



February 16, 2015

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC V5A 1S6

Re: ENSC 440W Functional Specification for the Cart-Follow-X1 Capstone Project

Dear Dr. Rawicz,

The enclosed document is the functional specification for our product Cart-Follow-X1 from TechAuto Inc. Our design goal is to provide our customers with the most convenient experience in cargo carrying. By designing an automated control system and integrating it with the mechanical system, our product will provide the option to make the process of carrying cargo effortless and hands free.

The functional specification document provides the high level functionality requirements of the Cart-Follow-X1. Our team will be using this document as the principle guideline throughout development of the product to ensure that the Cart-Follow-X1 achieves the proposed performance and functionality.

TechAuto Inc. was founded by five senior computer and electronics engineering students from Simon Fraser University. The members include Evan Chen, Jeffrey Wang, Samin Semsarilar, Tom Weng, and James Zeng. If there are any questions or concerns, feel free to contact us at jawang@sfu.ca.

Sincerely,

A handwritten signature in black ink, appearing to read "Jeffrey Wang", is written in a cursive style.

Jeffrey Wang
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TECH AUTO

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Submitted to:

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Executive Summary

In everyday activities, people are always required to carry some sort of luggage or cargo. Currently the most common way of handling luggage is through manual labour, like pushing a shopping cart, or carrying a heavy bag. In an era of technology and automation, people will always look for the easiest and most convenient way to do things, and that is no different for carrying cargo.

The proposed project, Cart-Follow-X1, will address the problem of having to manually carry your belongings wherever you go. The Cart-Follow-X1 will have the function to follow its user automatically, giving the user a “hands-free” experience. This is Cart-Follow-X1’s “Follow Mode”, which uses ultrasonic sensor technology to follow its’ user while its movement is being powered by electric motors. These sensors not only act as components to measure distance from the cart to its user, but will also provide collision detection for the cart. The Cart-Follow-X1 will also be equipped with a collision avoidance system which automatically stops the cart if any object falls between the user and the cart.

With the “Follow Mode”, the cart provides convenience, but that is not all the Cart-Follow-X1 can do. At times when “Follow Mode” is not required, the “Assist Mode” comes in to play. The “Assist Mode” is Cart-Follow-X1’s secondary function, where the user will manually steer and control the cart, but with motor assistance. With this function, user’s will no longer need to deal with the physical stress of carrying cargo while still having full manual control over the cart.

This document lists all the functional requirements as well as engineering standards for the overall system design of the Cart-Follow-X1. 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

TechAuto Inc. plans to complete a proof-of concept by early March and a working prototype of the Cart-Follow-X1 by April 2015. Our goal is to bring a whole new experience of cargo transportation, and in doing so, 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
mA	Milliamps
A	Amps
s	Seconds
ms	Milliseconds

1 Introduction

Cart-Follow-X1 is a cargo carrier that resembles a four-wheel platform truck. With the “Follow Mode” and “Assist Mode”, the cart provide users with a convenient way of carrying cargo. The system is designed to be customizable for different uses, from commercial to industrial. The Cart-Follow-X1 is multi-purpose and easy to operate, therefore it is suitable for a wide range of people to use. Our product can not only provide convenience, but also prevent any lifting related injuries, such as low back pains [1, p,23].

1.1 Scope

This document describes the functional requirements of the Cart-Follow-X1. These requirements will be the base of the design process throughout the project.

1.2 Intended Audience

This documentation is intended to be used by all members of TechAuto Inc. Throughout the development of the Cart-Follow-X1, our team members can consult this document to ensure that our product includes pre-specified functions and meets all necessary requirements.

1.3 Classification

The functional requirement specification is shown in the following way:

[Rn-p]

‘R’ is an abbreviation for requirement, ‘n’ represents the functional requirement number and ‘p’ is the priority of the functional requirement. The priorities are ranked as follows:

- i Proof of Concept - requirements for the proof of concept system build
- ii Prototype - requirements for product prototype build
- iii Final Production - requirements for final consumer product

2 System Overview

Cart-Follow-X1 has the two operating modes:

- Assist - User has access to the cart's throttle control to assist with heavy cargo
- Follow - The cart utilizes its ultrasonic sensors to determine user position and follows automatically

The Cart-Follow-X1 obtains these functions using two main systems: The Control System, and The Mechanical System. When the cart is in "Follow Mode", The Control System utilizes ultrasonic sensors to track the user position and detect possible obstacles. Using the received information, it will evaluate the situation and send out the appropriate instructions to The Mechanical System (motor control) and control the movement of the cart. In "Assist Mode", The Control System takes direct input from the user and passes them to The Mechanical System to control the cart's movement however as user desires. This concept can be seen in Figure 1.

