EECE443 Assignment 2

PROJECT 1: VRL- Project Feeder- Package Delivery ROBOT

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VRL- Project Feeder- Package Delivery ROBOT

Anna C. Capdevielle, *Member, IEEE*, Joshua A. Freyou, *Member, IEEE*, Trent A. Garrett, *Member, IEEE*, Tobi M. Jackson, *Member, IEEE*, and Michael D. Reichert, *Member, IEEE*

***Abstract*—In the past decade or so, automation, along with machine learning, has become the raison d'etre of the engineering industry. Everything from vacuums to suitcases to cars are being implemented in ways that make certain tasks more efficient and the lives of humans easier. Though because these tasks are becoming more complex, the procedure of building reliable machines that can be easily maintained while also considering the compromises that must be made becomes all the more crucial. This paper looks at this process in a step-by-step manner in order to show what is necessary to deliver one of these devices; namely, an autonomous package delivery robot capable of distinguishing between packages and being able to deliver them regardless of both the packages' orientation and the layout of the building and obstacles around it. The proposed method uses a Pixy2 camera in order to differentiate the packages from each other along with their desired locations while mecanum wheels are being used in order to provide precise movement. The obstacles will be handled using IR sensors and both the wheels and the sensor will be connected to a Teensy 3.6 with functions for the procedures being coded onto the microcontroller using the Arduino IDE. The actual picking up and dropping off of the blocks will be handled by a robotic arm while both the arm and Teensy 3.6 are connected to a Raspberry Pi that uses the functions set up in both the Arduino IDE and Python IDE.**

Index Terms— Index Terms?

I. Introduction

THIS design project is building an autonomous package delivery robot for our Senior Design 1&2 class. The robot will have to traverse a 4x8ft board collecting blocks, 'packages' then after sorting then will have travel on the roads while avoiding obstacles in its way to deliver these packages to 1x1 ft houses that represent designated drop off points for the packages. The houses will have specific indications on them letting the robot know what package must go to what house. The obstacles on the board will be a combination of circular blocks with a ping pong ball on top representing pedestrians. The main facets of our design that will give us a competitive advantage are building a maintainable, repeatable, and self-improving.

A maintainable robot is built out of parts that are effective but cost conserving as well. Our design robot is 90% built from parts we have in the robotics lab. These parts were bought in bulk by the school for past design projects therefore creating multiples of the same components. Since any component in our robot design can go bad having multiple of the same components allows us to swap a component instantly. Being able to diagnose, locate and replace any component on the fly increases the functional reliability of our design.

Paper should not include conjuntions

A repeatable robot requires that the robot be made of parts that do not exceed our five-hundred-dollar budget. These parts must be easily obtainable, affordable, and don't require an excessive timeframe to come in. Since we only have till December of 2020 to finish the project, we cannot rely on parts that take a year to come in since testing and demonstrations are needed. However, for the robot to be repeatable the design must also not be extremely complicated. Having an extremely complicated design will leave growth and improvement of the preliminary design to be extremely difficult. Having a simple but well executed design will lead to greater improvements and expansions in the future.

Indent

A self-improving robot will require the robot to be able to understand and predict game board patterns. In the package delivery system, the robot will need to be able to read the roads, avoid pedestrians while traversing the map. A self-improving design however also would take one step further and have the robot remember the map as it traverses it. This understanding of pattern recognition is necessary to increase both the speed and precision to which the robot can deliver its packages.

"a and Avoid"

II. Serious Research of Work Done by Others

A. Traversal of Game Board

The initial step in our research was to identify what was given to us and how to implement those components into the robot. With these materials, the team was posed questions of how the robot would navigate the board, how would the machine recognize packages and obstacles all while delivering packages to their proper location, and how would robot guide itself through the course while communicating information to a computer. The robot was expected to complete these tasks in a reasonable amount of time.

The first aspect of the robot that was faced was how it would move on the game board. The team was initially given a 6 x 6 wooden board with four mecanum wheels attached to it. These wheels were to serve as our only means of locomotion for the robot. The development of

Add "(DOF)" after to know it will now be referenced as that

these wheels came due to a rising demand in the workplace for robot movement that would not require an excessive yaw rate path while operating in a "flexible, adaptive, and safe" manner in complex working environments [1]. There is a downside to this type of wheel, however. As pointed out by Jun Qian and his cohorts, while this wheel does provide the lateral and diagonal movement degree-of-freedom, the rollers that the wheel is comprised of will produce some slippage [1]. We ourselves have experienced and documented this very same problem as it pertains the lateral DOF of the wheels. While in more precise machines measures to deal with the subsequent movement errors as well as a compilation of datasets to predict the machine's position would need to be taken, this project operates on such as small scale that the only necessary step would be to increase the voltage being supplied to the dc motors rotating the wheels. In this case, instead of using a standard receiver 4 cell pack that outputs 6 volts for Alkaline and 4.8 volts for Nicad/NiMh, we used an 11-volt battery pack.

Awkward wording

~~Capital~~ Captalize

For the robot to avoid obstacles and hazards, the SHARP GP2Y0A21YK0F will be used in the testing phase. There are, however, some notable weaknesses with this device that will be worked around. The two main weaknesses are the sensor's "poor tolerance to light reflections such as ambient light or bright object colours" and its ownership of a dead zone [2]. This varies from one sensor to the next, with the model we are using having a dead zone of 10 cm. We feel that these weaknesses can be mitigated using the machine vision capabilities of the Pixy2 camera in addition to the IR sensor. However, inaccuracies due to weather conditions are not taken into account as the machine for this project is made to operate indoors [2].

~~Sta~~ Explain what this device is

B. *Guidance and Object Recognition*

The guidance and object recognition capabilities of the robot will be handled by the Pixy2 camera in combination with both the Raspberry Pi and Teensy 3.6 microcontroller. While the Pixy2 camera was a necessity due to the wishes of the client, the idea on how to implement its machine vision capabilities was up to the group. The Pixy2 camera, just like its predecessor, is capable of color identification and image processing independent of any outside device's help [3]. It can use these capabilities to find objects and track them or even differentiate between multiple objects of the same color. If this were the only necessary process of this machine, the Teensy 3.6 would have handle it just fine. The problem lies in all the other processes necessary for the robot to work in the specified manner. Also, while the various motors of the robot are to be handled using the Arduino IDE, the arm's programming is to be developed and implemented using Python. Because of this, we felt it best to go in the direction of a single board computer like the Raspberry Pi rather than try and force everything onto one device. During its retrieval and delivery of the package, the robot will be guided by its tracking of the package in addition to lines that will mark where it is appropriate to travel.

