Auto-following Luggage Platform

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ECE 445 Senior Design: Project Proposal

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1. Introduction

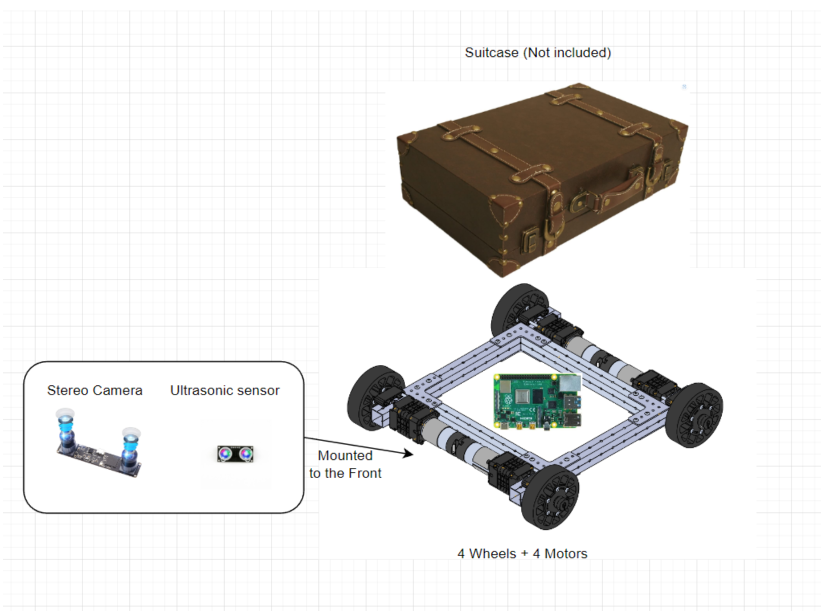
1.1 Problem

Sometimes carrying the suitcase might be the most unsatisfactory part of a trip. This dissatisfaction can also grow into annoyance when the amount of luggage is too large to be carried without the help of transportation tools. Therefore, people have dreamed about a suitcase that can automatically track its owners on its own, without requiring external forces from the owner to steer it. There have been so-called "smart suitcases" made for sale with different features including USB-port for charging, GPS localization, etc. However, the price is too high for the public to afford [1], and only a few with exceedingly high expenses might be capable of achieving the fully automatic following feature. The product currently being marketed online that meets the demands described above with the lowest price of 799 EUR can be found here Functions of Airwheel SR5 Intelligent Suitcase, which is still too costly for normal families.

1.2 Solution

We propose the Auto-following Luggage Platform project that aims to solve the problem with the cost of approximately 200 USD dollars, which is much cheaper than the market price of the "smart luggages" available online. More specifically, our intention is to build a general platform that could identify and follow the owner, while at the same time carrying a wide range of different suitcases. In that sense, the system that we will be building will be of a plug-and-use fashion, independent of the suitcases, and thus can have a more general application than those commercial products.

1.3 Visual Aid

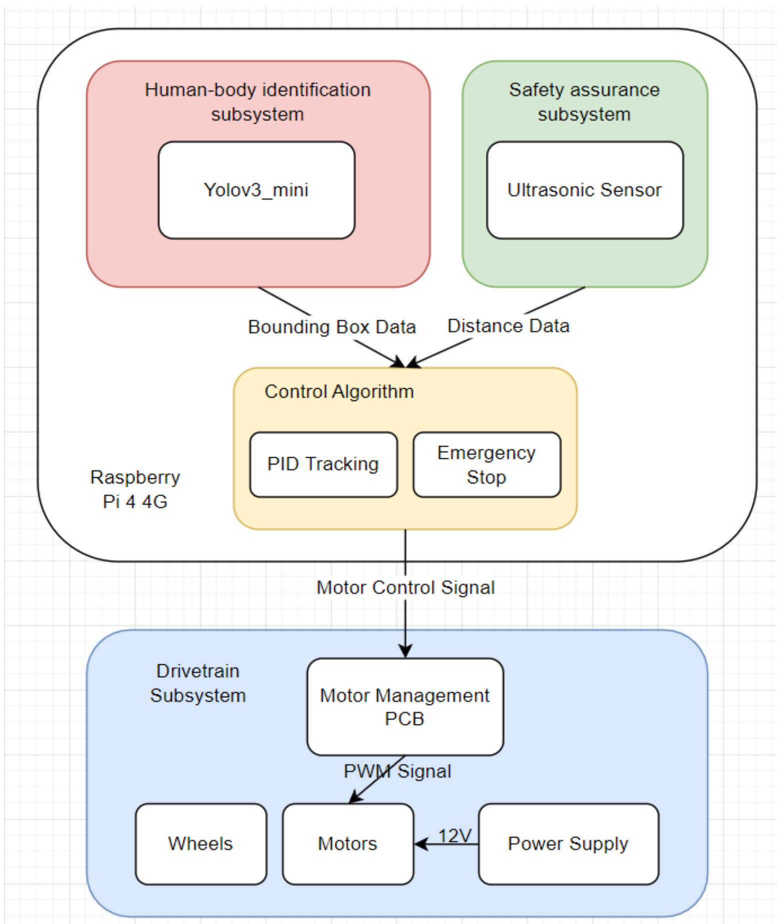


1.4 High-Level Requirements List

- The machine is able to carry weights up to 20kg while maintaining a safe speed between 2-4 mph.
- The machine is able to follow the owner when the owner is in the camera frame, and maintain a safe distance from the owner.
- The machine is able to locate the owner (put the owner back into the camera frame) autonomously when camera tracking is lost.
- The machine is able to avoid collisions with obstacles and humans.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview

2.2.1 Drivetrain

The drivetrain will consist of four motors. It will take input PWM signals given by Rasberry Pi 4 and drive the motor accordingly. The drivetrain's left and right motors will be independent, allowing the robot to turn at different speeds on the left and right.
Requirement: Torque provided by the motor system must be sufficient to drive the entire machine forward under full load of 20kg with speed above 2 mph but not exceeding the 4 mph. The torque at the left and right motors should also be sufficient to turn the machine around under full load.