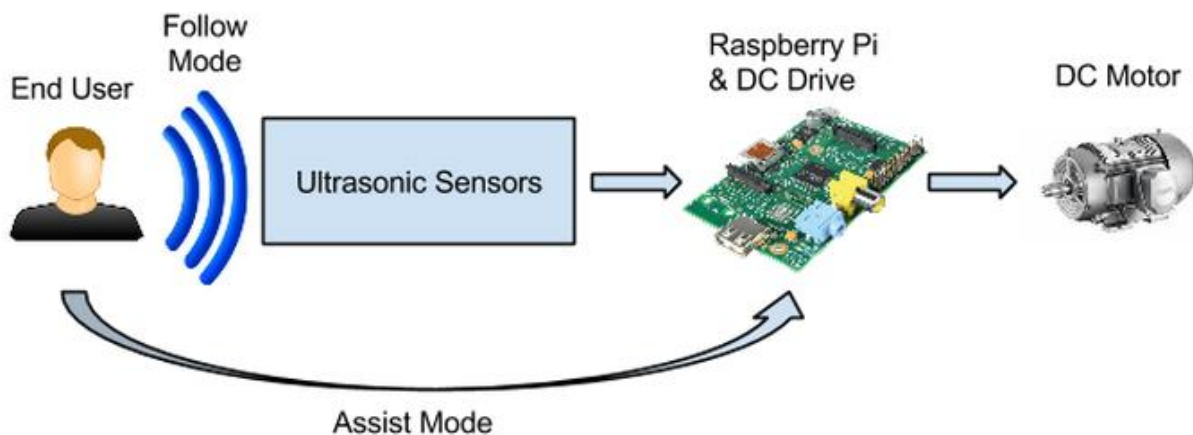


FIGURE 1: High Level Block Diagram

The Cart-Follow-X1 utilizes a variety of electronics. At the heart of our Control System are the two Raspberry Pi development boards. They will be used to process signals from sensors/user input and give instructions to a DC motor drive. The DC motor drive will then use the instructions to vary the speed of the two DC motors in order to control the cart's speed and steering. Figure 2 describes the path of operation in different modes.

