Sebastian the Scaling Robot

COMP208 Group Project

Anastasia Zaikina (az288756@falmouth.ac.uk)

Falmouth University Games Academy

Introduction

This project consists of constructing a weight-baring scaling robot. The robot is a closed-loop system that is capable of climbing, carrying a kilogram weight, and navigating a switchback staircase. It is constructed of materials including 3D-printed PLA and laser-cut wood ply for ease of prototyping. In real life application, this robot would be able to help people carry heavy loads, such as shopping bags up stairs. This is particularly valuable in places such as apartments where the lift is not easily accessible.

Materials

The Scaling robot was constructed from:

- Laser-cut components
  - 3 mm ply for general frame
  - Acrylic for weight-supporting wheels
- 3D printed components
  - Various parts for reinforced joints and item assembly (eg. L-brackets and corner braces)
  - Wheel gearing
- Miscellaneous
  - Cloth and string for weight carrier
  - Screws for assembly
- Electronics
  - Ultrasonic Sensor HC-SR04
  - 2 H-Bridges
  - Arduino
  - 4 Worm Motors
  - Tilt switch

Prototypes

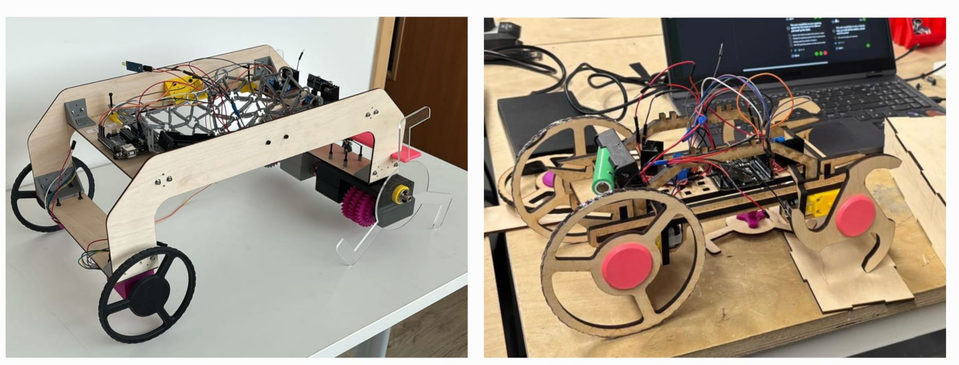

Figure 1: Version 1 and 0 Prototypes (Left, Right)

Version 0

- **Scale:** 1:3 ratio for material conservation and rapid prototyping.
- **Frame:** Designed with easy modifications in mind.
- **Wheels:** Tested various styles; final combination chosen for optimal grip and stability.
- **Limitations:** Original motors lacked torque for stair climbing.

V0 was designed with rapid prototyping in mind. The motors, simple dual axis yellow gear motors were attached to 3D printed wheel hubs with a tri-wing shape to quickly alternate wheel styles. Some gearing was implemented in v0, but none of them were kept due to the motors not having enough torque.

Version 1

- **Scale:** 2:3 ratio due to material constraints for stair climbing.
- **Verison Changes:**
  - Geared worm motors for better performance. [1]
  - L-brackets for assembly.
- **Features Added:**
  - Ultrasonic Sensors
  - Carrying system
  - Gear box

V1 was made to be the model to complete the climb in accordance with the contract. The chassis was sized up to 2:3 instead of 3:3 due to material constraints and the hypothesis that the smaller of the two would still be able to climb the stairs with no issue. With the switch of frame, the motors were changed to be higher powered as well, front two geared down for higher torque. The carrier system was originally planned as a cloth bag, made with a drawstring so items would not fall out. This was later changed to a 3D printed net found in the lab's abandoned print box.

Wheels

During prototyping, the team developed and tested various wheel designs, inspired by research papers and tested through cardboard and wooden prototypes. One of these wheel inspirations was the Curved-Spoke Tri-Wheel mechanism [3]. In this design, there was similarity to the already existing "Isle of man flag" wheel that had already been made by the group. Using Fusion 360, I replicated this concept in a new wheel, getting rid of the spokes, making it suitable to be 3D printed and leaving indents in the feet of the wheels for hot glue to be added for grip.

