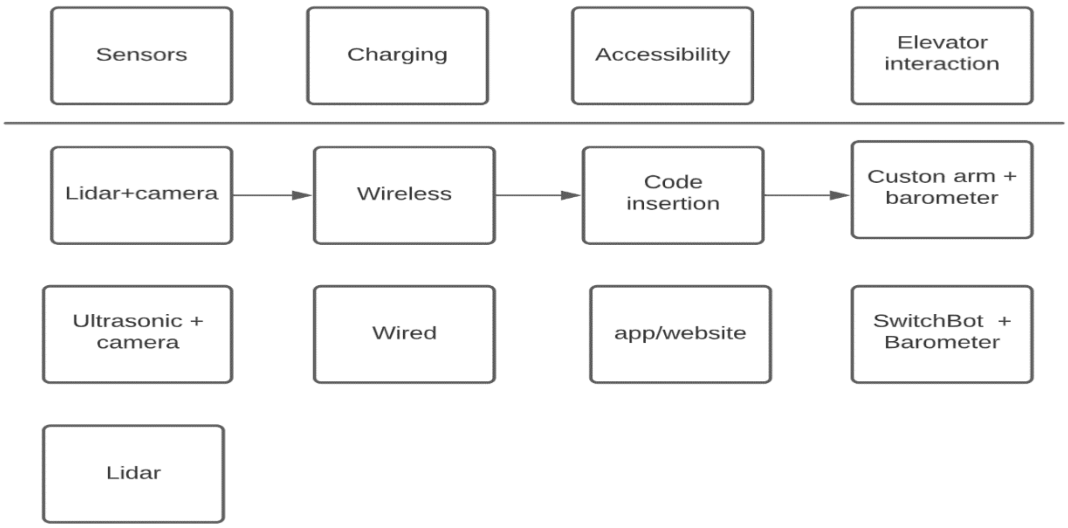


Fig. 23. Concept option 1

The first design consists of hard coding the paths to the different areas in the building and using lidar and cameras to assist the robot with object detection and potentially avoid collisions. For users to acquire the robot's services, the users would have to provide the delivery driver with a four-digit password and an area code for the delivery driver to enter when dropping off the food. The robot will use its custom-designed arm to click the floor buttons when going up and down the elevator. And when done delivering, the robot will automatically go back to its wireless charging station. The Figure below shows concept option one and the combination of features for the PantherBot.

a) Advantages

- Long-range detection and faster response time than the ultrasonic sensor.
- No internet connection is required since the robot works completely autonomously without a website or an app.
- No app or website design is required.
- A wireless charging station makes the charging very convenient.

b) Disadvantages

- Wireless charging causes a decrease in charging speed and efficiency compared to charging with a wired connection.
- There is no tracking available for the robot without using an app or website.
- Using a custom-designed arm to press the buttons in the elevator requires design, assembly, and might cause some reliability issues.

2) Option 2: Ultrasonic sensors + camera, wired Charging, Code insertion, Switchbot

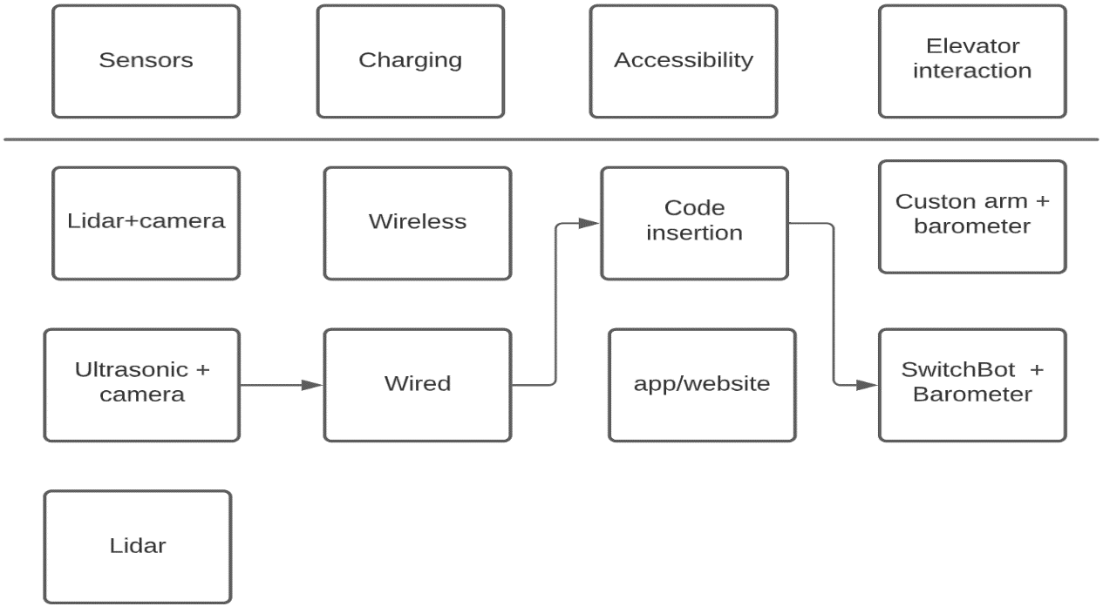


Fig. 24. Concept Option 2

The second option uses ultrasonic sensors instead of the Lidar sensors. The charging station would have a wired connection to the robot. This would charge the robot considerably faster but be harder and more time-consuming to incorporate autonomously. For this concept, the users would access the robot the same way as the first option, and that's through a code inserted by the delivery driver. And as for the elevator interaction, the robot would be mounted with a Switchbot. The Switchbot is an automatic button-pusher mounted next to the elevator buttons. The Figure above shows concept option two and the combination of features for the PantherBot.

a) Advantages

- The advantage of a wired charging station is the increase in charging speed and charging efficiency compared to the wireless station
- This concept implementation would be highly time-saving without the website and the Custom arm for the elevator.
- No App/website design required.
- No custom arm for elevator button-pushing needed since we are using the SwitchBot for the elevator button-pressing

b) Disadvantages

- The ultrasonic sensor has slower detection and response time than the lidar sensor.
- Autonomously charging the robot on a wired connection can be hard to incorporate.
- Mounting the SwitchBot next to the elevator buttons effectively modifying the elevator.
- There is no tracking available for the robot without using an app or website.

3) *Option 3: ultrasonic + camera, Wireless charging, Website/App, Switchbot*

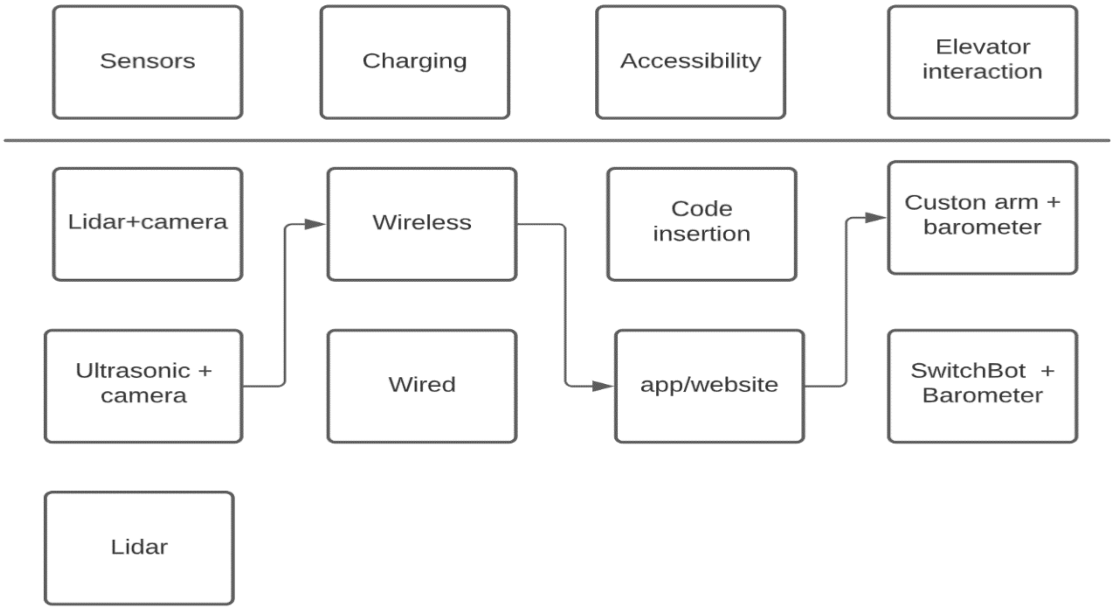


Fig. 25. Concept option 3

The third concept consists of ultrasonic sensors instead of lidar sensors, a wireless charging station, a website or app to schedule the robot, and a custom-designed arm for the elevator interaction. The website or app would allow users to schedule appointments with the robot and enable the users to use tracking too. However, this would require a fully functioning app or website that could be costly and time-consuming.

a) Advantages

- A wireless charging station makes the charging very convenient
- Users will be able to track the robot through the app or website when the robot is in the process of making deliveries
- No custom arm for elevator button-pushing needed since we are using the SwitchBot for the elevator button-pressing

b) Disadvantages

- The ultrasonic sensor has slower detection and response time compared to the lidar sensor.
- An internet connection is needed at all times when using the robot.
- Need to run and design a website or app, which can be time-consuming and costly
- Using a custom-designed arm to press the buttons in the elevator requires design, assembly, and might cause some reliability issues
- Wireless charging causes a decrease in charging speed and efficiency compared to charging with a wired connection.

4) Option 4: Lidar + camera, wireless charging, code insertion, SwitchBot.

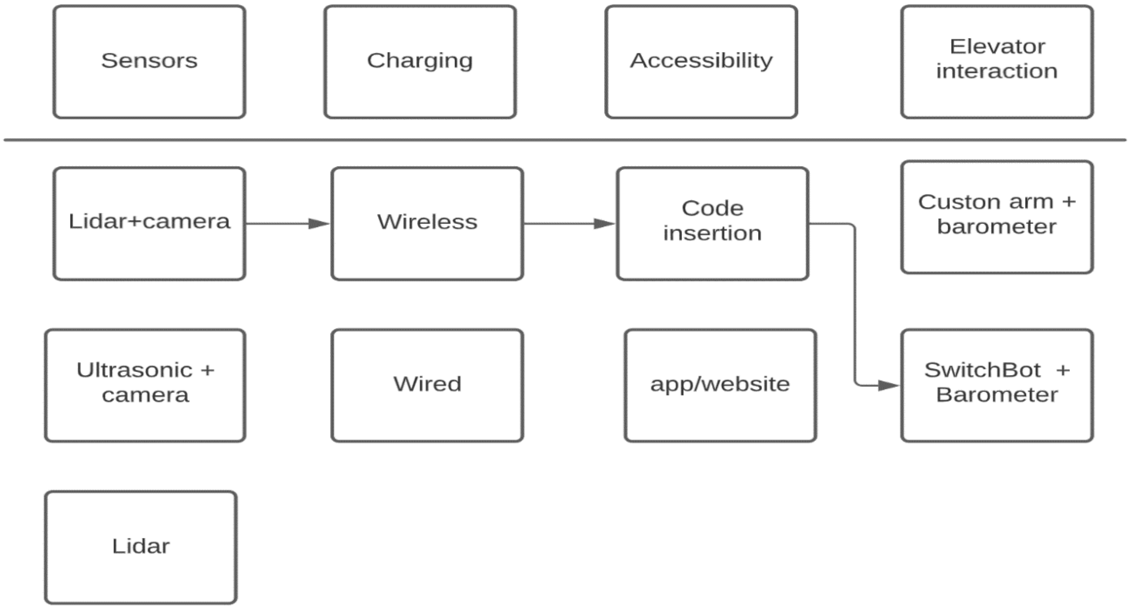


Fig. 26. Concept Option 4

The fourth concept uses lidar sensors and a camera for object detection instead of ultrasonic sensors. A wireless charging station instead of a wired one. This concept would feature the code insertion method. The user would gain access to the robot by providing a code to the delivery driver that the delivery driver would have to enter when placing the food inside the robot. And for the elevator interaction, the SwitchBot would be mounted next to the elevator buttons instead of designing a custom button-pressing arm. The Figure above shows concept option four and the combination of features for the PantherBot.