C. *Picking up the Blocks*

Currently, we have not decided on the best course of action when it comes to physically picking up the blocks from the gameboard. A robotic arm and robotic scoop have been proposed, and the pros and cons of each are currently being weighed out. A robotic arm has the capabilities of being very precise and accurate when picking up blocks directly from the board, but only one block can be picked up at a time. A scoop is not very precise but can hold more than one block at a time. To achieve the highest score possible on the game, the robot will need a combination of precision/accuracy and capability to hold more than one block at a time.

Indent

An Arduino will be used to control whichever robot extension we decide to use. A robot arm consists of a shoulder, elbow, wrist, and gripper joints interconnected by links [4]. The joints will have to be mounted with an accelerometer to track and monitor its movements. A flowchart (figure 1) of a robotic arm controller shows how the accelerometer sensor values compares with input values and ensures that the required position is reached [4].

III. Project Analysis

<u>Project Feasibility:</u>

Since we are still very early in the design process for the robot, the estimated cost for the project is currently a rough estimate based on our current design goals. As of now, we are considering purchasing a set of robotic arms to pick up the packages. Based on individual prices, we may have anywhere from one to four arms, but these arms will quickly take up a majority of our budget. Overall, we are estimating our budget to be up to $500.

Currently, we need to have the robot fully functioning to meet the deadline set on December of 2020. Our current goal is to get the 3D printed body built by March 1st of 2020. Shortly after this, we would like to get the robot's basic autonomous movement completed. If everything is working by that time, we would like to get the robotic arm started and finished by early next semester. In the far future, we wish to have the robot working by mid fall semester to allow for testing and minor improvements. With these goals in mind and if everything goes as planned, we should be able to deliver a finalized by the desired due date.

Technical feasibility for the robot depends on how quickly we are able to finish key requirements and how cost efficient the components will be. Ideally, we would like to get four fully functioning robotic arms for the project. This highly depends on the difficulty surrounding a robotic arm and the price of each arm. The arm would have to know exactly where the block is located and be able to reliably hold onto the block. We would also ideally like to have the robot learn its environment and be able to traverse a modular environment. This would require us to implement machine learning to enable the robot to learn from its surroundings. Whether or not we are able to implement this depends on how efficiently we can get the programming to function. period

Alternatives and Tradeoffs Considerations

A major consideration with this project is the method of which the robot will pick up blocks and store them. At the moment we plan on having an arm that can pick up the blocks and hold onto them until it will need to drop them off. If later on in the design process we need to change this plan, we have other proposed ideas of accomplishing this task. We have considered making a more advanced version of the arm if we are able to finish tasks ahead of schedule. This design would consist of a storage platform that the arm can place blocks on for later delivery. If our budget does not allow for the arms to be utilized in this build, we have also considered the option of using a type of scoop that can be placed under the robot. This scoop would work similar to a forklift, as a device would slide under the block, lifting it off the ground and placing it in its designated drop off location.

We also have different designs planned on how the robot will traverse the board. Our current planned option is to have a specific color of tape placed around the road that the robot will drive down. It will have a sensor in the front/sides that will be able to keep the robot on track. A second option we have considered is to utilize machine learning in order for the robot to learn about its environment. This would be an achievable plan if other aspects of the robot are finished in time based on our time feasibility analysis.

Preliminary Design

Unesessary

As opposed to a PIR sensor which detects the heat radiating off an object, an IR sensor simply reacts to a light it reflects off of objects that is then used to make decisions based on the program being run. We will start off by using a GP2Y0A21YK0F sensor to avoid obstacles. The one we are using is working as designed as it has a dead zone of about 10 centimeters. Mecanum wheels will be used for locomotion. The allow for the "They" movement of traditional wheels in addition to sideways and diagonal strafing. The wheels being using came with the project and while no datasheet is available, we do know that the maximum voltage the motors can handle is 25 volts.

- For Preliminary Design consider mentioning about how you used your level 1 diagram, code flow chart, schematic, bill of materials, and FMEA table to help guide you with your design.
- Also, ~~Be~~ for Preliminary Design, consider adding information of how the robot will move on the board, how the robot is coded, what software will be used, some simulations done to back your design, as some images.

IV. Experiments, Testing, and Data Results

Our experimentation so far has focused on how to optimize the movement of the robot. Our initial design that was prebuilt for us had multiple issues that we discovered through testing. By attempting to drive the robot in a perfectly straight line, we found that the robot drifted about one foot to the right for every five feet it traveled forward. In addition, the horizontal movement of the robot was not functioning at all. By creating a new frame for the motors and wheels to be mounted on, we were able to see the omnidirectional wheels functioning, but not well. At this point, we found that we needed to adjust the voltage levels to the motors in order to achieve a sufficient amount of torque to drive the wheels in the horizontal direction. After many different tests with different voltages, we found that about 8 volts to the motor is optimal. Any higher voltage and the wheels would lose traction with the ground, and any lower voltage will not supply enough torque. After these experiments and tests, we were able to almost completely eliminate drift by the robot and we now have the capability of horizontal movement.

V. Conclusions

Might want to take out until conclusions have actually been made.

The summarizing conclusion should go here. Here is where you summarize whether or not your project worked according to its requirements and the importance of your project and its

Acknowledgment

The authors would like to thank Dr. Darby for his mentorship and the University of Louisiana Lafayette for funding the project.

