Boston University
Electrical & Computer Engineering
EC463 Capstone Senior Design Project

Problem Definition and Requirements Review

SmoothOperator

Submitted to

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1 Project Summary

Since the supply of workers in the hospitality industry such as airports and hotels has significantly declined post-covid, people with mobility impairments face more challenges in moving heavy objects such as their luggage to their desired destinations. To improve their quality of life, SmoothOperator provides a general and elegant solution: a robotized dolly. We will develop a network of sensors, actuators, algorithms, and communication protocols for SmoothOperator to semi-autonomously transport luggage through various consumer environments through pre-determined locations or by user commands. In addition to the robotic platform, SmoothOperator system will have a user-friendly UI that allows users to connect and control a specific robot. These controls will have a safety layer that avoids obstacles and puts human interaction at the forefront of its navigation planning. SmoothOperator aims to revolutionize the hospitality industry, enhancing the quality of life for all, particularly individuals with mobility impairments.

2 Need for this Project

In fast-paced environments like airports and hotels, labor shortages are leading to a significant reduction in available service workers. In response, 90% of airports and 36% of hotels have shifted to self-service solutions, according to a recent study by Deloitte [1]. However, these self-service options do not fully address the needs of individuals with mobility impairments, who find it particularly challenging to move heavy luggage or other objects without assistance. As the number of available workers declines, the demand for solutions that cater to these individuals increases.

In airports, wheelchair service is done by human service workers. The process to get from the entrance of the airport to your gate is as follows: we request for wheelchair service, then wait until the next available worker comes to pick you up in a wheelchair [2]. These workers then carry your luggage and push your wheelchair to your gate. This process typically has long wait times. The decline of these workers have further exacerbated the problem, causing anxiety and discomfort among passengers with mobility impairments. There have been minimal efforts to directly resolve these challenges.

Currently, solutions like luggage carts, dollies, or robotized luggage often require substantial physical strength when fully loaded or are designed for very specific use cases. For example, carry-on robotic luggage can follow users, but it is limited to small, personal items. Other options, such as the gitaplus cargo-carrying dolly, can assist users by carrying up to 40 lbs, but its capacity and functionality are restricted to everyday objects within a small container. These solutions are either limited in carrying capacity or are overly specialized, providing little versatility in meeting broader needs. Additionally, they often require ownership by the user, which limits their availability in shared environments.

3 Problem Statement and Deliverables

3.1 Problem Statement

In fast-paced environments requiring hospitality such as airports and hotels, there is a decline in service workers in the U.S.. For those with mobility impairments, moving luggage and heavy objects can be a daunting task. As the number of service workers decreases, we aim to provide a new solution to enhance the quality of life by facilitating easy and safe movement of objects. We seek to create a common platform that can be adaptable to these environments with the ability to help people with mobility impairments or to replace repetitive object delivery services.

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Our solution, SmoothOperator, addresses these gaps by offering a semi-autonomous dolly system that not only transports but also lifts larger objects once positioned. Unlike current solutions, SmoothOperator is designed for use in shared environments like airports and hotels, making it available to all users. It can handle a variety of objects and is adaptable to different tasks, from moving luggage to transporting heavy or awkward items without requiring user effort. This system aims to improve mobility and independence for individuals with physical challenges while also providing a cost-effective solution for businesses experiencing labor shortages.

3.2 Deliverables

SmoothOperator System: A semi-autonomous dolly capable of navigating, lifting, and transporting objects with modular compatibility for various scenarios.

Hardware: Includes sensors (LiDAR), networking (Bluetooth, WiFi), embedded systems (I2C devices), mechanical components (scissor lift), and actuators (stepper and DC motors) for precise positioning and transport.

Software: A user-friendly app for teleoperation, goal setting, and fleet management. Intelligent navigation will use pose estimation techniques, sensors (LiDAR, IMU), and SLAM for safe movement.

