Autonomous Delivery Robot

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1 Introduction

1.1 Objective

Robot is so called the next generation technology and indeed has been brought to our life in many aspects such as education, military and so on. With the occurrence of robots in varieties of areas, a new revolution is happening in real life since robots have their own advantages – low labor cost and stable working performance. In a word, robots have been part of the society in a deep level but there is still a lot improvements needed to enhance the performance. For example, in the coffee shop in the future, not only does the robot make coffee, but also delivers safely by itself. An autopilot robot that is able to deliver food will save a lot labor cost, but the way to its destination is not always smooth and safe, therefore, a solution is needed to deal with different kinds of special situations and potential obstacles. It is difficult for robots to recognize the surrounding objects and react as it supposed to but failure of avoiding obstacles raises the concern of safety. High performance detection, analysis and controlling systems are capable of decreasing the failure rate. However, it would cost too much to be afford for industrial applications. Due to this reason, delivery robot is still far away to daily life.

Our goal is to find a low-cost solution so that delivery robots becomes applicable in the real life. We will use combinations of 2D lidar and other sensors to lower the cost but keep the functionalities. These sensors will collect data and communicate with processor. After processing the data and calculate the desired actions, the robot will adjust the motor to avoid the obstacles. After dealing with all the problems it encountered, the robot will navigate to the destination in the end.

1.2 Background

YummyFuture has been part of the revolution in food industry by robots and they had a prototype of robot coffee stand which still need improvement in delivery system. Many previous solutions for detection use 3D lidar with camera to recognize the surrounding areas. This solution works well but a 3D lidar costs more than $1000 and need a high-performance processor, making the solution cost too much for industry.

We are going to use 2D lidar about $200 instead to drop the cost significantly. Many other sensors such as sonar and infrared detectors are used to make up the functionality of detection and increase the accuracy. In this way, using the combination of sensors, we can achieve a low-cost solution with an equivalent accuracy of output.

