Automated Cart Checkout

Fall 2019 ECE 445 Project Proposal

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1. Introduction

1.1. Objective

People want to have a seamless shopping experience, but they are often met with various parts of shopping that delay and otherwise frustrate the customer. Most current shopping systems employ manual checkout, either via a cashier or through self-checkout. These systems both lead to long checkout lines when a store is crowded, creating a point of “friction” in the shopping experience.

We propose a solution that would reduce friction in the shopping experience at a significantly lower cost than Amazon Go’s solution. We propose adding a modified portable self-checkout system to a store’s shopping card. The system would include a barcode scanner and weight sensors to handle all items in the store that the consumer might buy. For most products, the customer would pick up a product off of the shelf, scan its barcode with their in-cart system, and add it to their cart. For products that are priced by weight, like tomatoes or other produce, the customer would put it on the weight sensor to get the correct price.

1.2. Background

Historically, the checkout process has been tiring and time consuming for consumers as many wait in line to complete their shopping. The process creates a disconnect between the shopper and their goal of buying items. Many companies are aware of this issue and have tried to address it using new shopping models. Amazon Go is by far the most popular of these, utilizing a sophisticated computer vision system to track customers through the store.

However, the Amazon Go model has downsides. It is prohibitively expensive, costing around $1 million to set up each store [6]. In addition, its computer vision system is extremely complex, taking up years of development time at one of the world’s largest companies and incurring heavy capital sunk costs. One example of an issue Amazon has had was being unable to handle more than 20 people shopping concurrently [3]. Another example is a practical problem of children moving items around shelves or consumers being mis-identified [2]. Thus, the need for a solution to the checkout experience is ongoing.

1.3. High-level requirements list

- Customer must be able to use the device to add all types of products in a store to their cart. For products with a barcode, they must be able to scan the barcode to add it to their cart. Additionally, for products that are priced by weight, they must be able to use the scale to get the correct price.
- System must be responsive, fast, and easy to interact with. Quantitatively, this means scanning a product's barcode should be possible in under 3 seconds and weighing an object should be possible in under 5 seconds.
- All system modules should be as cheap as possible; ideally, the total cost of all system modules should be under $200.

