ECE 445 Design Document

Spring 2020

TA: Ruhao Xia

Autobin

An automated trash bin that comes to you

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Introduction

Objective:

Alot of elderly people and people with disabilities have a hard time with simple tasks that we might take for granted. One such task is to continuously get up and go to the trash can to drop off any garbage. This seems like a very simple task, but if you have arthritis and every inch or your body is aching and sore you really wouldn't want to get out of bed to continually drop off trash. That's where an autonomous trash can comes in so handy because it is making life easier and the purpose of any invention is to make life easier. Nowadays automation is seen everywhere to make life more convenient: cleaning the floor (roomba), self driving cars, etc. and we believe a smart trash can that is capable of coming to where you are located may ease the burden of elderly/disabled people when having to get up and walk in order to throw something away. Our project would be limited to one floor, as the trash can wouldn't be able to climb stairs, and would be summoned through an app that we would make that connects to the trash can to provide the location of the user as well as monitors the capacity of the trash can through the use of sensors in which the user will be able to see how full the trash can is through the app. We would also like to include a motion sensor so that the user can simply wave their hand to open the trash can.

Background:

There is a need for such a project as this to exist because this will be a pioneer in smart application. There already are many smart house applications that exist today, but none that can navigate through the house with an starting point to an ending point. Things like the Romba just wander around the house without a goal, but this would actually be more practical and with this many other projects could come into need like an automated table. This could come in handy if you have patients you can load up their foods on the table and it would be able to navigate to patients rooms and deliver food so this project is definitely a pioneer and a necessity for the future. With the integration of smartphone use already found in everyday life, we are tapping into the average user's lifestyle and making it a bit more convenient.

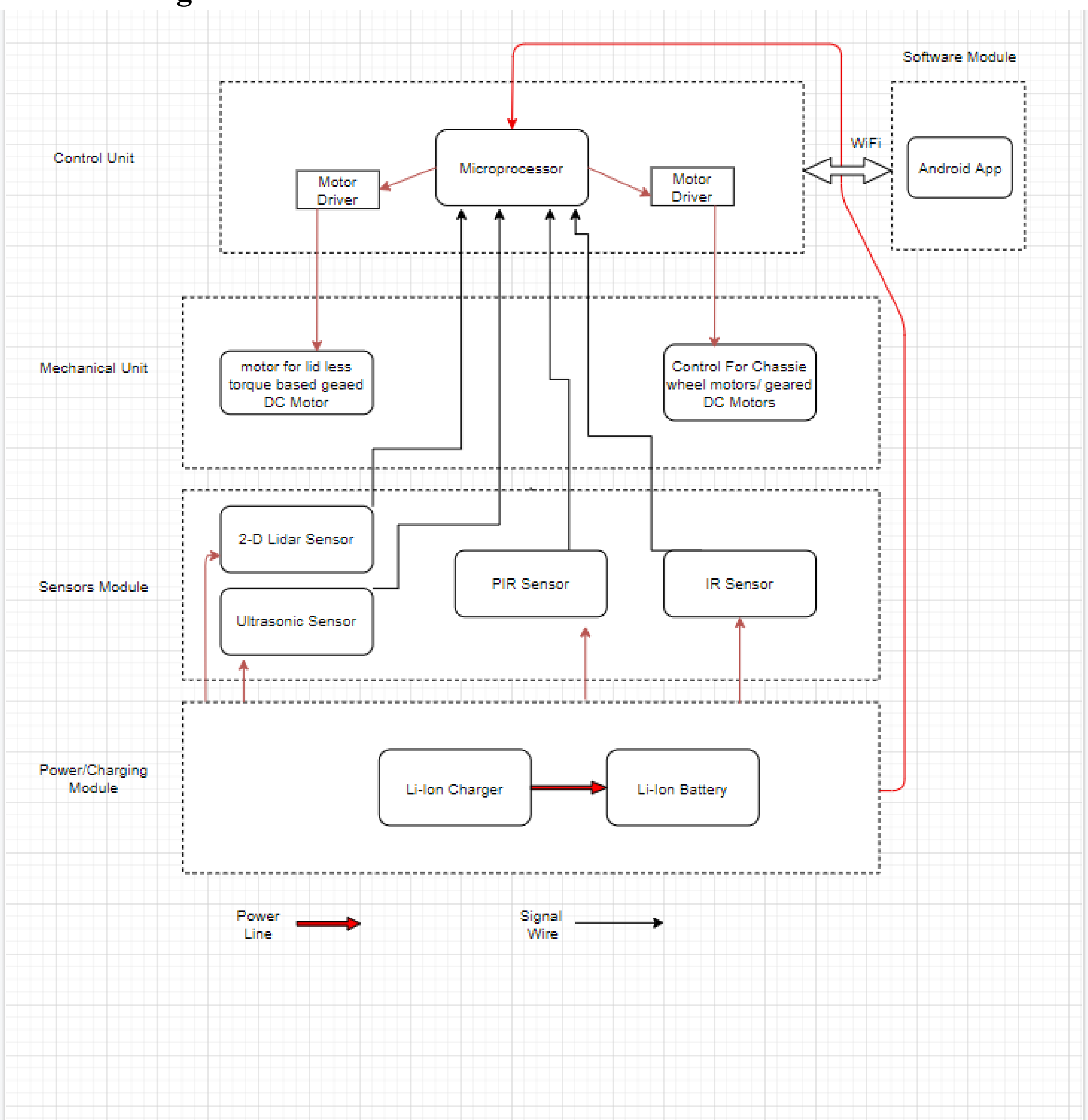
High-level requirements list:

