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Granny Needs This: An Intelligent Shopping Cart

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ABSTRACT

Living in the bustling urban jungle of New York City can be both exciting and challenging. While having a grocery store on almost every corner is a convenience for many, it can pose a major obstacle for the elderly and disabled. The tedious task of navigating crowded sidewalks, uneven terrain, and stairs with heavy grocery bags can be daunting. Fortunately, our revolutionary product offers a practical solution to this problem. Introducing our innovative grocery-carrying robot! This device is designed to effortlessly transport your groceries for you, with adjustable features to cater to your unique needs. Equipped with four sturdy wheels, two hub-motors, and a GPS navigation system, the robot can autonomously follow you, no matter where you go. It is also equipped with safety features to prevent any mishaps, and a secure compartment to keep your groceries safe, carrying up to 50 pounds of groceries, including temperature-sensitive items, making shopping a breeze for everyone, especially the elderly.

INTRODUCTION

At the moment, the world population has reached approximately 7.9 billion, far beyond the seven billion mark set 10 years ago on October 31, 2011 [1]. While the world population is projected to hit 9.7 billion in 2050, according to the World Health Organization, “the world’s population of people aged 60 years and older will double (2.1 billion). The number of persons aged 80 years or older is expected to triple between 2020 and 2050 to reach 426 million” [2]. Moving the focus to the United States, in 2021, the population of those aged 65 and above made up 16.9% of the entire population, according to the KFF (Kaiser Family Foundation) estimates based on the 2008-2021 American Community Survey, 1-Year Estimates[3]. These numbers mark the gradual transition of our society moving toward a society of increasing aging population, where health problems and the proclivity toward a elderly friendly environment became an essential and indispensable part of social development. The problem that society sees is where people get groceries in urban areas or carry very heavy items from point A to point B. The solution that can solve this problem is creating an autonomous motorized cart that helps people carry their heavy items.

While the motorized shopping cart had a long history, it was used occasionally by the groups in need at grocery stores, where the cart’s considerable size hinders its mobility and makes it difficult to maneuver especially in the crowded city. Moreover, the carts lack the convenience in transporting merchandise from the grocery stores to the users' houses through public transportation or even in walking distance. There is a lack of consistent assistance for those who are in need. After thorough consultation with our targeted users from a survey of 50 elderly people in their 60s and early 80s, the data showed that they had an inconvenience in using the traditional shopping cart and difficulty in carrying groceries up the stairs when taking the subways.

Unlike the existing products in the market, such as motorized handicapped shopping carts [4] — the Smart Chair XT and Smart Shopper from RW Rogers Company—our cart will follow the user around autonomously carrying up to 50 pounds of merchandise with its 2000 cubic inches capacity and traveling a maximum distance of three miles at a maximum speed of three miles per hour.

The product is built upon a shopping cart that has an opening and closing mechanism that is like a closet door handle where we modify it and fit it with insulation compartments, and motor to free the users from the laborious task of carrying.

Figure 1: Smart Chair from RW Roger Company [4]

This data was derived from the fact that there are 10,534 grocery stores spanning across the 300 square miles of New York City in 2023[5], which means an average of 35 grocery stores within every square mile.

Different approaches are considered at the early stage of development, one of which is the use of RGBD cameras. The camera will be installed on the cart to gather information of the surrounding environment and map the environment. The data will then be transferred to the microcomputer to process. As a fail-safe mechanism, ultrasonic sensors, bluetooth, and GPS modules will also be installed on the cart in case the camera malfunctions. The cart turns out to apply the latter method.

The product shows exceptional mobility in its innovative wheel design, where the cart can climb up stairs with a bit of assistance from the user when elevators are not available. As the security of merchandise remains a potential problem we have fitted the cart with a magnetic lock.

Components are categorized into three major parts: frame, locomotion, sensors, and storage.

For locomotion, the key components are the motor and battery. The battery was based off of the motor. The hub motor chosen was running at 1000 watts and 48V. It also needed to deliver at least 13 pound feet of torque. We chose to go with a 48V battery that runs at 10 ah to power our hub motors.

For storage, the major component is the insulation layer. The insulating materials should have a low thermal conductivity to maintain the grocery's initial temperature.As a result, the most economical material would be styrofoam. Styrofoam has a thermal conductivity of 0.033 W per m*K, which is comparable to standard industry grade refrigerator walls, which are made out of polyurethane, which has a thermal conductivity of 0.02 W per m*K.

