Thesis Project Portfolio

Self-Correcting Ping Pong Launching Robot (PPLR)

A Dive into Microcontrollers: A Dark Horse Technology

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

David Chen
April 28, 2022
Department of Electrical and Computer Engineering

Table of Contents

Executive Summary

Technical Project

The technical project is a user-controlled ping-pong ball-launching robot that has a deterministic feedback loop with a self-correction procedure. The robot can aim at 1 of 9 target squares with immense accuracy. Using image processing, the detection of the ping pong ball will be reported back to the robot and if it is missed it will readjust and make a correction to fire again. The project uses a combination of a pan/tilt mount controlled by servo motors, a push solenoid, and a computer user interface as a control mechanism for aiming. The overall system is controlled by an MSP432P401R Microcontroller (MCU) that communicates with the UI via Universal Asynchronous Receiver/Transmitter (UART) communication protocol. The microcontroller acts as the central brain for the robot as it powers and communicates to all Input/Output (IO) peripherals mentioned earlier. The primary reason for deploying this technical project is to explore an automatic feedback system and use multiple interdisciplinary topics within the ECE major to create a complete project.

In order to achieve the goal of a self-targeting and self-correcting ping-pong ball launcher there are three hardware systems. There are the servo motor-controlled pan/tilt mount that aims the launching mechanism towards the target, the solenoid-powered launching mechanism itself, and the real-time communication between the computer user interface and the microcontroller. The power, protection, and connections to these major systems are all housed in a Texas Instruments MSP432 microcontroller header board. The projects adopt hardware systems that are taught in fundamentals courses within the major.

The biggest software system is the self-correction procedure which uses a Kalman filter. The Kalman filter, also known as linear quadratic estimation, is a common and simple estimation

algorithm. At its most basic level, the Kalman filter calculates unknown variables in a system using prior measurement data, noise levels in a system, and the current state of the system. While traditional applications include object tracking or image detection, Kalman filters can be as simple as maintaining data values and updating functions on data input. In our project, the motor commands were to be updated on any discrepancy in launch and location. Overall, the technical project was a huge success and managed to surpass all criteria set for the project at the beginning of the year.

STS Project

The STS project will encompass the development and impact of microcontrollers on both the social consumer and the engineer. A microcontroller is a compact integrated circuit designed to perform a specific operation in an embedded system. Microcontrollers are embedded inside a large system to control a function of a larger component. In this project, I will explore how the rise in the digital age and society's reliance on electronic devices has ascended the versatility and usability of the MCU. The project will first inform individuals about MCUs and their history and how they have changed over time. We will look at specific points in history which made MCU technology much more relevant.

Understanding a microcontroller and discussing its timeline and history is essential in revealing how impactful it has been for industry and society. There will be a deep dive into how the MCU applies both to an engineer and to the average consumer. For an engineer, MCUs are found to be a critical technology in building automation, robotics, the Internet of Things, and communications. The project will specifically discuss the versatility of the MCU and how they can be used in various types of architecture and variants. The increase in technology and architecture of the MCU has had a huge role in industries like defense technology, industrial

automation, and medical devices. For a consumer, the MCU is not widely known as a technology primarily due to its lack of reach in the consumer realm. However, despite microcontrollers not being the flashiest consumer electronics, the MCU exists in most electronic systems used by daily consumers. The project will continue to discuss how the MCU can control systems like televisions, refrigerators, and AC. In this application portion, there will be a specific discussion on how the digital age has replaced archaic systems and the MCU has been at the forefront of digitizing everyday consumer electronic systems.

Following the application, there will be an overall discussion regarding impact. I will explore, specifically, how the MCU has impacted the development of Computer Engineering and also how educational MCUs like Arduino have worked to expose younger students to the world of engineering. Using technological determinism, the paper will explore how this theory coincides with MCUs and thus reveal why they are so relevant and impactful for society. Overall, the paper will encompass the full breadth of information and positively show the reader why MCUs are one of the most influential pieces of technology in our modern age.