2. Design

2.1. Block Diagram

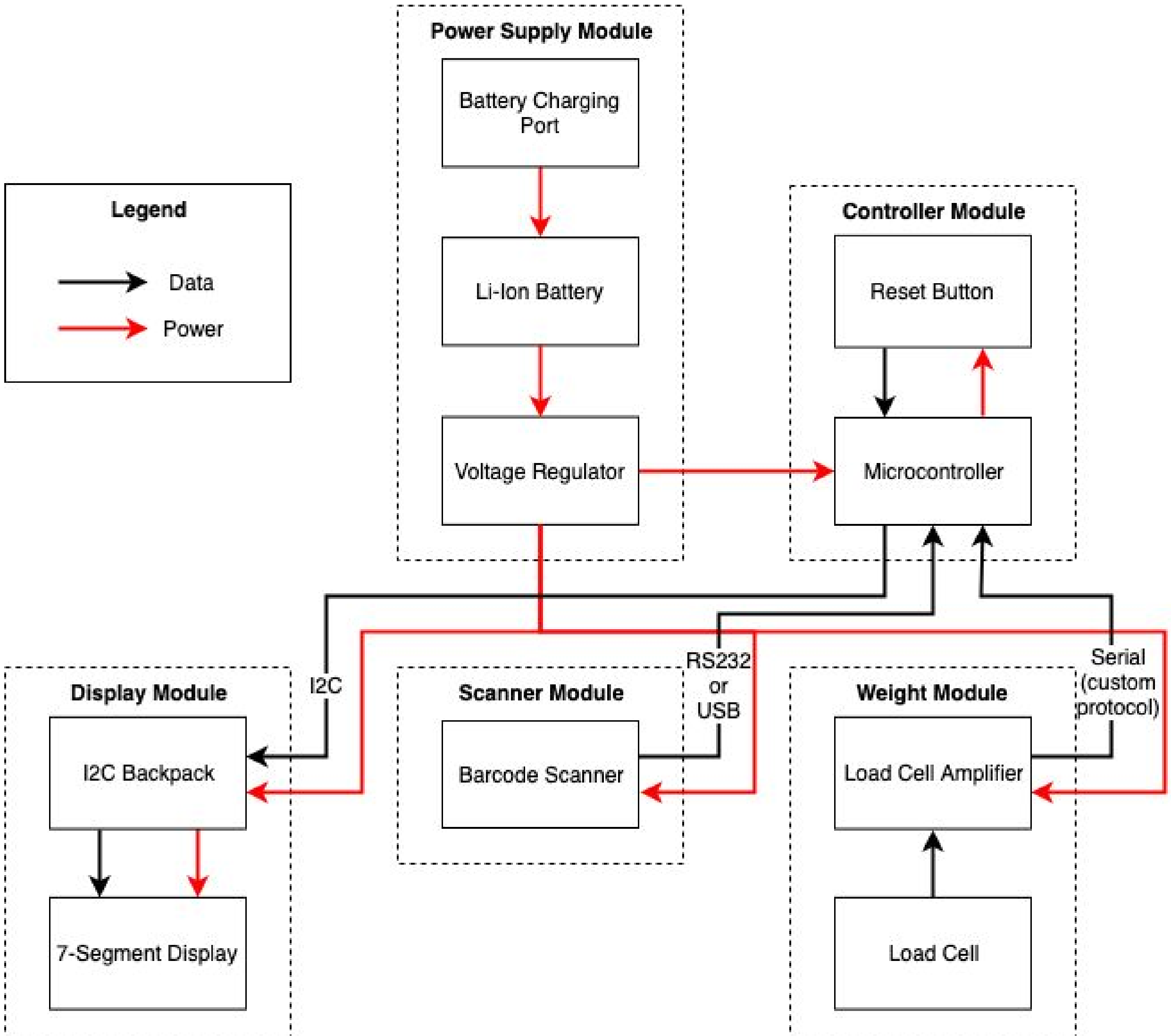

Figure 1: High-Level Block Diagram

2.2. Functional Overview

2.2.1. Scanner Module

The scanner module will scan barcodes placed in front of it and report the scanned value to the controller module. This module will allow us to scan the barcodes of products to identify them.

We will use the YHD-M800 barcode scanner. It will connect to the controller module using either RS232 or USB protocol and send it data about the barcode that was scanned. It will be connected to the 5V power supply.

2.2.2. Weight Module

The weight module will measure the weight of objects placed on it and report the weight to the controller module. This module will allow us to determine the correct cost for objects that are priced by weight.

2.2.2.1. Load Cell

The load cell is able to report the weight of objects that are placed on it. This will allow us to measure the weight of objects.

We will use the SEN-10245 load cell. It has a 50kg weight limit. It connects directly to the load cell amplifier with no additional connections.

2.2.2.2. Load Cell Amplifier

The load cell amplifier interfaces the load cell with the controller module. It allows the weight measured by the load cell to be reported to the controller module.

We will use the HX711 load cell amplifier. It will be connected to the load cell and the controller module to pass data between the two using a custom serial protocol specific to the chip. It will also be connected to the 5V power supply.

2.2.3. Display Module

The price display gauge will display the total price of objects that have been scanned so far. This will allow the customer to see their current total.

2.2.3.1. 7-Segment Display (x2)

The 7-segment display will display the price total for all items scanned so far. This gives the customer a visual indicator of their total.

We will use a generic 7-segment display. It will be connected to the I2C backpack.

2.2.3.2. 7-Segment Display I2C Backpack (x2)

The backpack will interface the controller to the 7-segment display.

We would use the HT16K33. It will be mounted on the back of the 7-segment display. It will be connected to the controller module to receive data about the numeric price total to display. The communication with the controller uses I2C. The chip will be connected to the 5V power supply.

2.2.4. Controller Module

The controller will provide an interface for all other subsystems. This will allow the components of the device to function together properly. It would also keep track of the items that the customer scanned and the total price of all items scanned so far. Initially, prices for objects will be hardcoded into the controller; however, given time, a database can be built to replace the hardcoded values once initial functionality is achieved.

2.2.4.1. Microcontroller

We would use the ATMEGA328P or a similar controller.

2.2.4.2. Checkout Button

When the user is finished shopping, they would press this button to “check out”. Since checkout is outside the scope of this project, this button will simply reset the system to a neutral state instead.

We would use a generic button.

2.2.5. Power Supply Module

The power supply module will provide power for all device components. This will ensure all components get the power they require.

2.2.5.1. Li-ion Battery Charger

The Li-ion battery charger will ensure that the Li-ion battery capacity will be ready to go for the next user of the shopping cart.

2.2.5.2. Li-ion Battery

The Li-ion battery will store power for the system. Using a battery will allow the device to be portable and able to be installed in a shopping cart.

We will use a 5V battery.

2.2.5.3. Voltage Regulator

The voltage regulator will convert the battery voltage to the voltage needed by each module.

The voltage regulator will output 5V.

2.3. Block Requirements

Module		Requirements
Scanner Module		1) Must correctly scan barcodes placed in front of it at least 9 times out of 10. 2) Scanning the object must take less than 3 seconds.
Weight Module	**Load cell**	1) Must correctly report weight of object placed on it within +/-5% accuracy. 2) Reported weight value should fall within acceptable accuracy range in under 5 seconds. 3) Must correctly report weights of objects up to 10 lbs (~4.5 kg).
	Load cell amplifier	1) Must be able to interface the load cell's output with the controller module inputs.
Display Module		1) Must be able to display a numeric value with two decimal digits up to 999.99 2) Must be able to receive output from the controller module.
Controller Module	**Microcontroller**	1) Must be able to connect to and support communications with the scanner module, weight module, and display module concurrently 2) Must be able to perform basic arithmetic, like keeping a running sum for price totalling 3) Must be able to keep data in memory, like a map from barcodes to prices
	Reset Button	1) Must be able to communicate button press status to the microcontroller
Power Supply Module	**Battery Charger**	1) Battery Charger must be able to charge the battery in under 5 hours 2) Battery Charger must be able to either sustain 2 full charges, or be run on a continuous supply
	Battery	1) Must provide enough power to support the power requirements of all components simultaneously, estimated at 2500 mW 2) Fully-charged battery must provide power for at least 2 hours when system is powered on, or 3 hours on standby
	Voltage Regulator	1) Must take in battery voltage and convert if necessary 2) Must output 4.5 to 5.5 volts (0.5 volts tolerance)