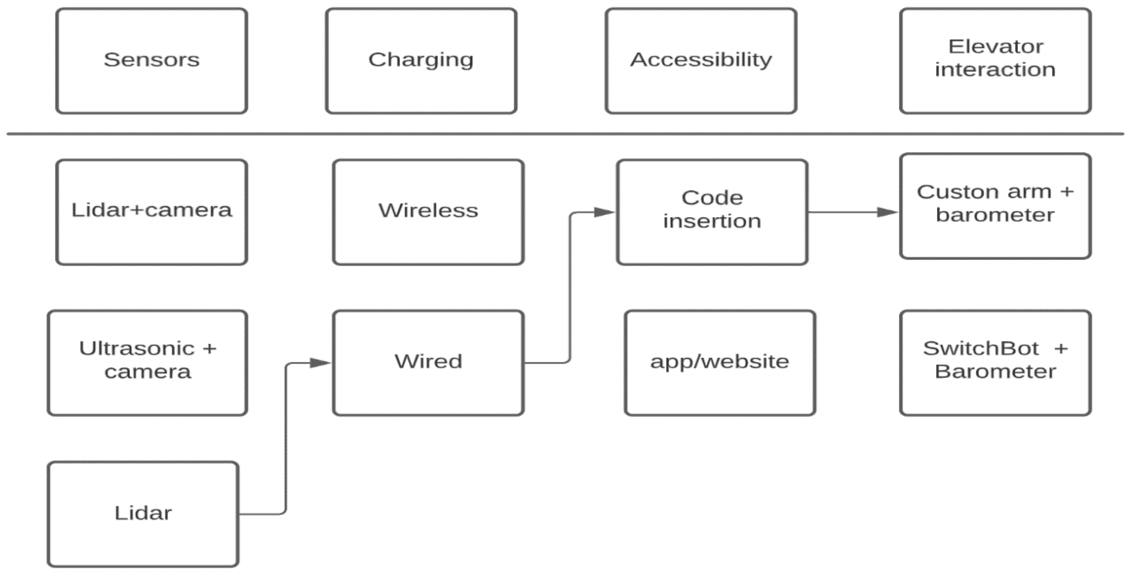
1) Advantages

- This concept implementation would be highly time-saving without the website and the custom arm for the elevator
- Long-range detection and faster response time compared to the ultrasonic sensors
- No app, website, or custom arm design is required.
- A wireless charging station makes the charging very convenient.

2) Disadvantages

- Mounting the SwitchBot next to the elevator buttons effectively modifying the elevator.
- Wireless charging causes a decrease in charging speed and efficiency compared to charging with a wired connection
- There is no tracking available for the robot without using an app or website.

5) Option 5: Lidar, Wired, Code Insertion, Selfmade arm



The fifth concept uses lidar sensors for object detection instead of ultrasonic sensors. A wired charging station instead of a wireless one. This concept would feature the code insertion method. The user would gain access to the robot by providing a code to the delivery driver that the delivery driver would have to enter when placing the package inside the robot. And for the elevator interaction, the selfmade arm would be mounted onto the chassis instead of using the switchBot. The Figure above shows concept option five and the combination of features for the PantherBot.

3) Advantages

- This concept implementation would be simple since it doesn't use a website/app
- Long-range detection and faster response time compared to the ultrasonic sensors
- No app, website design is required.
- A wired charging station makes charging faster and the setup is not as complicated.

4) Disadvantages

- Designing a custom arm.
- There is no tracking available for the robot without using an app or website.
- The precision for the custom arm to press the elevator buttons has to be very precise.
- Autonomously charging the robot on a wired connection can be hard to incorporate.

*B. **Concept selection***

The tables below determine the importance each of the five categories holds. They compare the project's objectives to each other, and the score indicated the importance of one objective relative to the other. A number one indicates equal importance, three indicates moderately more importance, five indicates strongly more importance, and seven indicates very strong importance over the objectives.

Importance Scale : 1 =equal, 3 = moderate, 5 = strong, 7 = very strong, 9 = extreme

TABLE XXII. CONCEPT SELECTION IMPORTANCE SCORE

	Power efficiency	Implementation	Ease of use	Reliability	Navigation
Power Efficiency	1	1/3	1/5	1/3	1
Implementation	3	1	1/3	1/3	1
Ease of use	5	3	1	1	5
Reliability	3	3	1	1	3
Navigation	1	1	1/5	1/3	1

TABLE XXIII. CONCEPT SELECTION WEIGHT CALCULATION

	Power efficiency	Implementation	Ease of use	Reliability	Navigation	G.Mean	w
Power efficiency	1.00	0.33	0.2	0.33	1	0.47	0.08
Implementation	3.00	1.00	0.33	0.33	1	0.80	0.13
Ease of use	5.00	3.00	1.00	1.00	5.00	2.37	0.39
Reliability	3.00	3.00	1.00	1.00	3.00	1.93	0.31
Navigation	1.00	1.00	0.2	0.33	1.00	0.58	0.09
					Total	6.15	

$$G.Mean = (A_1 \times A_2 \times A_3 \ldots \times A_n)^{1/n}$$

$$Weight = \frac{G.mean}{Total}$$

Table shows the decision-making process between the multiple concept options. We first check if all concepts comply with our constraints and then rank the concept options based on their features using a scale from one through five. After ranking the features, we multiply those rankings by their corresponding weight calculated in the previous tables.

TABLE XXIV. CONCEPT SELECTION TOTAL SCORES

		Option 1		Option 2		Option 3		Option 4		Option5	
Constraints											
Under $750		Yes		Yes		Yes		Yes		Yes	
Rechargeable		Yes		Yes		Yes		Yes		Yes	
Easy maintenance		Yes		Yes		Yes		Yes		Yes	
Objectives	W										
Power Efficiency	0.08	1	0.08	4	0.32	2	0.16	2	0.16	3	0.24
Implementation	0.13	2	0.39	2	0.26	1	0.13	3	0.39	4	0.52
Ease of use	0.39	3	1.17	3	1.17	3	1.17	3	1.17	4	1.56
Reliability	0.31	4	1.24	2	0.62	2	0.62	4	1.24	2	0.62
Navigation	0.09	2	0.27	1	0.09	4	0.27	2	0.18	3	0.27
Total		3.06		2.46		2.44		3.15		3.21	

All in all, after analysis and after each option or feature has been weighed in terms of importance, the weighed calculation table above shows that the best option for this project is concept option 5, which consists of the lidar sensors, wired charging, code insertion instead of an app or website, and the a custom made arm with a barometer. This option had its best advantages in terms of implementation and ease of use, mainly because of the arm, code insertion method, and lidar sensors. However, this is a change from our original selection in Senior design one which was option 4. We changed our initial selection because the implementation of wireless charging and the swichbot was causing to many issues, and the need for a camera was unnecessary. Our initial selection were the lidars + camera, wireless charging, code insertion, and switchBot.

XVIII. End Product Description and Other Deliverables

When designing or developing a product, it is essential to establish a clear end product description and the product's deliverables. The end product description is vital to future users and or designers because it explains how the product will function or be used. For designers, it helps them get a basic understanding and make better decisions on components to be added to the final product. And for users, it is essential to understand precisely how a product works before deciding whether to buy or use the product. Using diagrams, the end product description describes the product or project on three levels; the higher the level, the higher the specificity. The end product description will explain the functions of the PantherBot and reassure the goals for the PantherBot. And after that, the specifications and deliverables of the product are defined. This section will help both designers and users better understand the PantherBot and ultimately show how the PantherBot works.

A. *End product description*

This section aims to demonstrate how the device works and its primary purpose, as described above. In addition, the components will be broken down into a more detailed structure to be better understood.

The PantherBot consists of a few main parts. These parts will be broken down with a level system where each level goes more into detail about the system, where the top levels contain the least detail, and the lower levels contain the most. The Level 0 view of the system is a basic BlackBox diagram that focuses solely on the input and output that describes our project in the most straightforward way possible. This level consists of just the user's code input, food added to the container, power to charge the chassis, the "BlackBox" or PantherBot, and output which is the PantherBot delivering the food to its desired destination.

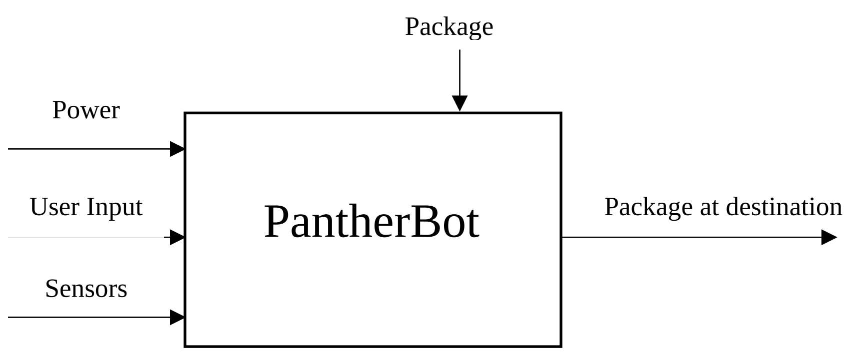


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Fig. 27. Level 0 View of the PantherBot

Fig. 25. is the black box diagram for our project. Power is supplied to charge the battery of the chassis and the delivery driver sets the package into the container and locks the door with a code given to the driver by the customer. The code entered by the delivery driver sends the necessary information to the microcontroller for the chassis to set the final destination and also sends the information to the other microcontroller for the lock system to open the container when the PantherBot has reached its destination.

TABLE XXV. LEVEL 0 FUNCTIONALITY OF THE PANTHERBOT

	PantherBot
Input	Package placed in the container
	Delivery driver inserts code given by the customer
	Power supplied to the chassis battery
Output	PantherBot delivers package to the desired destination
Function	Get the data from the user and delivery driver to send the PantherBot to the customer's location

Fig. 2. shows the Level 1 view of the system which is intended to be a general description of the internal systems of the PantherBot. The system will use a battery to power the RaspberryPi, chassis, and the User Interface. The user input is entered through the User Interface and a signal is sent to the RaspberryPi to set the destination and control the chassis. The code is also sent to the storage area where the code is used to lock the compartment when the food is being placed inside and to unlock the solenoid locks when the PantherBot reaches its destination. The RaspberryPi also get data from the sensors while moving.