- The Autobin must be able to successfully traverse from its current location to the target location of the user when summoned by the user (via smartphone app)
- The Autobin must be able to successfully detect obstacle in the way and maneuver around them while maintaining target oath
- The Autobin must successfully detect motion from the user and open the lid and close the lid in a timely manner (open within ~2 seconds and close after ~5 seconds if no additional motion detected)

2. Design

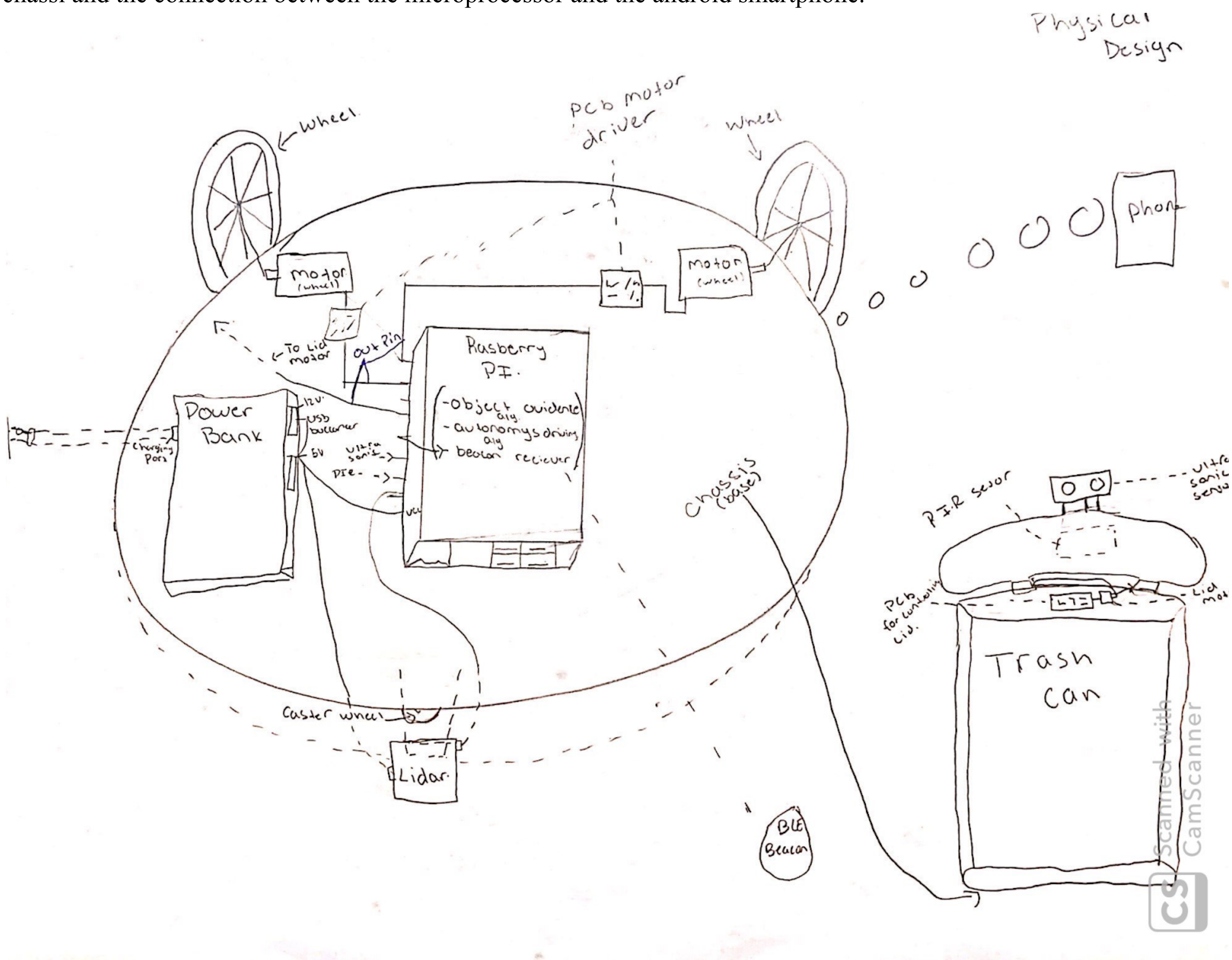
Block Diagram: A general block diagram of the design of your solution. Each block should be as modular as possible and represent a subsystem of your design. In other words, they can be implemented independently and re-assembled later. The block diagram should be accompanied by a brief (1 paragraph) description of the high level design justifying that the design will satisfy the high-level requirements.