References

[1] Qian, Jun, et al. "The Design and Development of an Omni-Directional Mobile Robot Oriented to an Intelligent Manufacturing System." Sensors, vol. 17, no. 9, Oct. 2017, p. 2073., doi:10.3390/s17092073. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5620741/

[2] Ismail, R, et al. "Obstacle-Avoiding Robot with IR and PIR Motion Sensors." IOP Conference Series: Materials Science and Engineering, vol. 152, 2016, p. 012064., doi:10.1088/1757-899x/152/1/012064. Available: https://iopscience.iop.org/article/10.1088/1757-899X/152/1/012064/pdf

[3] Daud bin Isa, Mohd, et al. “Vision Mobile Robot System with Color Optical Sensor.” ARPN Journal of Engineering and Applied Sciences, vol. 12, no. 4, February 2017, p. 1291., ISSN 1819-6608.
Available:
https://pdfs.semanticscholar.org/916a/1b918f96d830694b9be4376acb3f6ec312d3.pdf

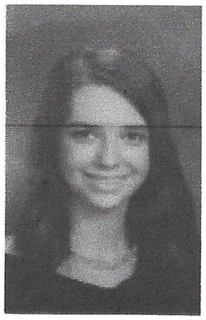
[5] Alldatasheet.com. “GP2Y0A21YK0F Pdf, GP2Y0A21YK0F Description, GP2Y0A21YK0F Datasheets, GP2Y0A21YK0F View ::: ALLDATASHEET :::” ALLDATASHEET

[4] K. Jahnavi and P. Sivraj, "Teaching and learning robotic arm model," 2017 International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT), Kannur, 2017, pp. 1570-157

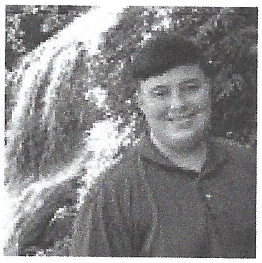
Available:
pdf1.alldatasheet.com/datasheetpdf/view/412635/SHARP/GP2Y0A21YK0F.html.

[6] “Teensy 4.0 Pins.”
Available: PJRC, www.pjrc.com/teensy/pinout.html.

Bibliography:



Anna C. Capdevielle is from Baton Rouge, Louisiana. She graduated from St. Joseph's Academy High school in 2016. She is currently a senior in Electrical Engineering with a minor in mathematics at the University of Louisiana at Lafayette.



Joshua A. Freyou is from Breaux Bridge, Louisiana. He was homeschooled through high school and is currently a senior at the University of Louisiana at Lafayette. He is currently pursing a degree in Electrical Engineering with a minor in mathematics. He has also been a member of the UL branch of IEEE for the past four years.

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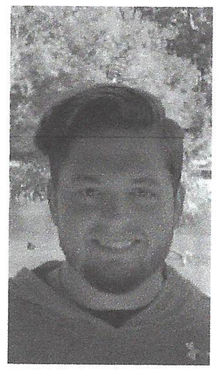


Michael D. Reichert Is from St. Louis, Missouri. He graduated from Waterloo High School in 2016 and is now a senior studying electrical engineering at the University of Louisiana at Lafayette. He has been a member of the UL branch of IEEE for three years.

Appendix A: Scope of Work:

For our senior design project, we were tasked with designing and building a package delivery robot. Our robot design must be both highly efficient as well as practical. We must have our robot designed and built before December of 2021. We have five design team members along with two helpers working on this project. Our end goal is an autonomous robot that completes that delivers packages to and from the post office fast and efficiently.

Adhering to rules of the game:

Along with successfully delivering packages the robot has to adhere to specific rules set up by Dr. Darby. These rules contain the information about how the robot recognizes packages and its ability to deliver these packages to and from the post office. There are also protocols on how the robot perceives and goes around obstacles. These obstacles include things such as the road markers labeled on the board, houses that surround the road, and blocks we have labeled as pedestrians that can be on or lining the road. These things need to be done efficiently since the robot is being graded on timing as well as precision

High performance design:

Our goal is to design a robot that performs efficiently by optimizing the best strategy to traverse the board. To efficiently traverse the board in the minimum time required will require a robot that can carry around three to four blocks at a time eliminating travel time around the board. We plan to build a robot capable of efficiently understanding the best way to distribute the packages that it's carrying to the right houses. Since we are using Mecanum wheels the robot is able to move sideways along with forwards and backwards eliminating unnecessary time to move around the board.

Deadlines:

Since starting the senior design process in the Spring semester, we will have our final design choices due by the end of the Spring semester. After finishing our design plans, we will implement the design for the following semester and have a working robot by the end of the fall semester. This gives us an approximate timeline of slightly less than one year to have our senior design project done. In order to succeed in completing this robot, it is critical that we implement deadlines and stay on track in order to have it fully autonomously running by the end of Fall.

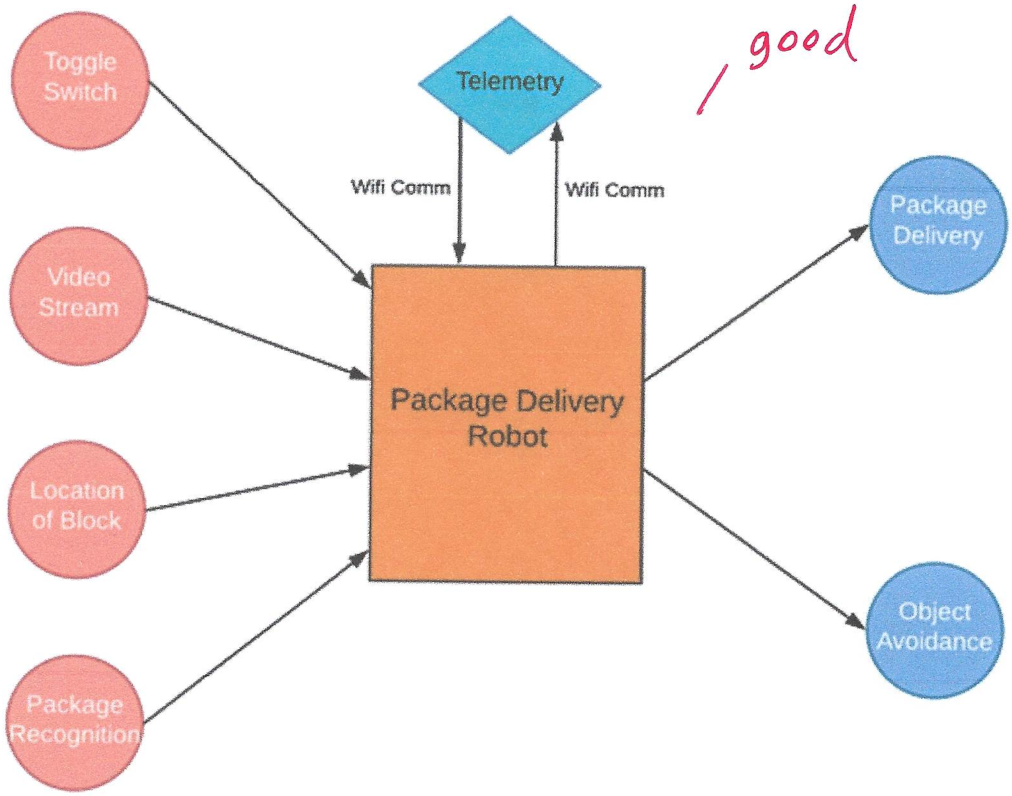
Performance vs Cost:

