ECE 445 Design Document

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TA: Ruhao Xia

Autobin

An automated trash bin that comes to you

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Introduction

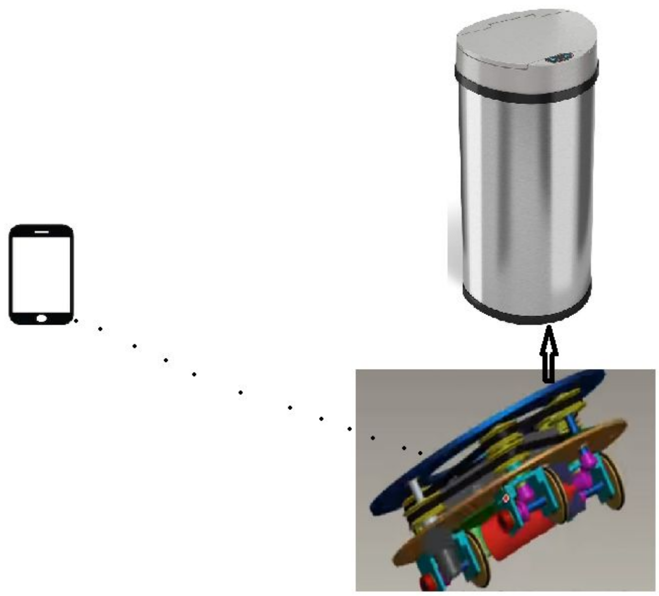
Objective:

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.

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.

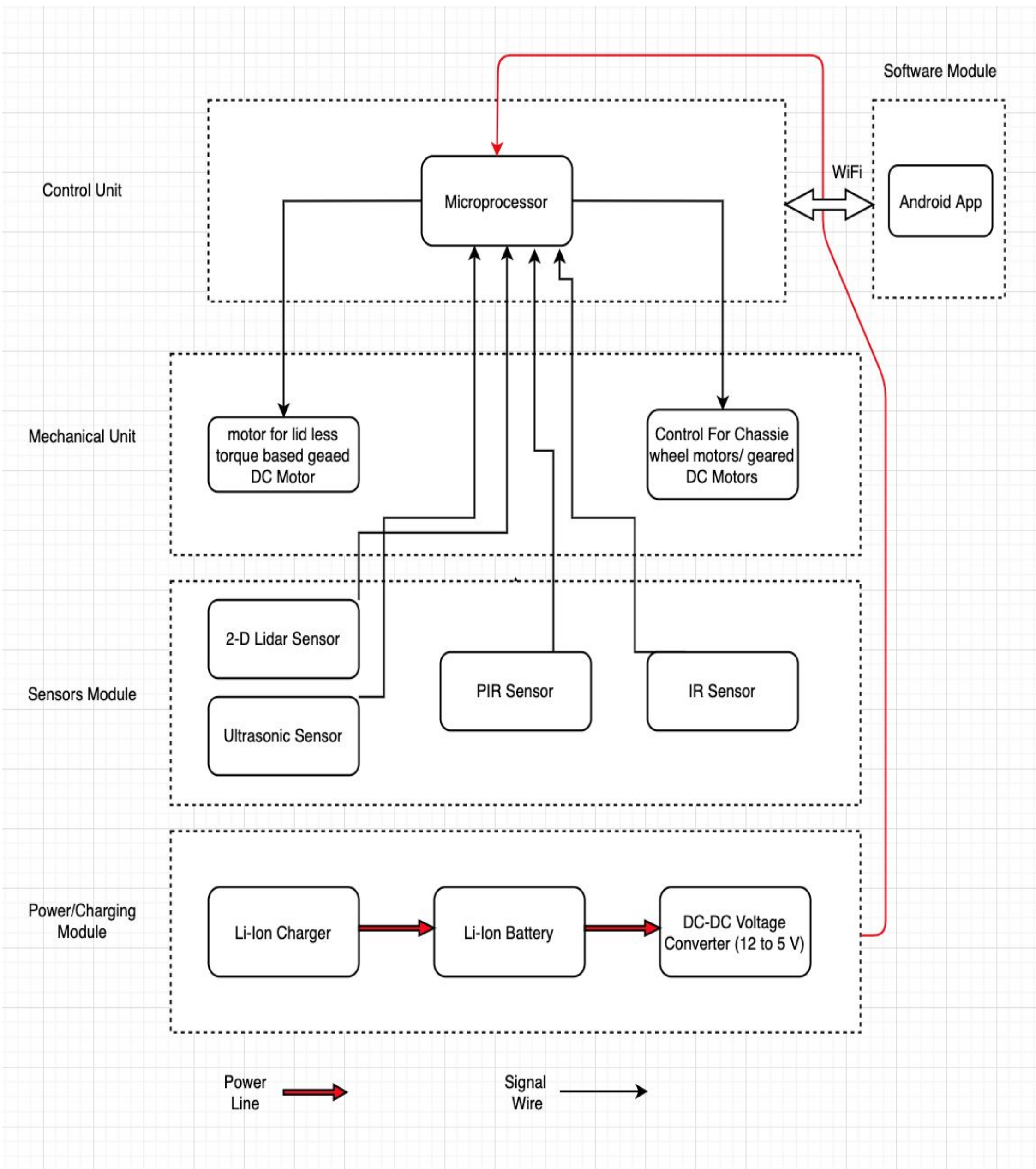


High-level requirements list:

- 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) and avoid common household obstacles on the way
- 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)
- The battery must be able to be charged successfully by the charging dock, the trash can must also be able to be "docked" autonomously by the user back to the charging dock (via smartphone app)

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.



Functional Overview/Block-level Requirements

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
(https://www.newark.com/multicomp/287-2520/dc-motor-with-180-1-gear-reducer/dp/52Y4441?COM=ref_hackster&CMP=Hackster-NA-project-8d09bc-Feb-20)

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.

Requirements:
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**

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.

Requirements:
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.

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.

Requirements:
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.

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:
Our sensor should be able to successfully measure distance from 2 cm to 4 meters with a ranging accuracy up to 3 mm. Our sensor will operate at 5v DC so the correct amount of power must be supplied 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. Using the DC-DC converter we will be able to ensure that our voltage that we supply will be constantly at 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

PIR 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:
The PIR sensor operates in the range from 3.3v to 5v DC and so the correct amount of power must be supplied to this sensor, since the sensor gives a TTL output, we must directly connect it properly to our micro-controller or relay through a transistor. Our sensor must be able to successfully detect infrared in an effective sensing range of about 20 feet (with a 120 degree view).

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

IV. Power/Charging Module

Battery Charger

Description:
This battery charger must be able to safely charge the battery whenever the smart trash can is in the standby mode, or sent by the user to go back to the charging dock. Since the smart trash can will be on standby through most of the day, it must be able to charge safely rather than quickly, but still within a

reasonable amount of time. A state-of-charge meter will also be used to accurately read the percent charge of the battery at all times. (Considering A400 3-4S Lipo Battery charger).

Requirements:
The charger must charge the battery to maximum capacity within 24 hours safely under operating temperatures of 150 degrees Celsius.

Battery

Description:
The rechargeable battery is in charge of powering all of the components on the smart trash can, including the DC-DC converter, the sensors for the charging dock, automatic lid and navigation, as well as the motors for the lid and wheels. (Considering the 14.8V 3- 4S Rechargeable Li-Po Battery)

Requirements:
The battery (Lithium Ion) should provide steady power (5-12 V) for all our components and operate at safe conditions

DC-DC Voltage Converter (12-5 V)

Description:
The Buck DC-DC converter we plan to use is needed to safely step down the voltage so that the Li-Ion battery can be used to power all the electronic parts. The Raspberry Pi operates at 5V, while the motors take anywhere from 3-12V. The ultrasonic/infrared sensors can take up 3-5 V.

Requirements:
The converter must maintain safe operating thermal temperatures below 150 degrees Celsius.

