February 20th, 2017

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, British Columbia
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Re: ENSC 405W Requirement Spec for an Automated Cart Delivery System Capstone Project

Dear Dr. Rawicz:

The enclosed document, *Requirement Spec for an Automated Cart Delivery System***,** describe our Capstone project ideas for ENSC440. Our goal is to optimize consumers' shopping experience by delivering shopping bag from one destination to another. By designing an automated cart delivery system, our product will solve the problem of carrying several shopping bags.

The requirement specification document provides a high-level functionality requirement, sustainability, and safety for both proof-of-concept and the final Deliverbot system. Autotrack will use this document as a reference by all of the engineers involved in the project for research and development.

AutoTrack was founded by three dedicated senior electronics, systems, and computer engineering students from Simon Fraser University. The team members include Eason Tsai, Benjamin Tsai, and JackyTeng. If there are any questions or concerns about our proposal or project ideas, please do not hesitate to contact me at syt8@sfu.ca.

Sincerely,

Benjamin Tsai

AutoTrack Inc.

Requirement Specification for

Automated Cart Delivery System

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Issue Date:

February 20, 2017

Executive Summary

Have you ever imagined what it would be like when you are in a mall picking discount products and don't need to carry shopping bags? When during long shopping experiences with a bunch of heavy baskets or plastic grocery bags, people feel like the load is cutting their pleasure of shopping off. Therefore, we are introducing a smart device that will help shoppers to have a hands-free experience of products transfer

AutoTrack is going to design an auto-deliver cart, which will carry customers' products to the pickup locations. Shoppers put the products in the cart, and the cart will follow the colored tape mounted on the ground to deliver purchased items to pick-up locations automatically. Shoppers only need to pick their items up from pickup locations once they finish shopping.

The Deliverbot comes with two modes of operation, auto mode, and manual mode. In the "Auto" mode, the cart will deliver items from stores to pick up locations automatically with its dynamic tracking system. Therefore, the speed of Deliverbot will be around 10 km/hr, which can provide the best performance between safety and efficiency. On the other hand, the motor speed will be manual control by trained staff in the "Manual" mode.

This document lists all the functional requirements as well as engineering standards for the overall system design of the Deliverbot. Sustainability of the cart frame material and electronic components will also be discussed. The requirements will be given a priority level based on the stage of development. The overall system will be discussed in the following sections of the document:

- System Overview - General system requirements and engineering standards
- Mechanical System - DC drive, steering, motors and brakes
- Control System - Development boards, and sensors

The AutoTrack plans to complete a proof-of-concept by prototype by the end of the semester. Our goal is to bring a whole new experience of cargo transportation, and in doing so, to improve the quality of life for all our users.

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Glossary

DC	Direct Current
kg	Kilograms
cm	Centimeters
m	Meters
V	Volts
A	Amps
s	Seconds

1. Introduction

Deliverbot is a shopping bag carrier that resembles a four-wheel automated cart. With the auto mode, the Deliverbot will deliver products to the certain location automatically. When in Manual mode, the Deliverbot will act as a normal cart and allow staff to move them without difficulties. Deliverbot will mainly be used in large scales shopping centers such as Metrotown or Vancouver airport outlet. Our product will not only make a shopping trip more enjoyable and convenient but also bring increasing profits to the investors.

1.1Scope

This document outlines the requirement specification of all Deliverbot produced by Autotrack. The specifications in this document fully describe the proof-of-concept(POC) and the prototype, as well as future iterations of the product.

1.2Intended Audience

The specification is intended for all of the engineers at Autotrack. The requirements will be used to guide the design and implementation of Deliverbot, to ensure that all of the listed requirements are met. Autotrack will use this document as a reference by all of the engineers involved in the project for research and development. This document will also be referred to during the testing phase to ensure proper functionality.

1.3Classification

Throughout this document, the following convention will be used to specify the requirements of different phases of development:

[Rn-p]

Where “R” is an abbreviation for the requirement, “n” represents the requirement specification number, and "p” denotes the priority of functional requirement, which is classified as following notation:

I High: this requirement will be met for the proof of concept

II Medium: this requirement will be met for the prototype

III Low: this requirement will be met for the final production stage if time permits

2. System Overview

There are two operating modes in Deliverbot:

1. Auto: the cart will deliver items from stores to pick up locations automatically with its dynamic tracking systems. Therefore, the speed of Deliverbot will be at low constant speed, which can provide the best performance between safety and efficiency.
2. Manual: when the Auto mode of the cart is off, the motor speed will be manually controlled by trained staff in the "Manual" mode