4 Visualization

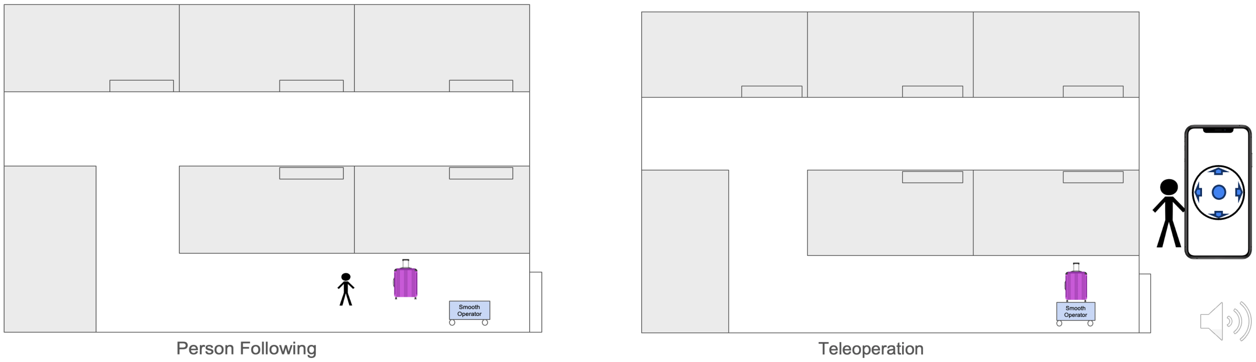

Figure 1: *Examples of proposed operations of luggage use case of SmoothOperator.*