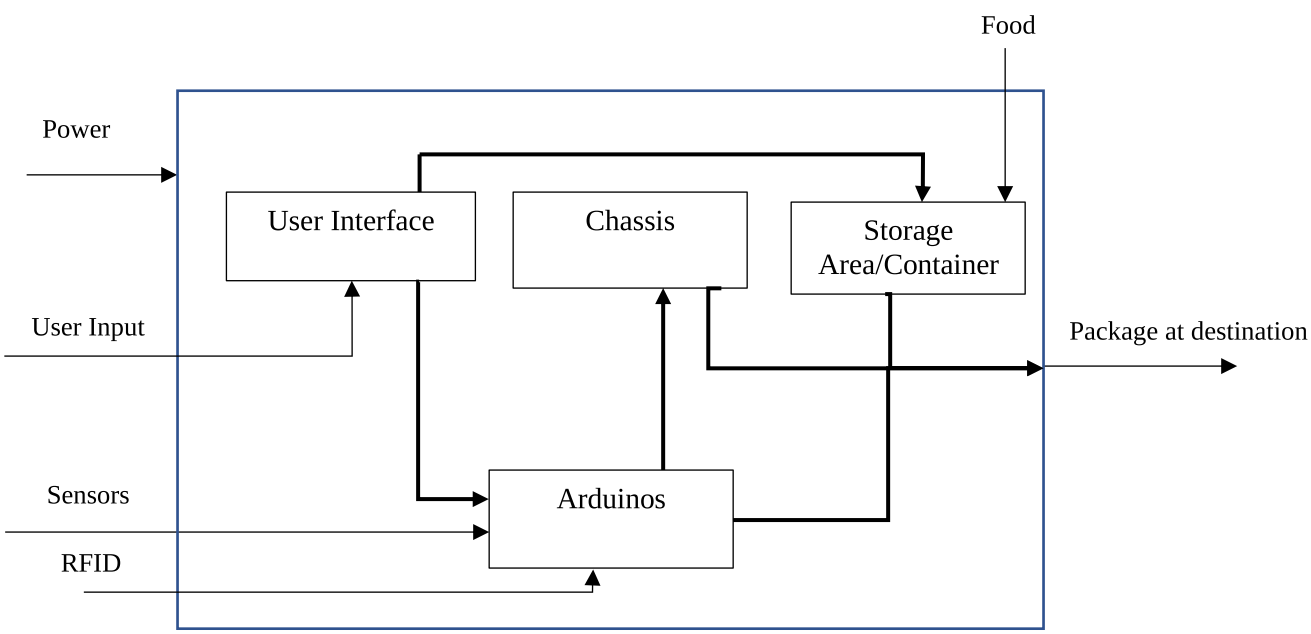

Fig. 28. Level 1 View of the PantherBot

B. ***Functions***

Now, to have a better understanding of the complete system we need to look more into the individual functions of the parts of the system. Each of the parts and their specific purposes and functionality within the system will be discussed in the next section. These parts were carefully chosen by our team to fit the best for the system.

1) User Interface

The User Interface is to help the user interact with the PantherBot. The Interface needs to process the user's input and display messages when needed. We tried to keep this as simple as possible to avoid any confusion with the delivery driver. The keypad is connected to the Arduino through a relay and after a code is entered the Arduino uses that code to implement the password to unlock the compartment and implement the path.

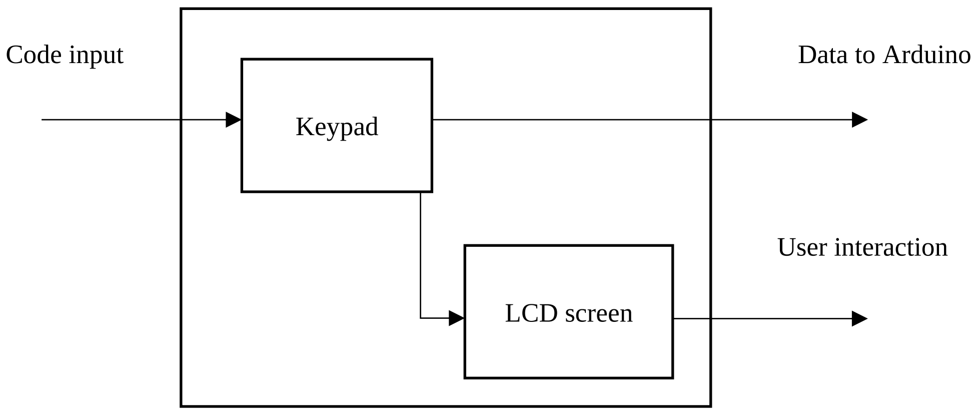

Fig. 29. Level 2 View of the User Interface

TABLE XXVI. FUNCTIONALITY OF USER INTERFACE

	User Interface
Input	User Code entered by delivery driver
Output	LCD and Button feedback
Function	User interaction and send data to the Arduino

2) Arduinos

The Arduinos are connected to all of the other parts of the system and is essentially the brain of the PantherBot. The Arduinos contain a microprocessor to process information, sensor data, supply the GUI, and control the chassis. The Arduino has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. The Arduinos also use the data from the RFID tags to send instructions to the chassis.

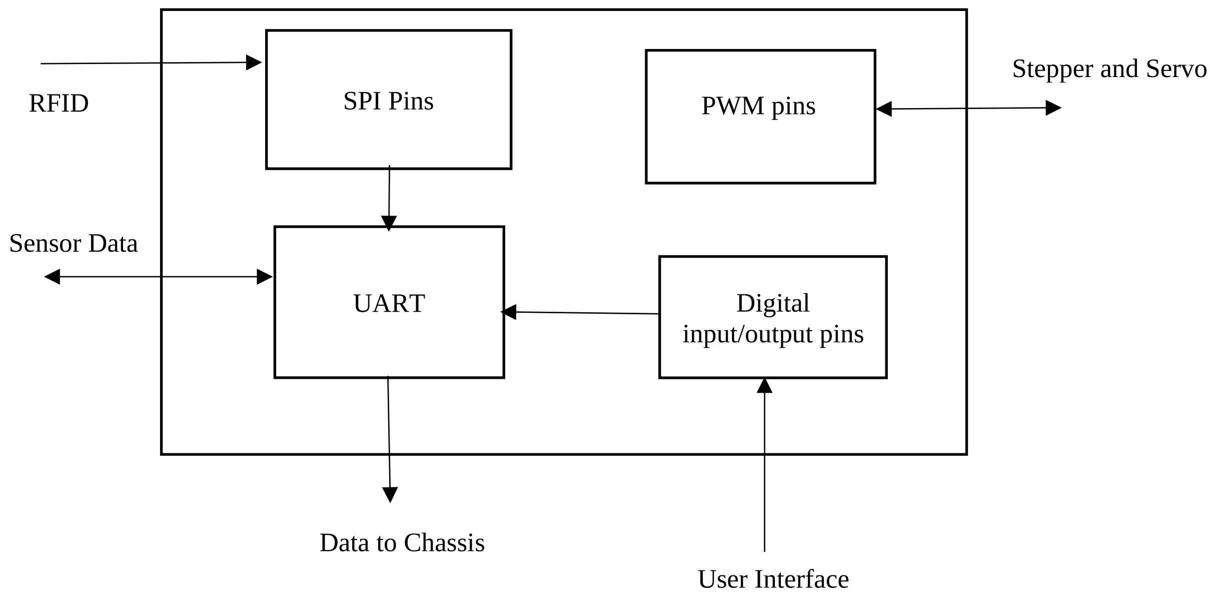

Fig. 30. Level 2 View of the Arduino

TABLE XXVII. FUNCTION OF ARDUINO

	Arduino
Input	User code through the keypad
	Receive sensor data while moving towards the destination
	Connect user interface to digital pins
	RFID antenna to SPI pins
Output	Send data to Stepper and Servo to press button
	Send data to the chassis
Function	Receive and process data from the sensor, user interface, and RFID tags.

3) Chassis

The next part of the system is the chassis. The main purpose of the chassis is that it is the PantherBot's transportation device. It reads its surroundings using sensors and RFID and sends that data back to the Arduino to process to avoid objects or people if necessary. The coordinates and travel path are hard programmed so the chassis will not be using a GPS. The chassis will receive the necessary data from the Arduino regarding the activation of the motors and final destination and if needed, the PantherBot is also capable of using an arm to select elevator buttons. Giving it the ability to go up and down elevators.

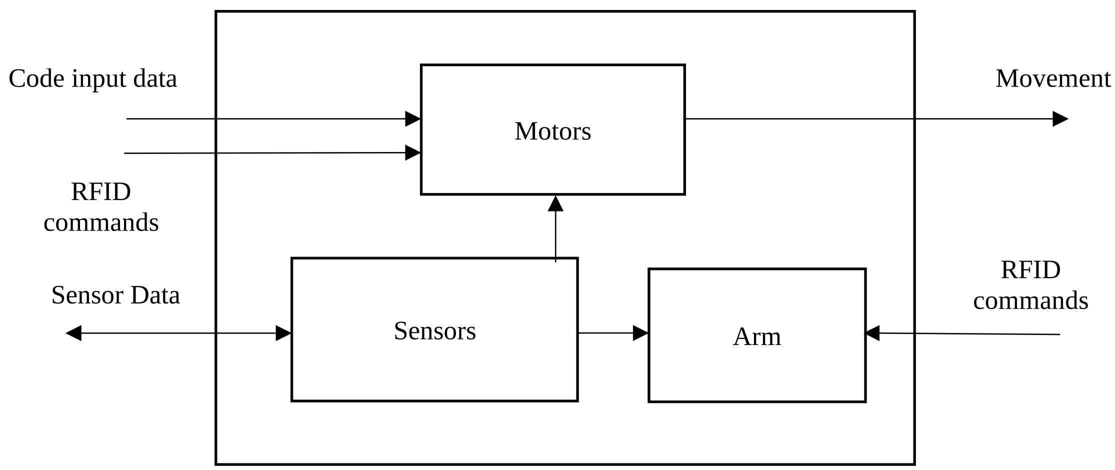

Fig. 31. Level 2 View of the Chassis

TABLE XXVIII. FUNCTION OF CHASSIS

	Chassis
Input	Code input data
	Sensor data to stop or maneuver around objects
	RFID commands
Output	Movement towards the final destination
	Sensor data picked up by the sensors
Function	Move the PantherBot and the package to the customer's location

4) Storage Area/Container

The final component of the PantherBot system is the Storage Area. This part consists of the food compartment, solenoid locks, a relay, and an Arduino. The food compartment is to keep the food safe and is intended to be insulated to keep the food hot or cold. The solenoid locks keep the compartment shut until the customer enters the password. And the Arduino is there to control the locks and send the data received from the User Interface to the RaspberryPi. The solenoid locks are controlled by the Arduino but aren't directly connected with each other. The solenoid locks are connected with the Arduino through the relay. The main function of the storage area is to keep the food safe while it's being transported to the customer

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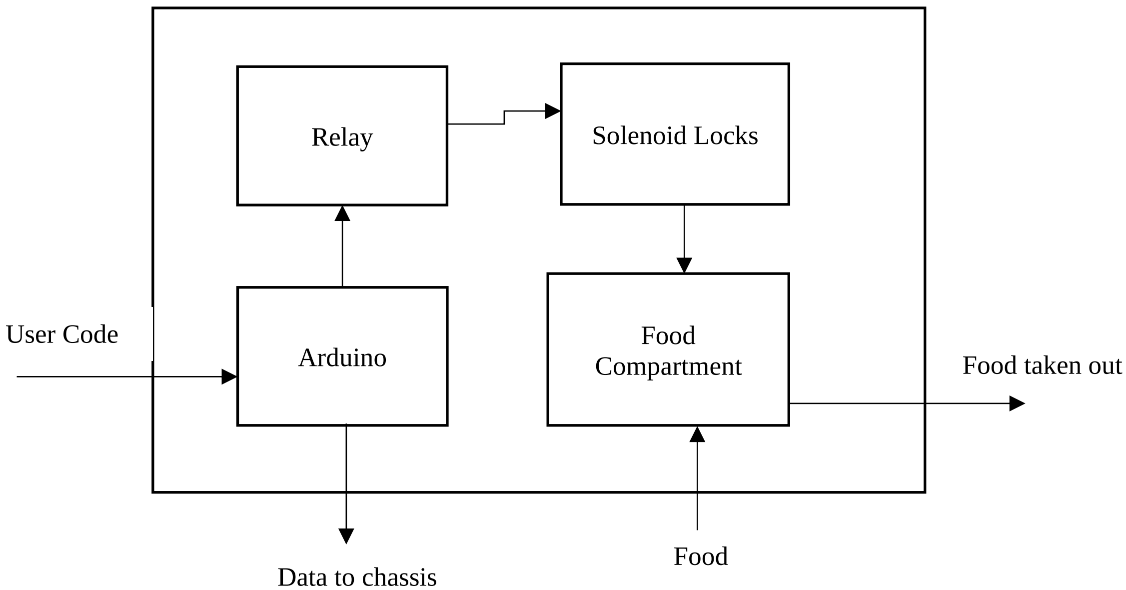