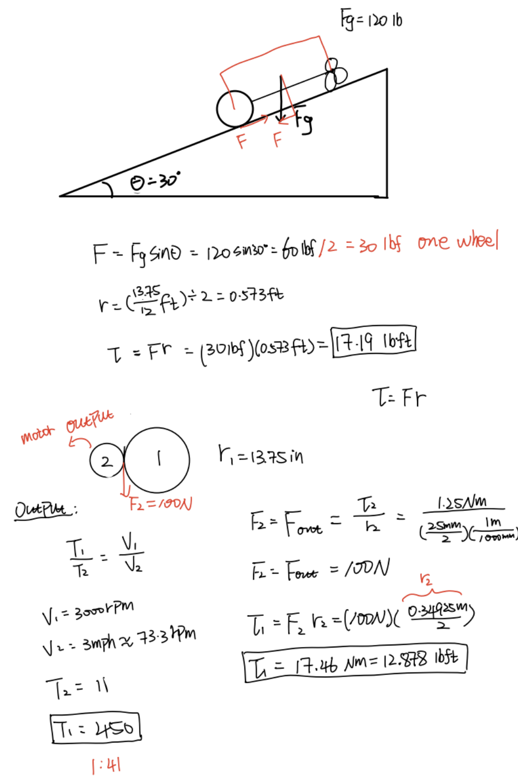

Figure 2: Calculations for Torque

DESIGN AND METHODS

The cart must have ample, insulated, easy-to-open storage space in order to carry groceries for a user. The design must have wheels that can assist with movement over stairs, steps, or small ledges (like those of a sidewalk). The design must also have room for a magnetic locking mechanism and a navigation system. The overall design of our vehicle is shown in Figure 3.

There are two different sets of wheels: back wheels and front tri-wheels. two compartments for storage, one of which will contain the equipment used for the locking and navigation systems. The doors on the storage compartments use common hinges to open and close for easy inside access by the user. The vehicle has roughly 2000 cubic inches of storage space. The storage space is rectangular, which makes it easier to fit insulation within and makes it easier to organize its contents. Both sets of wheels are able to turn, allowing for more drastic movements to be made by the vehicle in case obstacles come in the vehicle's path. The bottom of the storage box has cutouts to provide space to the motor, battery, and servo of the driving mechanism. However, since the original design had two 350W brushed motors that deliver less torque than minimum required as the cart gross weight grew substantially, we had to seek for new solutions. One potential solution was to fit both motors with a gearbox and magnify the output torque. Nevertheless, we faced difficulty in finding a gearbox that delivered the exact amount of torque as needed, and it was not cost-effective to build a gearbox on our own. Thus, we went with the second solution: replacing the brushed motors with 1000W electric bike hub motors. Though the heavier and more expensive hub motors added substantial weight and cost to the cart, they were superior to brushed motors in their larger torque and higher efficiency. Ultimately, due to their incompatibility with Arduino control, we had to control the hub motors manually with thumb throttles, and the auto-tracking functions was eventually divided into two subcategories: following the user automatically and maneuvering manually. These cutouts are shown in Figure 4:

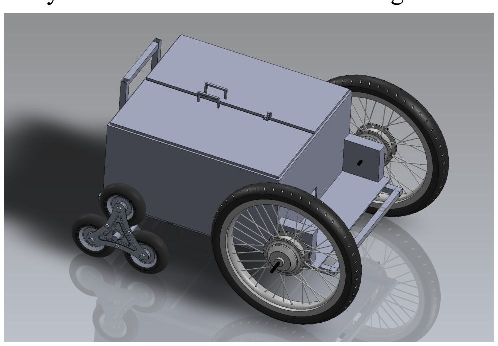

Figure 3: Isometric View of Vehicle

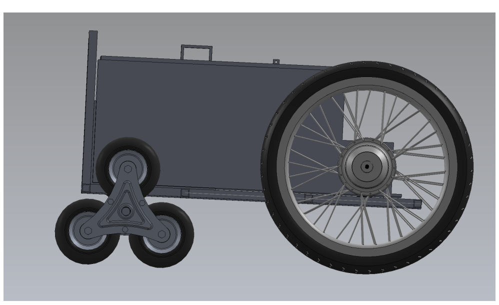

Figure 4: Side View of Vehicle

STORAGE

The storage component will have dimensions of 24 inches, 21.5 inches, and 12 inches of length, width, height respectively. This gives 9600 cubic inches of space for hardware components and users objects to carry in the product. Part of the components will store the locomotors, sensors, and battery on the bottom of the storage unit.