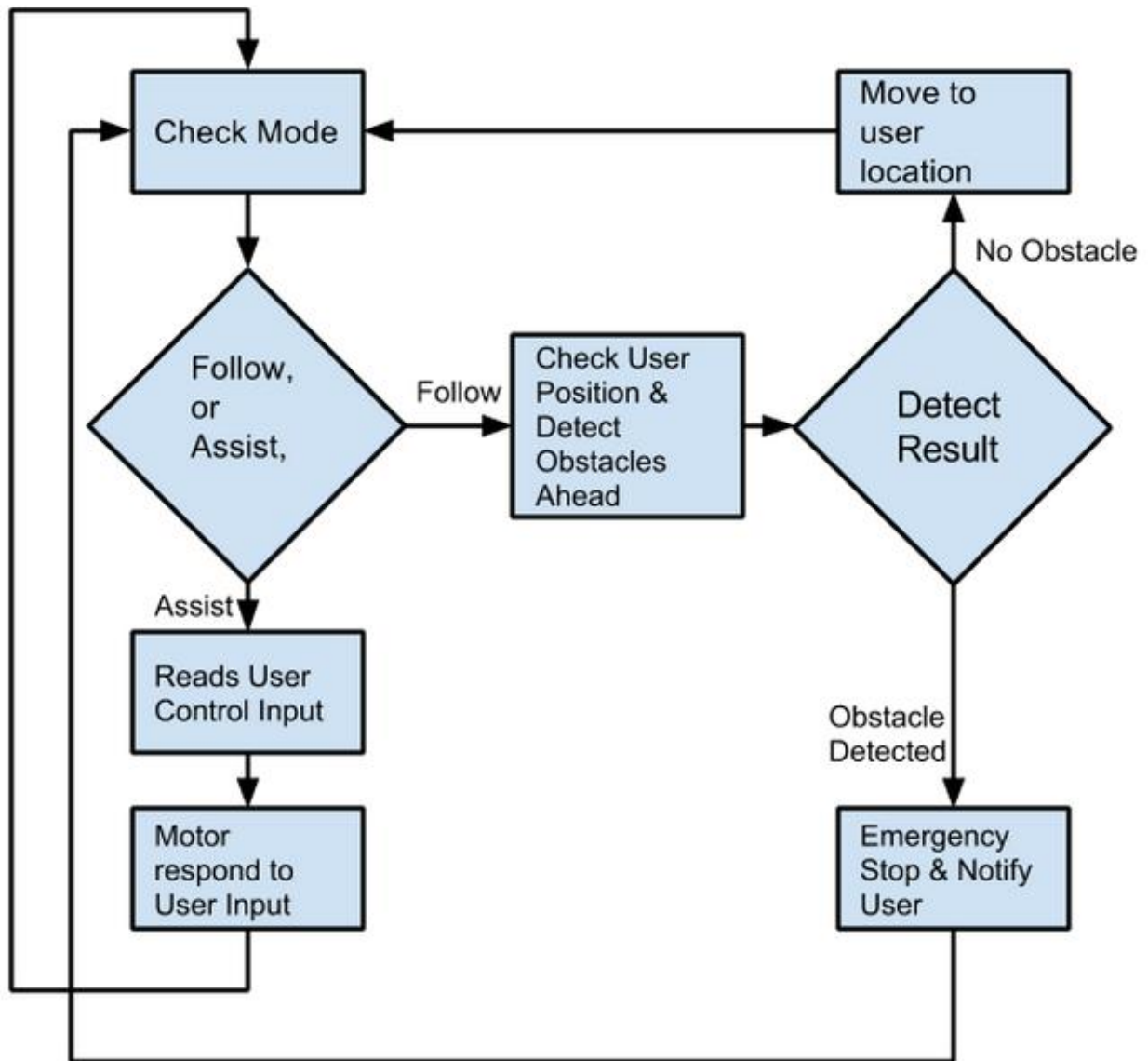


FIGURE 2: Operational Flowchart

2.1 General Requirements

- [R1-iii] Cart-Follow-X1 is designed to operate on all terrains
- [R2-iii] Cart-Follow-X1 shall operate under all weather conditions
- [R3-iii] The final production price of Cart-Follow-X1 shall not exceed \$750.00 CAD
- [R4-iii] Customizations for the Cart-Follow-X1 can be purchased separately
- [R5-ii] Cart-Follow-X1 shall be easy to operate for all users
- [R6-ii] Cart-Follow-X1 shall be rechargeable

2.2 User Interface Requirements

- [R7-i] A power button will be available to turn off all electrical components
- [R8-i] A throttle control will be available to directly control motor speed
- [R9-i] A brake control will be available to stop the cart's movement
- [R10-i] A mode selection will be available to determine the operation mode of the cart
- [R11-i] A LED battery indicator will be available to display battery status of the system

2.3 Physical Requirements

- [R12-iii] The cart shall not exceed 12 kg in weight
- [R13-ii] The cart shall not exceed 41x41x105 (cm) in dimension
- [R14-iii] The cart shall be compatible with different customization add-ons
- [R15-iii] The user remote shall be small and portable
- [R16-iii] The cart frame shall handle a load capacity of 150 kg without electrical assistance

2.4 Electrical Requirements

- [R17-i] The battery is rechargeable
- [R18-i] The battery is replaceable
- [R19-ii] A 12 V battery will be sufficient to power all systems on the cart
- [R20-ii] 500 mA current and 13.65 V should fully recharge the battery in 5 hours [3]

2.5 Reliability & Durability Requirements

- [R21-iii] The cart frame will be chemical, corrosion and rust proof
- [R22-iii] The system shall not expect mechanical or electrical failure during the first 5 years of its lifetime
- [R23-iii] The cart shall be able to operate continuously for 5 hours with a fully charged battery
- [R24-i] Broken components can be easily replaced by trained technicians

2.6 Standards

- [R25-ii] The electronic components shall conform to CAN/CSA-C22.2 NO.60335-1.11 for safety of electrical appliances for household and similar purposes [4]

- [R26-ii] The electronic components shall conform to ISO/TC 22/SC 3 for Electrical and electronic equipment [5]
- [R27-ii] The system shall conform to CSA Z463 standards for maintenance of electrical systems [6]
- [R28-ii] The system shall conform to CSA Z462 standards for workplace electrical safety [7]
- [R29-ii] The motors shall conform to C22.2 NO. 100-14 for Motors and Generators [8]

3 Mechanical System

The Mechanical System of Cart-Follow-X1 is consisted of two 12 V electric motors which will be powered by a 12 V lead-acid battery. These motors will provide the movement, steering and braking mechanism for the cart. In the "Follow Mode", the motor speed will depend on how far away the user is from the cart, and in the "Assist Mode", the motor speed will be manually controlled by the user.