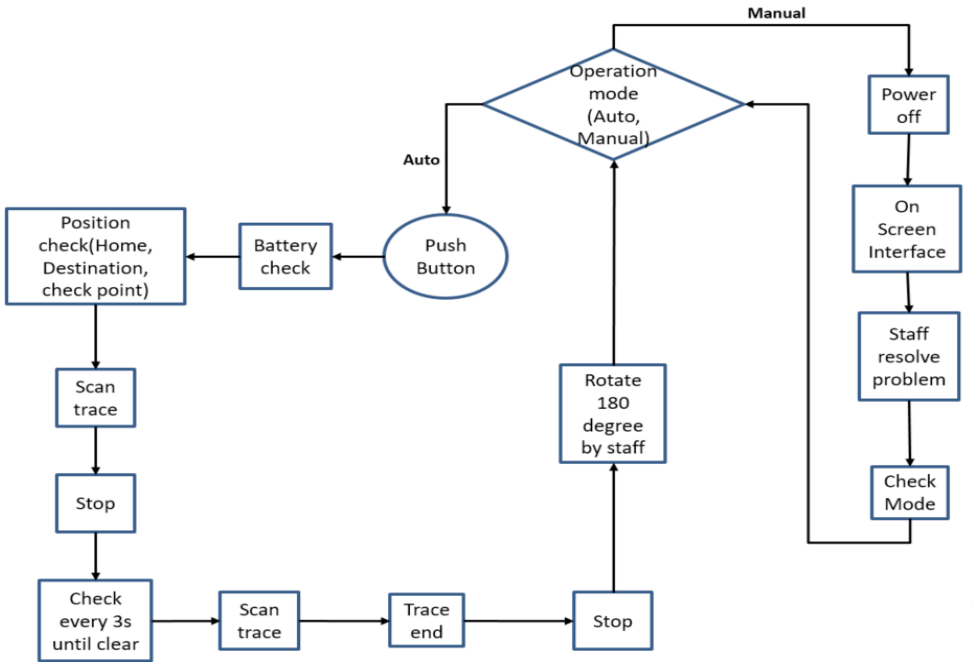

Figure 1: System Flow Diagram

The proposed solution of autopiloting is to use the colored tapes to create a visible path on the ground, which can be detected by the camera. In addition, different color patterns can be used as checkpoints to identify the current location of the cart. When in the corner the route, the cart will stop right here and the camera will look into both left side and right side by 180 degrees to find the desired color to follow. When there is an overlap of the different colors in an intersection, the camera will have 3 ways to find the desired color: simply look both left and right side by 180 degrees to find the desired color, and look forward a small distance to find if the desired color is in front of the intersection. The taps on the ground are supposed to be cleaned in every several hours to keep it clear for the camera to recognize. In addition, the taps will probably use the colors that vary significantly in tone. In this case, the camera won't have any issue to distinguish between different colors.

2.1 General Requirements

[R1-iii] The cost of the system should be less than $450

[R2-iii] Customizations for the Deliverbot can be purchased separately

2.2 Physical Requirments

[R3-iii] The cart shall not exceed 20 kg in weight

[R4-ii] The cart shall not exceed 41x41x105 (cm) in dimension

[R5-ii] Deliverbot shall have a touch screen LCD

[R6-iii] The cart frame shall handle a load capacity of 150 kg without electrical assistance

2.3 Electrical Requirements

[R7-ii] Battery shall be rechargeable and replaceable

[R8-i] A 12 V battery will be sufficient to power all systems on the cart

[R9-ii] Any electrical component including wires shall not interfere with user's operating shopping cart

2.4 Performance Requirements

[R10-iii] Deliverbot shall have one locker to keep the shoppers' products safe

[R11-iii] Deliverbot is designed to operate on all terrains

[R12-iii] Deliverbot shall operate under all weather conditions

[R13-ii] Deliverbot shall be easy to operate for all users

3. Mechanical System

The Mechanical system of Deliverbot is contained of one 12VDC electronics DC motor, which is powered by a 12V rechargeable lead acid battery. The motor will provide around 1-2 horsepower to control the movement, steering system, and braking mechanism of Deliverbot. There are two operating modes in Deliverbot. In the "Auto" mode, the cart will deliver items from stores to pick up locations automatically with its dynamic tracking system. Therefore, the speed of Deliverbot will be around 10 km/hr, which can provide the best performance between safety and efficiency. On the other hand, the motor speed will be manual control by trained staff in the "Manual" mode.