Fig. 32. Level 2 View of the Storage Area

TABLE XXIX. FUNCTION OF THE STORAGE AREA

	Storage Area
Input	User Code to lock or unlock the Compartment
	Food added to the compartment by the delivery driver
Output	Food is taken out of the food Compartment if correct code is entered
	Data sent to Raspberrypi from arduino
Function	Safe storage of the food

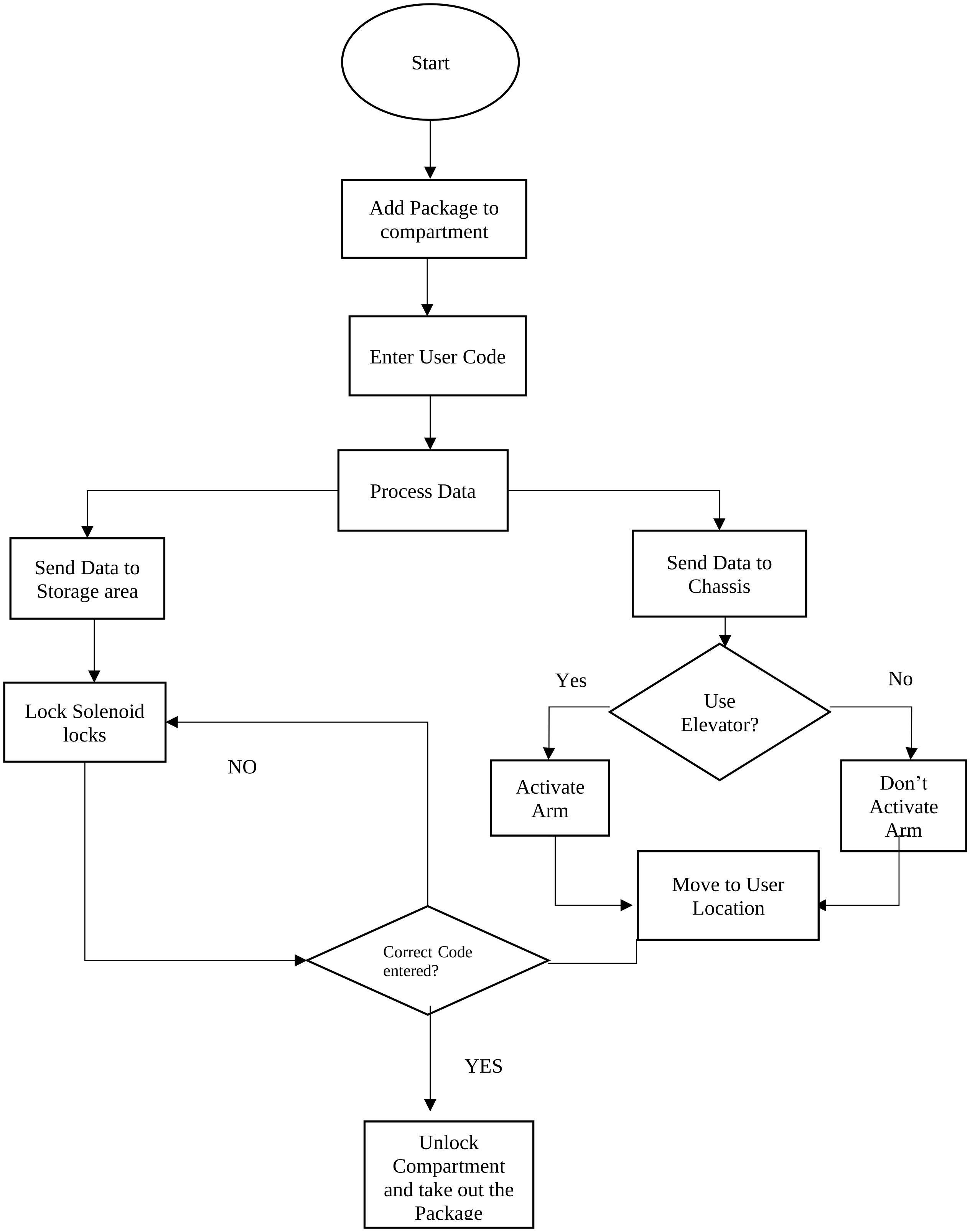


Fig. 33. Flowchart

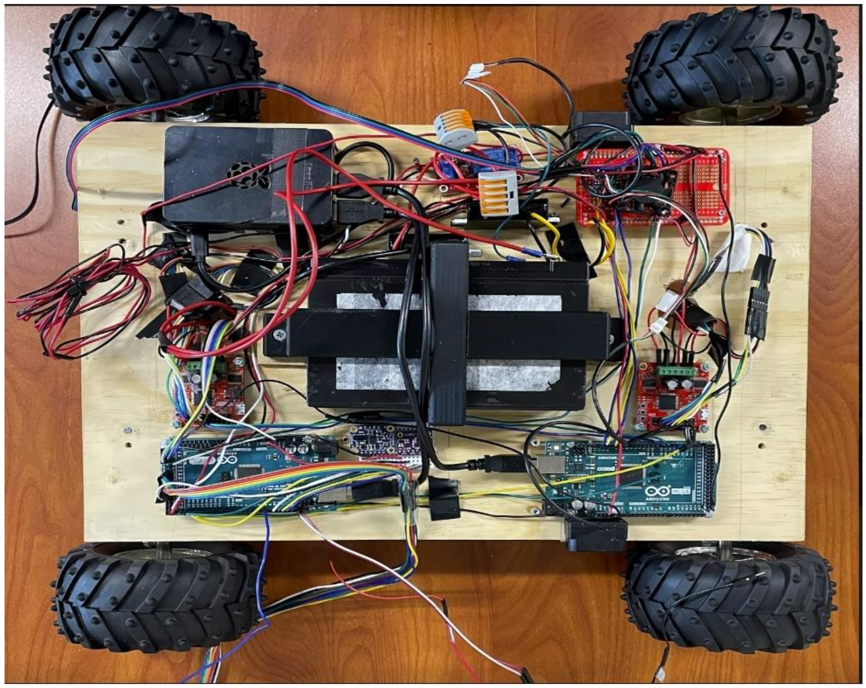


Fig. 34. Chassis

Fig. 35. Fully assembled PantherBot

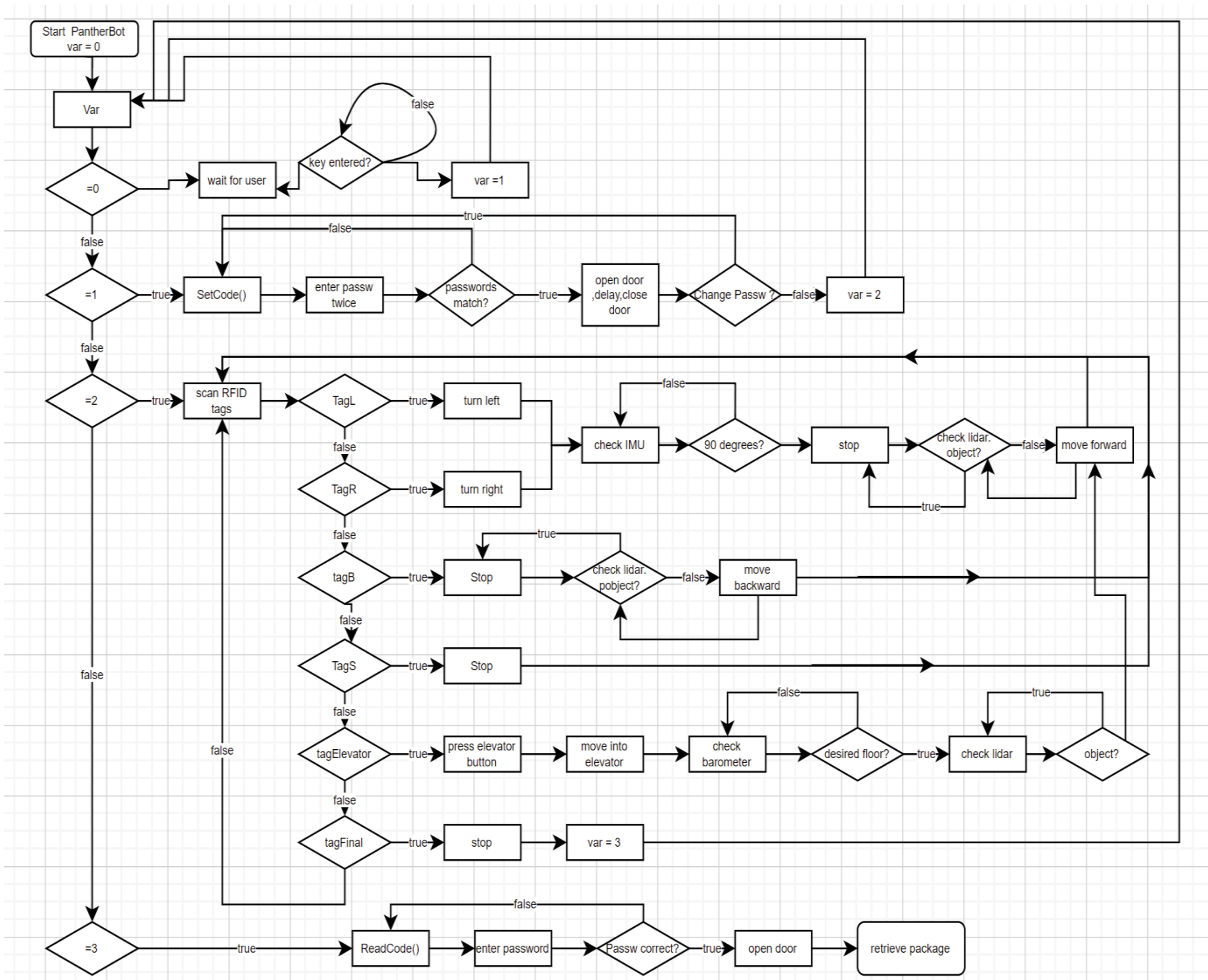


Fig. 36. Software flowchart

The program starts by waiting for a user. When it recognizes an input, the program set var equals to 1 and goes into the next case. In case ‘1’, the function SetCode is called, then asks the user to enter and re-enter a password. After entering their password, the lock opens and the user can insert their package and close the lid. After closing the lid, the program will ask the user if they want to reopen incase they forgot to add an item. If not, the program goes to case ‘2’. In case ‘2’, the PantherBot moves forward and activates its RFID scanner. The RFID tags placed on the floor will help the robot navigate to its final destination. Along the way, RFID tags will be placed in specific sections to determine whether the robot should make a right, left, stop, move backwards, reached an elevator, and its final destination. When the robot reaches the RFID tag at its final destination the program goes into case ‘3’. The program will then ask the user to enter the password used at the start and if the password is correct, the door unlocks and the user can retrieve their package and the case is then reset to ‘0.’

