SoutheastCon 2009

Mechanics of Bottle Acquisition

ECE400 - Senior Design

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Table of Contents

Introduction

SoutheastCon is the IEEE Region Three conference held annually at various locations throughout the southeast. The 2009 conference, themed "Engineers Making the World a Better Place," will be held in Atlanta, Georgia. Along with technical sessions and tutorials, the conference also has a student competition. Schools from around the southeast compete in various contests measuring engineering skill. Our team is constructing an autonomous robot for the hardware competition. I will be focusing on the mechanics of bottle acquisition.

Rules of the Competition

Overview

This year's robot has the task of solving a problem plaguing college campuses. After athletic events, the area surrounding the sports venue tends to be littered with bottle and cans. This cleanup can be costly and wasteful. The goal is to build a robot that will autonomously collect the bottles and cans, identify the material used to construct them, and sort them into separate containers for recycling.

Objective

The robot is to traverse the playing, collecting and sorting bottles as it goes. Points will be given for each item collected, and extra points will be given for items correctly sorted. The robot is to complete all sorting on-board.

Playing Field

The playing field consists of a 10' by 10' square of green Astroturf. A hard border surrounds the field to prevent to robot from leaving the field. An underground electric dog fence transmitter (provided by the conference upon registration) is to be placed under the Astroturf one foot inside the hard boundary. A grid of white dots spaced one foot apart exists to mark the potential places that bottles could be located.

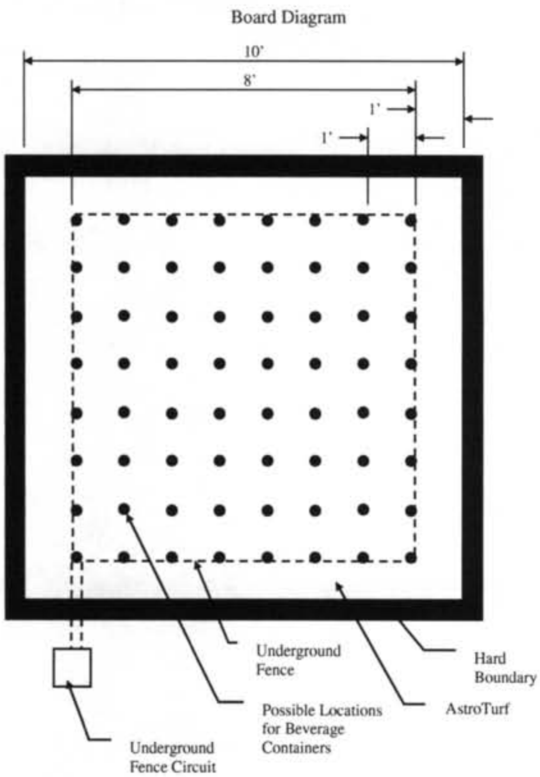

Figure 1: Field Diagram

Recyclables

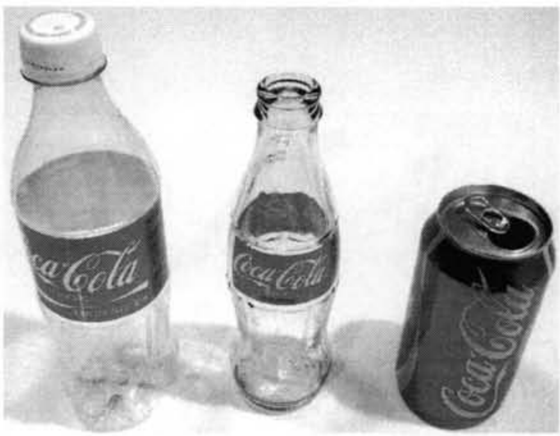

Figure 2: Recyclables

Ten cans/bottles will be placed on the filed at random positions: five aluminum cans, three plastic bottles, and 2 glass bottles. All of the recyclables are Coca-Cola brand so that consistent color, shape, and size can be depended on.

Robot Construction

The robot must be able to fit within a 12" x 12" x 18" box at the start of the round, however it can expand to any size after the round has begun. It should have three separate, removable plastic bags in which the items will be placed.

Game Play

A button labeled "Start" must exist on the robot to begin the round. Play time is four minutes. During that time, the robot should collect and sort as many items as possible.

