Automated Trash Can

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1 Introduction

1.1 Objective

Trash management is an integral part of our daily lives. Just by doing simple everyday tasks like cooking or cleaning, we generate a substantial amount of waste. However, without proper monitoring, waste can stagnate in our trash cans, leading to unpleasant odors that spread throughout the household. A possible solution is to take out the trash frequently, but that may also be wasteful if the trash can is mostly empty. Likewise, different amounts of waste are generated day by day, so predicting exactly when to take out the trash becomes more difficult. Moreover, since the average person generates roughly 4.6 pounds of trash a day[1], the frequency in which we need to check and maintain our trash cans becomes greater. This becomes even more difficult considering the number of trash cans in a household. We can expect a kitchen trash can, individual room waste bins, and bathroom waste bins.

Our goal is to improve the trash can by automating parts of the trash management process. We will integrate a microcontroller, sensors, as well as servos with wheels to a small waste bin. Using an ultrasonic sensor placed on the lid of our trash can, we can detect the level of waste. When our waste level passes a certain threshold, our microcontroller sends a notification to our phones via Bluetooth. The trash can then move itself to the door using a predetermined route. By doing so, we eliminate the need to constantly check the trash and provide a convenient reminder when the trash is full. If we see that the trash can is by the door, we know we can take out the trash on the way out.

1.2 Background

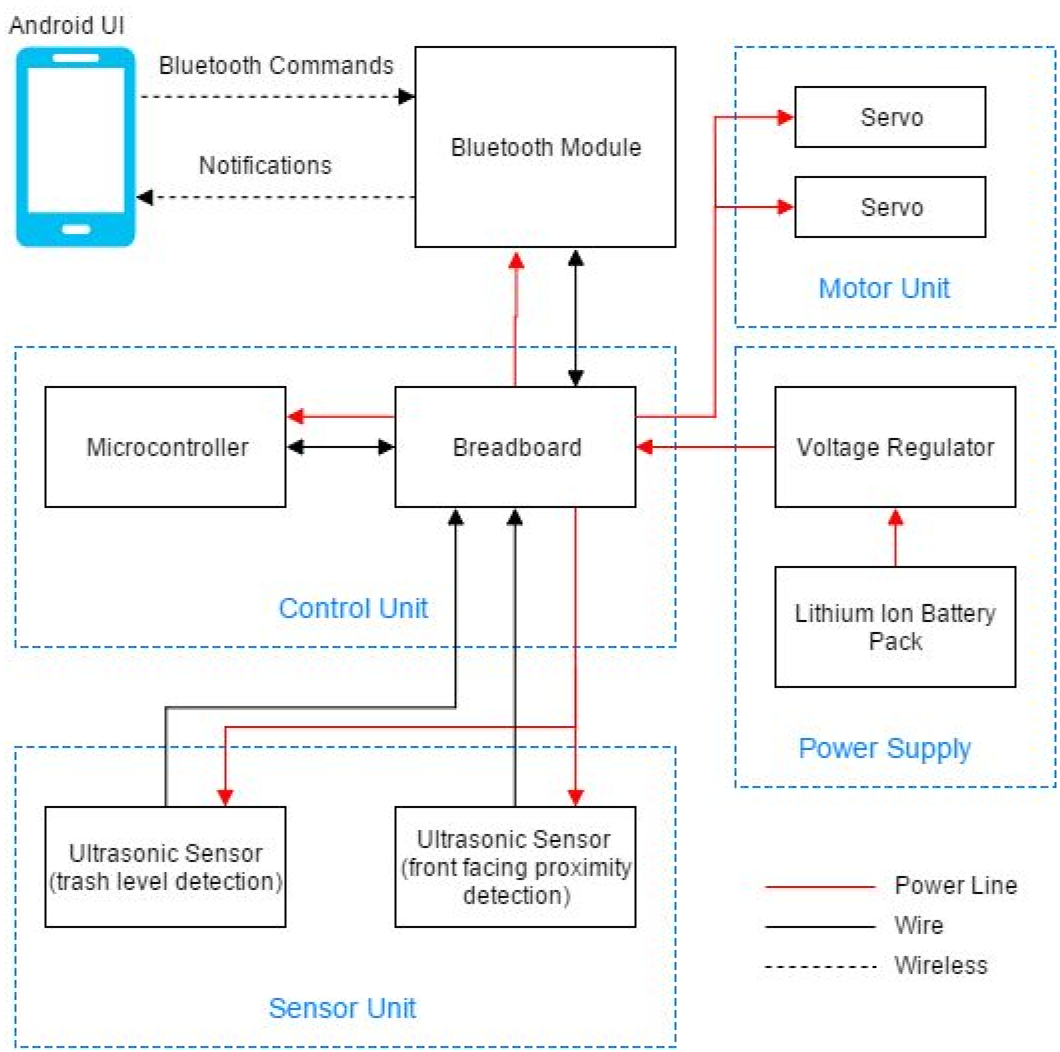
Existing attempts to automate the trash can are few and far between. Ecube Labs provides a trash automation system for municipal trash management. This is for much larger scale deployments and is not geared towards the average consumer. Likewise, these existing large scale attempts focus primarily on the detection aspect of waste management, so that garbage trucks can better plan their pickup routes.