2.4. Risk Analysis

The block that poses the greatest risk to successful completion of the project would be the scanner module. If the scanner were to fail, we would be unable to scan a product's item code via barcode or QR code. Thus, the whole system would fail to satisfy the solution and solve the initial problem. Additionally, there is a high risk for this module due to the lack of initial resources (e.g. course staff, online tutorials) when determining technical parameters and factors that would help decide which scanner to use beyond a high-level of understanding. This is in contrast to the microcontroller; it has a similarly important role in the project, but we have a breadth of resources to use when implementing this component.

Regarding the other blocks, the power supply module has risk in terms of safety, but power is not hard to come by, so it bears little risk to the completion of the project. A display module that can display more than 5 digits might be hard to find and/or integrate, but it is not a huge risk given that the other components do not rely on the display module. The weight module comes close to being a great risk in case of failure, as items priced on weight would not be able to be bought or priced. However, other items would still be functional, so the overall project's functionality and demonstration would still be intact.

3. Ethics and Safety

During the development of the project, we shall follow #7 on the IEEE Code of Ethics - we will listen to instructors, classmates, and other individuals who give advice and criticism on the details of our technical implementation. This feedback ensures that the project brings quality to the problem at hand and does not degrade [4]. this transparency ensures that #9 on the IEEE Code of Ethics will be followed and consumer reputation will be protected.

There are a number of ethical issues concerning the completed project. We must correctly report the price to the consumers and not misconstrue the price in light of #3 on the IEEE Code of Ethics [4].

One major ethical concern involves theft associated with self-checkout systems. People could misuse the product to commit theft, either intentionally or absentmindedly. While this is an ethical issue, it has financial implications for any store using this technology. A study by criminologists at the University of Leicester found that self-checkout services led to a loss rate of 4% of the total value of purchases, or a 122% increase over the average loss rate [1, 5]. We note these concerns to anyone seeking to use this product in accordance with the IEEE Code of Ethics, "to be honest and realistic in static claims or estimates based on available data."

This project shares a number of safety concerns with all consumer electronics. We need to take steps to ensure the device doesn't fail in a catastrophic way and consequently injuring customers using it. This concern means we need to be extremely cautious in every step of the design. We need to make sure the battery isn't being overdrawn. We also need to make sure the user can't injure themselves, either through an electrical fault or a sharp edge on the device.

Developing this device also poses safety issues to us as its developers as well. Generally, these safety concerns are mitigated by our years of experience working in ECE labs, but we still have to take precautions. For instance, soldering the PCB can be dangerous if it is not done properly. We would lessen this risk by reviewing proper soldering procedures before performing any soldering. Holistically, we understand that following defined safety procedures is the best way to develop this product effectively.

4. References

[1] Beck, A. and Hopkins, M. (2016). Mobile Scan and Pay Technology could promote supermarket theft, study suggests. [online] University of Leicester. Available at: https://www2.le.ac.uk/offices/press/press-releases/2016/august/mobile-scan-and-pay-technology-could-promote-supermarket-theft-study-suggests [Accessed 17 Sep. 2019].

[2] Day, M. and Morley, K. (2018). Amazon's new store without checkouts doesn't quite Go to plan. [online] Stuff. Available at: https://www.stuff.co.nz/business/world/100796913/amazon-go-store-with-no-checkouts-opens-to-the-public-in-seattle [Accessed 14 Sep. 2019].

[3] Hern, A. (2017). Amazon's checkout-free physical shop 'can't cope with more than 20 people'. [online] The Guardian. Available at: https://www.theguardian.com/technology/2017/mar/29/amazon-go-checkout-free-physical-shop-delayed-camera-sensor-people [Accessed 14 Sep. 2019].

[4] Ieee.org. (2019). IEEE Code of Ethics. [online] Available at: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 14 Sep. 2019].

[5] Mele, C. (2019). Self-Service Checkouts Can Turn Customers Into Shoplifters, Study Says. [online] Nytimes.com. Available at: https://www.nytimes.com/2016/08/11/business/self-service-checkouts-can-turn-customers-into-shoplifters-study-says.html [Accessed 17 Sep. 2019].

[6] Verhage and S. Soper, "Amazon Could Spend $3 Billion on ‘Go’ Stores, Analyst Says", Bloomberg.com, 2018. [Online]. Available: https://www.bloomberg.com/news/articles/2018-09-20/amazon-could-spend-3-billion-on-go-stores-analyst-says. [Accessed: 14-Sep-2019]