At the beginning of the Spring semester we were given a budget around 500 dollars to be used in the design of our robot. However, we have access to all the spare parts of the robotics and senior design room. This leaves us with multiple options on how we can spend our budget since we are not constrained to buy every part needed to make the robot run. Having lots of spare parts allows us to show creativity in the design process without maxing our limited budget.

Functional Requirements

1) Ability to Navigate Board
   a) Board Sensing
      i) Distance and Mapping sensors
   b) Obstacles detection
      i) Road, Pedestrians, Houses
2) Ability to Pick Up Packages
   a) Grabbing Apparatus
3) Ability to Hold Packages
   a) Design layout
4) Ability to Distribute Packages
   a) Sorting Packages
      i) Delivering to and from post office

good



Figre 1: Level 0 Diagram

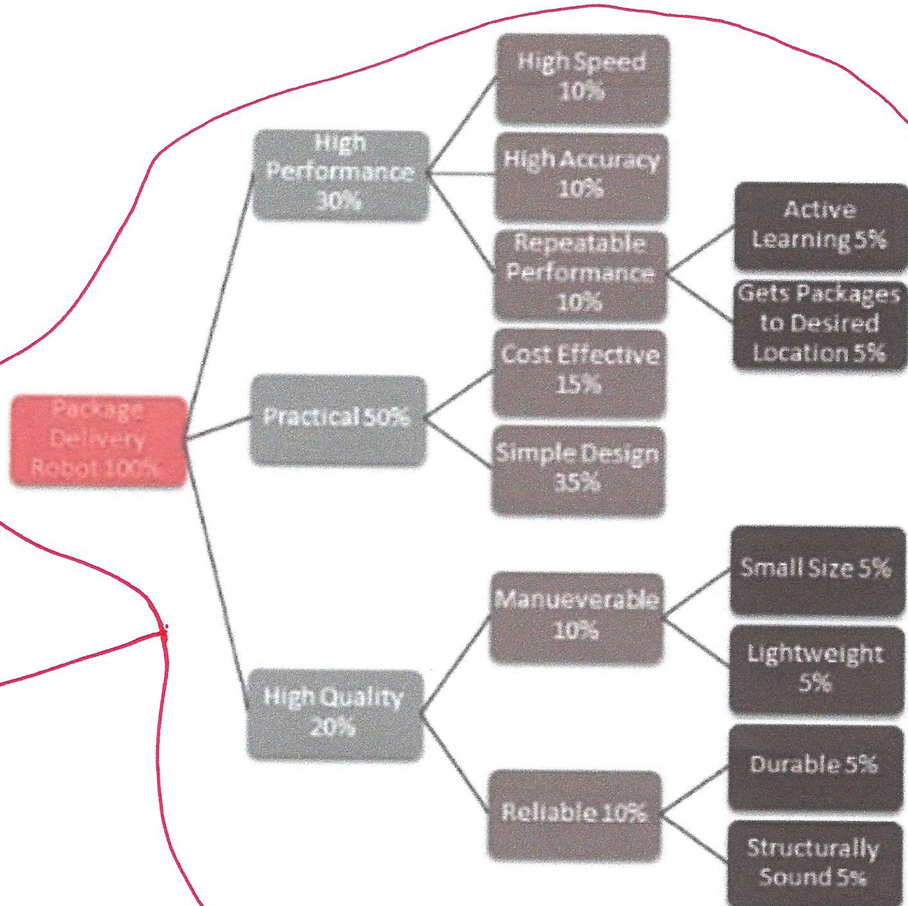


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Figure 2: Objective Tree

Appendix B: Feasibility Assessment:

Cost Feasibility:

This section is the same content as the first paragraph of project feasibility

Since we are still very early in the design process for the robot, the estimated cost for the project is currently a rough estimate based on our current design goals. As of now, we are considering purchasing a set of robotic arms to pick up the packages. Based on individual prices, we may have anywhere from one to four arms, but these arms will quickly take up a majority of our budget. Prices for these arms vary greatly, as do their mechanical capabilities. For this project, it is feasible to purchase a cheaper set as the blocks we plan on picking up do not weigh much. The arm should also only make simple motions, so a complex arm is most likely not needed. Overall, we are estimating our budget to be up to $500, but we may vary from this number as we go on with the design process.

Time Feasibility:

same content as second paragraph of project feasibility

Did you achieve goal?

Currently, we need to have the robot fully functioning to meet the deadline set on December of 2020. Our current goal is to get the 3D printed body built by March 1st, 2020. Shortly after this, we would like to get the robot's basic autonomous movement completed. This would require the method of sensing the environment. If everything is working by that time, we would like to get the robotic arm started and finished by early next semester. In the far future, we wish to have the robot working by mid fall semester to allow for testing and minor improvements. With these goals in mind and if everything goes as planned, we should be able to deliver a finalized by the desired due date.

