Calculus II Future Maker Lab

Final Presentation

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Contents

Project 3 Overview

Project 3 aimed to create a self-balancing robot using an Arduino Uno and a PID controller

- The chassis of the robot was laser-cut to educate students about the laser cutter.
- The robot was assembled using an Arduino, two stepper motors with drivers, and an accelerometer.
- Students then tuned the variables of the PID controller to keep the robot balancing as long as possible

Technologies Used

Laser Cutting

Figure: TROTEC Laser Cutter

Laser cutting was an important part of the maker/prototyping skills developed in this project

PID Controllers

A PID controller is a device to regulate a system using a feedback loop and calculated error. It uses three mathematical functions: a proportional function that increases output linearly with error, a derivative function that changes output based on long-term accumulation of error, and a derivative term that changes to smooth/dampen the oscillations by pulling against high rates of change.

This Presentation

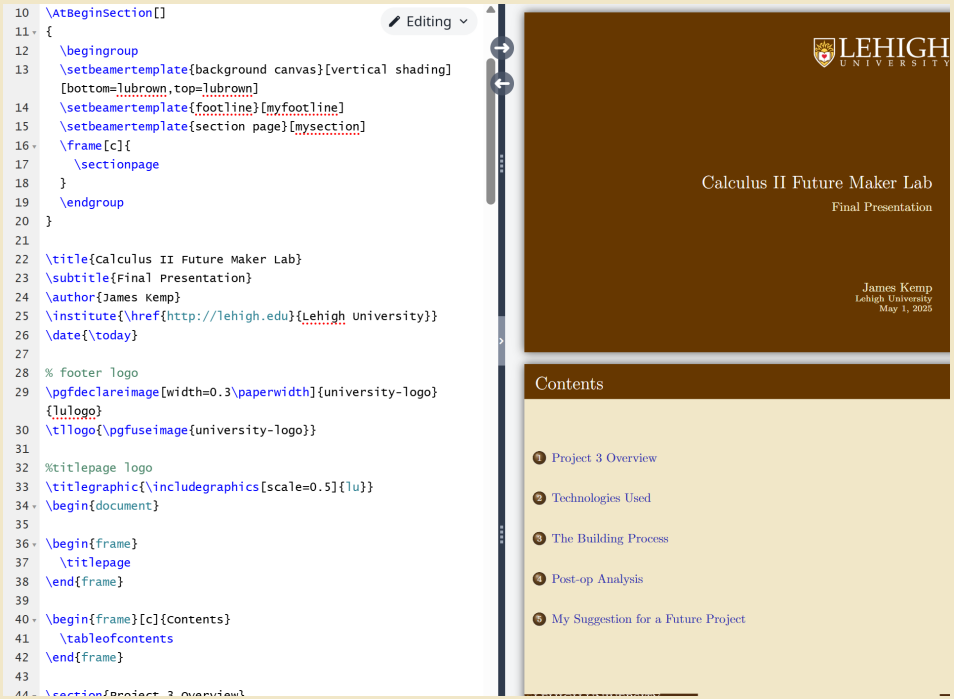


Figure: The Code Running the Slideshow

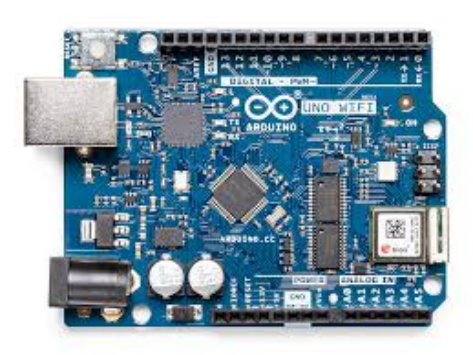
This slieshow was created using LaTeX, a typographic human-readable format for stylizing text. It's popular in mathematical circles because it allows the rendering of equations. I used Beamer (a special slideshow library for LaTeX) for this presentation so as to improve my skill with Markdown.

The Robot as a Whole

- Runs PID software on an Arduino IDE
- Chassis was laser-cut
- Uses stepper motors for balancing (although this may have introduced vibrations)

Demonstrates calculus by virtue of running the Integral and Derivative terms of the PID controller. Allows the rate of change of a function to physically be represented in the robot's movement

The Building Process



1. Laser cutter training was completed online. We learned key safety features, including making sure the fume extractor is on, ensuring the material to be cut is safe, and ensuring lines on the design are spaced out and not doubled up to prevent a fire. We discussed how to log in to Trotec Ruby, how to send files to the laser cutter, how to schedule a cut time and how to turn on and calibrate the laser and fume extractor.
2. We practiced this process with pre-designed files for the balancing robot, adding our initials to a lower structural bar
3. We assemble the robot's frame, adding rubber wheels, stepper motors, and breadboards
4. We assembled the circuitry of the robot, wiring the Arduino Uno to stepper motor drivers, a power jack and the accelerometer.
5. We uploaded a sketch to the Arduino Uno to run the PID-program.
6. We spent time tweaking the parameters of the program to tune the equation and get better balancing from our robot

Post-op Analysis

This project was my favorite of the three because it combined two practical skills (laser cutting and PID) with what could have been the most intuitive way to see calculus ”at work”. Unfortunately the fickle nature of the robots themselves got in the way of much of our possible experimentation.

My Suggestion for a Future Project

Figure: An on-brand, math-heavy introductory project

This project would be best at the start of the lab, or mid-lab at the latest (when CoM is introduced in class). It would involve students creating an area in Desmos or another program described by several functions that they would then integrate to find the centroids of. For an added challenge, they could make this point close to the edge as in the bird on the previous slide. A basic "mountian hawk" design could be a starting point, but I want to stress that this project must let ALL of the math be done by the student. I'm strongly against simply handing the studnts a design, or even giving them a design to tweak. The actual assembly time of this project will be short, so there's time for more math.

- Define the Area Between Functions In Desmos
- Find the Centroid using

$$\bar{x} = \frac{1}{A}\int x\,dA, \quad \bar{y} = \frac{1}{A}\int y\,dA$$

(1)

- Export the Shape for Laser Cutting Use Desmos Geometry, or trace the shape in a vector tool like Inkscape or GeoGebra.
- Export as SVG (vector file for laser cutter)
- Cut from a uniform material (like acrylic or wood)
- Balance the Shape Drill a tiny hole at the calculated centroid Suspend the shape from a pin or string—if it's balanced, the centroid is correct.