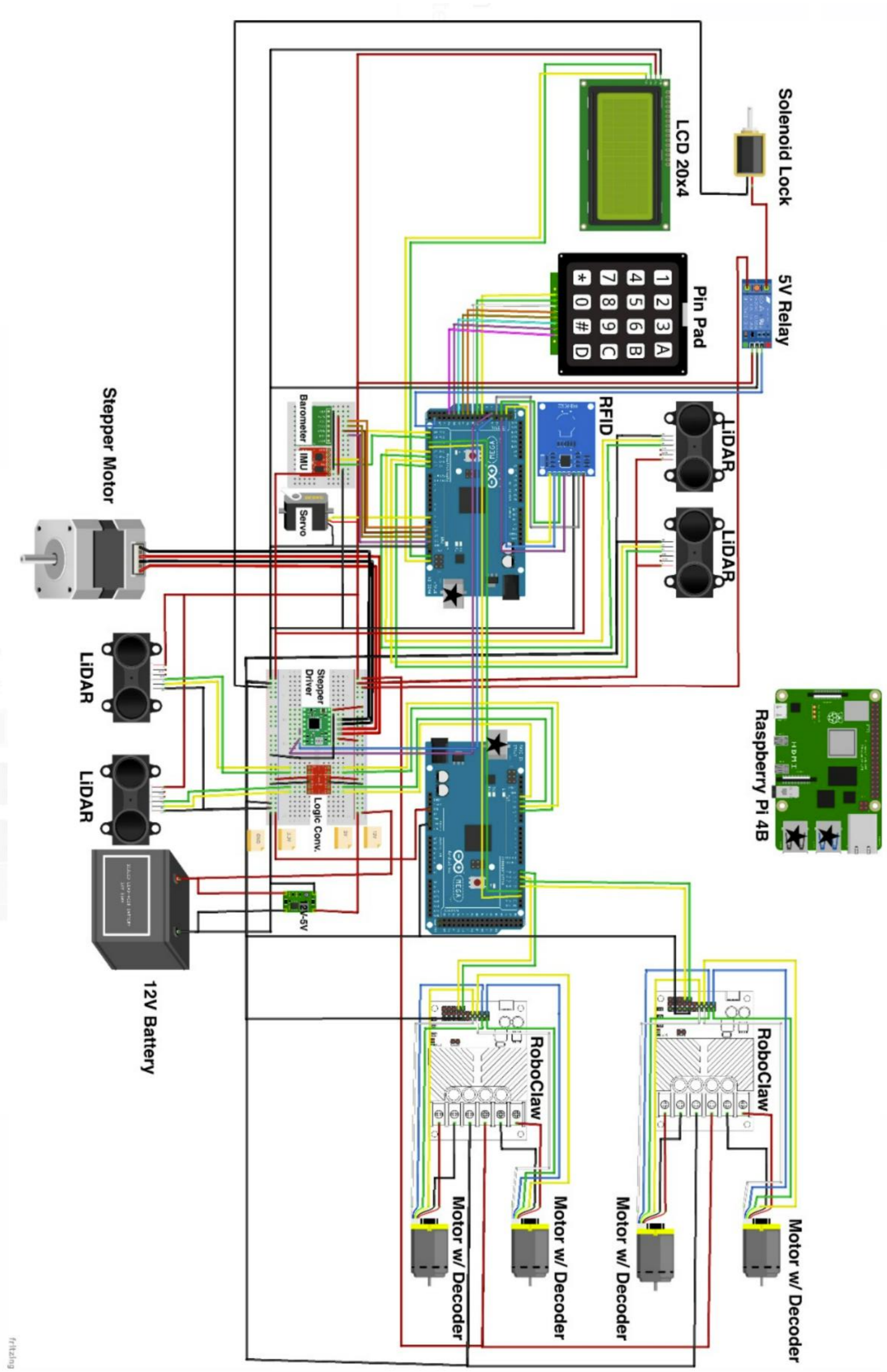


Fig. 37. Circuit Diagram

C. Specifications

The following section and TABLE VIII. will provide the users and designers with a list of parts needed for the PantherBot. This might also help the users on when or why they should replace certain parts. After an in-depth explanation of all of the parts, the table below shows all of the components required and their specifications.

TABLE XXX. SPECIFICATIONS

	New Components					
User Interface	2004A character LCD module 5V	Matrix Keypad 4x4 5V				
Arduinos	Micro-controller ATmega2560(a single chip micro-controller)	Digital I/O pins	Analog input pins	Power pins		
Chassis	TF Mini-plus Lidar sensor	18650 Battery Pack 12.6 V	Encoder TT motors 6V	Self-made arm with stepper and servo motor	BNO 055(IMU)	BMP 388(Barometer)
Storage Area	Electric Latch Lock 5V – 2A	12V Relay Module with Optocoupler High or Low-Level Trigger Expansion Board	Arduino mega 2560	Cooler Box		
Programming Language	C/C++					

	Old Components			
User Interface	2004A character LCD module 5V	Matrix Keypad 4x4 5V		
RaspberryPi	BCM2837 Quad ARM Cortex-A53	DSI Display Connector	5V 2A DC power	
Chassis	HC-SR04 Ultrasonic sensor 3-5.5V MPU6050 gyroscope sensor	18650 Battery Pack 12.6 V	Encoder TT motors 6V	SwitchBot with CR2 batteries
Storage Area	Electric Latch Lock 5V – 2A	12V Relay Module with Optocoupler High or Low-Level Trigger Expansion Board	Arduino Uno REV3 12V	Acrylic Box with an insulated liner 16x16x20
Programming Language	Python			

D. Other Deliverables

New projects often require deliverables to promote the use of the product. Deliverables help better understand the product and can increase the use and potentially help with the funding of the product. Products like ours often require some more explanation on how to use the product correctly and this is done by providing the users with other deliverables. Some of the deliverables we plan on providing users are:

1) Flyers

The team will create flyers to place around the Engineering campus to promote the use of the PantherBot and also provide information on how to use the PantherBot.

2) Video Presentation

A video will be made showing the PantherBot. This will include how the PantherBot is set up, how it functions on the elevator, and just overall how the PantherBot works during delivery.

3) Final Report

The final report will provide future designers and users the ability to fully understand the product and all the specifics that come along with it. This might not be the best option for casual users of the products, but it could be very useful for designers to potentially make improvements.

XIX. PLAN OF ACTION

Using time efficiently is an integral part of the project and helps to complete the project in time. A plan of action helps in organizing the work and keeps the team focused and adhering to the project. Project milestone and the important responsibility of the project is outlined by plan action. The plan of action further helps in breaking the project into sub-parts and assigning it to team members, it is widely used by team members to finish their sub-tasks on time which ultimately leads them to complete the project on time. The PantherBot is an autonomous robot particularly designed for delivery services monitored by an operator remotely; the design, its successful creation, and implementation demand the proper plan of action. Therefore, a plan of action was developed that helped in the proper implementation of PantherBot. In this action plan, we divide the task into subcategories and assigned specific intervals for each task to accomplish it. This not only helps us develop the PantherBot, but it also helps us to properly manage time, develop problem-solving strategies, use engineering skills and information technology tools efficiently and boost our independent learning ability.

*A. **Statement of work:***

Statement of work emphasizes the identification of all tasks that are a part of the project and that have to be completed in a specific interval. In this section, we elaborate on the scope of work, the location where we implemented and assembled the system, and the duration in which we completed the overall project. The distribution of tasks and responsibilities among the group members and the final date for delivering the project is decided in the statement of work.

1) Scope

The final product of the team that is delivered is the Panther Bot, an autonomous robot particularly designed for delivery services monitored by an operator remotely, avoids striking obstacles and the hurdles that the robot cannot clear on its path. PantherBot facilitates us in accomplishing the delivery tasks on various platforms like food or package delivery, which can be used in hospitals, hotels, and other room services, helping with time efficiency. It further helps make the system more convenient as it is low cost and environmentally friendly. The team designed the physical structure of the robot and power bank for both operations, and programming of the microcontrollers, then further assembled to execute delivery tasks.

2) Location

All major tasks were done and accomplished at the Florida International University engineering center, while part of this was completed remotely using online resources. For the design of the physical structure of the robot and the other hardware parts, our team used the IoT lab of the Engineering center. Our team members collaborated in programming the microcontrollers and assembling the structure of the PantherBot in the IoT lab of the Engineering center.

3) Period

The project was started on January 10, 2022, and the first preliminary deliverables like the presentation, the final draft of the report, and the initial videos were prepared for demonstration by the end of April 20, 2022. The test of the assembled system started on April 20, 2022, and is completed to present on July 29, 2022.

TIME-DIVISION OF TASKS

Serial Number	Tasks	Time for completion
1	[1] Research about project know about the basics and create a perfect action plan	[2] 2 Weeks
2	[3] Designing the physical structure of the PantherBot with appropriate dimensions and the wheel tracking	[4] 4 Weeks
3	[5] Microcontroller programming and coding	[6] 3 Weeks
4	[7] Sensor interfacing and relay implementation	[8] 2 Weeks
5	[9] Wiring and battery assembling	[10] 1 Week
6	[11] Integrated functional testing of the system with all the components assembled as a single unit	[12] 3 Weeks
7	[13] Miscellaneous activities	[14] 1 Week

4) Responsibilities

Every member of the group was assigned a specific task and their contribution was valuable for accomplishing this project. Every team member is knowledgeable on programming and other engineering skills. The individual specified roles of each team member is listed below.

David Lungus Team Leader – Was responsible for overseeing the entire project and scheduling meetings to make sure everything is on pace for completion. He assisted in software and hardware structuring along with Ricardo Flores; while mainly focusing on microcontroller integration.

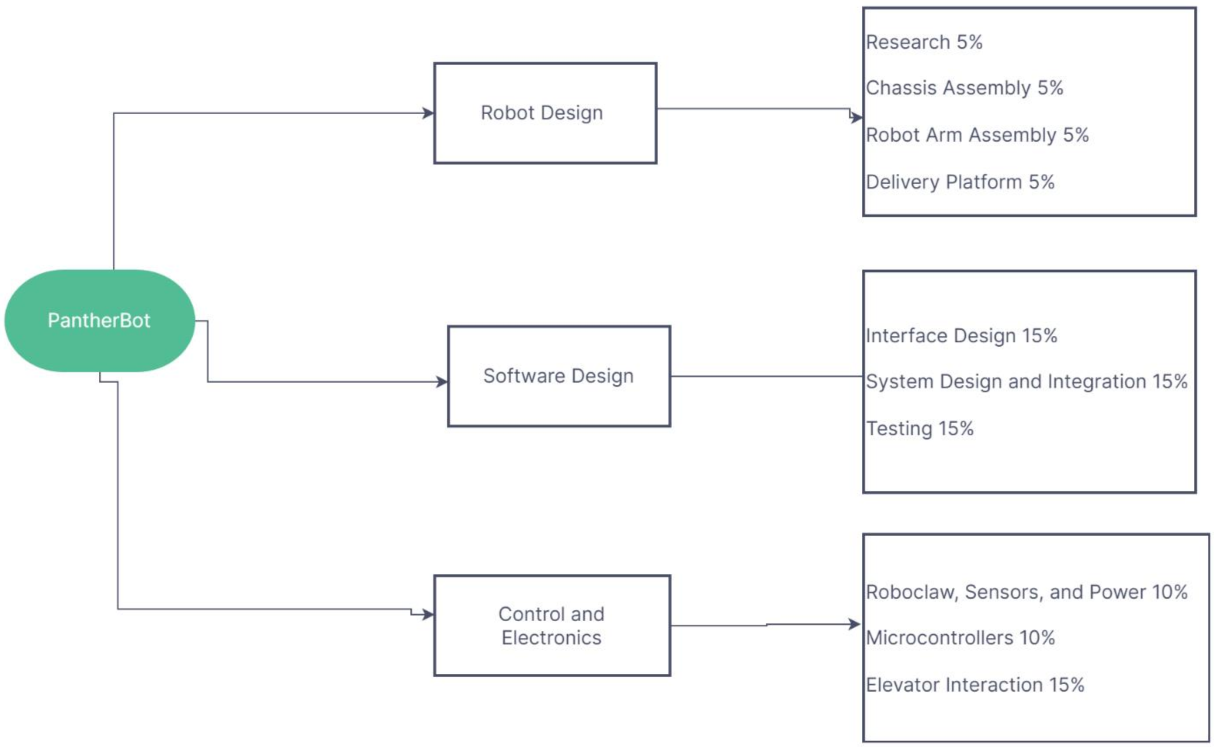
Ricardo Flores Programmer: Sensors were interfaced with Microcontroller and he was also responsible for the logic of the robot determining the floor level.

