ECE 445 Project Proposal

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TA: Ruhao Xia

Autobin

An automated trash bin that comes to you

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Introduction

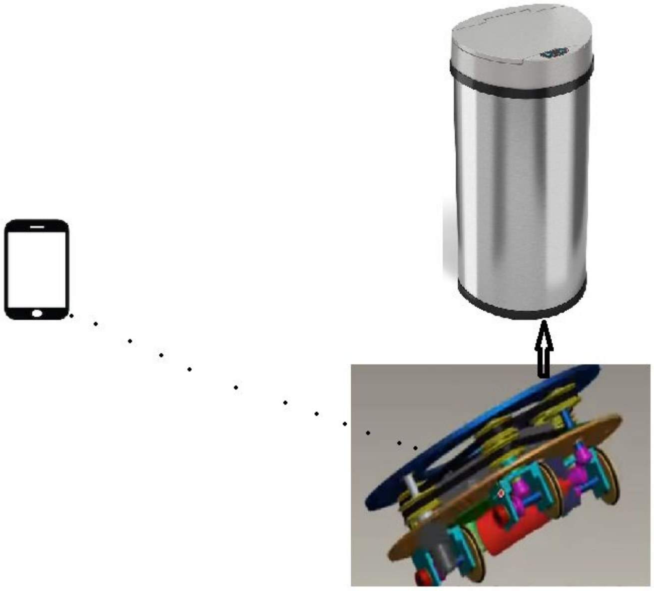
Objective:

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.

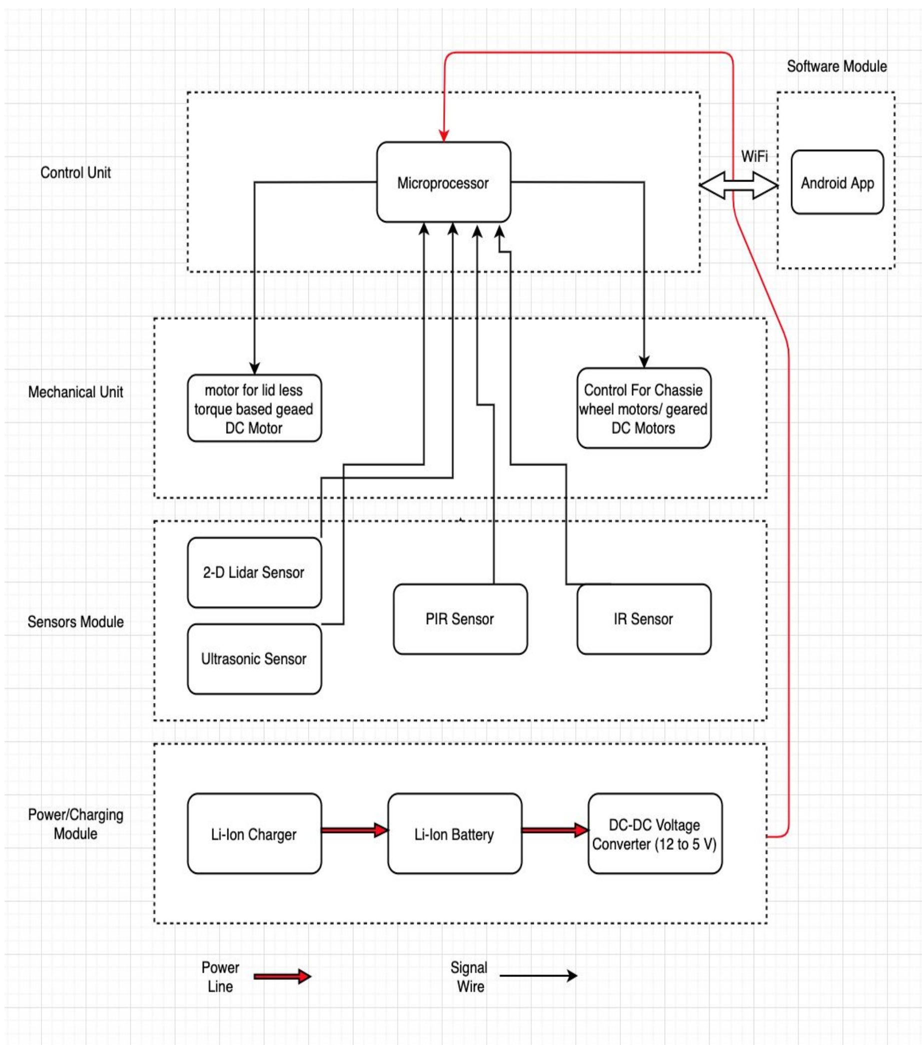


High-level requirements list:

- 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 (wireless charger), 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.



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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 LiDAR for help with surrounding environment mapping, and then further input from the beacons/ultrasonic sensors for self-localization and navigation. 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:

- The Raspberry Pi takes in a 5v DC input as a power source so the correct power must be supplied. Since it is built from commercial chips, operating temperatures of the SoC must be within the temperature range of -40 ℃ to 85 ℃.
- The Raspberry Pi must be wirelessly WiFi enabled, we plan 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.

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.

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.

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

2-D Lidar Sensor (navigation)

Description:
The Lidar sensor uses a method which sends out laser light to a target whilst using a built in sensor to measure out the distance from base to end of the light beam. The sensors operate at a very high rate of 100hz and the mechanical built ins to the laser allow it to toggle the angles so that it can give you a 180deg view mapping.

Requirements:
The way we plan on using the lidar sensor is to attach it to our chasse. Once on the chasse we will connect it to the microprocessor and input the data gotten from the sensor into our navigation algorithm. The inputted data will map out objects on a 180 degree plane which will allow us to avoid obstacles using our program. The radius that the laser reaches is 16 meters which is way more than enough for an indoor

space. The Lidar sensor operates on 5V, we will ensure this is the correct amount of voltage given to the sensor.

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.

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).

IR Receiver/Emitter (charging dock)

Description:
Composed of two parts, the IR transmitter and the IR receiver. The transmitter transmits infrared waves, which gets reflected back from that object and received by the IR receiver, which then sends a signal through the V output pin to our microcontroller. If no infrared waves are received by the receiver, then a low signal will be sent to our microprocessor to indicate that no object was detected.

Requirements:
The charging dock must be able to transmit encoded infrared-signals @ 950nm [2] that a receiver on the smart trash can can detect and decode at in-house ranges (around 10-20 feet). The receiver must be able to

decode the IR signal (10-20 feet) received from the charging dock and without misinterpretation from other IR noise within the surrounding environment.

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/Wifi 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].

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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