Smart Shopping Cart

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***Abstract*— Shopping carts have greatly improved the buying experience of customers across the world. An innovation providing the direct ability for an individual to organize and manage what they buy as they travel throughout a grocery store. These carts function as a modern convenience that makes shopping both easier and more efficient; however, not much attention is placed on what occurs after a customer completes their shopping. The lack of proper management in regard to returning carts is a challenge that has continually plagued the shopping industry. In this report, we detail our work and research in creating an ideal solution to the presented issue; a process we have dedicated our time and efforts on during the academic year. It is through our research that we have developed an autonomous shopping cart that drives itself back to the store once a customer finishes their shopping and exits the store. In addition to this, it also avoids obstacles within its path and can refrain from getting close to cars in the parking lot so as to not disrupt other individuals parking or leaving the store. Our shopping cart is able to move within a path on the floor and stop in the presence of an object facing it head-on. In this study, we have employed modular implementation for ease of configuration and organization and have developed numerous prototypes before ending up with our final cart design. Utilizing four DC motors we constructed a scale model cart to do the aforementioned tasks which allow the cart to move forward, backward, stop, and turn when necessary. The cart also contains IR sensors used to ensure that the cart follows a predesignated path whilst being spatially aware of its surroundings. An ultrasonic sensor is also used to detect any objects that come in the path of the cart to avoid collisions. Through our work, we have developed the hardware and software required to allow the cart to make these decisions autonomously.**

I. INTRODUCTION

This document provides an overview of our Smart Shopping Cart. Our shopping cart's main capability is to autonomously drive itself back to a store without the need for human supervision or interference. The idea of this shopping cart stems from the number of times we have been to the grocery store and have consistently seen shopping carts blocking the only available parking spots. This creates parking lot congestion, negatively impacting customer experience before they even step foot in the store. As shown in Fig 1 below, out of laziness previous customers tend to place carts in inconvenient places leaving future customers to handle the mess which can be excruciatingly more irritating during peak hours. Our cart would benefit much smaller locally owned stores that don't have sufficient manpower to bring carts back into the store. Having our self-driving carts will ensure that new customers will always have a cart readily available all while not having to worry about a cart intruding on their parking space. Since the shopping cart is autonomous, it will also allow the stores to give cart pushers a job that does not have to deal with the extreme conditions outside. Smaller stores will save on having to pay an employee average of $33k a year [1] and instead can use that manpower for another useful task. During our research phase, we came across a very disturbing statistic from Pediatric Emergency Care [2] which states that on average, 24,000 children are sent to the ER every year in shopping cart accidents. Most of these accidents come from the split-second parents letting go of the cart to put groceries away which allows the cart to roll away uncontrollably. Our shopping cart will have the ability to detect a runaway cart and be able to avoid obstacles to safely bring the cart to a halt. This will prevent thousands of children from visiting the ER and create a safer shopping experience for everyone. Additionally another issue arises when carts are removed from the premises of their original store creating clutter within private residences and scattered around in public environments. With these carts left out in the open, absent-minded children may end up entrapped and injured after meddling around with the cart or accidentally stumbling upon them [3]. With the cart's ability to return itself back to the store the possibility of this misadventure occurring is reduced to zero.

Our main goal during this project was to allow our cart to drive itself along a marked path and be able to come to a halt if an object is detected. The path could be decided by the store to either go back to the store or back to the corral. Throughout the year, we encountered many setbacks. When we first began this project we wanted a very basic rear wheel system using just one 3V DC motor attached to two wheels. Once we implemented this system we quickly realized the DC motor was not strong enough to drive the cart forward. This set us back quite a bit since we needed to come up with a new design and order new parts. We also ran into major issues with the wheels not properly fitting onto the axle. This caused testing to keep having problems with the cart not moving in a straight line.We then moved on to using two 5V motors to control the rear wheels and have an Ackerman steering design for the front wheels. However, we quickly realized that the Ackerman steering design would not allow for fast and precise turning capabilities due to its design [4]. We then moved onto a three-wheel design but this also did not allow for a smooth turn. We ultimately decided to use four 5V motors, one on each wheel, and use motor direction in order to turn. The

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setbacks we ran into were great teaching lessons of how engineering is a constant battle of solving problems.

