Hangrob: A Whiteboard Drawing Robot

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Introduction

Inspired by Delta 3D printer designs and hanging stadium cameras, the idea for this project was to use the two motors and quadrature encoders to control the amount of line slack in two support cables. This would control the position of the robot in a 2D plane. The support cables were mounted on a whiteboard, and the robot had a marker mounted on the backside, allowing for the drawing of commanded shapes based on input cartesian positions. We chose this project because of our class experience with mobile robots, and such a design provided the opportunity to perform significant hardware modification of the mobile robot and experiment with a new method of robot position manipulation.

Design

The initial hardware redesign of the mobile robot went through many design iterations after considering the specific objectives and physical constraints of the robot as well as after receiving input from the experience of the course instructors. In the initial conception of the robot as seen in Figure 1, it was seen to be best to have the spools mounted with their axis normal to the whiteboard surface and roller supports to maintain contact being above the spools and Raspberry Pi. Upon considering that this would place the center of mass above the spool feeds, the design considered was inverted to have the rollers below the center of mass and the spool connections above. The spools were also turned to have their axis parallel to the whiteboard and ground.

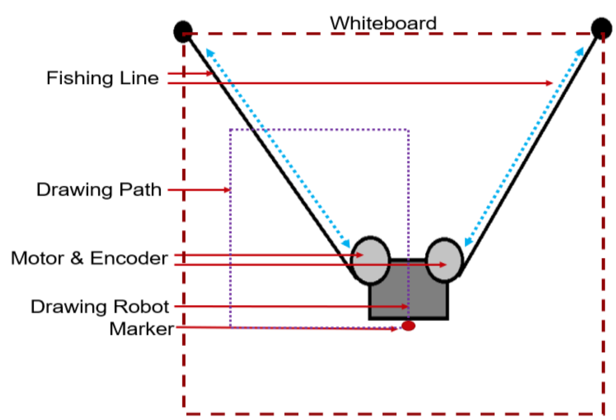

Figure 1. Initial proposed design

A simple base structure was modeled in SolidWorks. While this design was not perfect, it served as a valid prototype upon which to modify and expand to fit the design needs. The design was created with two roller supports to create a stable three points of contact with the board with the marker being included as the third. Due to accessibility, 3D printing was chosen as the means of producing both the body and the spools. They were printed in PLA to keep project costs low and because of the immediate accessibility of PLA 3D printing material.

With this design in place, it was noticed that it was relatively easy for the line to come off the spool. To remedy this, line guides were produced to be mounted on the existing base. This, ultimately, covers the core features of the final design as depicted in Figure 2. The center of mass positioned low and behind the line connections, spool guides, and low roller supports come together to maintain marker contact with the board and neatly collect retracted line into the spools. The battery is given no defined location so that it can be mounted in a position that maintains a good center of mass balance.

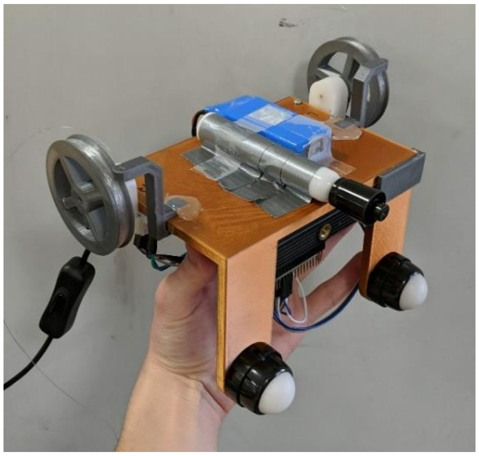

Figure 2. Final robot design

Following the construction of a suitable physical design, the robot needed to be coded to perform a calculated spool retraction or release based on a change from its current position to the desired new one. Initially, the plan was to do this via a vector projection method between start and end points, using the cable vectors as a basis. Eventually, the plan became much simpler: calculate the initial line lengths given the known initial position; calculate the end line lengths at the intended position; and rotate the motors the amount of encoder counts corresponding to the change in line length using the known gear ratio, counts per revolution, and spool diameter.

To accomplish this change accurately, the velocities were fed into the existing mobile robot wheel controller node, and the encoders were checked until the destination was reached. To ensure that the hanging robot took a direct route between the start and end points, the velocity for each line was normalized according to the maximum distance to be covered by any one line. Thus, both lines completed the state change in approximately the same time.

Results

In the latest round of testing the robot performed well in some ways and needed improvement when it came to others. The distances covered seemed to very clearly reflect the anticipated distance covered by the robot. Additionally, the robot moved in straight lines between points, so the scaling of velocities is clearly an effective method for performing such an action. However, one aspect of the robot that performed less than ideally was the direction the robot is supposed to go. In all the movements, there was some degree of drift from the intended path. This could be a result of many factors including the initial defined position of the robot, the defined position of the line anchor points, or even just the accumulated error compounding over many movements. Another possible source of such error could be a result of some tipping of the robot. In horizontal movements, the robot would tilt slightly, violating the assumption in the math that the robot maintains level positioning. This can be fixed with improved body design by lowering the center of mass or implementing some sort of stability adjustment features. Other than that, the contact balance was good; the marker never lost contact with the board. This accomplished the objective as intended, however the support rollers occasionally lost contact, implying that the center of mass could be moved farther back and down.

Discussion

There are many personal takeaways from this project, but some notable ones are the use of a different form of spacial manipulation beyond anything we directly worked on in class and the interfacing of new code with existing code. The math behind movement using cables can be scaled up into 3D very easily, and the use of the mobile robot PID controller made developing the motion stability much easier. As far as improvement goes beyond anything previously mentioned, the primary thing to fix would be the position control method. Due to time constraints in development, open-loop control is used to position the robot. This leads to some level of compounding error in the position of the robot, especially after many movements. Thus, the implementation of a closed-loop control technique such as dead reckoning would be beneficial to the overall accuracy of the positioning, particularly in the long term.

Despite any shortcomings that this robot may have, it was an exciting project to build and felt like a unique extension of much of the material that was covered in class.

Contributions

	Ben	Yifei
Concept/Planning/Research	70%	30%
Design - Hardware	60%	40%
Design - Logic	50%	50%
Programming	70%	30%
Presentation	50%	50%
Report	50%	50%