Technical Feasibility:

same content as third paragraph of project feasibility

Technical feasibility for the robot depends on how quickly we are able to finish key requirements and how cost efficient the components will be. Ideally, we would like to get four fully functioning robotic arms for the project. This highly depends on the difficulty surrounding a robotic arm and the price of each arm. The arm would have to know exactly where the block is located and be able to reliably hold onto the block. We would also ideally like to have the robot learn its environment and be able to traverse a modular environment. This would require us to implement machine learning to enable the robot to learn from its surroundings. Whether or not we are able to implement this depends on how efficiently we can get the programming to function.

Requirement Specifications:

Included in this project are several requirement specifications for the robot to satisfy. These requirements were given by the project mentor and must be accounted for by the group to the best of their ability when planning and building the robot.

Robot Requirements:

There are several requirements for the robot itself to comply with. Firstly, the robot should move around using the mecanum wheels provided by the mentor for the project. These wheels allow for multidirectional input and that should be utilized in the robot design. Secondly, the robot must be able to pick up blocks to transport. This can be done with either a claw or some other moving device. The only requirement is the robot is able to move the blocks across the board. Part of moving the blocks is the quantity that the block can move at a time. It is expected that the robot can move three or more blocks at a time to allow for multitasking and time saving. However, the robot isn't expected to just deliver unidentified blocks. The robot must keep track of each block it collects and moves. It must be able to sort blocks by the letter on it, a marking on the block, or some other identification method. Using this information, it must then deliver the block on the game board to the correct location to drop off.

Board Requirements:

The robot isn't the only aspect to the project. The robot is to be operated on a 4x8 ft. or similar board while allowing room for both houses and obstacles. Given for the houses are 8 in. square blocks that are to be used as houses. The robot is expected to not run into any of these houses while searching the board. In addition to the houses, there will be obstacles placed on the board to simulate pedestrians. The robot is expected to identify these obstacles and avoid them by finding an alternate route. Both the houses and obstacles can be arranged in many different ways and the robot is expected to adapt to the environment. Finally, the robot is expected to pick up the blocks that will be used for the experiment. The blocks given are about 1.5 square inches in size with letters on them. The robot must identify these blocks by either reading the letter or some other marking on the blocks.

General Project Requirements:

Besides direct requirements on the board and robot, there are a few other requirements that this project must fulfill. The final design of the game board and robot must be built in a way where it can be removed from the robotics room and be transported for demonstration. Any changes or additions to the board must allow for this mobility. Second, the entire project should run in under two minutes. This time requirement can change but a points-based system was mentioned by the mentor to judge the robot. Speed of delivery, avoiding obstacles, and delivery accuracy are all factors that can determine the value of the points scored in each round.

This whole section is a copy and paste from the main paper, this section in the appendix should be used to be more detailed than the paper, along with diagrams and explainations

Appendix C: Alternatives and Tradeoffs

Project Feasibility:

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We also have different designs planned on how the robot will traverse the board. Our current planned option is to have a specific color of tape placed around the road that the robot will drive down. It will have a sensor in the front/sides that will be able to keep the robot on track. A second option we have considered is to utilize machine learning in order for the robot to learn about its environment. This would be an achievable plan if other aspects of the robot are finished in time based on our time feasibility analysis.

Preliminary Design

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Experiments, Testing, and Data Results

Our experimentation so far has focused on how to optimize the movement of the robot. Our initial design that was prebuilt for us had multiple issues that we discovered through testing. By attempting to drive the robot in a perfectly straight line, we found that the robot drifted about one foot to the right for every five feet it traveled forward. In addition, the horizontal movement of the robot was not functioning at all. By creating a new frame for the motors and wheels to be mounted on, we were able to see the omnidirectional wheels functioning, but not well. At this point, we found that we needed to adjust the voltage levels to the motors in order to achieve a sufficient amount of torque to drive the wheels in the horizontal direction. After many different tests with different voltages, we found that about 8 volts to the motor is optimal. Any higher voltage and the wheels would lose traction with the ground, and any lower voltage will not supply enough torque. After these experiments and tests, we were able to almost completely eliminate drift by the robot and we now have the capability of horizontal movement.

Include descriptions above figures to clarify setup of figure or reasoning.

Appendix D: Preliminary System/Subsystem Design Alternatives:

The robot is still in its early stages. Ideas are currently being pitched regarding the best course of action when it comes to constructing the Package Delivery Robot by making it fully autonomous and successfully completing the game in the shortest amount of time possible.

The robot that we were tasked with building already had wheels mounted on them. The wheels have the ability to move frontwards, backwards, sideways, and even turn within a one square foot area. A program was implemented to test the wheel capabilities. The wheels work but maneuvering sideways is still a challenge. A conclusion was made that the wheels will have to be taken off and adjusted to achieve its maximum capabilities. The current wheels are the only option that is allowed.

Identifying the lettered blocks and houses (pickup and drop-off locations) proves to be more challenging than anticipated. The lettered blocks are to not be heavily modified. On the blocks, the letters are black, and the background is white, so identifying the letters based on the black/white differentials will not be simple because the camera may pick up other objects that are black and/or white causing a white wall, for example, to be mistaken for a block. So, utilizing a Pixy 2 Cam Image Sensor, which is required, may be the best option. The blocks can be modified by adding a single dot of color. This will make it easy to identify by the Pixy 2 Cam Image Sensor. Then it can carry out those instructions based on the color alone. Another idea that was introduced, was utilizing QR codes. A simple QR code can be placed on the blocks and once the QR code has been read by the Pixy 2 Cam, the robot will carry out the instructions associated with that code. From a coding perspective, this will be the easiest course of action.

Picking up and dropping off the blocks will not be an easy feat. Using an arm and/or scoop and a conveyor belt to hold and drop off blocks are ideas that are currently being explored. A robotic arm has the capabilities of being very precise and accurate when picking up blocks directly from the board, but only one block can be picked up at a time. A scoop is not very precise but can hold more than one block at a time. To achieve the highest score possible on the game, the robot will need a combination of precision/accuracy and capability to hold more than one block at a time.

Designing the robot to hold/secure the blocks and contain all the necessary components while in motion will be imperative to the robot's success. Building a housing that is too wide will knock down game board pieces. The best option for the housing is to simply build vertical. To create the housing, 3D printing is the method of choice. An online CAD software called TINKERCAD and SolidWorks will be used to design a proper housing for the Package Delivery Robot.