The PantherBot operation microcontroller programming responsibility was taken by Andres Ferreira and Jeremy Yskes, they also ensured the proper operation of the robot driving path in the hallways using sensors.

Ramon Johnson was responsible for the robot assembling and collection of data, and wire connection of the components. He collaborated with Jeremy Yskes for building the compartments of the PantherBot.

B. ***Work breakdown structure:***

With the help of the work breakdown structure, the team managed the time perfectly. In breakdown, our team realized the importance of every section of the project and its worth along with its percentage in quantified manners. Percentage demonstrates how each portion of the project contributed to the assembling of the overall system. The project is classified into different phases and each phase is composed of subtasks.



Work Breakdown Structure

1) *Phase 1: Robot Design*

- Aims and goals: Researched and designed a specific structure well suited for the PantherBot physical structure, robot arm, wheel tracking, and chassis assembly that enhances the stability of the robot.

- Approach: Reviewed papers and journals about delivery robot structure and schematics that we used as a robot arm. Chose the best material suited for both structures and the methods of PantherBot build.

- Expected Results: Well-designed structure, the robot arm is designed for elevator operation on delivery robots.

2) *Phase 2: Software designing*

- Aims and goals: Programmed the microcontroller according to the requirement of the autonomous delivery robot, system interfacing, integrated and designed the system, and then finally tested our end product.

- Approach: Sensors were interfaced one by one; along with their respective output. After that, we worked on programming for the initial movement of the robot when given a command.

- Expected Results: Microcontroller was tested for performing certain functions when a command was sent.

3) Phase 3: Software designing

- Aims and goals: Researched and chose the electrical components such as the Lidar sensors, servo motor, and all the other components that we used for the build of the PantherBot.
- Approach: Researched and calculated the power requirement of the different components that are used on the PantherBot, and determined the roles of each microcontroller and functions of the components that are connected to them.
- Expected Results: The battery provides enough power required for the operation of the robot, components attached to the microcontroller operate in accordance, assembly and control of the arm operating in the elevator, and the structure of the PantherBot functioned successfully.

*C. **Project Milestones***

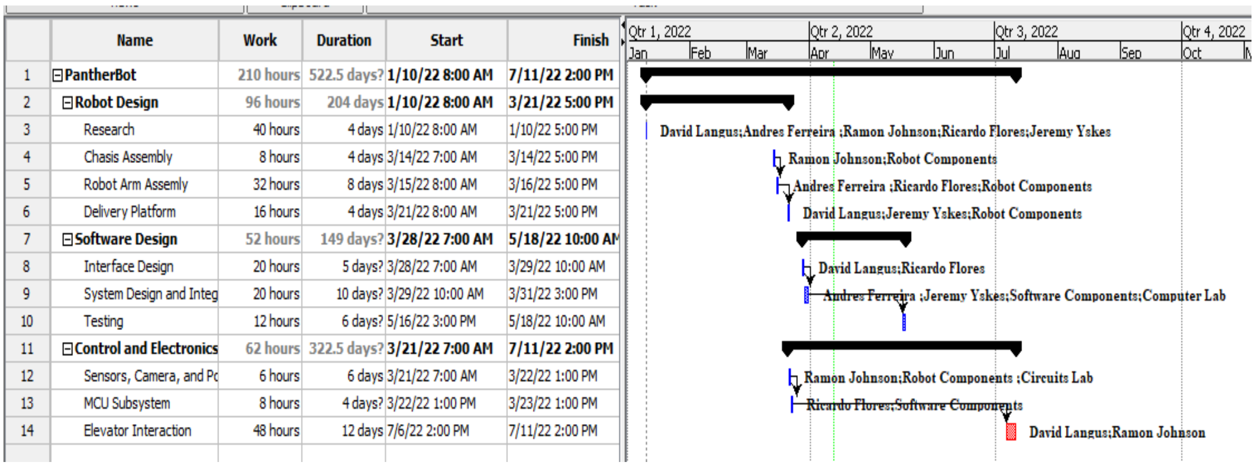
For a project to be completed on schedule, milestones are created to ensure that goals are achieved before a certain time. Milestones show the progress of the project and will keep the team focused on the tasks to achieve the milestone. The project has four milestones:

- Research- 3/17/2022
- Hardware Design- 4/25/2022
- Software Design- 6/17/2022
- Prototype- 7/29/2022

For the research phase, the team gathered all of the background information on materials and required devices. This stage required a month to determine the necessary materials to complete this project. After the research phase milestone is complete, we focused on the hardware design. This milestone was the hardest to achieve and required the majority of the time we spent on the build of the PantherBot, due to trials and failures encountered in the build. The last milestone is the prototype; this displays the fully functional product ready for a demonstration before the deadline in July 2022.

*D. **Gantt Chart***

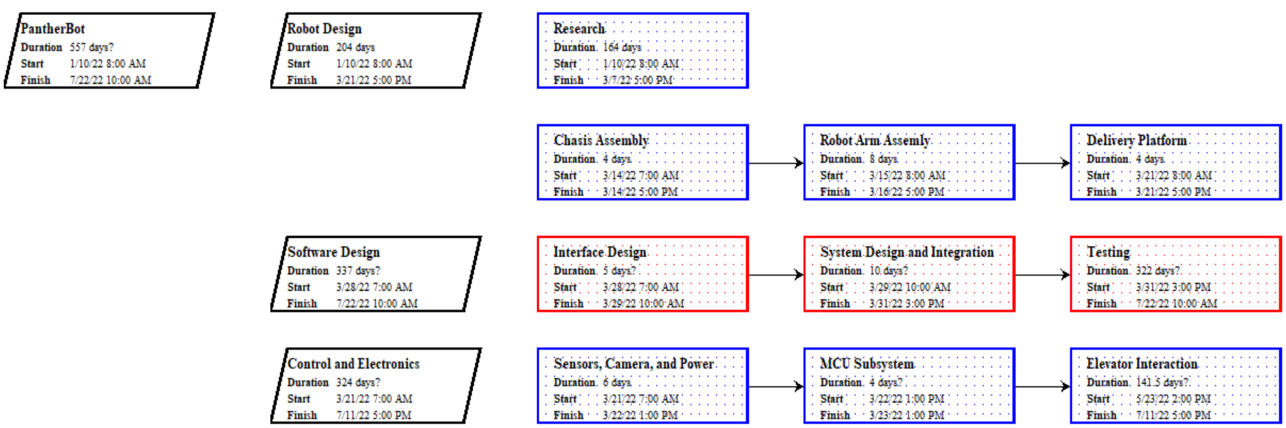
The Gantt Chart shows the phases; obtained from the Work Breakdown Structure, with their corresponding tasks. The chart displays the period that each task was completed, thus improving time management. Dependencies between tasks are also shown in the schedule. The Gantt chart was used for our project to organize and plan the outcome of the end product of the prototype. Fig. 9 is the Gantt chart for the PantherBot created in the Project Libre software.



Gantt Chart

E. PERT Chart

The Program Evaluation Review Technique Chart was utilized to organize and manage tasks for our project. The PERT chart is used similarly to the Gantt chart in which it outlines visually the tasks we needed to complete the project and their dependencies. It facilitates the process by finding the critical path, which is the longest chain of dependent tasks we encountered in the completion of the project. Fig. 10 shows the PERT chart for the PantherBot, which is derived from the Gantt chart created in the Project Libre software.



PERT Chart

The plan of action yielded a Gantt chart and a PERT chart, both of which outline the milestones of the project. The Gantt chart is a resource that allows the team to optimize task handling, and management; while assisting in the design of the hardware and software components effectively. The PERT chart highlights important deadlines and tasks that must be completed before the overall demonstration of the prototype by July 2022. The deadlines in the PERT chart accounted for extra time to safeguard from unforeseen circumstances that delayed the project. Effective planning and time usage were extremely important for the delivery of the PantherBot project.

XX. MULTIDISCIPLINARY ASPECTS

When two or more academic fields interact for a specific goal, this is referred to as multidisciplinary research. As a result, a multidisciplinary team approach brings together experts with various talents and experience to address an issue. Even though a multidisciplinary approach incorporates skills and information from other academic disciplines, learning from other subjects stays separate, even if the distinctions between them are minor. This section will explore the value of multifunctional teams and show how ours fits into that category. To do so, we'll describe what distinguishes one teammate from the others and how we complement one another as a unit.

Engineers' education is increasingly emphasizing multidisciplinary abilities. Engineers must be able to collaborate successfully with colleagues from many disciplines as globalization and technological advancements expand. Working in a diverse team has several benefits that aid in the effective completion of the project. Combining multiple areas of knowledge can result in innovative and high-impact research. It will also prevent the project from being viewed from only one perspective, which will eliminate issues in the later design stages.

Four computer engineers (David, Andres, Ricardo, and Jeremy) plus an electrical engineer make up our team (Ramon). The PantherBot design includes both software and hardware, which requires a multidisciplinary team. The electrical engineer is responsible for the design, development, testing, and management of electrical components; meanwhile the computer engineers are responsible for developing and installing the PantherBot software system.

TABLE XXXI. PANTHERBOT TEAM TASKS

Serial Number	Tasks	Discipline	Team Member
1	Tools arrangement, Soldering, wiring, oscilloscope, and breadboard.	General	All team
2	Financial handling and record, Inventory control, and components purchasing	Business Management	David Langus
3	Components soldering, wiring, sensor interacting, power	Electrical	Ramon Johnson and Andres Ferreira
4	Using IDE for programming the microcontroller.	Computer Programming	Ricardo Flores and Jeremy Yskes
5	Buzzer speaker and manipulator installing and amplification the signal	Electronics	Ramon Johnson
6	Designing the physical structure of the robot and wheel tracking	Mechanical	Andres Ferreira and Ricardo Flores
7	Integrated functional testing of the system with all the components assembled as a single unit	Electrical/ Mechanical/ Computer Programming	All team members
9	Documentation and presentation	Computer	Jeremy Yskes and David Langus

Major activities involve the skills of electronics and electrical. Using a microcontroller is a major part of the electrical discipline using embedded systems. The expertise of mechanical engineering was required for creating the physical structure of the bot with appropriate dimensions. For documentation and presentation, we acquired the skills of computer engineering.

The projected work activities were split, and individual team members were allocated duties. Each of the listed jobs was treated as its own entity, with team members assigned to them based on their credentials, experience, and interests. The recognized team member must perform the allocated assignment according to the plan of action. The identified team members were instructed to concentrate on their assigned tasks while also assisting others with their recommendations, ideas, and labor. The periodic evaluation was carried out to confirm that all of the operations were proceeding as planned. All decisions were made in a group setting, with team members debating among themselves before coming to a resolution.

Our team will be in contact, either in person or online, to minimize the delay in activities caused by the one-week vacation between semesters. We developed a Whatsapp group in which we are constantly communicating. Our objective is to meet at least twice a week to discuss the next steps in our project. Working in a diverse team has several benefits that aid in the effective completion of the project. Combining multiple areas of knowledge can result in research that is both original and high-impact. We are a multidisciplinary team since we have a computer and electrical engineers on our team. Each team member brings talents and experience that make them indispensable in the development of our products. Adaptability, collaboration, and flexibility are all traits that benefit us as a group.

