Undergraduate Thesis Prospectus

Robotics in Entertainment: An Autonomous Foosball Opponent

(technical research project in Electrical Engineering)

Alternative Forms of Interaction:
How Educators Apply Technology in Special Education

(sociotechnical research project)

by

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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General Research Problem

How are automated systems augmenting classroom education?

Automated systems pervade every aspect of modern life, both professionally and personally. People's finances, communication, entertainment, and more depend heavily on these systems. While such technologies often abstract complexity, users still require the knowledge to select and leverage appropriate technology. DiSessa (2000) proposes a new "computational literacy" to characterize this ability; she explains that similar to conventional literacy, computational literacy should be a skill constantly practiced during schooling (diSessa, 2000). A computationally literate student would integrate more naturally into a society packed with automated systems. Wing (2006) characterizes a subset of this ability as "Computational Thinking" and proposes that computational thinking is the next step forward in today's world of ubiquitous computing (Wing, 2006). One method classroom educators use to impart these skills is consistent exposure to automated systems. As of 2020, the Institute of Education Sciences reports that 45% of schools in the United States (US) have a computer for every student (Gray & Lewis, 2021). In the same report, schools indicate that technology in the classroom helps students think critically, learn more actively, and be more independent.

Robotic Applications in Entertainment: An Autonomous Game Opponent

How can computer vision and robotics be applied in entertainment?

For the electrical engineering capstone project advised by Prof. Harry Powell, a team of five will work to take a project from concept to "alpha stage" prototype. This team consists of Hudson Burke, Zachary Yahn, Aidan Himley, Coleman Jenkins, and James Long. The team chose to design and build an autonomous foosball playing robot; the robot will operate half of a foosball table to compete against a human opponent. Foosball is a table game resembling soccer; to move the ball, players rotate and slide rods to which small figures are attached.

The rapid improvement of image processing speed and reliability allows for many new applications of robotic systems using computer vision. The US Department of Transportation (USDOT) released its Automated Vehicles Comprehensive Plan in 2021, outlining its goals and regulatory strategy for automated vehicles (USDOT, 2021). Automated vehicles implement computer vision systems to detect their surroundings, and the USDOT expects them to rise in prevalence in the coming years. In a related application, researchers present a computer vision system capable of monitoring pedestrian, bike, and vehicle traffic flow in urban areas (Li & Wang, 2006). Similar computer vision systems could inform connected robotic systems, reveal high-level trends, and contribute to relevant data sets. As a demonstration of computer vision's potential in small-scale manipulation and adaptive control, Chen and Wang (2016) presented a humanoid chess playing robot that uses a computer vision subsystem to perceive the game state (Chen & Wang, 2016). The addition of artificial intelligence models to computer vision systems expands their potential even further, influencing fields such as healthcare, facial recognition, security, and virtual reality (Mihajlovic, 2019). Because many tasks performed by humans rely heavily on an individual's sense of sight, it is intuitive that transferring this capability to a robotic system yields many exciting possibilities.

The computer vision market is often grouped with associated artificial intelligence technologies due to their commercial codependence. As of 2020, the computer vision market size was valued at 9.45 billion and is projected to reach 41.11 billion by 2030 (Abhijith, 2021). This indicates a projected compound annual growth rate of 16%. While the majority of this market share is in industrial manufacturing applications, other market segments are also expected to grow (Abhijith, 2021). This capstone project is an application of computer vision and robotics in entertainment, one of many areas where similar systems may become widespread. The technical aspect of the project aims to provide insight into the limitations and capabilities of future products while also providing practical design experience for a robotic system implementing computer vision.

Robotic Foosball Table – Overview, Design, and Prior Works

The robotic foosball table system will consist of a mechanical interface to move the foosball players, a camera and microprocessor to detect the ball, and a microcontroller with connected circuit boards to collect sensor data, plan a desired state, and control motors. Each of these subsystems will be electrically connected to one another such that information regarding the state of the foosball game can be collected, processed, and converted into a desirable response like blocking an opponent's shot or hitting the ball towards the goal. A system level overview is shown in Figure 1 below.