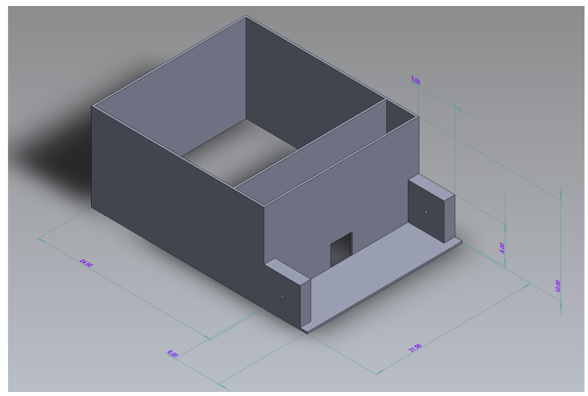

Figure 5: Storage Box

Issues that occurred in creating a storage unit were the features like a cooling system to deal with groceries such as meat, vegetables, soups, and etc. Another issue would be the door that closes the storage compartment seeing if it would be best to have the door closed with a passcode, or have a manual door for easy access. Solutions to fixing these two issues were to use styrofoam on the inner section of the storage compartment for its simplicity as well as the pricing that fits the budget of this project overall. As for the second issue, a door handle was the best solution for its simplicity of the user to open and close for easy access. This is the most ideal solution and design that would be best for the product due to the budget and the simplicity of the product.

Wheels

The main problem when deciding a design for the wheels is how the cart will climb up stairs. Three different solutions are considered when implementing wheels to the cart. The first design is lever assisted mechanism as shown in figure 4. A lever attached to the shaft of the wheels rotate with the wheels. As the lever hits the stair, the cart is easily pulled up with the help of the wheels.

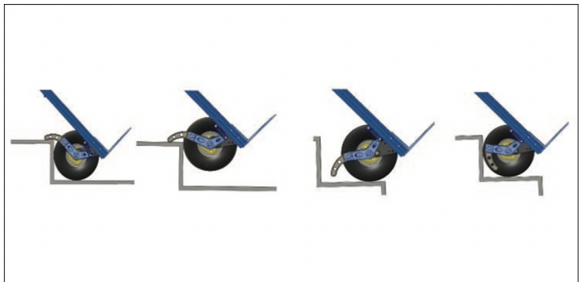

Figure 6: Example of a Lever-Assisted Wheel Mechanism [6]

The second solution being considered is an expanding wheel mechanism. Wheels consisting of three or four spokes expand upon hitting stairs as shown in figure 5. The expansion is achieved with the help of motors and gears. The higher apparent surface area is able to reach stairs of varying heights. The sharp points of the spokes behave as levers like the previous example and pull the cart up the stairs. After reaching a flat surface, the wheels contract to become smooth and round.

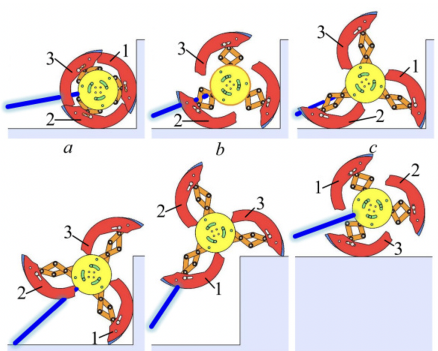

Figure 7: Example of an Expanding Wheel Mechanism [7]

The third solution is a simple, tri-wheel mechanism as shown in figure 6. In addition to each individual wheel rotating, the center bore connecting the three wheels on each side also rotates about its center. The center bore stays the same orientation when the cart maneuvers on a flat surface. When the wheels come into contact with stairs, the center bore rotates which consequently pushes the cart up the stairs.