2.1 Block diagram



2.2 Physical Design

Physical Design: A high level overview of our project design, which includes the smart lid ,the base chassi and the connection between the microprocessor and the android smartphone.



2.3 Subsystem Descriptions

I. Control Unit

Microprocessor

Description:
We plan on using the Raspberry Pi 4 as our microprocessor. This microprocessor will receive input from the ultrasonic sensor to navigate between beacons as well as obstacle avoidance. We plan on creating a 'path' with these beacons which will be bluetooth enabled via our smartphone app. We will use this input to construct both navigation and obstacle detection/avoidance algorithms which will tell the motor wheels the speed and direction to go. We also equip our microcontroller with Wi-Fi compatibility so that it may communicate with an Android App which a user can control [1]. The last thing the Raspberry Pi will control is the motor of the lid, in which the input is received from the IR sensors.

Requirements	Verification
1. Receive object distances from the ultrasonic sensors 2. Receive detection/heat from user via the IR sensor for lid functionality 3. Process and output signals according to the data received 4. The Raspberry Pi must be wirelessly WiFi enabled	1. Our program will continuously monitor the input of the ultrasonic sensor and print it out to the compiler output, which we can monitor to correctly analyze if we are receiving an accurate reading 2. Similar to the ultrasonic sensor we will create a bool variable which will let us know if the IR sensor detects any motion and this will turn to True when it does detect motion/heat and we will print this to the compiler output and once again analyze if we are receiving an accurate reading from the sensor. 3. We can test this by seeing if the Raspberry Pi prints out the correct amount of voltage in accordance with the modules' inputs and our algorithm. 4. We plan to do so by using an SD card, by flashing the OS on the SD card and enabling SSH and wifi credentials, we can then plug the SD card into our Pi and connect over SSH, we can verify by checking that there is an established connection on the server.

II. Mechanical Unit

DC Lid Motor

Description:
The DC Lid Motors will also be getting their instructions from the Microprocessor. Once the IR Sensor detects an hand the processor will tell activate the lids which is pretty much just sending power to the motors to activate which opens the lid.

We will be using a very small Motor for the lid as the lid will not be too heavy. Our motor will operate on 12V of battery. It will produce a torque of 150g.cm and it will have a max RPM of 18000. This motor needs to be quite small of around 38mm so that we can neatly and concisely keep it in the lid and we don't want to add unnecessary weight so it will be only around 260g.

Requirements	Verification
1. Must be able to provide enough to torque to lift the lid within 2±1 seconds	1. Apply 12 Volts to motor and ensure lid opens within 2±1 seconds 2. Calculate rotation speed needed to achieve lid rotation/opening of 2±1 seconds 3. Using digital luggage scale or spring scale calculate torque output falls within range needed to lift the lid 4. The RPM of the motor can be calculated by counting the number of rotations of the wheel in a given time frame. 5. Resulting power can be found by multiplying angular velocity and torque

DC Wheel Motors

Description:
The DC Motors will be one of the “outputs” from the Microprocessor. They will be the ones that will be attached to wheels which inturn will allow for our project to move around. The motors need to be strong enough so that they can carry the load of a full trash can, the chassis, and all of the sensors that will be on our trash can.

The DC wheel motors output max power of up to 3150 Watts which is a lot, but this will come in very hand if the load of the garbage can is really heavy. The motor will need a 12v DC power connection which we will be able to provide from our battery. The max amps produced will be 80 amps and the weight should be around 1 pound as we need it to be lightweight.

Requirements	Verification
1. Motor must be able to drive the trash can which can weigh up to 10 kg (22 pounds) with a minimum speed no less than 3.81 cm/s (1.5 inches/sec)	1. Test motor and chassis separately with a 10-20 kg load and ensure the speed in centimeters per second of the trash can is equal to or above 3.81 cm/sec.

Chassis

Description:
The chassis should act as the main platform that our trash can is built on top of. The chassis will contain our microprocessor, battery, wheels and motor.

Our chassis should be made of material that is both light and strong, we plan on going to the ECE machine shop to build one for us using a material like aluminum. The chassis must also provide enough space and interfaces for all of our components and designed in a way that keeps our trash can balanced (at various weights) while moving at various speeds.

Requirements	Verification
1. The chassis will need to support at most 20 pounds of of weight 2. The chassis will need to make place for all the register and be “modular” in sense that it can attach our garbage can on top of it	1. We will insure this by making the the chassis out of an aluminium compound which will be light and strong also we will unit test this by placing 40 pounds of weight upon it to see if it can handle it 2. The way we will ensure this is by making sure that we buy all our necessary sensors in advance and then we will design the cad design accordingly. We will also add a grove in our base so that the garbage can of our choosing will sit flush with our chassis

III. Sensors Module

Ultrasonic Sensor (navigation)

Description:

The sensor emits an ultrasound (at 40,000 Hz) which travels through the air, if there is an object or obstacle in its path, it will bounce back to the module. Using a simple algorithm, we can consider the travel time and speed of sound in order to calculate the distance and feed that to the microprocessor to tell the motors how to navigate past that obstacle accordingly.