V. Software Module

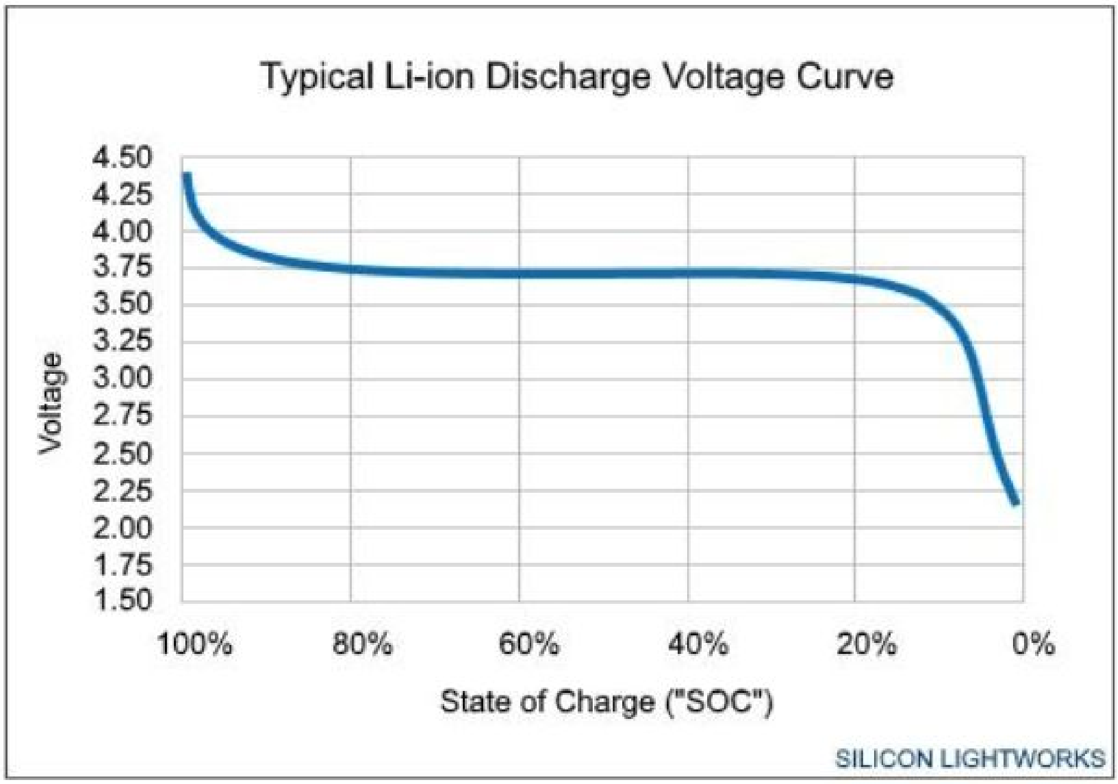
Android App

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.). The app would also display the current battery level of the trash can for monitoring.

Requirements:
The app must successfully be able to communicate with the Raspberry Pi in real time so we'll need an active server. The software that we'll most likely be using is Apache 2, PHP, PHPMyAdmin and a

MySQL database. For exchanging data between server and client we will be using JSON. We'll also need a functional android phone to download the corresponding app made on Android Studios [3]. The app will communicate with the beacons via bluetooth, this will allow the user to select a path for the Autobin to take and turn on the corresponding beacon to notify the Autobin.

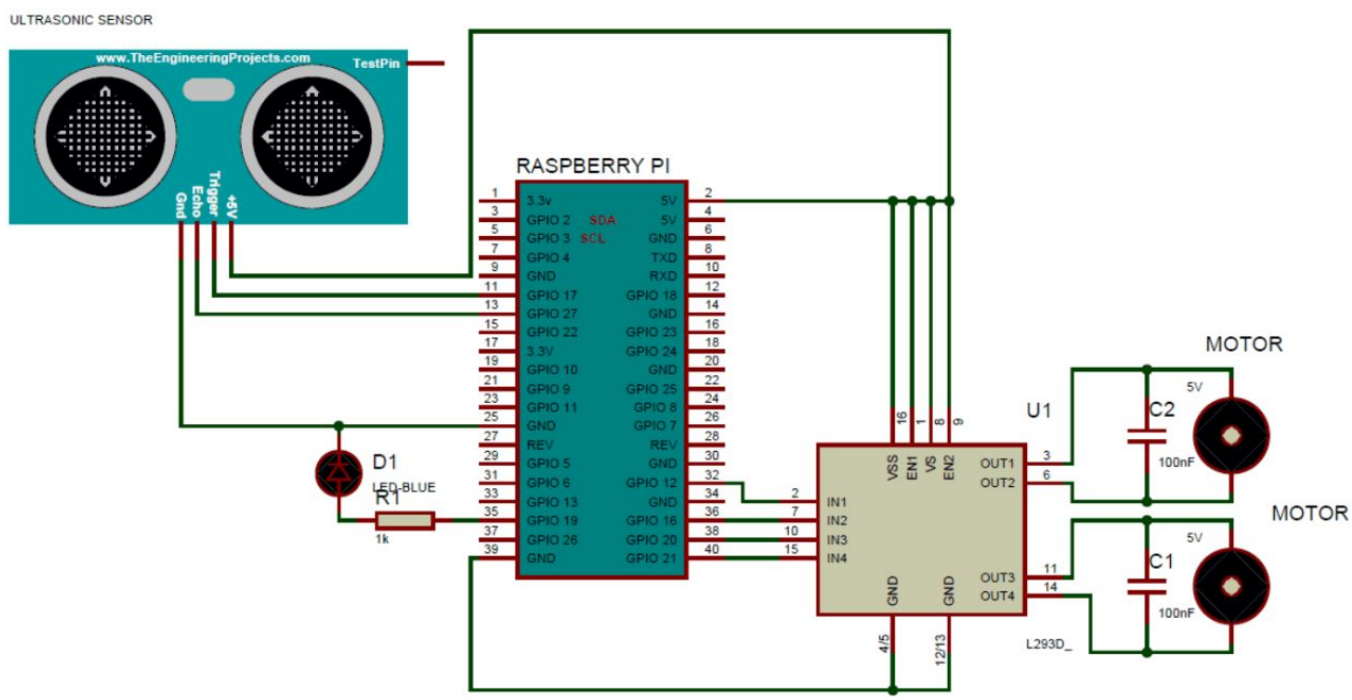
Plot:



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).

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.

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.

References

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