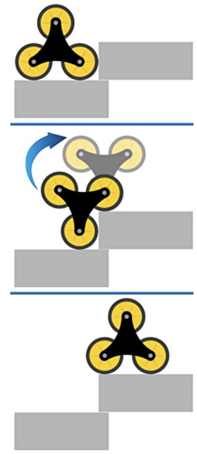

Figure 8: Example of a Tri-Wheel Mechanism [8]

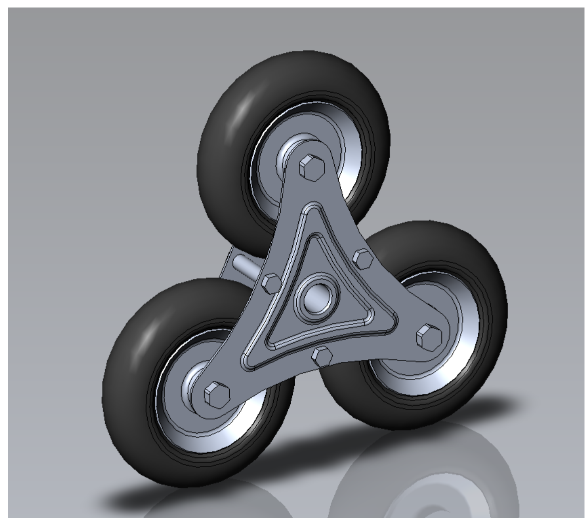

Figure 9: Tri-wheel

The tri-wheel design is currently given priority as it is the simplest mechanism to implement which also requires the least amount of resources. As for the large rear wheels that will be implemented on the prototype, it will allow the product to climb the stairs with more clearance to the ground.

The rear wheels that best fit out design are 16” in diameter and 2.5” in width. This is because the diameter of the rear wheels need to be more than or equal to twice the height of a stair step. For easy implementation, we choose e-bike hub motors. The hub motors need to provide 18 Nm of torque to go up stairs at a 35 degree incline with sufficient loading.

Figure 10: Hub Motor

Tracking

The team has researched various tracking methods from RGBD camera to bluetooth/GPS connection. A secured connection is established for the latter method.

The RGBD camera combines RGB color information with per-pixel depth information. The goal is to have the user in view at all times and maintain the distance of three feet. It maintains all the features of a camera which would be used for object identification, in this case tracking the user. In addition, the extra dimension of distance is mainly used for obstacle avoidance in the case of emergency. This method is the easiest in terms of mounting and wiring. However, there are still risks including difficult coding missions. As an all-in-one device, the team also risks losing all sight and tracking capability if failure occurs on the one single component the robot relies on. Also, the price for RGBD cameras are usually significantly higher than normal cameras which would cause a burden to the budget.

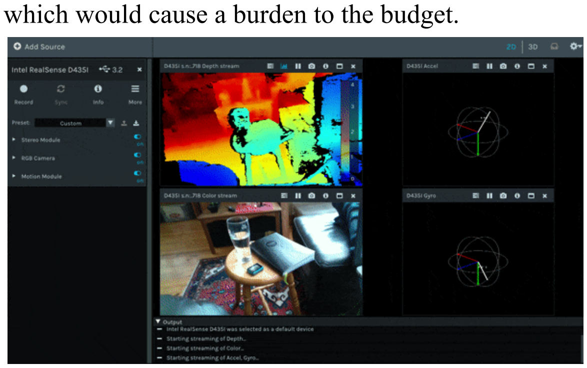

Figure 11: Example of Information Provided by an RGBD Camera

To overcome the risks mentioned above, the second tracking method is proposed that consists of a combination of one camera and one ultrasonic sensor. By splitting the task, the 2D camera would be responsible for human tracking and the ultrasonic sensor would be monitoring the distance. The camera would be mounted to a rotational joint that would revolve around to keep the object frame within sight. The risk is now splitted into two parts and the coding pressure will be released. However, the device would suffer from the limitation of the operating angle of the ultrasonic sensor and sometimes the identification would interrupt due to objects in between the user and camera. This method is thus disregarded as well.

Figure 12: Semantic Segmentation in pursuit of User Identification.