Requirements	Verification
1. Due to the high voltage range of the battery we will need to regulate it so that we provide a constant 5V to the sensor 2. The sensor must be compatible with the chassis so that we can mount 3 sensors while not blocking the view of the sensor	1. Due to using a power bank one advantage is that there is a 5V and a 12 V output so we will connect/test the output to see if is indeed and connect accordingly 5V 2. Our chassis design will take into fact that there will be three ultrasonic sensors that need to be mounted on at a 90deg angle while wires built into the chassis ensure that the power is being supplied to the sensors

IR Sensor (lid)

Description:
The combination of the fresnel lens (which focuses the infrared signals) and pyroelectric sensor will detect energy/heat given off by other objects (e.g human hand) and give off a ‘high’ voltage signal when an object is detected. The PIR sensor module will be connected to our microprocessor and thus the output from the sensor will tell the microprocessor to open the lid if a ‘high’ signal is detected and activate the opening of the lid.

Requirements	Verification
1. Due to the high voltage range of the battery we will need to regulate it so that we provide a constant 5V to the sensor 2. We will need to test and configure the sensor so that it only detects motion of a height of 4 feet above lid	1. Due to using a power bank one advantage is that there is a 5V and a 12 V output so we will connect/test the output to see if is indeed and connect accordingly 5V 2. We will use the oscillator to provide a constant voltage of 5V and have measure out distances from which we can test when the sensor activates and detects motion

BLE Beacons (Blue-tooth Low Energy)

Description:
We plan on utilizing beacons (such as the Gimbal beacon made by Qualcomm), these beacons are fully programmable to the user needs and has a ready to use interface for making an app. Bluetooth beacons are small radio transmitters that send out signals in a radius of 10-30 meters. The advantages of beacons are clear: They are cost-effective, can be installed with minimal effort, determine a position accurately up to 1 meter and are supported by many operating systems and devices. BLE standard is also very energy efficient. Beacons can be used for both client-based as well as server-based applications. Being able to detect the current floor for our Autobin to use to navigate the floor.

Requirements	Verification
1. Must connect and send location to the mobile application via bluetooth 2. Communicate with the Raspberry Pi via bluetooth to bluetooth connection	1. We can test this by using the signal strength measurement (rssi) for localization 2. We can verify a connection by simply seeing the feedback from the Raspberry Pi and matching it with the output of the beacon

(DIDRICK)

IV. Power/Charging Module

Power Bank

Description:
The power bank is in charge of powering all of the components on the smart trash can, including the sensors for automatic lid and navigation, as well as the motors for the lid and wheels. We are proposing to use a power bank vs battery pack because it operates on low power for a prolonged period of time, which is more applicable to our design considerations, taking into account that a smart trash can in an elderly/disabled person’s home should be able to operate for multiple days in a row without recharge. Also, the power bank we are planning to use comes with a state-of-charge meter.

Requirements	Verification
1. Must have two output ports at 12 V and 5 V at full charge 2. Must store at least 1,000 mAh of charge 3. Must be rechargeable	1. Using a digital mulit-meter, the voltage can be measured across the power bank when it is at 100% charge 2. Connect fully charged power bank with a positive and negative terminal at VDD and ground respectively and discharge battery 200mA for 5 hours 3. Make use of voltmeter to ensure voltage remains above 3 V for 5 V output, 7.2 V for 12 V output 4. From discharge state, recharge power bank and use voltmeter to ensure power bank is 12 V again.