Robot Design

As a group, we went through several iterations of what we believed the optimal design would be. We started with a system that used a rake to scoop the bottles into the various containers. We had issues determining which material the item was made of. A second design included a robotic arm that would grasp the item and move it to the desired bin. This would require a great deal of design, as such systems are very complicated and expensive. We decided this was impractical. The final design we chose uses a caddy system. The robot drives over the bottle, causing the item to be placed on the caddy. Once inside, we can use photogates to measure the length and make a good determination of the item type. We then raise the caddy to the appropriate height where a servo pushes the bottle off the caddy and into the appropriate bag. Flippers on the front were later added to ensure the bottle is in the proper orientation.

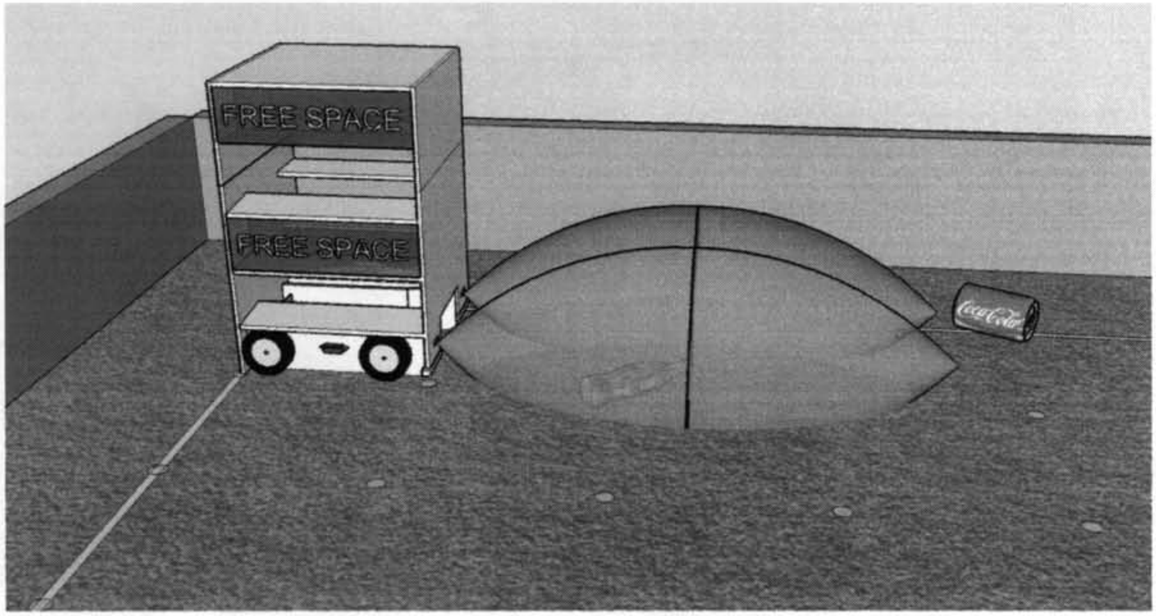

Figure 3: Final Design

Responsibilities

My responsibility is to design, construct, and test the mechanical components required to acquire the recyclables. I have to work closely with the people responsible for the chassis, sensors, and programming to ensure that all the parts will work together properly.

Front Flippers

The front flippers are designed to help orient the recyclables so that they can more easily move into the caddy channel. Two arms need to be precisely positioned at three locations with knowledge of "home" to ensure they will not obstruct the bottles. Thus, servos are the perfect motor to cause the rotation. Due to size constraints, one of the servos had to be a mini servo (Futaba S3107) if we wanted full motion of the flipper arms. Although it has lower torque, it was determined that it would be strong enough to move the bottles into position. The other, stronger one was a Hitec HS-322HD.