<u>How things are installed</u>

This robot will be powered by an 11-volt battery pack that provides varying levels of voltage to different parts of the robot. To safely provide power to the arm and the 5-volt pin on the microcontroller, the voltage will be fed through two voltage regulators. The voltage will also be connected to the breadboard where it will act as a power rail to supply power to other components. This includes the IR sensor, the camera servo motor, and the Pixy2. The power from the battery pack will also be fed directly into the motor drivers in order to supply the mecanum wheels with the power necessary for them to not catch. The 3.3-volt pin on the microcontroller will be used to power a Wi-Fi chip used for telemetry.

This should be under the "Preliminary Design" section.

Appendix E: Final Design and Final Design Details ~~Include description~~

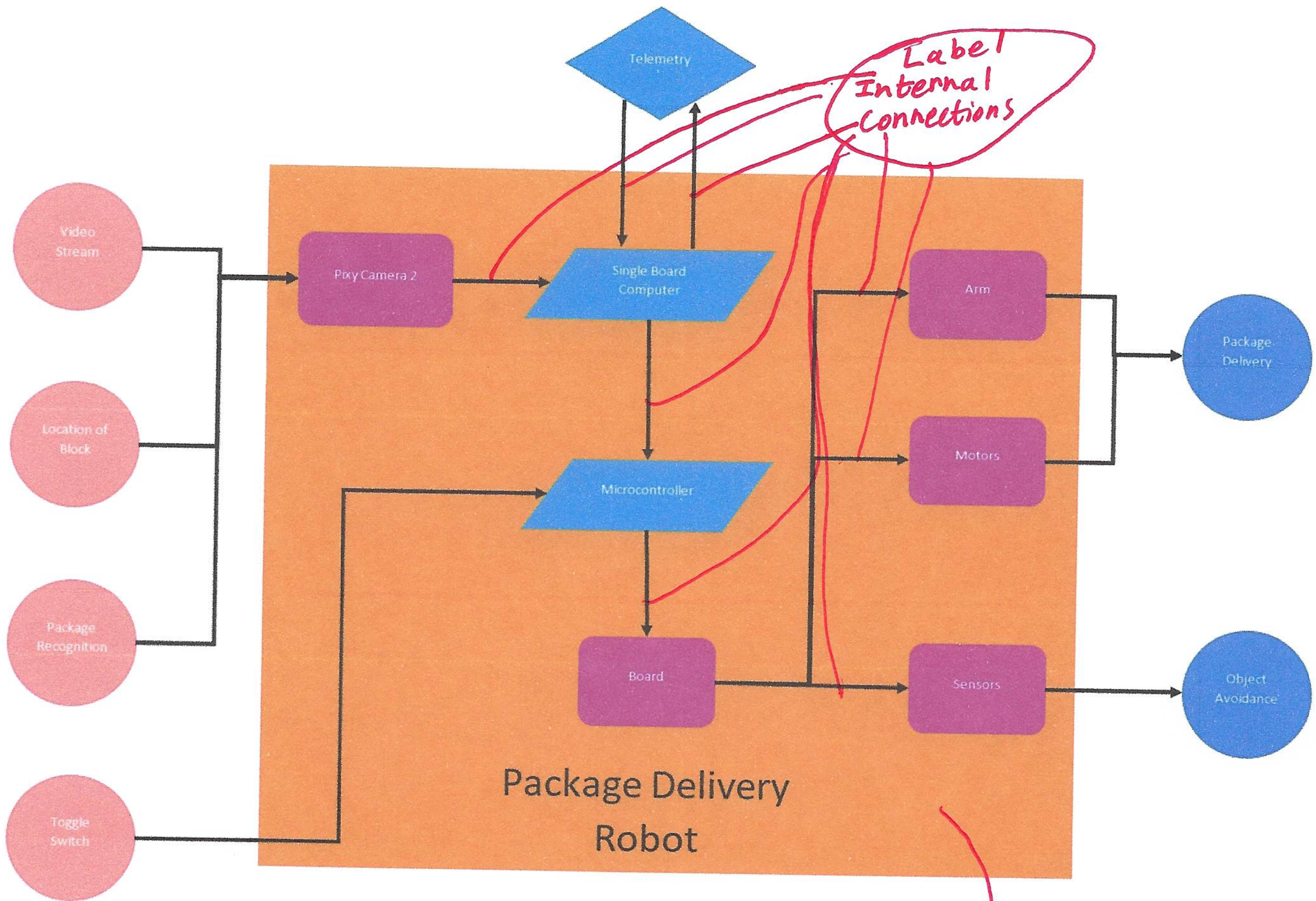

Figure E.1: Level 1 Diagram

Include Bluetooth chip in diagram

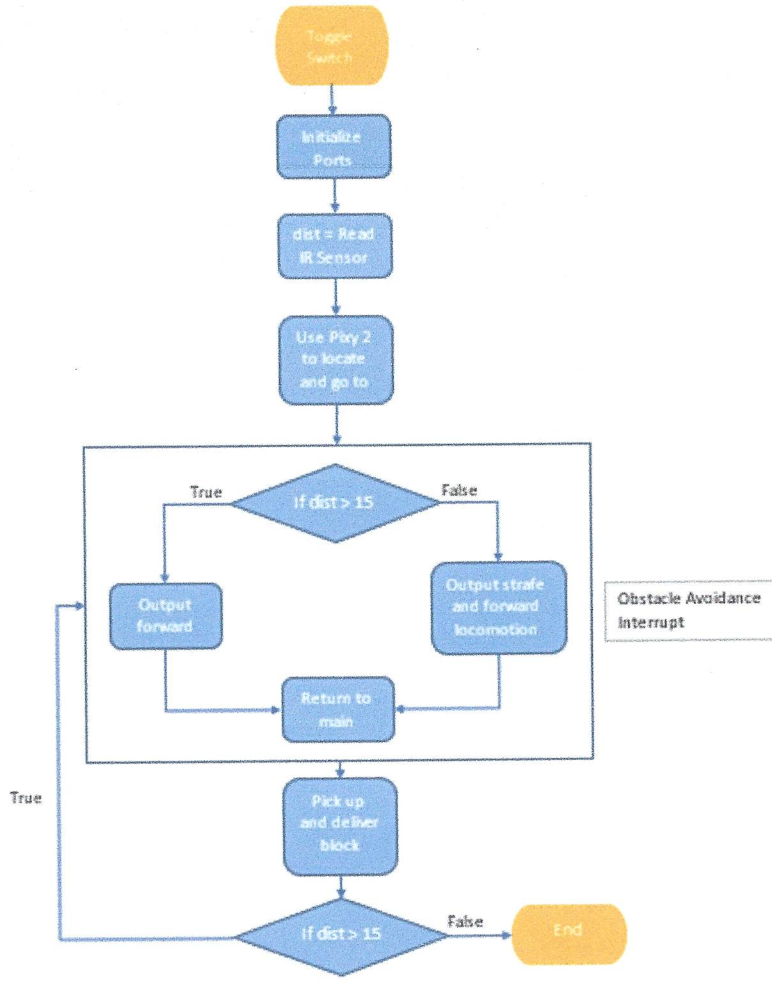

Figure E.2: Code Flowchart/ Level 2 Diagram

- Flowchart is a bit confusing to follow.
- Be more specific with each step.

Consider powering the arduino with the battery through the battery jack

Why is a bluetooth chip necessary? Please explain in paper why it is need.

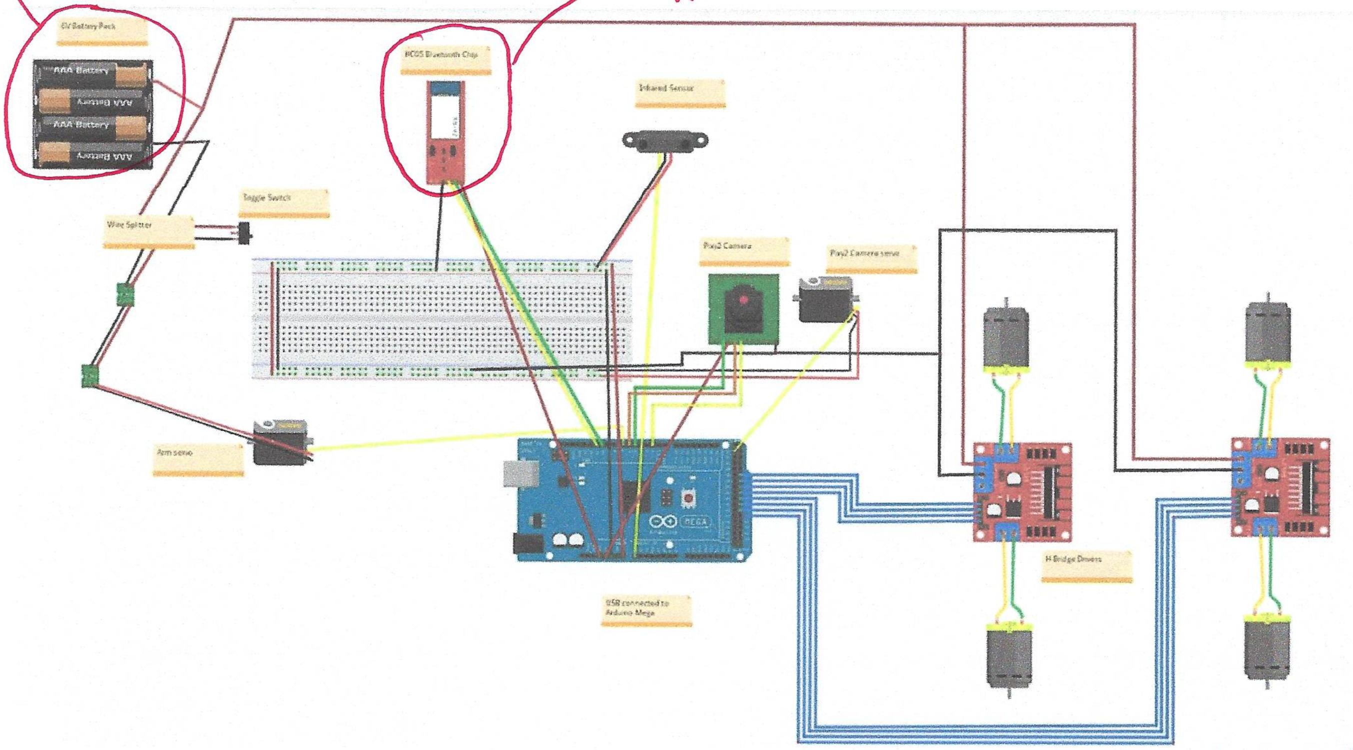

Figure E.3: Wiring Schematics

The wiring schematic could be arranged in a neater fashion.