V. Software Module

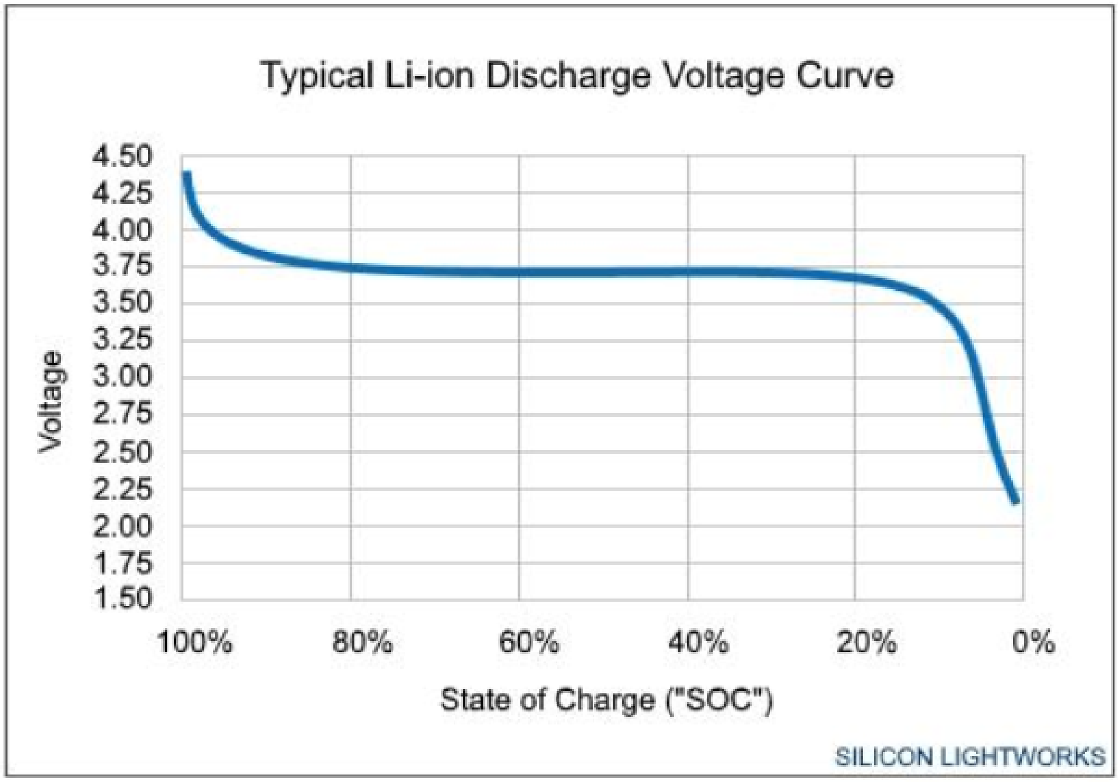
Android App

Description:
The android app acts as a remote control for the user. The app will feature buttons for the user to press to call the trash can to come to a certain location specified by the user. For example, buttons may include different rooms within a house on the same level (Kitchen, bathroom, living room, etc.).

Requirements	Verification
1. The app must allow the user to select what location for the Autobin to traverse to (kitchen, bedroom, bathroom etc.) 2. The app and Pi must be able to receive information from the BLE beacons.	1. We can test that the app is successfully communicating by first checking if the Raspberry Pi's GPIO pins are reacting to the user's response on the app. We can also check if the IP address in the app matches the IP address on the Pi. We can also check that our server is active and data is being exchanged between the server and client. 2. We can review the apps code to ensure that the Android Beacon Library is imported and that you have chosen the beacon type that we are using (iBeacon). We can also verify this by seeing if we have requested and gotten permission from the user to access the iBeacons location. We can also check that the correct experimental features on our Raspberry Pi are enabled in order to detect BLE devices.

2.4 Supporting Material

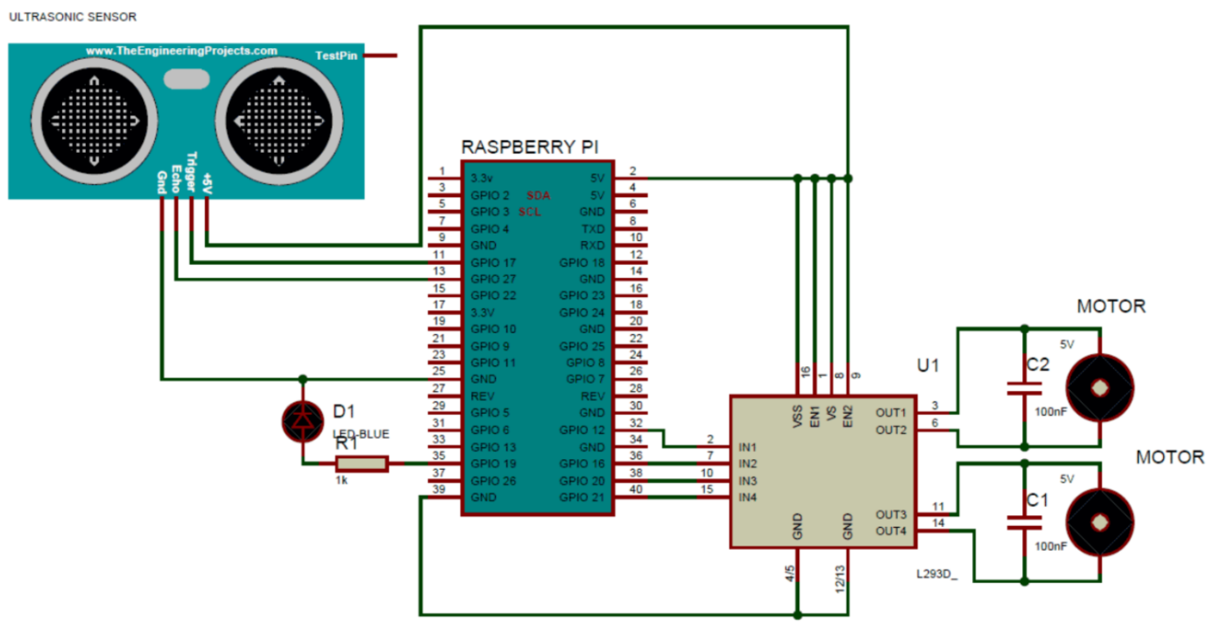
Plot:



The above plot [8] shows the relationship between the State of Charge (SOC) of the Lithium Ion battery and the discharge voltage. As shown above, a SOC of over 20% can guarantee a steady voltage output, but a rapid fall of voltage occurs below 20% SOC. This rapid fall of voltage means that at below 20% the SOC drops more rapidly the lower the SOC is. This can lead to an over-discharged condition in which the battery is exposed to prolonged low voltage conditions. This, for Lithium-ion battery, can lead to a dissolution of copper into the electrolyte solution. This can compromise the battery cell performance, such a reduction in capacity and life cycle.