Our aims to be more readily available to an average consumer. Likewise, our focus shifts towards improving the notification system beyond simple phone messages. By having the trash can automatically navigate to the door, we are conveniently reminded to take out the trash on the way. Furthermore, the navigational aspect can be expanded for use in suburban homes where waste pickup occurs the same day every week. Our system could potentially be configured to automatically move itself to the curb prior to pickup and move itself back afterwards. This completely removes the need to manually do a weekly task for suburban homeowners.

1.3 High Level Requirements

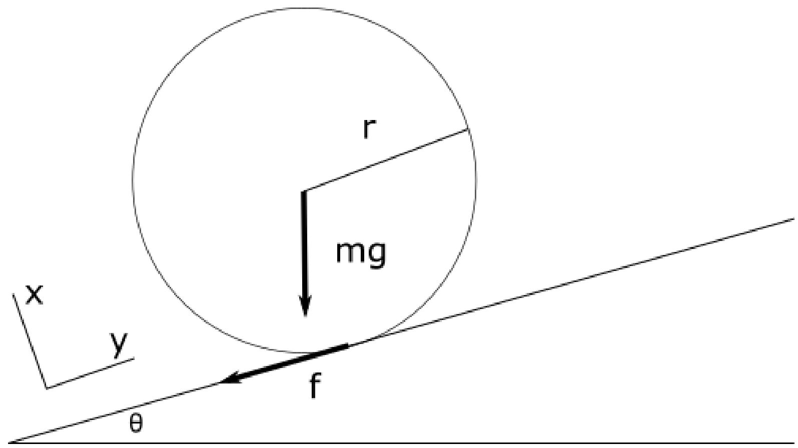
- Microcontroller must be able to reliable detect when the trash can is over 80% full.
- With a completely unobstructed path, the trash can should be able to navigate to the door with 90% accuracy. With the presence of minor obstacles, the trash can should be able to navigate to the door with 70% accuracy.

2 Design



2.1 Power Supply

We can calculate the power required to drive the motors using some basic mechanics. There are two ballpark numbers here that we are interested in. The first is the power required to keep the trashcan in motion, and the second is the power required to get the trashcan moving in the first place. Before we try to estimate those numbers, let us consider the following assumptions. Say that the maximum mass of the trashcan, including all the electronics is about $m = 10\ kg$. We estimate the coefficient of rolling friction between the wheels of the trashcan and the flooring to be $\mu = 0.6$.[2] Let us also assume that the trashcan is trying to move up an incline of $\theta = 3°$. Let the radius of the wheels be $r = 5\ cm$. Let us also assume that our motors run with an efficiency of 60%.



Let us calculate the power required to keep the trashcan moving at a constant speed of $v = 5cm/s$. To do that we must first calculate the torque required to rotate the wheel. The force here will be provided by the friction between the wheel and the floor. Balancing the forces in the x direction, we get $f + mg\ sin(\theta) = F$, where f is friction, and F is the force required to keep the object moving. The force of friction here is $f = mg\ cos(\theta)\ \mu$. The torque is therefore, $\tau = fr = mg\ (sin(\theta) + \mu\ cos(\theta))\ r$. The mechanical power required to keep the wheel moving is $P = \tau\omega$ where $\omega = v/r$ is the angular velocity of the wheels. Plugging in all the numbers we can get an estimate on the power to be $P = 3.4W$. Factoring in the efficiency of the motors, the real power required will be about 5.5W.