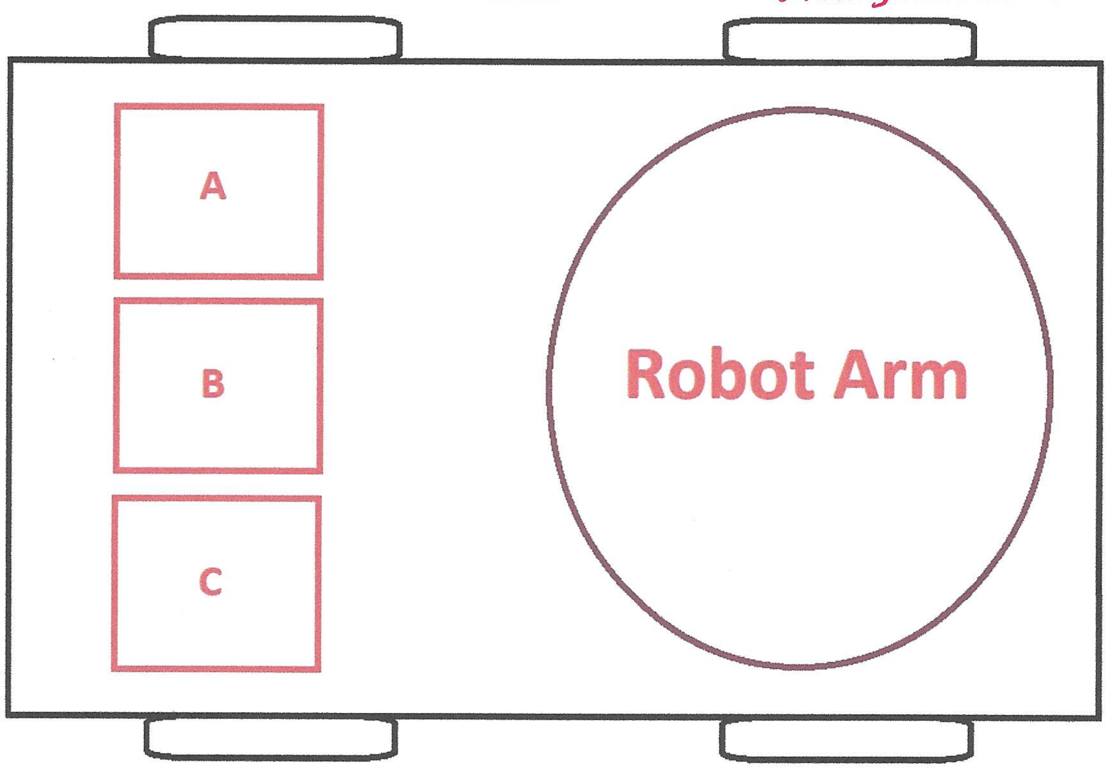

Figure E.4: Top level of the robot with block placement locations after picking them up

Use same format for all tables in paper, it will look more professional.

Componet	Stock	Cost per componet	Componet details
Arduino Uno	15	Provided	
Pixie Cam 2.0	1	Provided	Can sense up to 1.2 megapixels, which can recognize colors and shapes.
Mecanum wheel	4	Provided	Axis rotatio at 45 degrees to the wheel pane and axis line.
Raspberry Pi	1	Provided	Processor speed of 700MHz to 1.4GHz
9 Volt battery	4	$10.97	
Jumper wires	100	Provided	
11 Volt battery	1	Provided	
Bread board	10	Provided	
voltmeter	1	Provided	
LDX-218 digital servo	2	$15.16	17kg large torque, full metal gear, dual ball bearing, plugging wire
power adapter	1	$15.10	
electrical tape	3	Provided	
LFD-06 digital servo	2	$16.14	High temperature resistance, used for claw
LD-1501 MG digital servo	1	$16.90	17kg large torque, full metal gea, use for large bottom plate.
Bluetooth servo	1	$20.10	Uses 6 channel servo controller with built in bluetooth 4.0 module. 16M large capacity with all interfaces have over-current protention.
Sharp IR sensor	1	Provided	Sensor range is 10-80cm(4-32"). requires a 4.5-5.0V power supply
H-bridges	2	Provided	
HC06 bluetooth module	1	Provided	Baud Rate 9600,8,1,n coverage up to 30ft with operating voltage 3.3V
HC05 bluetooth module	1	Provided	Baud Rate 38400, operating voltage from 1.8 to 3.6V
Arduino mega	1	Provided	Operating voltage 5.0V has 256KB of flash memory

Figure E.5: Parts List

FMEA (Failure Modes and Effects Analysis)			
Function	**Failure Mode: What could go wrong?**	**Failure Causes**	**Actions to Reduce Occurrence of Failure**
Mecanum wheel	Wheels could become loose and possibly fall off. Robot could stop moving. Wheels could move at different speeds.	Poor connection to gear motor. Loss of power from arduino to wheels. Disconnected wire(s). Programming errors.	Ensure connection to gear motor is secure. Ensure batteries are sufficiently charged. Connect wires that avoids all possible ways of possibly disconnecting.
Navigating the board	Robot could bump into the perimeter of the game board and game pieces such as "pedestrians" and "buildings". Robot cannot stay on the road.	Failure of perimeter sensing sensors. Coding errors. Poor commuincation between sensors, arduino, and wheels. Failure of line following sensors.	Review any coding errors coming from perimeter sensing sensors and correct them.
Image Processing	Robot is not detecting colors. Robot cannot differentiate between colors from the buildings and blocks.	Pixie 2.0 Camera coding failure and/or Pixie 2.0 Camera is not functioning properly	Throughly test image processing at every stage during the coding stage.
Obstacle Avoidance	IR sensor failure. Lack of communication between IR sensor and arduino.Code not functioning properly.	IR sensor not functioning properly. Coding errors.	Analyze IR sensors and code before every test. Purchase new IR sensors if defect or continual failure occurs.
Finding blocks	Pixie 2.0 Camera mistakes block for another game piece. IR sensor detects block and confuses it for an obstacle thus not allowing the Pixie 2.0 camera to "read" the block.	Communication between IR sensor and Pixie 2.0 camera not functioning. Failure of IR sensor and/or Pixie 2.0 camera components. Not enough light for the Pixie 2.0 camera to properly "see".	Ensure wiring of IR sensors and Pixie 2.0 camera is correct. Check for coding errors. Make sure the room is well lit for the Pixie 2 Camera to "see". Replace IR sensors if needed.
Picking up/delivering blocks from correct destination	Robotic arm could not firmly hold the block thus it loosening from its grip. Robotic arm lacks precision and could not precisely deliver blocks in designated area. Robot could knock building downs. Robotic arm could interfere with objects on board.	Arm joints or clasps are not tight enough to bear the weight of the blocks. The joints of the arms are too loose causing flailing. Arm is too big and/or cannot remain flush with the robot thus adding more width to it.	Modify the arm to ensure that the joints and clasps can bear the weight of the blocks. Make sure that the arm will retract back to robot when not in use so that it will not interfere with anything on the game board.
Game Board	Roads are too small for the robot to travel on. Buildings are not adequately spaced apart.	Error of the game board designer. Robot pushed buildings too close and/or too far from eachother.	Correctly measure the width of the robot to ensure that the roads are wide enough for the robot to safely move around without touching any game board objects.

Figure E.6: FMEA