A resolution of this issue is to add safety circuits that protect the battery cells from extreme high and low voltages. For overall circuit protection of the PCB board circuit to the motors we considered looking into transient voltage suppressors and flyback diodes to prevent a sudden spike in voltage across inductive loads when a current is suddenly reduced. We thought of using a similar approach for the battery cell protection circuit, but upon further research and discussion with our TA, we have decided to use a power bank with built in protection circuits that can provide a steady 12 V output for the motors and 5 V output for the Raspberry Pi by making use of USB-A Male plug to 5-pin terminal block.

Schematic:



Above is a general schematic of what our circuit will look like [9]. We have our ultrasonic sensor for proximity sensing for obstacle detection/avoidance. In between the Raspberry Pi and the motors is the Motor Driver which (L293D - common driver which can drive 2 motors simultaneously) for amplifying the low-current output from the Raspberry Pi to a higher output current that can operate the motors. Not shown is our Bluetooth Low Energy (BLE) beacon receiver which will be attached to our Raspberry Pi (model 3 and above comes with Wi-Fi/Bluetooth compatibility).

Calculation: Running time of Autobin

Battery pack- 20000 mAh

[$13] Greartisan DC 12V 148RPM N20 High Torque Speed Reduction Motor (150 mA - rated current)

(20000 mAh) / (150 mA x 2) = 66.66 hours

[$3] 287-2520 - DC Motor, 12 V, 180 rpm, 500 g-cm, DC Motor (180 mA - rated current)
(20000 mAh) / (180 mA x 2) = 55.55 hours

The above calculation is the run time in hours of how long our battery pack (20000 mAh) can operate two different motors. The first motor is considerably more expensive, but outputs a greater torque (1.5kg-cm) and requires a lower current (150 mA). This means that this motor can also operate more efficiently during a heavier load (when the trash can fills up). The second motor is cheaper, but requires a greater current and provides a lower torque. We are planning to use the first motor for reliability purposes (can operate with a heavier load and can run for longer before recharging is required).

2.5 Tolerance Analysis

Efficiency :

$\eta_m = P_{out} / P_{in}$

Pin = I * V

Pout = τ * ω

ω = rpm * 2π / 60

Given motor power:

Voltage = 12V, Current = 0.15A, Torque = 50 kg/m

Assuming: 148RPM

Weight 5lb = 2.27kg

Pin = 12V * 0.15A = 1.8W

The component that poses the greatest risk to our overall project is the motors for the wheels. The reason it poses the greatest risk is because of the possibility of failure depending on the weight of our trash can load. For an empty trash can, we can assume an overall load weight of around 2 kg, or about 5 lbs. We would like our smart trash can to handle loads of up to 10 kgs. To ensure this, we plan on testing with loads up to even 15-20 kg. A motor which operates at a comfortable speed at this 2 kg might not operate successfully at 15-20 kg. Considering the opposite scenario, a motor designed to operate at moderate speeds with heavy loads might not be efficient and may result in power loss/inefficiencies. Our analysis below assesses the efficiency of the motors at different load weights.

τ = 10 kg * 1 m/s^2 * 0.5 m = 5 Nm

Once we calculate the minimum required torque needed to rotate the heaviest load, we apply a 5x multiplier to the needed torque as a safety target. Assuming the closest available gear ratio to meet our torque requirements while at the same time providing maximum angular speed is 20:1 reduction, we have a max torque of around 30 Nm.

(20/1) * (30A) * (0.05 Nm/A) = 30 Nm

Taking into account the worse case condition of the motor driver, the resulting possible max torque output is 98% of the maximum possible. Assuming the worst case scenario, the torque constant of the motor is required to be at least 0.049 Nm/A.

0.045/0.998 = 0.04509

0.04509/0.05 = 90.18%

Now that we have confirmed the value of the torque constant of our motor is within 9.82% of the manufacturer specified value, we can be sure our motor is capable of delivering enough torque to the wheels at all times to provide a moderate rotational speed at all loads.

3. Cost and Schedule

3.1.1 Labor

According to the ECE department the average salary of a ECE undergrad graduate is $84,250. Taking in the salary and that on average an engineer works for ~40 hours a week. We find that in an ideal situation they work for 52 weeks which averages around 2080 hours for the year. From this we are able to figure out that the engineer will be getting paid 40 dollars a hour. Our calculation for each members salary is as follows:

($/hour) x 2.5 x weeks till deadline x hours/week= TOTAL

40 x 2.5 x 10 x 15 = $15,000

So on average the engineers should be getting paid ~$15,000 for their efforts and labors for this project