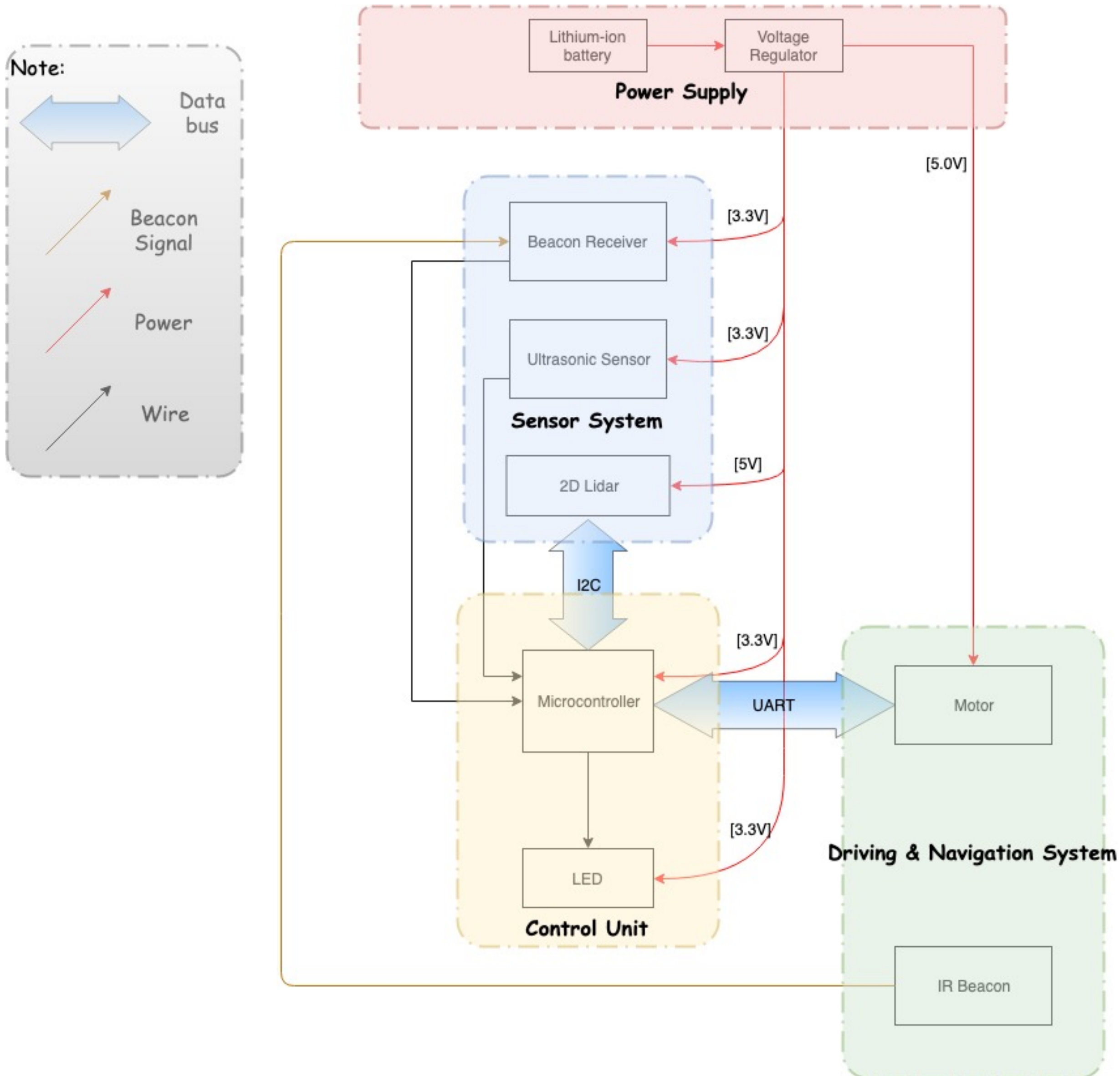
High level Requirements

1. Robot must be able to detect the standing and moving obstacles in its path in 50cm using its sensor and adjust motors correspondingly.
2. Robot must be able to navigate to the destination.
3. Robot must be lost-cost comparing to the existing solutions, the cost should be lowered by $500.

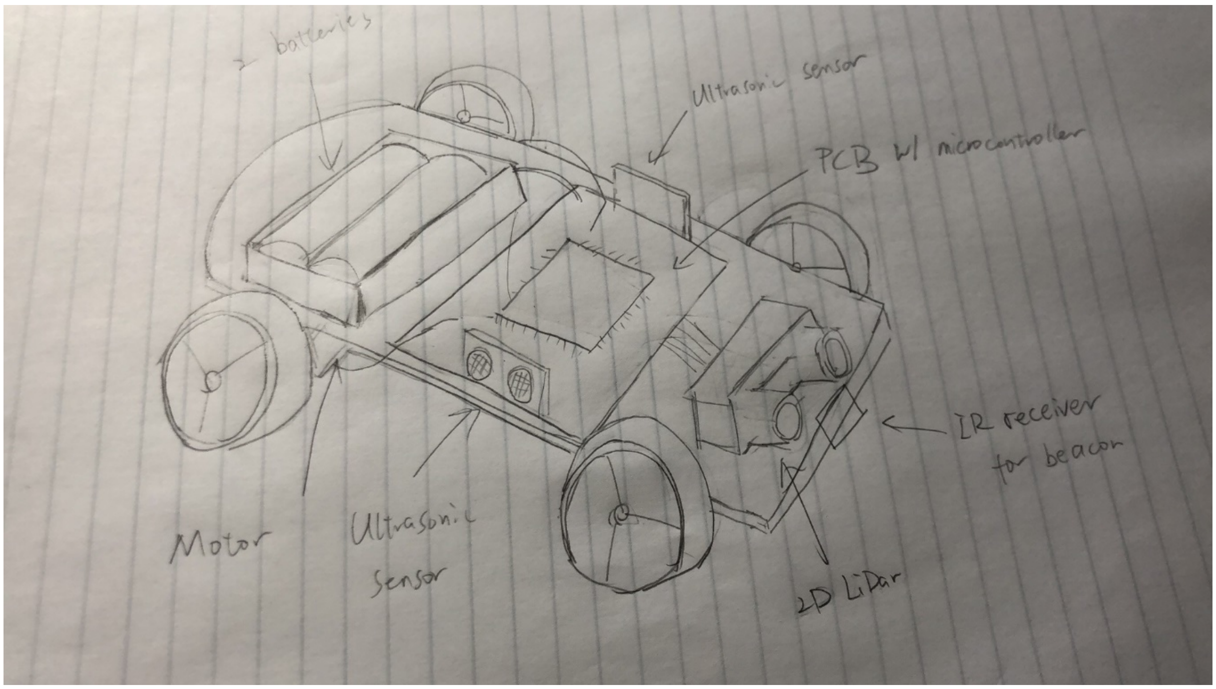
2. Design:

The entire project consists of four functional sections: Power supply system, sensor system, control unit and the driving & navigation system. The power supply is designed for keeping the project working properly including achieving all the expected functions. The sensor system is used for collecting the data from the surrounding areas, especially the potential obstacles. The control unit will be able to analyze all the data collected from all the sensors and make decisions for the driving system to execute. The driving & navigation system is supposed to make the corresponding actions according to the commands received from the control unit, and then make the vehicle approaching the pre-assigned destination.

Block Diagram



Physical Design:



Physical structure description: Our chassis will contain two batteries as DC power supply, two motors, two ultrasonic sensors, a 2D LiDar and an IR receive for beacon, and all components are connected to the PCB with microcontroller in the middle of the chassis. The motors are installed adjacent to the two rear wheels. Two ultrasonic sensors are on the both sides of the chassis and a 2D LiDar is at the front of the car to detect the potential obstacle. There is also an IR receiver can locate the IR transmitter beacon so that the car can drive towards the destination.

2.1 Power Supply

The power supply is providing all the energy that whole project needs. It consists of two lithium-ion batteries and a voltage regulator.

2.1.1 Lithium-ion battery

Two batteries, each providing 3.6 Volts and DC current. The batteries are the energy source for the entire vehicle to continuously work for a certain period, which lasts for 1.5 hours.

Requirement	*Verification*
1. Each battery should provide 3.6V *2. Each battery stores at least 1.25 AH of charge*	*1. A) Connect the voltage regulator to two Li-ion battery* *B) Check if each battery provides 3.6 V.* *2. A) Connect a fully charged Lithium-ion battery with the positive terminal at VDD and the negative at ground.* *B) Discharge the battery at 250mA for 5 hours.* *C) Use a voltmeter to ensure the battery voltage remains above 2.2 V*

2.1.2 Voltage regulator

This component is used to generate the corresponding desired voltages that the electronic components in other modules require. It should be providing 5.0 Volts and 3.3Volts and max current 1A.

Requirement	*Verification*
1. It should provide voltages in 3.3V and 5.0V and max current 1 A	*1. A) Connect the voltage regulator to two Li-ion battery each providing 3.6 V.* *B) Add a resistive load to circuit such that the voltage drop is 5.0 V and 3.3V respectively.* *C) Ensure the current through the load is below 1 A in series which can be tested by amp meter.*

2.2 Driving & Navigation System

This module is designed as the main dynamic part of the project. There are two main functions that this module will be able to realize, avoiding hitting on the obstacles and finding the path approaching to the destination.

2.2.1 Motor

The motors are the dynamic energy source of the four wheels, each motor is supposed to be independently controlled by the output signal from the microcontroller in order to achieve the direction adjusting. We used L293D as H-bridge.

Requirement	*Verification*
1. Two motors should control two wheels to operate at different speeds.	*1. A) Connect motors with two wheels* *B) Connect 5V power supply to motors such that they are in parallel* *C) Add different resistive load in series with motors such that they have different current which can be tested by amp meter.* *D) Ensure the wheels are operating at different speed.*

2.2.2IR Beacon

The IR beacon serves as an indicate of desired ending position for the vehicle. The beacon must be installed at the pre-assigned destination and the receiver which is able to catch the signal sent by the beacon must be set on the vehicle. After the signals are processed by the microcontroller, the vehicle should be able to recognize the correct direction towards the destination.

Requirement	*Verification*
1. IR Beacon and receiver should be able to work in the range of 0.5m to 20m.	*1. A) Connect IR Beacon with an AC power supply and put it at the destination.* *B) Connect the receiver with resistive load and ensure the voltage is 3.3V by a voltage meter and current is 500 mA by an amp meter.* *C) Move the receiver from location that is 0.5m away from IR Beacon to a location that is 20m away.* *D) Ensure the receiver outputs the correct data.*

2.3 Control Unit

The control unit serves as a part to set up connection between sensors and motors, which means it will store the data from sensors and send result as signal to motors via UART (universal asynchronous receiver-transmitter) port after computation. The unit also contains a LED will be turned on as alarm while encountering obstacle or while reaching destination.