The methodology we followed was to test functionality on our cart with non-permanent solutions. When tested and successful, we would adjust our cart to have the permanent feature.We followed this standard approach of trying a new attachment such as the motors to drive the cart, or the sensors we will use to detect objects, then implementing. Using this methodology of theory, testing, and then implementation allowed us to work through the problems until we eventually met our desired goal.

Fig. 1. Photo was taken by Fabian Colin during a grocery trip

II. Materials

Our main shopping cart chassis is made from plastic materials originating from a miniature toy Target cart. We decided to use a toy shopping cart in order to not waste time or resources on creating a highly demanding design since our main objective is to make the software and hardware necessary for autonomous driving. We equipped the cart with 3-inch plastic omnidirectional wheels to get better traction and lessen the friction with the ground as it travels. The tires will also provide stability and will wear less on the concrete in contrast to plastic wheels which could easily melt in hot weather and deteriorate.

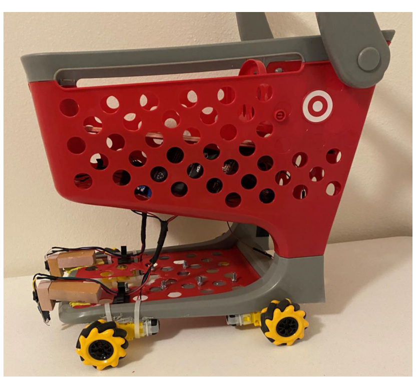

Fig. 2. Our smart shopping cart

III. Hardware

Our hardware design consists of two IR sensors to track a path line on the ground, one HC-SR04 ultrasonic sensor to detect obstacles and the cart's velocity, four 5V DC motor-driven wheels for forward/backward and turning movement, two L298N Motor Drive to control carts speed, and all this will be controlled by a Raspberry pi 3.0 powered by a PiSugar 2 5000 mAh battery.

A. Motors

In order to make our cart move, four 5V DC motor-driven omnidirectional wheels are used. This allows the cart to be driven forward and backward and also the ability to turn. The DC motors are controlled by an L298N motor driver which allows us to have full control of the speed of the cart. The motor drivers are connected to specific GPIO pins on the Raspberry pi to send signals to the motors. We are able to keep the cart at a constant speed when no objects are detected and slow down for a turn and come to a halt if an object is detected. When an object has been detected a signal is sent to all four DC motors to immediately slow down and stop the cart. In order to make a turn, a signal is sent to the motors to change their direction. To turn right, the left motors are kept going forwards however the right motors are flipped to go backward. Turning left has the same concept with the right motors going forward and the right motors going backward. This allows the cart to efficiently turn in the desired direction as designated by its route line to the store..

Fig. 3. Hardware Overview Diagram

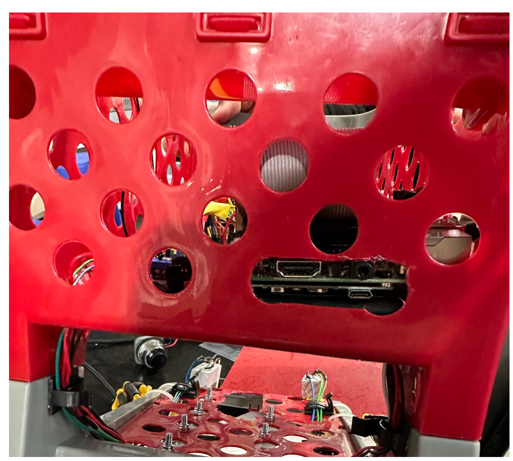

Fig. 4. Raspberry pi mounted on the back of the cart for easy access

B. Sensors

The two infrareds used to follow the cart's path line are 3-pin reflective photoelectric light intensity sensors. For our design, we supply 3V to each of these sensors and attach their control pins to specific GPIO pins on the Raspberry pi. These sensors work by sending a laser signal from one source of the sensor and then the other source waits to see if the signal can be received. Using this concept the sensor will send signals that will be reflected off of light-colored surfaces and absorbed by black-colored surfaces. We can use this to create a white painted line on black concrete to calculate when the cart moves off the white line course and adjust its movements accordingly. The software we created will read the data from the two infrared sensors and determine when the cart is moving off path and how much the cart needs to move in the opposite direction. The same concept is used for a black line on a white surface. The other sensor used in the autonomous cart is an ultrasonic sensor. This sensor is used to detect unwanted collisions by calculating when the cart is in an unstable position slowing it down or bringing it to a stop. We can determine the distance between the cart and the object it could collide with by measuring the time the signal takes to travel to the object and back and can then calculate the distance. The ultrasonic sensor is taking data for a period of 1 second. Using these two sensor types our cart is able to move and stop according to obstacles that are in the way of the cart's destination back to the cart corrals and store.