3.1 General Requirements

- [R30-i] Steering of the cart shall be done using speed differential of the two rear wheels
- [R31-ii] Cart-Follow-X1 shall be able to move both forward and reverse directions
- [R32-ii] Movement of the cart shall be stable with or without a load

3.2 Physical Requirements

- [R33-ii] The electric motors shall not exceed 10x5x5 (cm) in dimension
- [R34-iii] The whole mechanical system shall not exceed 10 kg in weight
- [R35-ii] The wheels of Cart-Follow-X1 shall give a ground clearance of 10 cm
- [R36-iii] The motors shall be easily replaceable
- [R37-ii] The mechanical system shall not protrude beyond the cart frame

3.3 Electrical Requirements

- [R38-ii] The electric motors shall operate at 12 V

- [R39-ii] A minimum supply current of 2 A are required to move the cart and carry a cargo load of 150 kg

3.4 Performance Requirements

- [R40-ii] The cart shall be able to brake to a complete stop in less than 1 s
- [R41-ii] The motor shall have enough power to move the cart with a load of 150 kg at a speed of at least 4 km/h
- [R42-ii] The minimum turn radius of the cart shall be less than 1 m

3.5 Environmental Requirements

- [R43-iii] The system shall operate normally under regular vibration caused by various terrains
- [R44-iii] System shall operate under shock and vibrations from travelling on different terrains
- [R45-iii] The motors shall operate normally in an environmental temperature range of (-40, 45 °C)
- [R46-iii] The cart shall be able to operate under rain and snow conditions

4 Control System

The Control System of Cart-Follow-X1 consists of two Raspberry Pi development boards, five ultrasonic sensors and a DC motor drive. One of the development boards will be used on the remote while the other one will be used on the cart. The two boards will first utilize the five ultrasonic sensors to track user position and detect obstacles, and then send instructions to the DC motor drive to control the cart's mechanical system.

4.1 General Requirements

- [R47-i] The system shall be programmed in Python
- [R48-ii] The maximum following angle in follow mode shall be 75 degrees
- [R49-i] The remote requires direct line of sight to operate in "Follow Mode"
- [R50-i] The system shall use ultrasonic sensors for all measurements

4.2 Physical Requirements

- [R51-ii] All components shall not protrude past the device's casing
- [R52-i] The tracking sensors shall be placed at the back of the cart, in line of sight of the user
- [R53-iii] The remote can be easily clipped to the back of the user

4.3 Electrical Requirements

- [R54-ii] The control system shall use the same power source as the mechanical system through a 5V output on the DC motor drive
- [R55-ii] The remote shall use two standard AAA batteries as its power source
- [R56-i] The ultrasonic sensors shall have a range of operation of 2cm - 4m range of sensitivity
- [R57-i] The ultrasonic sensors shall have an accuracy of +/- 5 cm
- [R58-i] The sensors shall not cause interference with external or internal electronics

4.4 Performance Requirements

- [R59-ii] The user tracking system shall have a response time of less than 50 ms
- [R60-i] Cart-Follow-X1 shall be able to track user at a maximum distance of 4 m
- [R61-i] Cart-Follow-X1 shall have a minimum following distance of 0.5 m
- [R62-i] The obstacle detection system shall have a response time of less than 100 ms
- [R63-i] The Cart-Follow-X1 shall halt and notify the user when it fails to receive signals from the remote in "Follow Mode"

5 Sustainability & Safety

5.1 Sustainability

At TechAuto Inc., the “cradle-to-cradle” cycle is one of our main focus when designing our products, and it is no different for the Cart-Follow-X1. Each component used in the design of the product is carefully considered in its recyclability and its environmental impact.

The three main components of the Cart-Follow-X1 are the cart frame, mechanical components and the electronic components. A detailed breakdown of the materials and its method of disposal can be seen in Table 1.

TABLE 1: Material Considerations

Components	Materials	Method of Disposal
Cart Frame	Nylon	Recyclable/Landfill [9]
Cart Handle, Screws, Wheels	Alloy	Recyclable [10]
Tires and Wire Enclosures	Rubber, ABS, Polystyrene	Recyclable/Landfill [11]
Wires	Copper	Recyclable [12]
Sensors, Development Boards, Resistors	PCBs, Silicon	Recyclable/Landfill [13]
Solder	Tin	Recyclable [14]
Lead-Acid Battery	Lead, Sulphuric Acid, other Metals	Recyclable [15]

As shown, most of the material used to produce the Cart-Follow-X1 can be recycled, and those that cannot can be safely stored in landfills.

5.2 Safety

Cart-Follow-X1 is designed to be a safe product, it’s active collision detection system enables the cart to detect obstacles ahead and brake to avoid collisions. All of its electrical and mechanical components are safely contained to avoid causing any damage to the user or the system.

6

Conclusion

Cart-Follow-X1 is currently under development. Our goal is to integrate automation into cargo transportation to improve quality of life. In this function specification document, we have listed the functional requirements of our marketable prototype as well as features that we hope to include in the final product. All of the basic functions will be developed by April, 2015. Our personal level of success will be gauged by the number of functional requirements that are met by this date.

7

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