3.1.2 Part Cost

Part	Description	Manufacturer	Part #	Quantity	Cost
Battery (power bank)	Quick Charge 3.0 with 2 Output max 3A for 2 Devices: With 5V-3A, 9V-2A, 12V-1.5A,Fast Charging 2 output port	Metecsmart (amazon)	N/A	1	$27.98
2-D Lidar Sensor	optical distance measurement sensor, single-stripe laser transmitter, 4 m Radian x 2 m Radian beam divergence, and an optical aperture of 12.5mm	sparkfun	14032	1	$129.99
Microcontroller (raspberry Pi)	SoC: Broadcom BCM2837. CPU: 4× ARM Cortex-A53, 1.2GHz. GPU: Broadcom VideoCore IV. RAM: 1GB LPDDR2 (900 MHz) Networking: 10/100 Ethernet, 2.4GHz 802.11n wireless. Bluetooth: Bluetooth 4.1 Classic, Bluetooth Low Energy. Storage: microSD.	raspberrypi	4	1	$45 (we already have one so $0)
USB Buccaneer	Cable Assembly Rectangular 05 pos Plug to USB A Male Plug 0.33' (100.0mm)	Bulgin	14193	1	$7
Ble Beacons	Bluetooth BLE iBeacon	Blue Charm Beacons	BC037S	4	18*4= $72

Chassis	Our based upon which we will have mount all of our projects sensors, microcontroller, etc..	ECE Workshop	N/A	1	~$10
Motors	DC Motor, 12 V, 180 rpm, 500 g-cm, Torque = 50 kg-m Greartisan DC 12V 100RPM	Greartisan multicomp	287-2520 N/A	2-Greartisan 1-multicomp	32+3 = $35
Resistors, Capacitors	Basic electrical components	ECE Shop	N/A	N/A	~$10
PCB	Creating our own PCB design on Eagle and printing out to our specifications	ECE Shop	N/A	1	~$15
IR Sensor	Runs on 5V-12V power detect motion from pets/humanoids from about 20 feet away	adafruit	N/A	1	$10
TOTAL					~$316

3.1.3 Total Cost

The total cost of this project from our calculated opinion will be around $60,306. This includes the cost of each of the parts and the labor from all the people contributing to this project

3.2 Schedule

Week	**Syed A.**	**Didrick M.**	**Ming L.**	**Mike C.**
2/24	Narrow down algorithm used for navigation	Research different motors types	Finalize circuit schematic for motor driver	Determine Raspberry Pi compatibility with BLE beacons and app interfacing
3/2	Connect wheel	Confirm power	Draft of chassis	Implement pairing

	motors and logic to power	supply details and motor specs.	design/talk with Machine Shop	of phone to bluetooth module
3/9	Able to control wheel motors through Raspberry Pi through the motor drivers	Design layers of the base/placement of sensors, trash can, power bank, etc.	Have IR/ ultrasonic sensors and LIDAR ready for testing	Be sure to have BLE beacons ready for testing
3/16	Have ultrasonic sensors and LIDAR ready for testing	Connect ultrasonic and IR sensors to the rest of subsystem	1st Draft PCB design	Equip sensor data from beacons to user app
3/23	Interfacing with LIDAR and ultrasonic for obstacle detection	Continue work on installation of sensors/help with PCB design	Final Draft PCB design/ order PCB	Design phone application interface
3/30	Finishing algorithm for navigation so trash can follows beacons	Installation of sensors to the motors/chassis body	Install and test motors	
4/6	Finish algorithm for obstacle avoidance so trash can also avoids obstacles while following beacons	Conduct testing of electrical components/fix any errors	Install and test sensors and PCB	Work with Syed to user can interface beacons with user app
4/13	Being Final Paper	Peer review code for sensors and android phone application.	Help fix code for sensors and fix remaining	Clean up application code for android phone/bluetooth pairing and fix remaining bugs
4/20	Help clean up application code for navigation/fix remaining bugs	Clean up application code for obstacle avoidance and fix remaining bugs	Address any additional errors	Continue working on final paper
4/27	Prepare for demonstration and final presentation	Prepare for demonstration and final presentation	Prepare for demonstration and final	Prepare for demonstration and final presentation

			presentation	
5/4	Turn in final design paperwork and final presentation	Turn in final design paperwork and final presentation	Turn in final design paperwork and final presentation	Turn in final design paperwork and final presentation

4. Discussion of Ethics and Safety

4.1 Ethics and Safety

We believe addressing ethical and safety issues are of utmost importance in ensuring that we devote ourselves to proper conducts which can have an overall impact on our community. as we are obligated to devote ourselves to good conducts which positively affect our communities.

Several safety and ethics issues are relevant to our project. In reference to the first point in the IEEE Code of Ethics [4], we have to ensure that the materials we use are safe for in-house use and are non-toxic to household plants, animals, and people. Other than the effect on the material to household items, we also have to take into consideration the impact on the environment once the *smart trash can* is disposed of. We will take into account design considerations that affect these areas, such as potential pollutants of the battery or chassis base material.

A big potential safety hazard within our project is hazards regarding the battery which we plan to use, whether it be Li-Po or Li-Ion. The first hazard regarding the battery is possible explosion if it is overheated or overcharged [5]. Thermal runaway is a nasty side effect of a positive feedback loop of the discharge rate and temperature which can lead to failure of the battery if exposed to temperatures past 130°C, and possibly even explosion if exposed to temperatures well past that. In order to monitor the amount of charge in the battery at a given time, we will make use of a state-of-charge meter to accurately display the available power left. In order to monitor the temperature, we will consider the use of a thermistor which can disconnect the battery from the charging circuit if temperatures above a given range are detected.