At this point of the project, the top priority would be to develop the tracking feature of the robot. The team selects bluetooth connection to track through GPS coordinates between the cart and the user's smart device. The method is tested on the robot car with Arduino as microcontroller. The modules used are NEO 6M GPS module, HC-05 bluetooth module, GY-511 compass, and L298N motor controller. The components are connected through a breadboard to Arduino, which is powered by the controller from the battery. The code is shown in the Github page. [9]

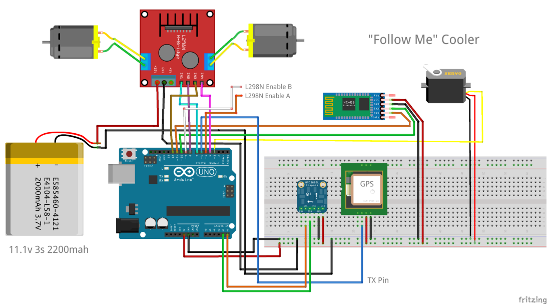

Figure 13: Electrical Schematic of the Robot Car

An app is developed for the users using the Blynk platform to command the robotcar. To minimize complexity, users are expected to operate only two buttons: a power button and an emergency stop button, after a secure bluetooth connection is established.

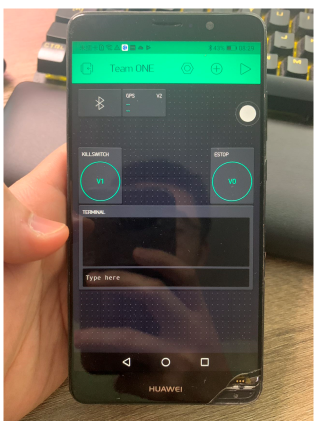

Figure 14: User Interface

TESTING AND EVALUATION

Tests have been made for certain mechanical components. The tri-wheel was successfully tested and the full storage cart was able to aid climbing up the stairs. The cart was able to remain stable on the stairs without any human interference, adding another layer of safety.

The hub motors were tested with the mechanical throttles and worked well before being mounted to the cart. Due to a design failure of the mount, the friction between the wheels and the ground was larger than that between the mount and the hub motors, leading to a result of the shaft rotating but the cart failed to move forward. An improvement could be made on the mount design.

As for the security system, there were tests to see if the container is able to close shut and open with a mechanical lock, “MasterLock”. The tests for the security system were to open the doors of the lock around 100 times to see the smoothness of the user. Another test that was focused on was the cooling system with a “Haagen dazs” ice cream bar. The data that was collected for the cooling system was that it melted after 52 minutes since the time the ice cream bar was taken out the freezer and placed in the cart.

The bluetooth connection was successfully tested as the board collects GPS coordinates from both the user’s device and the robot car. The killswitch button was also successfully tested as when the user clicks the button all motions were stopped.

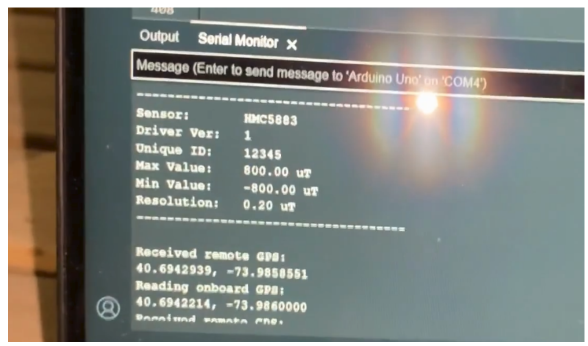

Figure 15: GPS Test Successful

SUSTAINABILITY

Granny Needs This is mainly composed of wood, aluminum, and steel. These are all highly sustainable materials. The cart is powered using rechargeable lithium ion batteries. While there are some disadvantages to this, the environmental benefits far outweigh them when compared to other alternatives. The only environmentally harmful material is the styrofoam used for insulation. However, there is no need for concern as the amount is insignificant. Furthermore, we plan to add a better insulation system in future versions of the product. There are also plans to have a mapping and path storage system that have the ability to be uploaded to the cloud in order to better facilitate the journey of the users. A record system of the paths taken will greatly assist in the objective of the product as it can use these recorded paths to more efficiently travel to and from its destination. The recharging system can also be changed to fit into public charging ports in hopes that the journey can be prolonged.

CONCLUSION

Overall, the shopping cart was a success through many tests that were run from cooling insulation, to following the user around. With implementing many parts to build this component focusing on many systems like mechanical systems, tracking systems, hardware systems, and etc. The cart was meant to be very sustainable for the user as long as possible and as reusable as possible, recharging the battery for every use. Future work for the cart is able to be constantly improved and able to launch to the public for the near future so many more shopping carts like this could be produced on a massive scale.

Figure 16: Full Cart

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