We know that the power required to get the trashcan moving will be higher than this number, we can accelerate slowly to this speed and reduce the angular speed requirements by using an appropriate gear assembly. Since we will have two driving motors, each motor will draw about half of that power.

Using these rough numbers, we can now state the following power supply requirements for our project.

2.1.1 Li-ion battery

Judging by the power requirements. We will require a driving battery pack that can supply at least 12V, with a current supply of at least 500mA.
Requirement: Battery pack with Voltage supply of at least 12V and current > 500mA

2.1.2 Rectifier

We will be drawing AC power from the wall, which needs to be converted to DC. Commercially available USB chargers can be used for this purpose as they provide all the safety circuitry as well.
Requirement: Rectify wall AC current to DC current usable by charger.

2.1.3 Li-ion charger

We will need a charging IC that can charge our battery steadily over time. Since the trashcan is stationary for long periods of time, we can charge slowly.
Requirement: Must charge the battery to it's 12V with a continuous charge of 300mA charge current from the output of the rectifier.

2.1.4 Thermocouple/Thermistor circuit

Safety measure to cutoff motors and charging circuitry in case of high temperatures.
Requirement: Should be able to detect temperatures of 45C or below 0C and cutoff the electronics form the battery.

2.1.3 Voltage/Current regulator

Because some of our digital components require 5V supply with a maximum of 200mA current, we will need a regulator circuit to drop the current and voltage to acceptable amounts.
Requirement: Lower Voltage and Current to 5V and <200mA for digital components.

2.2 Control Unit

The control unit is a microcontroller that manages the data coming from the sensors and controls the servos in our motor unit. It also interfaces with our bluetooth module to allow for communication with our android phone application. These connections are made on a breadboard.

2.2.1 Microcontroller

The microcontroller we will be using is the Arduino Uno. It takes in input data from the ultrasonic sensors and controls both servos in the motor unit.

Requirement 1: The microcontroller must be able to ground 3-5V for the ultrasonic sensors, bluetooth module, and servos.
Requirement 2: The microcontroller must have enough onboard memory to follow a predetermined route.

2.2.2 Breadboard

The breadboard is used as a hub for all of the connections we make between our microcontroller and peripheral devices, *Requirement: The breadboard must be large enough to support all our devices.*

2.3 Sensor Unit

The sensor unit contains the two ultrasonic sensors we will be using in our automated trash can. The first ultrasonic sensor is placed on the lid of the trash can and is used to detect trash level. The second ultrasonic sensor is placed on the front of the trash can as a proximity sensor for obstacles. This will be integrated into our navigation so that we can support simple obstacle avoidance.

The ultrasonic sensor unit we will be using is the HC-SR04. This ranging sensor has a detection distance from 2cm to 4m with up to 3mm accuracy. It operates on 5V DC and 15mA. The sensor has 4 pins: Vcc, Trig, Echo and GND. A pulse is sent to the trig pin to start the ranging and the echo pin returns a signal when the ranging is complete. By measuring the interval between the start of the trig signal and the received echo signal, we can measure distance (range to the current trash level or object in front of trash can)[3].

2.4 Motor Unit

The motor unit consists of the servos, gear train, and wheels and will allow the trash can to navigate and bypass obstacles. The components will feed off of the power supplied by the power unit through the breadboard.

2.4.1 Servos

There will be two servos units that will attach to the back two wheels on the trash can. The servos will have integrated gears and shafts that can be precisely controlled. Both the servos will draw a considerable amount of power especially when the motor is starting up. This could drop the voltage on the Arduino board. To protect against this, a capacitor can be used so that the motor can draw from it as well as from the Arduino power supply to get going.

Requirement 1: A high value capacitor > 470uF
Requirement 2: Each servos will have to have continuous rotation motors that will operate with ~5V

2.4.2 Gear Train

The gear train will be placed between the servos and the wheels and will be used to more efficiently change rotational speed, change torque, and change direction.