We will follow all OSHA safety standards for robots [6] and follow all the guidelines regarding circuit protection in order to ensure safety from circuit failure hazards. We will purchase all our circuit components including motors, ultrasonic/infrared sensors, 2D LiDAR, PCB board, converters, battery, and battery charger from qualified vendors and follow all product instruction protocols when in use. For overall circuit protection of the PCB board circuit to the motors we will consider looking into transient voltage suppressors and flyback diodes to prevent a sudden spike in voltage across inductive loads when a current is suddenly reduced.

When building the electrical circuit on the PCB board, we will follow the electrical safety guidelines [7] and all manuals related to the electrical components and double check the circuit before connecting to the battery to prevent electric shocks that can occur during electrical shorts. When building physical design, we will also have to take into consideration any sharp edges or any design flaws that can ruin household items or hurt household pets and residences. Because we plan to have our trash can circular shaped, we most likely will not run into any major issues regarding faulty design. The subsystem will consider most for design is the automatic lid since the user will be waving his/her hand close to the trash can. We need to ensure the closing speed of the lid is slow enough so that nobody's finger is caught between the trash and the lid.

4.2 Risk Analysis

The block that poses the greatest risk to successful completion of this project is the Microcontroller block, or the Raspberry Pi. The reason this block poses the greatest risk is that it communicates and is in charge of almost every other module in our smart trash can. One small error within the microcontroller can corrupt the functionality of every other component, especially the operation of the motors which control the movement of the smart trash can itself and the lid.

The first risk is with the memory constraints of the Raspberry Pi. As of right now, we plan to have one Raspberry Pi operate three or more motors, multiple IR/ultrasonic sensor, a LiDAR, as well as Wi-Fi compatibility to allow user control from the Android App. Not to mention that this Raspberry Pi will also have to run the navigation and obstacle avoidance algorithm all at the same time as operating the other parts. Memory will quickly become an issue if we are not careful about how we are using the memory. We will try to reduce the software memory usage and and store only needed data that is useful in helping make decisions.

Another risk associated with the control module is the accuracy of the navigation and obstacle avoidance of our algorithms. Currently, the hardest part is being able to communicate the two algorithms such that the smart trash can is able to actively detect obstacles and make certain movements to maneuver around the obstacle, while at the same time not wandering too far off from the set path. Another issue with the obstacle avoidance algorithm is figuring out the optimal move to make in order to avoid an object. A nonoptimal move can put the smart trash can in a maze-like configuration. We might have to implement another local motion calibration algorithm along with our 2D-LiDAR to recalculate positioning within a 2D mapping if we cannot both actively navigate to our desired location and avoid obstacles.

The last risk is associated with the physical design of the trash can itself. A device like the Roomba does not have to worry about falling over when bumping into an object or wall. However, a trash can that is about 3 feet tall is at risk of falling over and spilling all the contents inside. Our plan is to physically design the trash can sturdy enough such that we do not have to equip other sensors (e.g. gyroscope) in order to account for self-balancing of the smart trash can.

5. References

[1] Medium.com. Raspberry pi for IoT. [Online]. Available: https://medium.com/@ankur.kus1/how-to-setup-your-raspberry-pi-for-iot-e1d35147c88a [Accessed: Feb 2020]

[2] "IR Communication." SparkFun. [Online]. https://learn.sparkfun.com/tutorials/ir-communication/all [Accessed: 13-Feb-2020]

[3] Instructables.com. Raspberry Pi Android communication. [Online]. Available: https://www.instructables.com/id/Raspberry-Pi-Android-App-communication/ [Accessed: 13-Feb-2020]

[4] ieee.org, “IEEE Code of Ethics”, 2020. https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 13-Feb-2020]

[5] BatteryUniversity.com. Lithium ion safety concerns. [Online]. Available: https: //batteryuniversity.com/learn/archive/lithium_ion_safety_concerns. [Accessed: 13-Feb-2020]

[6] "UNITED STATES DEPARTMENT OF LABOR." Occupational Safety and Health Administration. [Online]. Available: https://www.osha.gov/enforcement/directives/std-01-12-002. [Accessed: 13-Feb-2020]

[7] “Electrical Safety in the Research Laboratory,” University of Illinois at Urbana-Champaign, Division of Research Safety, 26-Aug-2019. [Online]. Available: https://www.drs.illinois.edu/Page/SafetyLibrary/ElectricalSafetyInTheResearchLaboratory. [Accessed: 13-Feb-2020]

[8] siliconlightworks.com, Li-ion Voltage Analysis. “Silicon Lightworks” [Online]. Available: https://siliconlightworks.com/li-ion-voltage [Accessed: 23-Feb-2020]

[9] circuitdigest.com, Obstacle Avoiding Robot. “CircuitDigest” [Online]. Available: https://circuitdigest.com/microcontroller-projects/raspberry-pi-obstacle-avoiding-robot [Accessed: 23-Feb-2020]