2.3.1 Microcontroller

ATMEGA328P will be our microcontroller. It handles all data collected from lidar via I2C and ultrasonic sensors and takes the data as input of software part we designed inside to output signal that can control the motors appropriately via UART. Requirement: The microcontroller must be able to communicate via UART and I2C interfaces.

Requirement	*Verification*
1. ATMEGA328P can receive and transmit data over UART at a speed of 96 kbps	*1. A) Connect microcontroller to a USB UART bridge such as FT232 and to a terminal such as Putty.* *B) Set up terminal at 96 kbaud* *C) send and echo 100 characters* *D) Ensure the characters matched in two ends.*

2.3.2 LED

The LED will be turned on while it reaches its destination.

Requirement	*Verification*
1. The LED must be easily seen from 2 meters away by people near it.	*1. A) Connect the LED to a circuit with power supply and voltage meter to ensure the voltage is 3.3V* *B) Add a resistive load in parallel to ensure the current is 1A which can be tested by amp meter.* *C) Measure 2 meters distance away from LED* *D) Ensure that LED is visible at viewer's location.*

2.4 Sensors system

The sensors system manages navigation and obstacle detection of the robot, it will send feedback from different sensors (IR, LiDar, Ultrasonic) as data to the control unit.

2.4.1 LiDar

We will use LIDAR-Lite v3 as our LiDar that detect obstacle in front of the robot using laser, it will also measure the distance to the obstacle and communicate with microcontroller via I2C interface.

Requirement	*Verification*
1. It must be powered by voltage 5V with current 105mA in idle mode and 130mA in working mode. *2. It must emit laser in range 0-30m with accuracy +/- 10cm at distances greater than 1m and +/- 2.5cm at distance less than 1m.*	*1. A) Connect the lidar to a power supply and resistive load, ensure the input voltage is 5V.* *B) Change the current in series to 105mA and ensure the lidar is in idle mode.* *C) Ensure lidar is in working mode with current of 130 mA in series.* *2. A) Put laser sensors at distance at 1m and 30 m to ensure the working range.* *B) In the range of 1m – 30m, move laser sensor 10 cm backwards and forwards, and check the output of lidar to ensure the accuracy.* *C) In the range of 0m – 1m, move laser sensor 2.5 cm backwards and forwards, and check the output of lidar to ensure the accuracy.*

2.4.2 Ultrasonic sensors

HC-SR04 is chosen to be our ultrasonic sensors. They will be put on the side of the chassis to check surroundings and measure distance of close obstacles. These sensors basically support the 2D-LiDar in the sensor systems so that the robot is able to make right decision on turning left or right while encounter obstacle in front of it.

Requirement	*Verification*
1. It must work under 4.5-5V DC power and current below 2mA Requirement *2. It must detect obstacle in range from 5cm to 20m with resolution 1cm.*	*1. A) Connect the Ultrasonic sensor to a power supply and resistive load, ensure the input voltage is in the range of 4.5-5V. Ensure the maximum current is below 2mA in series.* *2. A) Put an obstacle at distance of 5 cm and 20 m to ensure the detection range.* *B) Move the obstacle 1cm, 10cm and 1m to ensure the resolution of output is 1cm.*

2.5 Tolerance Analysis

One important tolerance we must maintain is that the vehicle must be continue working for at least 1.5 hours without charging the batteries. The Lithium-Ion batteries that we plan to use is the Panasonic DMW-BCM13 Lithium-Ion Battery Pack, which will constantly provide 3.6V DC voltage and the total electrical energy it will provide is 1250mAh. Based on the equation