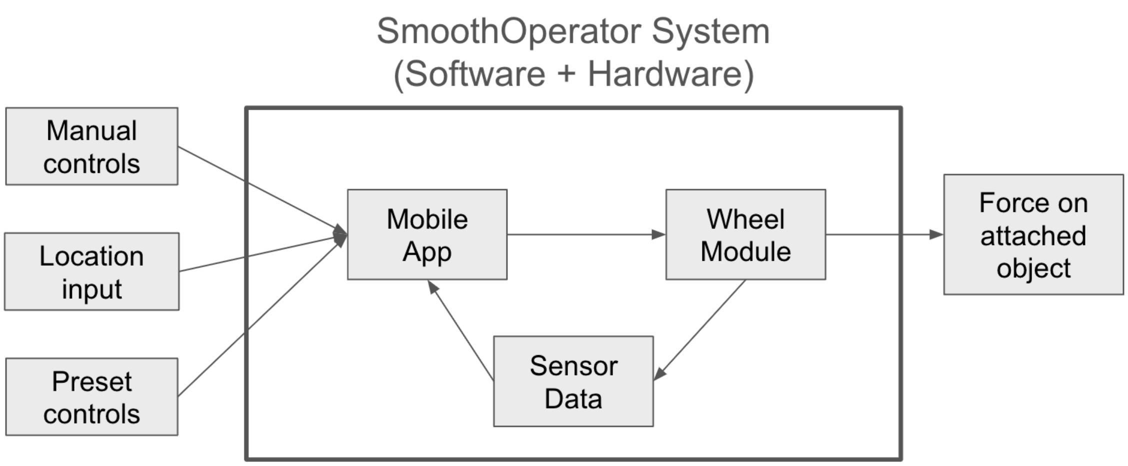

Figure 2: *Proposed high-level system block diagram.*

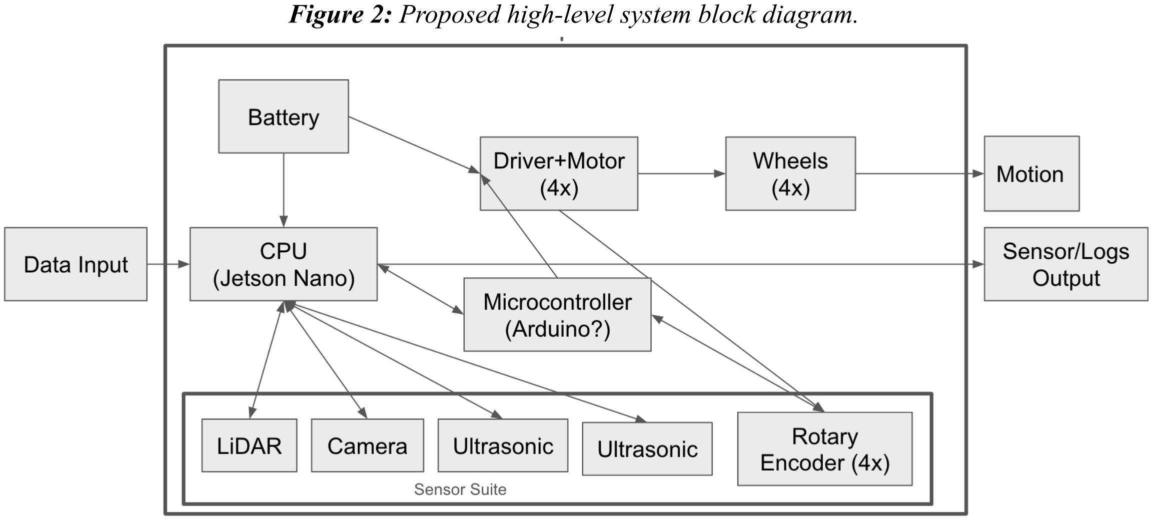

Figure 3: *Proposed robot hardware block diagram.*

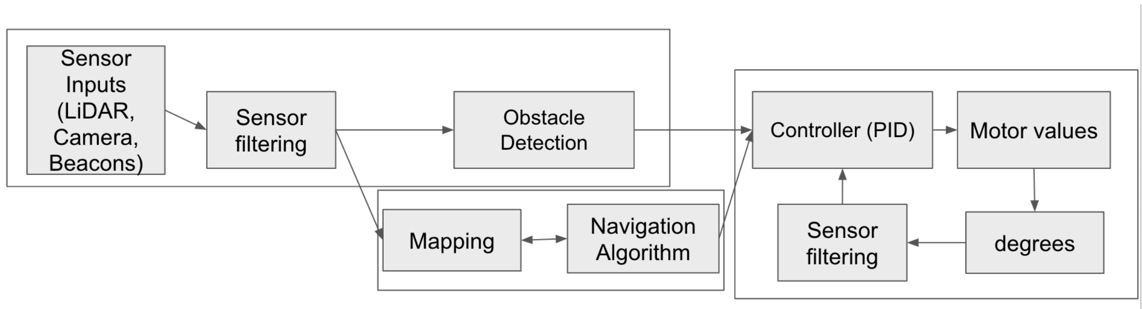

Figure 4: *Initialize (Offline) map from sensor suite.*

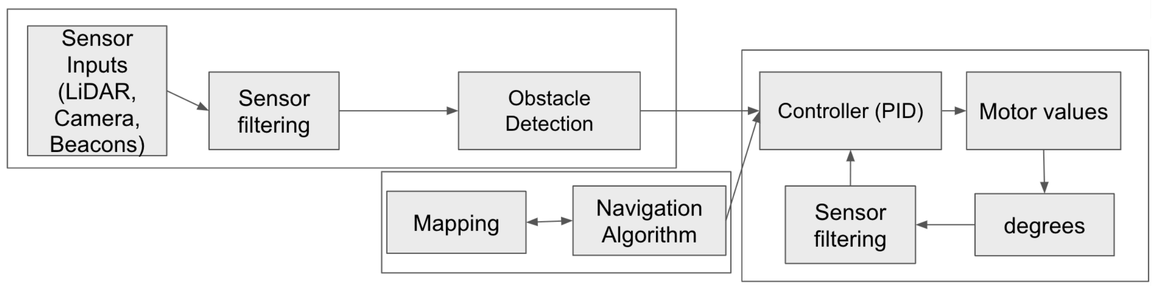

Figure 5: *Deployment (Online) of system with defined map of environment.*

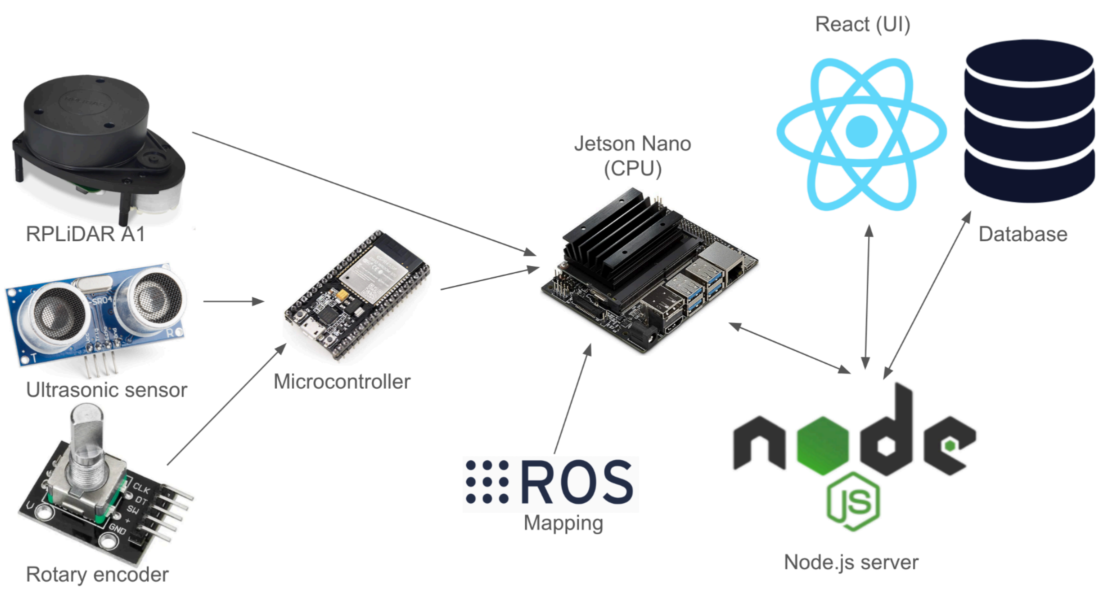

Figure 6: *Proposed data communication network diagram.*

5 Competing Technologies

There are a handful of companies that have developed or are developing robotics platforms for the purpose of transporting objects efficiently and safely between locations. Some of the most significant ones are Piaggio Fast Forward's gita Robot, and Amazon's Kiva, roboticized luggages.

5.1 gita Robots

Piaggio Fast Forward developed a cargo-carrying follower robot known as gita with two commercially available models: the gita*plus* and the gita*mini*. These robots were developed as a personal, hands-free means of transporting everyday items in a variety of settings. The gita*plus* has a load capacity of 40 pounds and an interior capacity of 4000 cubic inches, while the gita*mini* has a load capacity of 20 pounds and an interior capacity of 1000 cubic inches [5]. The gita has a self-balancing two-wheel design, and its motors are able to shift the wheels forward and backward to remain level while moving across a number of terrains [4]. Both models utilize an array of cameras and sensors to identify the user and follow them while navigating various environments. These robots possess a top speed of 6 miles per hour and adjust their following speed based on the user's speed to avoid collisions [4]. To further its role as a personal cargo robot, gita also possesses a USB Type-A charging port and an integrated Bluetooth speaker [5].