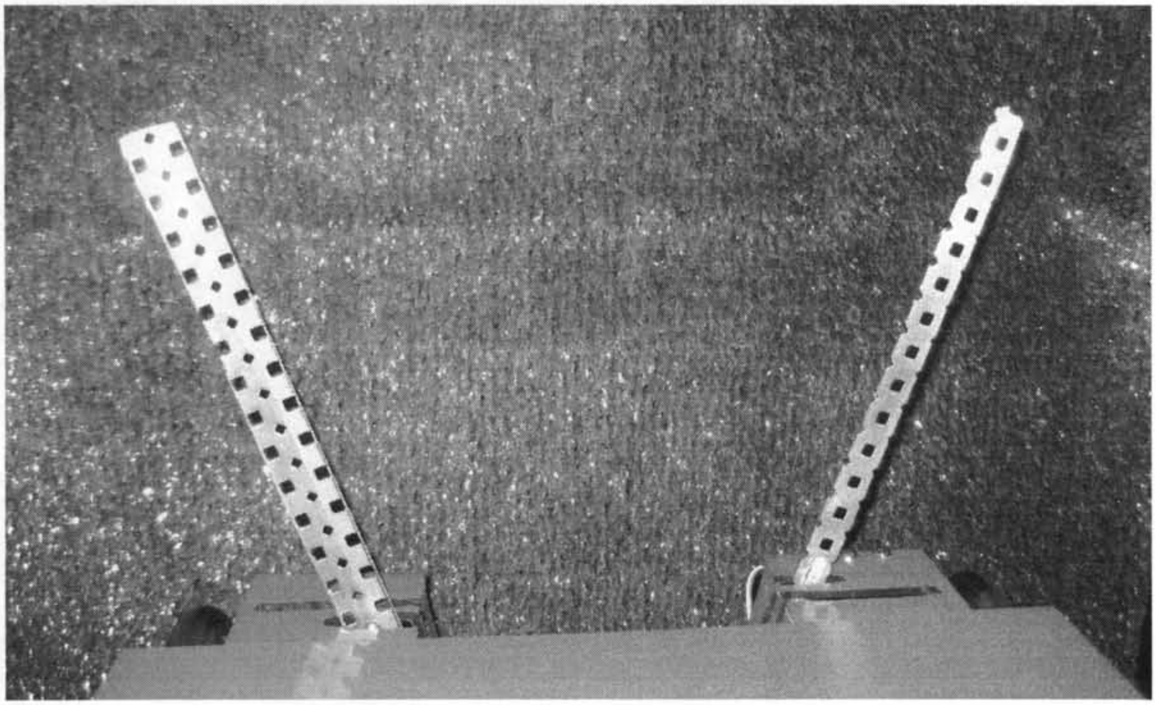

Figure 4: Top View of Front Flippers

The metal arms were machined to be the optimal size. The two arms are different lengths corresponding to the different size servomotors that control them- you want arms that are the same width as the servo to ensure the angles match up. These are controlled by PIC chips that Justin Kopp designed, along with an NPN BJT high-current driver that I installed. The PIC program allows the flippers to be placed in three positions: home (0 degrees), neutral (90 degrees), and open (120 degrees).

Vertical Motion System

The vertical motion system was probably the most complicated aspect of my responsibilities. I was tasked with finding a way to easily load the bottle onto a caddy and then raise that caddy over a foot vertically.

Caddy

The main design requirement of the caddy is to easily allow the bottle to be loaded. We do not want extra moving parts to load the recyclable onto the caddy. Thus we chose a design similar to a forklift. The original caddy was fabricated out of a metal sheet with holes in it. This was found to be too flimsy, so it was refabricated out of solid metal sheeting.

Figure 5: Original Caddy

Slide Rail

Initially I was planning on fabricating the slide rail myself. After some initial research, I determined that it would not be possible to make the motion as smooth as is needed for this application. Instead, I looked in local hardware stores and online for a commercial solution.

My first lead was a rail made for desk drawers. Unfortunately, it was telescoping, so it would not have ample support when fully extended. I found some very professional slides online, but they seemed very expensive. I found a company named Igus that has a program that donates parts to educational institutions. Looking through their catalog, I found the Drylin W. This looked to be exactly what I needed for the rail. After consulting with their engineers, I picked the exact part number and length I needed. I placed the order and our free part arrived a few days later.