$$U(Energy)=P*t$$

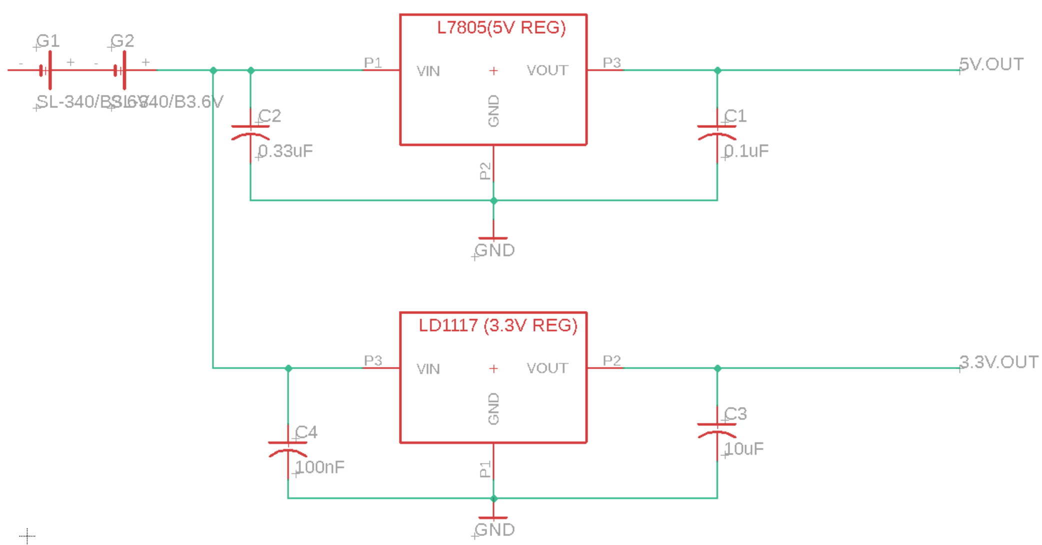
$$P(power)=V*I$$

we can find that the total DC current passing through the power source will be 833mA. The total impedance will be 8.643457 Ω, and there must some energy lost existing due to the heat produced on the resisters. Assuming the efficiency is 80%. Then we have to adjust the total impedance within 8.643457~10.8 Ω.

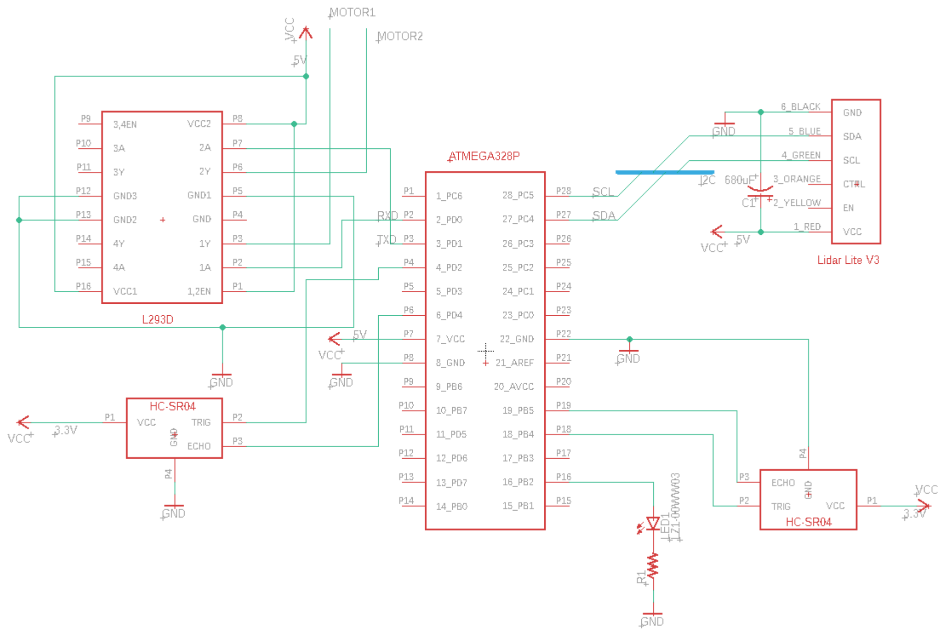
Since our original purpose was to use 2D lidar along with other sensors to achieve 3D detections, the sensitivity of the sensor system on this vehicle will be another important concern in tolerance. The sensitivity for the lidar and the ultrasonic sensors to get information from the obstacles will also has to be set a particular level. The ultrasonic sensors have to make responses when the vehicle is within a certain range from the potential obstacle. Assuming the vehicle will always perform 90° turning, the minimum distance from the vehicle to the obstacle will be the width of the chassis, so the threshold distance will be 0.15m~0.4m.