IV. Software

At its core, the software we defined in our research is an object-oriented system implemented using a controller to handle all decision-making of the cart. Other modules serve as interfaces for the Raspberry Pi hardware and their methods contain small utility functions used by the controller class to conduct movement. The structure of these modules is as shown below.

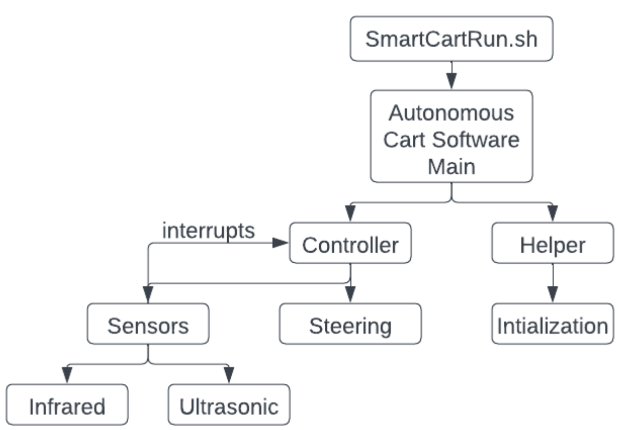

Fig. 5. Software UML Diagram

These modules hide calculations such as determining which direction to turn, finding the distance from cart to the obstacle, cart velocity, and PWM generation to drive the motors. Some of these methods were written from scratch and others, namely the distance and velocity functions, were inspired by Raspberry Pi Sensors by Rushi Gajjar [5]. These simplified operations can then be called upon from the controller class, effectively abstracting away any of the more complex aspects of achieving movement with hardware. This enables the passive pathing state of the controller to be implemented simply. It repeatedly polls the IR sensors, when the right one is obstructed, the controller knows it must turn right and does so by running the left motors forward and the right motors in reverse. This same process works in reverse for turning left. Additionally, after each time the IR sensors are polled, the Ultrasonic sensor is as well and the cart adjusts its velocity, slowing down as an obstacle approaches and eventually stopping if the obstacle is directly in front, resuming once more when the object leaves.

V. Methods

The main technique we employed during the development of the shopping cart was modular implementation. We gradually introduced sensors and motors to the design and tested them thoroughly. We separated each task into groups such as steering, detection, and speed. Through this we were able to tackle each task and set checkpoints to determine where our group needed to focus on next. When adding modules to our task ist we tested them independently to ensure they each worked before adding them to our full navigation system. Rigorous testing found flaws in our original three-wheel layouts and allowed us to redesign quickly. Upon collection of our findings on speed and detection we revisited our steering issues and found our solution in the installation of four omnidirectional wheels allowing for the cart to properly move in all directions the predetermined path may decide. We found this method of separating tasks into building blocks most efficient in both highlighting the issues of our design and leading us to the steps necessary to resolve them.

VI. Results and Performance

Our shopping cart has the capability to navigate itself autonomously following a drawn line on the floor. The cart is also able to successfully detect objects that come into the path and stop before a collision occurs. The cart is able to work on both black lines and white lines given the surrounding area contrasts in color. The cart is able to follow any path drawn on the floor regardless of it being straight or not and will stop once the line intercepts both IR sensors or is met with an object.

VII. Conclusion

Through our research we have been able to effectively develop a solution to parking lot congestion resulting from the laziness of departing customers failing to return carts. This solution will help prevent future accidents from occurring as well in regards to the safety of children since runaway carts will no longer be an issue as it will simply return itself back to the store rather than remain idle. By utilizing motors and sensors our cart is able to successfully navigate across a drawn line to a designated location representative of the cart parking commonly used in grocery stores. Utilizing the hardware components we have designed and physically attached to the cart, we have allowed the cart to steer itself and drive at a constant speed avoiding obstacles that may come within close contact by slowing down eventually coming to a stop if the obstacle remains. In our software module, we have provided the cart with the ability to be autonomous as it runs independently without an external controller guiding it.

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Fabian Colin, photograph not available at the time of publication.

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