XXI. PERSONNEL

A. ***Jeremy Yskes***

1) Strengths

- Knowledge of programming languages C, C++, Java, VHDL
- Understanding of advanced Data Structures and Embedded software
- Worked with Basys3, ESP8266, RaspberryPi, Beagle Boneblack, Arduino
- Knowledge of Loadable Kernel Modules and Device Drivers
- Used Design software Multisim and CoppeliaSim
- Technical and Analytical

2) Education

- Broward College 2017-2019
    - Associate of Arts
- Florida International University 2020 -2022
    - Majoring in Computer Engineering
    - Concentrating on Data Systems Software, Cybersecurity, and Embedded Systems Software
    - Current GPA 3.8

B. ***Andres Ferreira***

1) Strengths

- Knowledge of programming languages C, C++, Java, VHDL
- Worked with ESP8266, RaspberryPi, Beagle Boneblack, Arduino
- Knowledge of loadable kernel modules and Device Drivers
- Used design software such as Multisim, AutoCad, and SolidWorks
- Knowledge of Cyber Security, Telecommunication Systems, and Data Structures
- Technical

2) Education

- Miami Dade College 2016-2018
    - Associate of Arts
- Florida International University 2019-2022
    - Majoring in Computer Engineering
    - Concentrating on Data Systems Software, Network and Security, and Embedded Systems Software
    - Current GPA 3.2

*C. **Ricardo Flores***

1) Strengths

- Knowledge in programming languages C, C++, Java, VHDL
- Familiar with advanced Data Structures
- Worked with Basys3, Arduino, Beagle Boneblack
- Knowledge of loadable kernel modules and Device Drivers
- Used design software such as Multisim, and Quartus
- Technical

2) Education

- Miami Dade College 2017-2019
  - Associates in Arts
- Florida International University 2019-2022
  - Majoring in Computer Engineering
  - Concentrating on Data Systems Software, Embedded Systems Software, Cybersecurity, Digital Forensics, and Internet of Things
  - Current GPA 3.2

*D. **Ramon Johnson***

1) Strengths

- Critical Thinking
- Complex problem-solving skills.
- Installing and Testing of electrical components
- Design ways to use electrical power in product development
- Technical
- Knowledge of Power and Energy systems
- Understanding of IoT technology and internet-based technology

2) Education

- Broward College 2016-2019
  - Associated in Arts
- Florida International University 2019-2022
  - Majoring in Electrical Engineering
  - Concentrating in Power/Energy Systems and Artificial Intelligence and Big Data
  - GPA 3.2

*E. **David Langus***

1) Strengths

- Leadership
- Knowledge in programming languages C, C++, Python, VHDL, Java, MATLAB
- Worked with FPGAs, RaspberryPi, Beagle Boneblack, STM32, ESP8266, Arduino
- Knowledge of loadable Kernel Modules and Device Drivers
- Understanding of Microcontroller and microprocessor-based systems
- Machine learning
- Knowledgeable about Cyber Security
- Understanding of IoT technology and internet-based technology
- Worked with FreeRTOS

2) Education

- Florida International University 2018-2022
    - Majoring in Computer Engineering
    - Concentrating in Computer Architecture & Microprocessor Design and Cyber Security
    - Current GPA 3.8

XXII. BUDGET

Defining the budget is one of the most important steps for any project. It specifies the amount of money that will be used in the project. Where the money will come from and what it will be used for in relation to our design. In collaboration with our project mentor, Dr. Uluagac, a project sponsor will be identified towards finalizing the design. Then, the budget by phase and the budget by resource will be calculated using ProjectLibre.

SPONSOR

Sponsor	Amount
TBD	TBD

ProjectLibre was used to plan the project. Below is a breakdown of Phase Costs by Budget. Different tasks are assigned to each Phase. In the table below, there are only the phases that have a cost. The other tasks, such as Product Enhancement, Project Research, and End Product Testing, will be based on hours per group member.

BUDGET BY PHASE COST

PantherBot	**$5656.00**
Robot Design	$2418.00
Research	$1780.00
Chassis Assembly	$40.00
Robot Arm Assembly	$87.00
Delivery Platform	$521.00
Software Design	$1824.00
Interface Design	$22.00
Testing	$432.00
System Design and Integration	$1370.00
Control and Electronics	$1414.00
Sensors, Camera, and Power	$293.00
MCU Subsystem	$257.00
Elevator Interaction	$864.00

The Table below shows the Budget by Resource Cost and is also made form ProjectLibre. Every team member is assigned a certain number of hours depending on the tasks they are expected to do. This number is then multiplied by their hourly wage and the table also includes the price of hardware and software components.

BUDGET BY RESOURCE COST

	Hours/Use	**Cost Per Unit**	**Total**
David Langus	43.13	$18.00	$776.34
Andres Ferreira	30.667	$18.00	$552.00
Ramon Johnson	43	$18.00	$774.00
Ricardo Flores	45	$18.00	$810.00
Jeremy Yskes	30.667	$18.00	$552.00
Computer Lab	6.667	$100.00	$666.70
Circuits Lab	3	$15.00	$45.00
Robot Components	4	$300.00	$1220.00
Software Components	2	$130.00	$260.00
	Grand Total		$5656.00

The ProjectLibre software helped organize the phases and provide us with an estimate of the budget that we will need to execute this project. Phases that required no budget were left out of the Budget by Phase and the Budget by resource refers to the cost of the components and hourly pay each teammate will demand.

XXIII. Result Evaluation

PantherBot is a project done by 5 future engineers, out of which four will become computer engineers and one will become an electrical engineer. A project like this will demand a lot of effort from every single one of us. This section will mainly focus on the evaluation of the promises stipulated from our research throughout the design of the PantherBot.

*A. **Technical Results***

1) Project Objectives and Constraints

In the proposal, we stated that our objectives were that the PantherBot has a collision prevention protocol for safety, it need to efficiently deliver the package for it to be scalable, it needs to be user friendly, and the PantherBot needs to elevator friendly. As for the objectives, we essentially accomplished them all. We have a collision prevention system in place through the use of lidar sensors on the front, back, and sides. The package delivers even faster than predicted. The PantherBot takes about 4 minutes to get from the front door to the Panther pit. As for user friendliness, The PantherBot is incredibly simple to use and we included an LCD screen to tell the users exactly when to enter their password, when the door opens or closes, and options to reopen the door in case they need to. And lastly, the robot is also able to use the elevator through the use of custom-made arm controlled by a stepper motor and servo motor. The main constraints for this project were that the entire system had to cost around $750 and add a rechargeable battery. For the constraints, we missed our target budget mainly due to lack of knowledge of costs and updating equipment. However, we did manage to add a rechargeable battery and that is fairly easy to attach to the charger.

2) Standards

a) IEEE 1823-2015

The IEEE 1823-2015 standard was accomplished by having serial communication between the Arduinos and the Raspberry Pi via universal serial busses. This communication allowed the Arduinos to be powered, receive code, and send values to the Raspberry Pi.

b) ISO 14001:2015 (Environmental Management System)

The ISO 14001:2015 standard was accomplished by using a rechargeable and recyclable battery with long life span to reduce the impact in the environment when the battery needs to be replaced. Also, this standard was accomplish limiting the overall power consumption used by the entire system by using most components only when they are needed.

c) ISO 9001 Certification (Quality Management System)

The ISO 9001 Certification was not accomplished since the code used for the system was never examined by any auditing agencies. Therefore, the code that was used is not certified.

d) IEEE 802.11

The IEEE 802.11 standard was not accomplished since the system is not connected to the internet. The main factor of this decision was the construction of the arm over the SwitchBots to press the buttons of the elevator. This lower the complexity of the PantherBot, as well as the impact on the building by not modifying the building with addition of the SwitchBots.

3) Concepts

For the concepts, we initially had Lidar + camera, wireless charging, code insertion, and the us of the SwitchBot. We eventually swapper the lidar + camera for just the lidar, the wireless charging for wired charging, and instead of the switchbot designed a custom arm. The reason why we didn't use the camera is because it was redundant. The lidar itself was more then we expected to avoid any obstacles. The wireless charging station was changed to wired because of implementation issues. The first issue was that it was too expensive and would take up too much time. The switchbot was then replaced by the custom arm because of regulation issues.

4) Specifications

The Specifications for this project were, at least 4 DC motors big enough to provide enough torque to be able to move the whole robot and its cargo to at least 3 miles per hour, a set of cameras to set a redundant perimeter around the robot embedded with motion and proximity software, a lock and keypad to be able to control the access to the package inside the container, a microcontroller to manage the insertion and verification of the code as well as all the software to control the robot, a screen to display messages to the users. We managed to incorporate 4 motors capable of going 3 mph or even faster if programmed to, the lock and keypad, a microcontroller (2 Arduinos), and an LCD screen for user interaction. The reason why we didn't incorporate the cameras was because the front, back, and side lidars, gave the PantherBot enough data of its surroundings to avoid any object collision.

5) Deliverables

a) Flyers

The PantherBot team was not able meet the flyer deliverable due to a time constrain.

b) Video Presentation

The PantherBot team was able to meet with the video presentation deliverable. On this video we were able to explain the purpose, features, and logic of the robot's system.

c) Final Report

The PantherBot team was able to meet with the final report deliverable. On this report we were able to explain in detail every component and its circuitry with the whole system. Also, on this report we were able to show the software flow chart in detail. With this the constrains and its capabilities. This would allow to anyone who reads the final report to fully understand how the robot works and if possible, continue our work and make improvements to the PantherBot.

*B. **Globalization Retrospective***

As for the globalization of the project, our stance on if our project could become a global success has not changed. We still believe that the PantherBot can be a global success. As mentioned before, the current delivery system is becoming obsolete. Initially, these robots were fully controlled by humans, but as technology advances, there are becoming more autonomous with time. Therefore, now more places globally are implementing similar autonomous and semi-autonomous robots to perform this task. The way we implemented the PantherBot can essentially be implemented in any building. Some cultures may be opposed to the idea of even more automation, but automation is bound to happen and we believe that this is the next step. For now, we are just focusing and starting at the FIU engineering building. However, there might be some limitations regarding the trading barriers. Every country has their own regulations and some of the parts of the implementation might be going against their regulations. One of the issues could be the RFID tags. Not all buildings would allow the use of RFID tags on the floor or walls for its navigation. Apart from limitations from parts of our project, the situation with covid-19 and tension between Russia and Ukraine will affect the international trade.

Even though this is a simple evaluation to our project. The outcome of the evaluation will help us better understand our skills and the way these can come together to form a complete project. The PantherBot will not only be a school project. PantherBot will be a first step into our careers as computer and electrical engineers to society. After completing and evaluating the PantherBot, all of us will have finally reached the last stage in our bachelor's at Florida International University.

XXIV. LIFE-LONG LEARNING

Lifelong learning refers to the knowledge and skills obtained after formal education or after completing the project. It is built on prior learning and expanded through the lifetime to address new problems and processes. Designers must continue learning due to the rapid development of technology and change. Our team must stay updated on the industry and what actions should be taken to keep the PantherBot in the market. In this section, we explain what would be required to get the PantherBot into production and the diverse activities our team will implement to keep ourselves current on our project's topics. Since our end product will be a different approach to the basic delivery robot service, it will be our responsibility to continue learning over time.

The process of getting a brand-new product into production is a complex one that includes many stages. First, designers must make sure that the development proposed will meet the current market needs. In addition, research must be done to make sure the product created will be of value to the customer and not waste money, time, and ideas. Next is the design of the concept. Some factors that must be considered are the product functionality, the intended user and uses, total budget, software and hardware needed, etc. These primary steps are completed in the first semester of our design. Next, we will work on building and prototyping the design. Creating a prototype is essential because it will reduce uncertainty and decrease risks. We must imitate the projected end product as much as possible to catch design flaws or specific areas that require improvement. As we enter our launch, it is vital to provide beta testing and receive feedback from our product partners as we enter our launch phase. We would have a model as close as possible to our desired end product. The next step is to perfect the design and anticipate problems and related solutions. We must give attention to how we will set up and manage all aspects of production, deliver, and package our final product, revise that any patents are not an infringement and that our product will be sustainable.