5.2 Amazon's Kiva

In 2012, Amazon acquired a company previously known as Kiva Robotics that had developed a robot designed for large-scale warehouse use. Kiva's robot was intended to increase warehouse efficiency by moving inventory bins and items to inventory workers rather than vice versa [6]. To fulfill the goal of transporting large inventory racks throughout warehouses, Kiva's base model was designed to lift 454 kilograms, and its larger model was designed to lift 1362 kilograms. The Kiva possesses infrared sensors and touch-sensitive bumpers for collision detection, halting the robot if an object or person is in its path. It is also equipped with upwards and downwards-facing cameras that read barcodes under inventory racks and on the floor to provide location information to the robot, which is combined with sensor information from encoders, accelerometers, and rate gyros to determine vehicle navigation. The Kiva utilizes a large screw lift to elevate inventory racks 5 centimeters off the ground. Using the robot's two wheel tank drive, the drive wheels rotate in the opposite directions to maintain its stationary position when it elevates the racks [7]. The Kiva is capable of moving the racks at 1.3 meters per second [7].

5.3 Roboticized Luggages

There are many companies creating their version of a roboticized luggage. However, there is not one company that deems the most credible and dominant in this field yet. Currently, Airwheel positioned itself as a leading competitor with its innovative ride-on suitcase designs. Airwheel luggages cannot follow a person, rather it's more of a solution to turn your luggage into a vehicle for the airport. For an auto follow suitcase, there are many startups but none have released a solution that is up to standard for users.

Cowarobot was a pioneer in the autonomous luggage industry as they were able to raise over $500k in a crowdfunding campaign. The user would wear a wristband that would serve as a beacon for the luggage to follow the user. However, issues arose leading to the discontinuation of the luggage. For instance, the luggage would struggle to navigate in crowded areas resulting in the main selling point being nullified. Additionally, there were worries about the quality of the luggage and battery life which did not live up to expectations especially since there was a high asking price of $700 per luggage.

5.4 SmoothOperator

Our product is similar to these competitors in that we will also create a robot capable of carrying and transporting designated cargo. However, these competitors' products focus on specialized or personally owned robots. Our product is intended to be shared and reused throughout the day in spaces such as airports or hotels. Like gita, our product will follow the user to their destination while carrying their belongings. Unlike the gita, Smooth Operator is able to transport objects to its destination rather than just following the user and will be capable of transporting larger and heavier objects. SmoothOperator robot will additionally move at a speed of 1.4 meters per second, similar to Kiva's speed of 1.3 meters per second, to match the average adult walking speed. This walking speed was determined to allow for safe and functional operation for locations with heavy foot traffic like airports. Additionally, unlike roboticized luggage, SmoothOperator is intended as a multi-purpose robot. Moreover, while Airwheel luggage converts a suitcase into a mode of transportation at airports, it fails to address accessibility issues that SmoothOperator addresses.

6 Engineering Requirements

6.1 Mechanical Requirements

1. Load Capacity: The robot must be able to transport a 50 lbs luggage while maintaining balance and stability when in motion
2. Mobility: The robot must move at a consistent speed of 1.4 m/s (average walking speed)
3. Obstacle Avoidance: Obstacles within 0.5 meters must be detected by the real-time sensors and communicate this information to the onboard navigation
4. Emergency Systems: Must have an emergency stop as safety is our top priority for this device

6.2 Software

1. Autonomous Navigation and mapping: Must be able to use real-time sensor input with low latency and calculate the shortest path from point A to B. It will achieve an accuracy of ±0.5 meters
2. User Interface: The UI must be an intuitive interface that allows for low latency (<1000ms) manual operation and autonomous navigation. The user should receive real-time status updates

6.3 Hardware

1. Sensors: The robot will have a sensor suite (LiDAR, ultrasonic, IR) to detect obstacles, generate a map, and perform real-time adjustments for navigation
2. Power Supply and Battery: Robot will operate for at least 1 hour on a single charger under full load when performing tasks
3. Motors: The robot's motors must be powerful enough to transport a maximum load of 50 lbs while maining a speed of 1.4 m/s and support zero-degree turns

7 Appendix A References

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