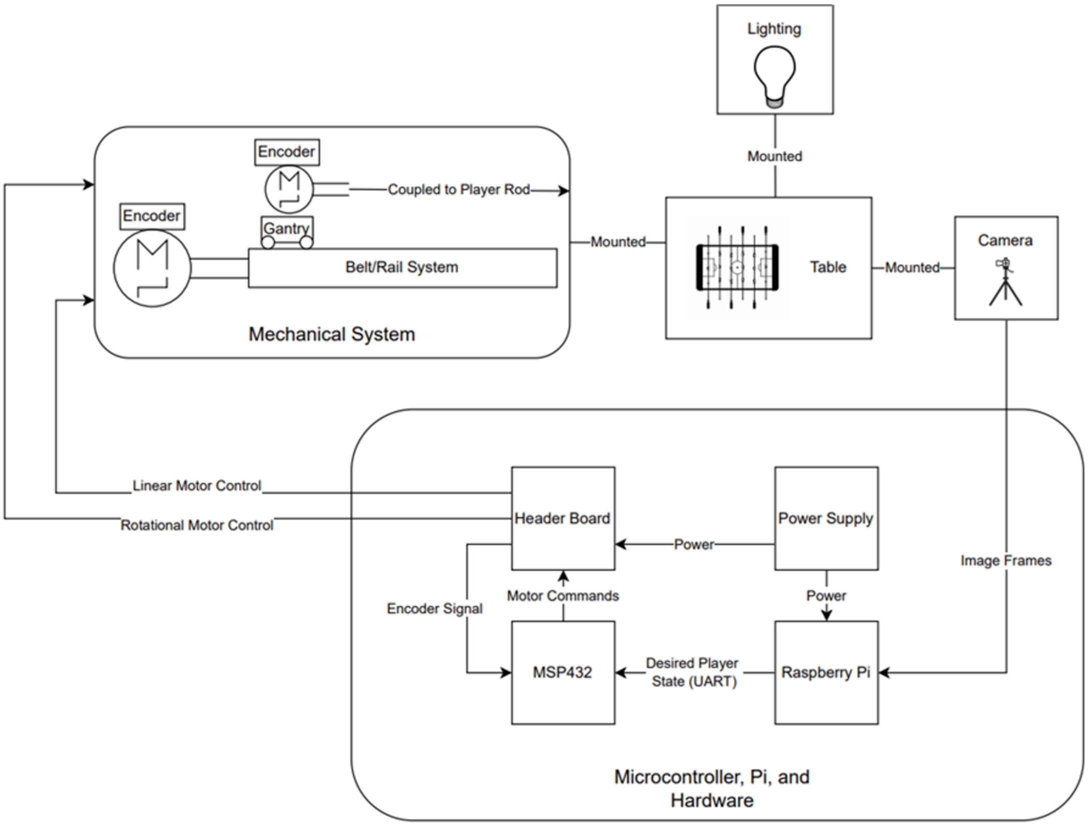

Figure 1. Robotic foosball table system-level block diagram

Students have created successful robotic foosball tables in the past, mostly in formats like this capstone project. One such example is the robot from École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland. The system created by the students at EPFL was the most powerful prior work found during our research; it tracks the ball using a 300 frames per second camera, hits the ball at 6 meters per second or more, and moves players with up to 9g of acceleration. To track the ball, the camera is situated below the table and pointed upward, viewing the game through a clear acrylic table surface (Pessina, 2013). Due to budget and time constraints, the robotic foosball table produced by this capstone project will not approach these performance metrics; however, this project will improve on hardware costs, processing power consumption, and image processing efficiency.

This project will require computer aided design (CAD) software for the mechanical assembly and circuit board layouts, access to 3D printers for part production, and an integrated development environment for embedded microcontrollers. Each subsystem of the final product will be individually prototyped and tested using an appropriate combination of oscilloscope measurements for hardware, debugging/timing tools for software, and custom simulators for intersystem communication. If successful, the result of this capstone project will be a functional prototype that operates one side a foosball table to play against a human opponent. The system will be capable of operating above baseline human performance, defined by analysis of games between two humans. Team members will gain practical design experience with robotic and computer vision systems, and the final presentation at the end-of-semester capstone fair will be interactive and enjoyable for visitors.

Alternative Forms of Interaction: How Educators Apply Technology in Special Education

In the U.S., how are educators competing to determine how best to apply classroom tech to serve children with special needs?

Special education programs serve students with physical, emotional , or behavioral disabilities (Riser-Kositsky, 2019). In the United States, the number of K-12 students with special learning needs has grown by nearly 1 million students in the last ten years (Riser-Kositsky, 2019). Spending on special education in the U.S. has not kept pace, compelling special educators to innovate and to apply technology to aid their students (Kolbe, 2022; Moreno, 2022). During the COVID-19 pandemic which forced many schools to begin remote learning, educators and other invested parties found opportunities to apply technology in special education classrooms (Wooten, Giosta & Howorth, 2021). How are special educators identifying these opportunities to apply technology to help their students?

Yet parents and educators disagree about how to serve students in special needs classrooms. Some groups form strategic alliances to serve common goals. Parents and educators generally want assistive technology (AT), such as text-to-speech systems for blind students, and therefore pressure administrators and school districts to secure funding. AccessComputing, a grant funded advocacy group, provides resources to organize parents to secure assistive technology (AT) for their children (Burgstahler, 2004). Parents and educators sometimes resort to litigation when AT cannot be secured by other means (Martin & Lindsay, 2017). Similar funding issues plague special educators trying to use new technologies in their classrooms (Langreo, 2022). Parents and educators disagree about the best use of computers in special education classrooms. One parent of a child with autism observed that “letting them use (technology) in the way that they do, has given me far more reward” (Stechyson, 2018). Others argue that, especially for children with autism, “screen time hinders the development of skills necessary for social interactions” (Dunckley, 2016).

Manufacturers of AT, education technology companies, and other businesses have material interests in technology in special needs classrooms. These groups largely market their products and services online, advertising to parents and educators involved in special education (NSEAI, 2022). The Assistive Technology Industry Association Manufacturers represents AT companies (ATIA, 2022).

Researchers have studied potential applications of technology in special education. Holzberg (1994) found that computers can help students with special needs improve their writing and communication skills (Holzberg, 1994). Hasselbring and Glaser (2000) suggested that “technology facilitates the students’ ability to make personal connections,” and offered recommendations for special education classrooms. Investigating special education teachers’ classroom experiences with technology, Anderson and Putman (2020) found that teachers valued technology that motivates students but were often disappointed by it (Anderson & Putman, 2020). To make technology more inclusive, Horejsi (2003) recommends inclusive design practices.

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