In order to keep ourselves current in the topics we will read and synthesize papers from various recognized journals with the help of the Florida International University Library. Also, we will attend technical conferences related to our field of study. In these conferences we will learn how our field is evolving and we will be able to inquire about any doubts we may have. Finally, we will make small group thinking events in which we will discuss current technical topics, think about what kind of impact they have and how we can make them better. By performing these simple tasks throughout the rest of our careers we will be able to stay competent engineers in a rapidly changing world.

After completing this project, most of us found a new passion for certain areas in the tech field that we probably never even considered looking into. This project has shown us that there is much more to learn than we thought. The capability of certain components like the Roboclaws and encoder motors have caught our attention and increased our curiosity. Working on this project has shown us the capability of components we have never even heard of. So, when being asked the question as to how the project has motivated us to engage in life-long learning, our team's answer would be is the unrealized potential of components that were entirely new to us and even the one's we have used in the past.

In conclusion, this lifelong learning is not only essential for us but also for the success of our product and future careers. Our team must keep pushing and developing alongside technology. We will enroll in technical organizations such as the Institute of Electrical and Electronics Engineers (IEEE) to help us stay updated in our fields topics. We must be ready for difficulties after the production of PantherBot and therefore must develop post-production activities such as questioners to inquire our clients. Finally, creating marketing and campaigns will help attract new clients and show them how easier their lives could become with our product.

XXVI. Conclusion

The PantherBot wasn't an idea that was pitched to us by a sponsor, nor was it a suggestion given to us by our mentor. Instead, our original concept for our project was going to revolve around drones. But what happens when you put five university students together late at night in the campus lounge next to the cafeteria. Well, that answer is simple for anyone, they get hungry. So, the idea was born from hunger and describing how we didn't want to stop our brainstorming of ideas. At the time we had no idea that designs for autonomous delivery robots were already on the market. Yet after discussing the idea more and pitching it to not just our mentor, but friends and other students. The overall acceptance of the idea became the foundation of our project. This was only the start of the development process. We still had to gather more information to get a good idea of what everyone would want from the product i.e., the need feasibility. Through this, we gathered great ideas to incorporate into the final design of the project. We used these exchanges of ideas with others and ensured that the engineering team would meet at a minimum of one time a week after class to discuss the project.

As for the result evaluation projections, most of them were met. The PantherBot is capable of making autonomous deliveries, it is able to use the elevator, it has collision prevention system, it is user-friendly, has a rechargeable battery, it complies with the ISO 14001 and IEEE 1823, the concept was achieved, all the specifications were met except for the set of cameras, and lastly the deliverables we only didn't manage to create the flyers.. The PantherBot strives to help all users not just the customers but also the person delivering the package. We hope to make it easier for the delivery driver and more efficient, allowing them to complete their rounds at a more optimal level. While making it easier for the customer to receive the package without having to leave their location to get the package.

The efficiency of the PantherBot is among its most notable advantages. Customers may now purchase meals or other things online and have them delivered right away to the Florida International University engineering center, saving them time waiting in line or moving around to receive their parcel. Additionally, the PantherBot is inexpensive in that all users need to do is get notified by the delivery driver when their package arrives and receives the passcode that allows them to access the storage compartment, making it one of the least expensive delivery services. The delivery robot is more dependable since, once it is launched, there are excellent possibilities that it will successfully arrive at its location. The PantherBot project was essential for our team members to achieve strong communication skills and teamwork, since the start of the project in May we decided to meet for roughly four hours each day of the week and sometimes on weekends when we needed to. Project management was a key factor that we adapted along the way, with multiple setbacks and how we overcame those issues to deliver our final prototype for the delivery deadline. Overall, we approached and applied various conditions encountered in our project milestones with engineering disciplinaries that we have learned along the way and new knowledge of different cases that we got introduced to while assembling the delivery robot.

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XXVIII. Appendices

A. ***Team Contract***

As a member of Team Number 1

I hereby agree to the following conditions:

1. I will demonstrate great interest to participate in class, share my ideas and discuss them openly with other team members.
2. I agree to follow the rules and guidelines that have been attained and established by the team in a “majority of votes” decision.
3. I am solely responsible for any assigned material by the team. I will submit my work on time and in good shape.
4. In case of an unforeseen absence, it is my responsibility to promptly contact my team members and learn of any new material. An announced and anticipated absence is much appreciated.
5. My performance is regularly reviewed and openly shared by the team. In case of a negative performance (decided by the majority of votes) I will be issued a written warning.
6. The team holds the right to release me after the third (3^{rd}) warning (decided by the majority of votes), I am thereof entitled to file an appeal to the class professor and request arbitration.
7. Reason(s) to issue a warning may be but are not restricted by the following reasons:
   a. Unable to submit an assignment on time.
   b. Lack of team participation.
   c. Obscene and improper conduct.
8. I am not allowed to abandon my team under any circumstances.

Team Leader Name	Signature	Date	Roles
David Langus		7/25/2022	Financial handling and record, Inventory control, and components purchasing
			Tools arrangement, Soldering, wiring, oscilloscope, and breadboard.
Team Member name	**Signature**		**Roles**
Ricardo Flores		7/25/2022	Using IDE for programming the microcontroller.
			Designing the physical structure of the robot and wheel tracking
Ramon Johnson	R. Johnson	7/25/2022	Components soldering, wiring, sensor interacting, power
			Buzzer speaker and manipulator installing and amplification the signal
Andres Ferreira	Andres Ferreira	7/25/2022	Components soldering, wiring, sensor interacting, power
			Designing the physical structure of the robot and wheel tracking
Jeremy Yskes		7/25/2022	Using IDE for programming the microcontroller.
			Tools arrangement, Soldering, wiring, oscilloscope, and breadboard.

B. *Intellectual Property Contract*

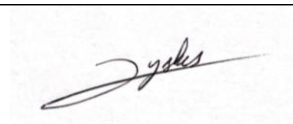
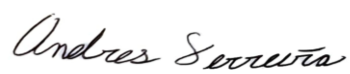
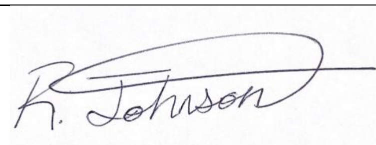
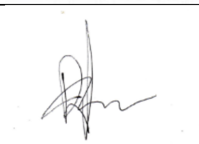
As a member of Team Number 1, we hereby agree to the following:

1. The team, consisting of David Langus, Jeremy Yskes, Andres Ferreira, Ramon Johnson, Ricardo Flores, has approved this contract.

2. The designated spokesman of Team Number 1 is David Langus

3. In case of the invention going to the market, the profit will be shared evenly amongst all the team members of Team Number 1.

4. Any decision regarding the intellectual property of Team Number 1 will be determined by majority vote between team members. All team members need to be physically present in order to hold a voting session. If a decision cannot be made by the team, the mentor will be consulted in order to make an informed decision.

Team Leader Name	Signature	Date
David Langus		7/25/2022
Team Member Name	**Signature**	**Date**
Jeremy Yskes		7/25/2022
Andres Ferreira		7/25/2022
Ramon Johnson		7/25/2022
Ricardo Flores		7/25/2022

C. Provisional Patent Form

Priority Mail Express® Label No. ______________________________

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Jeremy	Yskes	Davie, Florida
David	Langus	Hialeah, Florida
Ramon	Johnson	, Florida
Ricardo	Flores	West Kendall, Florida
Andres	Ferreira	, Florida

Additional inventors are being named on the ______________ separately numbered sheets attached hereto.

TITLE OF THE INVENTION (500 characters max):

PantherBot

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☐ The address corresponding to Customer Number:

OR

☑ Firm or Individual Name

Address 10555 W Flagler St

City Miami	State Florida	Zip 33174
Country USA	Telephone (305)348-2522	Email eceinfo@fiu.edu

ENCLOSED APPLICATION PARTS (*check all that apply*)

■ Application Data Sheet. See 37 CFR 1.76.

☐ CD(s), Number of CDs ______________

☑ Drawing(s) *Number of Sheets* ______________

☐ Other (specify) ______________

☑ Specification (e.g., description of the invention) *Number of Pages* ______________

Fees Due: Filing Fee of $300 ($150 for small entity) ($75 for micro entity). If the specification and drawings exceed 100 sheets of paper, an application size fee is also due, which is $420 ($210 for small entity) ($105 for micro entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

METHOD OF PAYMENT OF THE FILING FEE AND APPLICATION SIZE FEE FOR THIS PROVISIONAL APPLICATION FOR PATENT

☑ Applicant asserts small entity status. See 37 CFR 1.27.

☐ Applicant certifies micro entity status. See 37 CFR 1.29.
Applicant must attach form PTO/SB/15A or B or equivalent.

☐ A check or money order made payable to the *Director of the United States Patent and Trademark Office* is enclosed to cover the filing fee and application size fee (if applicable).

TOTAL FEE AMOUNT ($)

☐ Payment by credit card. Form PTO-2038 is attached.

☐ The Director is hereby authorized to charge the filing fee and application size fee (if applicable) or credit any overpayment to Deposit Account Number: ______________.

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

PTO/SB/16 (10-20)
Approved for use through 11/30/2020. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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PROVISIONAL APPLICATION FOR PATENT COVER SHEET – Page 2 of 2

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government. (NOTE: Providing this information on a provisional cover sheet, such as this Provisional Application for Patent Cover Sheet (Form PTO/SB/16), does not satisfy the requirement of 35 U.S.C. 202(c)(6), which requires that the *specification* contain a statement specifying that the invention was made with Government support and that the Government has certain rights in the invention.)

☑ No.

☐ Yes, the invention was made by an agency of the U.S. Government. The U.S. Government agency name is: ______

☐ Yes, the invention was made under a contract with an agency of the U.S. Government.

The contract number is: ______

The U.S. Government agency name is: ______

In accordance with 35 U.S.C. 202(c)(6) and 37 CFR 401.14(f)(4), the specifications of any United States patent applications and any patent issuing thereon covering the invention, including the enclosed provisional application, must state the following:

"This invention was made with government support under [IDENTIFY THE CONTRACT] awarded by [IDENTIFY THE FEDERAL AGENCY]. The government has certain rights in the invention."

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

SIGNATURE David Langus DATE 4/22/2022

TYPED OR PRINTED NAME David Langus REGISTRATION NO. ______
(*if appropriate*)

TELEPHONE (786) 564-1709 DOCKET NUMBER ______

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which mayresult in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided byyou in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to complywith the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treatyin this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Securityreview (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records maybe disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted byGSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records maybe disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

XXIX. SIGNATURES PAGE

Course Number: EEL 4921C Semester: ____**Summer**________ Year: __**2022**_________

Mentor Name: ____ **A. Selcuk Uluagac** ____

Senior II Instructor's Name_____**Wilmer Arellano**____

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David Langus	5961154	dlang029@fiu.edu	(786)564-1709

	PRINT	SIGNATURE	DATE
Team Leader	David Langus	[illegible]	07/25/2022
Team Member	Jeremy Yskes	[illegible]	07/25/2022
Team Member	Andres Ferreira	Andres Ferreira	07/25/2022
Team Member	Ricardo Flores	[illegible]	07/25/2022
Team Member	Ramon Johnson	R. Johnson	07/25/2022
Mentor	A. Selcuk Uluagac	Prof. Selcuk Uluagac	07/25/2022