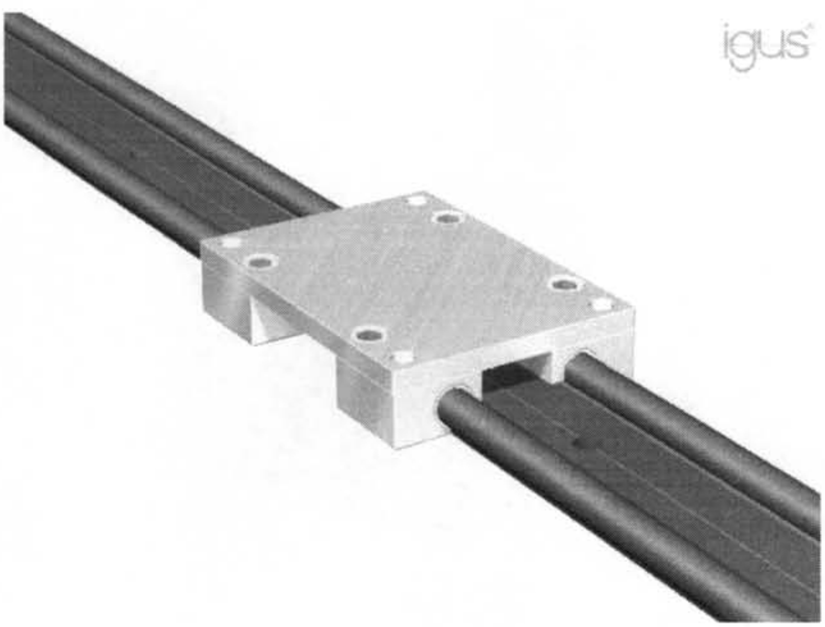

Figure 6: Igus Drylin W Slide Rail (CAD Drawing)

Stepper Motor and Sprockets

I had several options for actually raising and lowering the block on the slide rail. The simplest option was to attach a string to the block and motor. As the motor rotated, it would wind up and raise the caddy. Although this was simple, it would be unreliable. You never know exactly how the string will wind, so you will have differences every time. The next option was a rack and pinion system. This was promising, but you have to be very precise with spacing and angles. If you are off by too much, it simply won't work. On top of this, I had a hard time getting manufacturers to contact me back. The few that did quotes costs outside of our range. The final design that I evaluated was a sprocket and chain system with a stepper motor. This is what I ended up using.

Stepper motors work on discrete steps, so you can always count the number you have taken. Thus, steppers are perfect for applications were fine positioning is required. Based on my research, I determined a unipolar stepper would be easiest to control. IEEE had in its possession a unipolar stepper, but it was missing the datasheet. I used this for testing before we ordered parts, and found it to be almost perfect for our use.

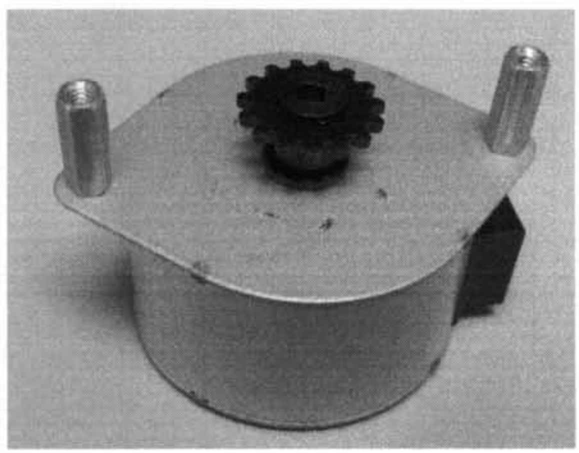

Figure 7: Stepper Motor with Sprocket

To find the pinout, you can measure resistance between the different pins.

Table 1: Resistance Between Pins of Stepper Motor

Pin Combo	Resistance	Pin Combo	Resistance	Pin Combo	Resistance
1-2	Inf	2-3	Inf	3-5	12
1-3	12	2-4	12	3-6	Inf
1-4	Inf	2-5	Inf	4-5	Inf
1-5	24	2-6	24	4-6	12
1-6	Inf	3-4	Inf	5-6	Inf