Requirement: The gears for the gear train will have to be carefully selected to provide the necessary gear ratio (i.e the number of teeths on each gear wheel, the outer diameter of each gear wheel)

2.4.3 Wheels

Four wheels, two on the front and two on the back, will guide the trash can in navigation. The front wheels will be used for stability and the back wheels be connected to the servos. The wheels will consist of thermoplastic silicone tires which will provide for good traction.

Requirement 1: The radius of the wheels will have to be big enough to provide for the necessary angular velocity assuming that the trash can will move at ~5cm/s

Requirement 2: The wheels will have to be compatible with the servos and gear train setup

2.5 Bluetooth Unit

The bluetooth unit consists of an android app and a bluetooth module to interface with the Arduino. The android app will provide specific control/navigation directions for the trash can to follow and have a notification feature for when the ultrasonic level sensor detects the trash is 80% full. Upon initial setup of the system, the user will use the app to guide the trash can to the door and the app will save the taken route. Now, upon detection of fullness, the trash can will follow the same set of directions the user provided in his or her route.

As for the bluetooth module, we plan on using the HC05 module to interact with both the application and the Arduino due to its low cost and flexibility with the Arduino. This module can communicate via bluetooth with a range of 10m and operate at around 3.3V with 3.3V signal levels [4].

2.6 Risk Analysis

The power unit in our design poses the greatest risk for our project. Clearly, for an automated trash can to be useful, it should be able to last for a significant amount of time without interference. Since we plan on having the trash can move on detection of 'fullness', we can't secure the trash can to a wall outlet. Instead, we need a portable power supply to allow for this type of mobility.

The portable power supply inherently raises several concerns. The portable battery pack needs to be able to last for a substantial amount of time (more than a week) to satisfy our use case. However depending on the size of our trash can, the weight of the trash itself can prove to be quite significant. The power needed for the servos to move ~10 kgs in addition to the energy requirements of the other sensors as well as the microcontroller itself may severely impact our battery longevity. Moreover, the power unit must output enough energy to sustain our entire system.

Li-ion battery packs are the most promising option for our requirements. They have allow for more number of charging cycles and are not prone to leaking like other battery choices. Since our payload of trash can be potentially inflammable and corrosive, we can not risk using batteries that leak. Housing the Li-ion battery in sturdy shielding that can protect the battery from mechanical damage and cutting-off the motors if a high temperature is detected can mitigate risks from fire.

We can configure our system to operate in cycles of idle and active operation. Since we don't need to continuously check for sensor data, we can simply have our system idle then check for sensor data every ~1 hour. Our trash can also has to move very infrequently, so periods of high energy utilization should be very small when compared to idle time.

3 Ethics and Safety

As far as we can tell, there are no potential ethical concerns or issues with our project.

The biggest safety issue stems from our use of lithium ion batteries. These batteries can explode due to several reasons, such as overcharging, physical damage, being exposed to high or very low temperatures etc. We will ensure that the battery is never overcharged by using commercially available tested chargers to charge our battery. We will make sure that the temperature of our battery does not exceed its operational limits by using a thermistor/thermocouple circuit to disconnect the battery from the rest of the circuit in case we detect temperatures higher than 45C or temperatures lower than 0C.

Another safety issue comes from the fact that the trash can potentially contain liquids or corrosive substances that might damage our circuitry. We will make sure that the trash compartment is completely isolated from the electronic compartment of the design.

Lastly, the intelligent trashcan can pose a threat to pets. We will ensure that this aspect is factored into the navigation circuitry and that the trashcan will not move if it detects moving obstacles.

References

[1]"Garbage-- Solid Waste." Garbage-- Solid Waste. N.p., n.d. Web. 09 Feb. 2017.
[2]Vol. 7, No. 1, January 2012, and Issn 1819-6608. FRICTION COEFFICIENT OF RUBBER SLIDING AGAINST FLOORING MATERIALS (n.d.): n. pag. Arpnjournals. ARPN, 1 Jan. 2012. Web. 9 Feb. 2017.
[3]"Ultrasonic Sensor - HC-SR04." SEN-13959 - SparkFun Electronics. N.p., n.d. Web. 09 Feb. 2017.
[4]"BlueTooth-HC05-HC06-Modules-How-To." Arduino-info - BlueTooth-HC05-HC06-Modules-How-To. N.p., n.d. Web. 09 Feb. 2017.