2.2.2 Control Subsystem

The control subsystem has two modes: tracking and locating. In the tracking mode, the human-body identification subsystem has found the owner and therefore the control subsystem should instruct the drivetrain to track the owner. Using the bounding box data calculated from the Human-body identification subsystem, we can calculate the deviation angle, and use PID to track and minimize this error. We will also use a separate algorithm to control the speed of the robot. Using an estimated distance value, we will speed up and slow down the robot accordingly as well. In the locating mode, the human-body identification subsystem failed to find the owner in the camera frame and therefore the control subsystem should instruct the drivetrain to locate the owner. This is done by instructing the motors to run at different speeds to turn the platform around circularly in order to locate the owner in frame.
Requirement: In the tracking mode, the machine should follow the trajectory stably, with oscillation within 10%. In the locating mode, the machine should turn around circularly with angular speed of less than 0.314 rad/ sec, such that the human-body identification subsystem can process each frame before the next critical frame comes in.

2.2.3 Human-body identification subsystem

We will use Yolo6 for human recognition and segmentation to produce bounding boxes. Each bounding box will be made into gait silhouettes and used for a gait-matching algorithm to identify the owner of the suitcase. This subsystem will return a boolean value that represents whether the owner is found in the current frame, and, if true, the correct bounding box of the identified owner. This boolean value and the offset will be sent to the control subsystem for controlling the drivetrain.
Requirement: With the pre-trained model on the owner's biometrics, the identification subsystem should be able to achieve at least 90% accuracy on identifying the owner within the camera frame, with obstacles and other humans present.

2.2.4 Safety assurance subsystem

The ultrasonic sensor equipped will report the distance to obstacles as well as a boolean value that represents safety with respect to possible collisions. The robot will stop immediately if the returned value is false to avoid collisions.
Requirement: The robot should immediately brake whenever an obstacle is within 50cm. The ultrasonic sensor's measurement should be within 10% of the actual distance.

2.3 Tolerance Analysis

2.3.1 Maximum Velocity

Our motor is rated for 3500 rpm along with a 100mm wheel. So we can derive it maximum velocity:

$$V_{max} = \omega\pi r^2 = 3500 * 3.14 * 0.1^2 / 60 = 1.83\, m/s$$

2.3.3 Battery Life

We will use a 12V 7.2 Ah battery to power our entire platform. Using an estimated 80% efficiency in the circuits, we can derive the maximum possible battery life of our platform:

$$T = \frac{E_{battery}\eta}{P_{motors} + P_{raspberry}} = \frac{12V * 7.2\, Ah * 0.8}{30W * 4 + 3.4W} = 0.56\, h$$

2.3.4 Challenges

Our main challenge would be maintaining tracking of the owner. At this point, we are not sure how well our identification and control algorithms can perform together under the real scenario. Specifically, we are not sure how much impact the estimation errors of the bounding box from the identification algorithm could affect the accuracy of the control algorithm. Also, a huge uncertainty will be imposed on the capability of the drivetrain subsystem before it's actually built and tested, as the above tolerance analysis involves too many assumptions and estimations. We will first focus on building the physical platform out, then building the drivetrain, and then moving on to tuning our tracking algorithms.

3. Ethics and Safety

As progress through the project, we will firmly adhere to the Code of Ethics described in IEEE and ACM. We'll ensure a fair distribution of workload and a healthy working environment free of discrimination and racism according to IEEE Code of Ethics II [2]. Equal rights and mutual respects will be valued the most as we are working on the project. In addition, we'll also respect and appreciate all external helps we receive. We will seriously consider and sincerely appreciate any advice given by course TAs and professors. We'll also carefully cite and give credit to all the external works done by others that have helped us along the way.

Regarding the safety of the project, one potential hazard will be the usage of a lithium battery. Therefore, we'll perform all the safety protocols to prevent any hazardous events arising from the lithium battery [3], including but not limited to keeping the temperature of the battery within the safety range of 32 to 130 Fahrenheit, avoiding sudden and drastic movement of the battery carrier, etc. Moreover, since the project involves a moving component at the ground level, there exists a possibility that it could crash on humans unexpectedly. Therefore, we'll limit the max movement speed of the project to 4 mph to prevent injuries if collisions happen. We'll also put a high priority in the safety assurance subsystem to prevent such collisions from happening under any conditions.

4. References

[1] mygita.com, 2023. [Online]. Available: https://mygita.com. [Accessed 8 Feb. 2023]

[2] “IEEE Code of Ethics,” IEEE. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed 8 Feb. 2023].

[3] Batteryuniversity.com, ‘Safety Concerns with Li-ion Batteries – Battery University’, 2023. [Online]. Available at: http://batteryuniversity.com/learn/article/safety_concerns_with_li_ion. [Accessed 8 Feb. 2023].