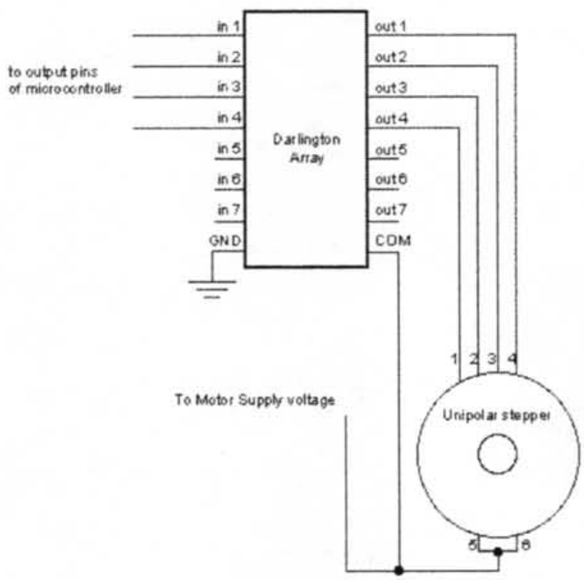

Figure 8: Stepper Control Circuit

The common pins are 3 and 4, and you apply voltage to pins 1, 2, 5, and 6 to step the motor. Half stepping is required to be able to lift the glass bottle. The step configuration for half stepping is show below. To reverse the direction, just step in the opposite order. A Darlington array is required to supply the high current required by the stepper. The Darlington takes a low-current 5V logic high from the PC104 and buffers the signal applying several hundred milliamps to the coils of the motor.

Table 2: Sequence for Half Stepping

0001
0011
0010
0110
0100
1100
1000
1001

I had to grind the shaft of the stepper to accept a sprocket. I chose a .1227" plastic roller chain with matching sprockets. The sprocket attached to the stepper was coupled via the chain to the rail's block and caddy. Thus, when the stepper spins, the caddy raises or lowers to the appropriate position.

Figure 9: .1227" Roller Chain

Bottle Ejection

Once the caddy has been raised to the proper height, another mechanism must then remove the recyclable from the caddy and put it in the bag. For this, a simple servomotor with a metal flipper was designed to push the bottles of the caddy. The flipper's servomotors are powered from the 5V supply and controlled by Justin Kopp's PIC program. A high-current NPN BJT buffer circuit was required.

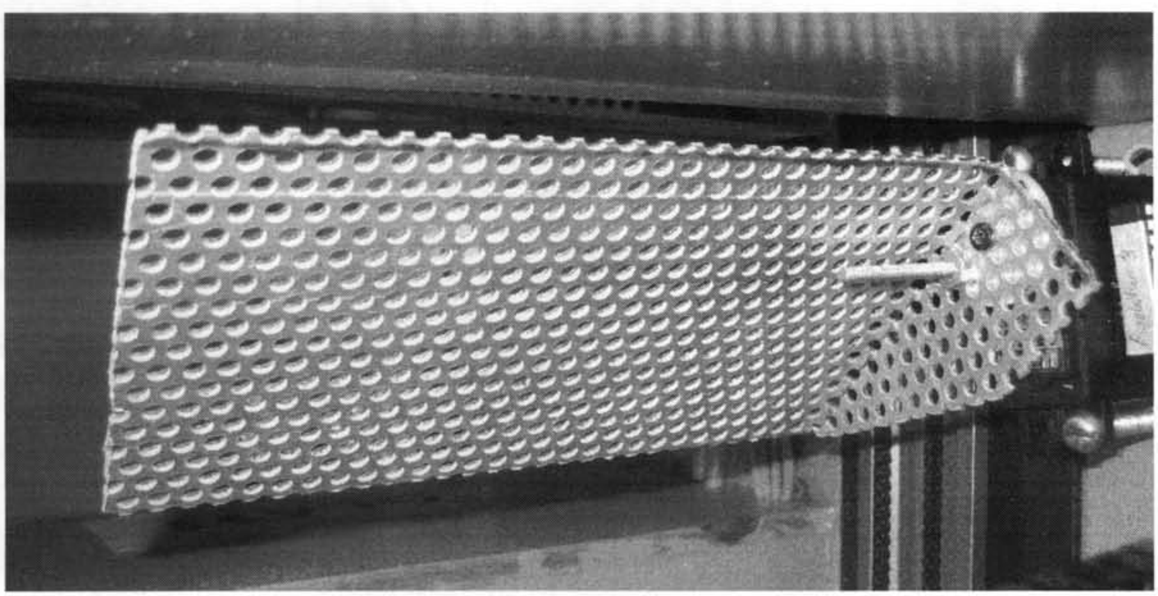

Figure 10: Rear View of a Side Flipper

Conclusion

Through this project, I have had the opportunity to learn about teamwork, project management, and system integration that I had not been exposed to previously. By accomplishing the goals set for myself, the robot is now able to orient, lift, and eject a recyclable. Although the robot still has a bit of refinement left, we are well on our way to a successful competition.