2.6 Schematics

Power:



Motor, sensor and controller:



3 Cost

The estimated labor cost is about $20/hour, 8hours/week for three team members. Assuming we are going to spend 14 weeks on finishing this project, the total labor cost will be:

3*$20/hour*8hours/week*14weeks*2.5=$16800

Part	Cost(prototype)	Cost(bulk)
Panasonic DMW-BCM13 Lithium-Ion Battery Pack	$32.00	$8.00
IR Beacon and receiver (SKU 902111-IR)	$30.00	$10.00
PCBs	$4.00	$0.10
Microcontroller (raspberry Pi 3; atmega328p)	$40.00	$1.62
Chassis and Motor	$17.99	$7.99
Resistors, capacitors, ICs, LEDs, sockets	$9.99	$0.99
2D lidar (LIDAR-Lite v3; atmega328p)	$129.99	$8.99
Ultrasonic Sensor (HC-SR04)	$3.95	$0.50
Voltage regulator (LD1117, L7805)	$3.00	$0.10
Total	$270.92	$38.29

Part cost + labor cost: $17070.92

4 Schedule

Week	Ningyuan Du	Jue Ni	Wuwen Wang
02/25	Version 1 PCB design	Initiate version 1 of Sensor design	Schematic design version 2
03/04	Finish Version 1 PCB design and revise the schematic design	Continue version 1 of sensor design	Initiate version 1 of microcontroller design
03/11	Version 2 PCB design	Unit test and bug fix on sensor design	Continue version 1 of microcontroller design
03/18	Initiate navigation design	Develop an algorithm to analyze the data from sensors	Unit test and bug fix on microcontroller design
03/25	Unit test and bug fix on navigation design	Continue work on sensors	Initiate work on communication between microcontroller and motor
04/01	Complete design of navigation	Continue work on sensors	Continue work on microcontroller
04/08	Prototype case	Complete design of sensors	Continue work on microcontroller
04/15	Test in real environment	Test in real environment	Finish work on microcontroller and test in real environment
04/22	Bug fix on navigation	Bug fix on sensors	Bug fix on microcontroller
04/29	begin final report and prepare presentation	begin final report and prepare presentation	begin final report and prepare presentation

5 Ethics and Safety

This project is pitched by Yummy Future because they want to find out a low-cost solution for the delivery system. After finished our project, we will share the outcomes with them to improve their understanding. This action is an implementation of #5 of the IEEE code of Ethics, “to improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems” [1]. We would like to share our outcome with anyone who is looking to improve their robots.

We are open to accept all criticisms with regarding to the delivery robot and in case it has defects or necessary improvement, we are willing to work on it to adjust. We designed our robots to have many replaceable parts so that we could improve it by placing more suitable parts. This is described in #7 of IEEE code of Ethics, “to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others” [1].

The most common ethics issue of robotics is that robots may hurt people’s health and property because of its failure of reacting properly. It is possible that a delivery robot navigates at a high speed and hit people or their property. This goes against #9 of the IEEE code of Ethics, "to avoid injuring others, their property, reputation, or employment by false or malicious action." [1]. During the process of designing our robot, we have carefully examined the design and make sure the ethics codes are followed. There is no harmful parts such as piercing parts in the structure of our robot, which prevents the potential hazard. In this way, the action of robot is more human-friendly.

Malicious actions that will hurt people are our biggest concern of safety and we have tried to prevent it by applying the solutions mentioned above. There is a safety standard ANSI/RIA R15.06-2012 for the industrial robot and many of the terms are relevant to our robot. For example, there is one standard that says, “Incidental contact between robot and person will not result in harm to person” and “Power and force limiting” [2]. Our design has carefully followed these standards by removing dangerous parts and adjusting speed. This delivery robot is designed to serve people, and should never have safety hazard. If there is any accident occurred because of our robot, we would accept the responsibility honestly and improve accordingly.

Reference

[1] Ieee.org, "IEEE Code of Ethics", 2019. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 07- Feb- 2019].

[2]robotics.org,“ANSI/RIA-R15.06”,2019.[Online].Available: https://www.robotics.org/robotics-standards. [Accessed: 07- Feb- 2019].