3.1 General Requirements

[R14-ii] Movement of Deliverbot have to be stable with or without any cargo

[R15-ii] Deliverbot shall be able to move on the track automatically

[R16-ii] Deliverbot shall be able to stop automatically if there are hazard or objects inside its range

3.2 Physical Requirments

[R17-ii] The electronic DC motor shall not exceed 100x100x50(mm) in dimension

[R18-ii] The whole mechanical system shall not exceed 15kg in weight

[R19-iii] The DC motor shall be replaceable simply

[R20-iii] The mechanical system shall be assembled easily

[R21-iii] The mechanical system shall not protrude beyond the cart frame

3.3 Electrical Requirements

[R22-ii] The electronic DC motor shall be powered by 12V lead acid battery

[R23-iii] A minimum supply current of 2.5A are required to move the cart and carry all of the bags

3.4 Performance Requirements

[R24-iii]	The smart wheel mechanism should be installed to prevent Deliverbot getting stolen
[R25-ii]	Deliverbot shall operate normally under rain and snow condition
[R26-iii]	The motor shall operate normally at an environmental temperature of -40C to 45C
[R27-ii]	The cart shall be able to brake completely less than 1s
[R28-iii]	Deliverbot shall function normally under vibrations from traveling on different terrains

4. Control System

The control system of Deliverbot incorporates one Raspberry Pi as a microcontroller, a motor to move wheels, eight distance sensors for safety concern and a camera to track the path. The Raspberry Pi receive the inputs from the camera and the distance sensors to evaluate whether the motor should be switch on and the direction of Deliverbot heading to.

4.1 Software Requirements

[R29-i]	The system shall be programmed in C on Raspberry Pi platform
[R30-i]	The program must be able to read input data from sensors and camera
[R31-i]	The program must be able to control the wheel motor
[R32-i]	The program must be able to analyze the real-time view from camera to guide Deliverbot with its direction
[R33-ii]	The program must be able to identify possible hazards from inputs of distance sensors
[R34-ii]	The program should have a start-up sequence that checks the position before moving the motor
[R35-ii]	The program must have a software stop to prevent dangers and injuries

4.2 Microcontroller Requirements

[R36-i] The unit must be able to accept inputs from all sensors and camera

[R37-i] The unit must be able to provide output signals through GPIO to motor

[R38-ii] The unit must be able to accept up to five inputs simultaneously

[R39-i] The unit must be able to perform in real time

4.3 Physical Requirements

[R40-i] The connection ports of microcontroller shall be easily accessible

[R41-ii] All components must not protrude over the device casing and protection

[R42-ii] The microcontroller must be electrostatically insulated

4.4 Electrical Requirements

[R43-i] The microcontroller shall use a 5V power supply

[R44-i] The motor shall use a 5V power supply

[R45-i] The microcontroller must provide 3.3V to power the camera and sensors

4.5 Performance Requirements

[R46-i] The system must follow the color path on the floor through camera

[R47-ii] The system must be able to operate continuously for up to 45 hours

[R48-ii] The tracking system must have a response time of less than 50 ms

[R49-ii] The speed of Deliverbot shall not be over 10km/hr

[R50-ii] The response time for obstacle detection shall be less than 100 ms

[R51-ii] The system shall have an alarm system for hazards and security purposes

[R52-ii] The system shall signal the user when it fails to follow the path

5. Sustainability and Safety

5.1 Sustainability

Our device aims to have zero waste, as to comply with the cradle-to-cradle design principle. Each component used in the design of the product is carefully considered in its recyclability and its environmental impact.

Keeping in mind the principles of the cradle-to-cradle life cycle, we were able to create Table 1 below that displays the materials used in the Deliverbot design.

Table 1: Product Material Consideration

Components	Materials	Method of Disposal
Cart Frame	Nylon	Recyclable/Landfill [1]
Cart Handle, Screws, Wheels	Alloy	Recyclable [2]
Tires and Wire Enclosures	Rubber, ABS, Polystyrene	Recyclable/Landfill [3]
Wires	Copper	Recyclable [4]
Sensors, Raspberry Pi, Resistors	PCBs, Silicon	Recyclable/Landfill [5]
Solder	Tin	Recyclable [6]
Lead-Acid Battery	Lead, Sulphuric Acid, other Metals	Recyclable [7]

As shown, most of the material used to produce the Deliverbot can be recycled, and those that can be safely stored in landfills.

5.2 Safety

Deliverbot is designed to be a safe product, so there will be sensors mounted on the cart to detect obstacles, and the cart response for obstacle detection shall be stopped as soon as possible. Therefore, the speed for the cart to move should be reasonably slow. The device will be fixed firmly onto the shopping cart to rule out any abuse to the electronic components enclosed within. Any faulty component is individually tested/replaced before it is integrated with the rest of the components in order to avoid any further damage. Furthermore, we are committed to making sure each component of our device is used in compliance with the safety guidelines as specified on their safety manuals. The cart should also have one locker that is isolated from the electronic components to ensure the safety of shoppers' products.

6. Conclusion

Currently Deliverbot is under development to prove our concept is possible to achieve. Our goal is to integrate automation into shopping malls so that customers are not required to carry bags of products during shopping and have a greater shopping experience overall. In this function specification document, we have listed our functional requirements for both the concept prototype and marketable prototype including the features we hope to achieve for each prototype. The first prototype including all basic functions will be developed by April 4, 2017, and our level of success will be gauged by the number of functional requirements that we will meet by this date.

7. Reference

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