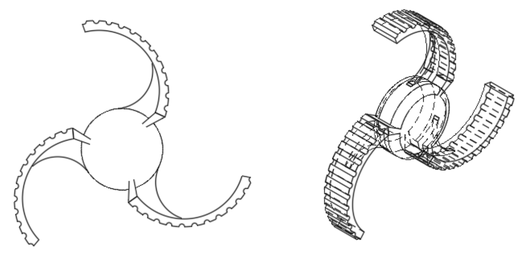

Figure 2: Fusion design for curved-spoke inspired wheels

State-Machine Diagram

The code is spit up into many void statements that allows for easy testing in the case that anything needs work separately. The main body of the code is represented in this state diagram:

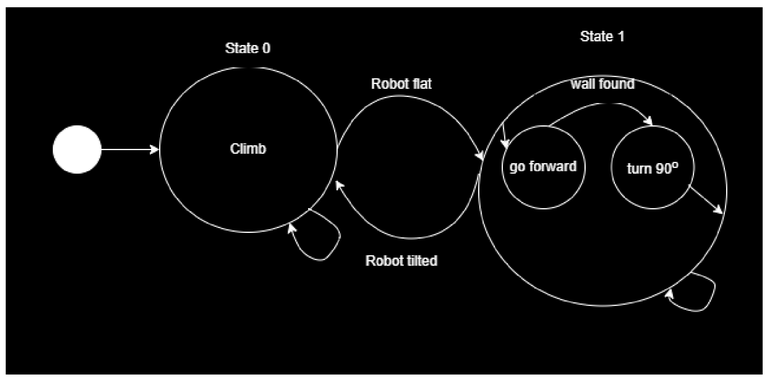

Figure 3: State diagram for scalingTurningStates

Research

Mechanisms: During initial prototyping, inspiration was drawn from the mechanical system in the game *Hungry Hungry Hippos*,[4] where one downwards push was translated into a out-up-down motion. This could have been an ideal use for a cam, with the "Isle of Man" wheel attached on the end for optimal grab of the stairs, considering they had a metal lip that would allow for it. In the end the idea was scrapped because in the original mechanism of the game, the system depends on the fact that the surface where the motion happens is flat, something that is not available on stairs.

Real-life Application: There are many different kinds of stair climbing robots, detailed in the book *Stair Climbing Robots and High-Grip Crawler*[6]. These robots were the starting point for drawing inspiration for our own robot, however they only focused on the task of climbing stairs. In real life application such stair climbing robots can be used in search and rescue operations[2], and for home care among aging society[5].

Forthcoming Research

With the knowledge gained during this project, many improvements could be made had we started again. Considering the initial plan was to scale the project down to cut down on prototype production time, testing the motors with 3 times the weight should have been the priority. This early testing would have given us more time to realize that the initial motors were too weak for the structure and that the gearing needed work.

Another consideration would be robot material. In this project, the main two composing materials are PLA and 3mm wood ply. While these mediums work well for the 1 kilo weight, this becomes an issue when the machine has to carry anything more. Selecting more robust materials in any future versions would ensure that the structure will be sturdy enough to carry heavier loads and not warp in the process.

References

[1] DA Hofmann. Gearing for high speed motors. In *IEE Colloquium on High Speed Bearings for Electrical Machines*, pages 3–1. IET, 1997.

[2] Naoki Igo, Shota Yamaguchi, Noriyuki Kimura, Kazuma Ueda, Kenji Iseya, Kazuma Kobayashi, Toyoaki Tomura, Satoshi Mitsui, and Toshifumi Satake. Robots climbing up and down a steep stairs and robots retrieving objects from high places. *Journal of Robotics and Mechatronics*, 34(3):509–522, 2022.

[3] Youngsoo Kim, Jongwon Kim, Hwa Soo Kim, and Taewon Seo. Curved-spoke tri-wheel mechanism for fast stair-climbing. *IEEE Access*, 7:173766–173773, 2019.

[4] Adrénaline Amusements Team. *Hungry hungry Hippos Operation Service Manual*. Adrénaline Amusements, 2.0 edition.

[5] Ming-Shyan Wang and Yi-Ming Tu. Design and implementation of a stair-climbing robot. In *2008 IEEE Workshop on Advanced robotics and Its Social Impacts*, pages 1–6. IEEE, 2008.

[6] Kan Yoneda, Yusuke Ota, and Shigeo Hirose. Stair climbing robots and high-grip crawler. In *Climbing and Walking Robots*. IntechOpen, 2010.

Repository

https://github.falmouth.ac.uk/GA-Undergrad-Student-Work-24-25/COMP208-GROUP-SCALING.git