Design of a High-Performance, Low-Cost Pickleball Training Machine

Analysis of Transforming Recreational Spaces in Response to Increased Demand for Pickleball Courts in the Washington D.C. Metropolitan Region

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Computer Engineering

By
Sharon Lu

October 27, 2023

Technical Team Members:
Christian Bliss and Clara Li

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.

ADVISORS

Benjamin Laugelli, Department of Engineering and Society
Adam Barnes, Department of Electrical and Computer Engineering

Introduction

Pickleball has emerged as the fastest-growing sport in the United States in recent years, with its surge in popularity attributed to its inherently social nature and ease of learning (DeMelo, 2022). Pickleball is a racquet sport with similarities to tennis, ping pong, and badminton. When playing pickleball, players experience less physical stress than in some other sports due to a smaller court size and slower ball speed. This makes the sport more accessible to the general population and is a reason it is particularly popular among older generations (Ryu et al., 2018). Studies have shown that sports have a positive impact on the mental and physical health of adults, helping to improve confidence and lower anxiety and stress (Eather et al., 2023). As the popularity of pickleball and the demand for pickleball resources grow, it becomes increasingly important to ensure that the health and well-being benefits are accessible to all groups.

Improving one's pickleball skills and endurance without a partner can be challenging, so companies have developed machines that launch balls from the opposite side of the court to the player. These machines are expensive, and while affordable alternatives do exist, they often come with limited features, such as smaller ball capacities and a restricted range of speeds and angles for ball shots (Mackie, 2023). In response to the shortcomings of existing machines, I propose the development of an affordable pickleball training machine that offers an intuitive user interface and comparable range of motion to more expensive machines. To ensure that the machine meets user needs, it is crucial to consider the social factors impacting the recreational spaces where the machine will be used. I will draw on the STS framework of social construction of technology (SCOT) to analyze how social groups and their perspectives have influenced the development of pickleball facilities in the Washington D.C. metropolitan region.

Given the nature of increasing accessibility to pickleball, neglecting to consider both technical and social aspects leads to the risk of missed opportunities to promote well-being and ineffective solutions to increase access to training resources. Therefore, because the problem is sociotechnical in nature, both elements must be addressed. The following sections will outline two research proposals: a technical project for designing a pickleball training machine and an STS project that explores the social dimensions shaping the recreational spaces in the Washington D.C. metropolitan region in response to the growing demand for pickleball facilities. As I continue to develop the proposed machine, I will leverage insights from the study of changing recreational spaces to create a more effective and marketable design.

Technical Project Proposal

While companies have developed pickleball machines at different price points, a noticeable gap in the market remains for an affordable machine that offers the same range of features as more expensive alternatives. Companies such as Lobster and Sports Tutor have developed machines with impressive features, including launching balls with topspin and backspin at speeds of up to 65 mph. The machines also have preprogrammed drills that deliver balls to a player's forehand and backhand in various sequences. However, the machines are over $1,000 which renders them inaccessible to many enthusiasts ("Pickleball Tutor Plus Ultra," 2023; "Lobster Pickle Two Ball Machine," 2023). A popular alternative is the Furlihong Launch Machine, which retails for around $200. Nevertheless, it falls short in critical aspects. The machine shoots balls at a maximum speed of 30 miles per hour and a distance of 9 feet, which is a fraction of the 44-foot length of a pickleball court ("Pickleball Courts," n.d.). Additionally, the machine's vertical adjustment is manual, and it does not have a rechargeable battery ("Furlihong 680PBH Pickleball Starter Kit," n.d.).

The goal of this technical project is to design a machine capable of launching pickleballs across the court at different speeds, spins, and angles thereby enhancing the user's training experience. The development budget for this project is $500, so the machine will be able to compete effectively in the market as a budget-friendly option. Figure 1 shows an overview of the project architecture. The machine will be powered by a 12V rechargeable battery, and an STM32 Nucleo microcontroller will handle the control systems. A microcontroller is a computer on a small integrated circuit. The printed circuit board (PCB) is responsible for supplying power to different mechanical components, regulating the speed and direction of the motors and linear actuators, and ensuring that the board itself does not overheat. A linear actuator is a device that extends or retracts in a linear motion. The microcontroller will run the internal logic for the system, controlling the dispensing frequency, launch speed, and trajectory of the balls. It will also interface with the LCD screen where the user will select different settings.

Figure 2(a) and Figure 2(b) provide a detailed look at the computer aided design (CAD) model and prototype of the internal mechanical components of the proposed training machine. A disk rotates at the base of the ball reservoir knocking pickleballs into the chute that feeds into the metal launching frame. Two motors spin concurrently to eject pickleballs up to 40 mph, and the varying speeds of the two motors will allow for different types of shots such as topspin and backspin. When the top motor spins faster than the bottom motor, the ball will rotate backward producing a backspin. When the bottom motor spins faster than the top motor, the ball will have a topspin. The relative motor speeds were determined by analyzing the physics of a tennis ball with topspin and backspin ("The Physics of Tennis | Ball Spin In Flight," 2014). The first linear actuator is mounted to the rotating base below the metal launching frame. As the actuator extends and retracts, the launching mechanism pivots horizontally. The second linear actuator is

mounted to the metal launching frame. As it extends and retracts, it pushes and pulls the frame about the hinge which increases or decreases the vertical launch angle.

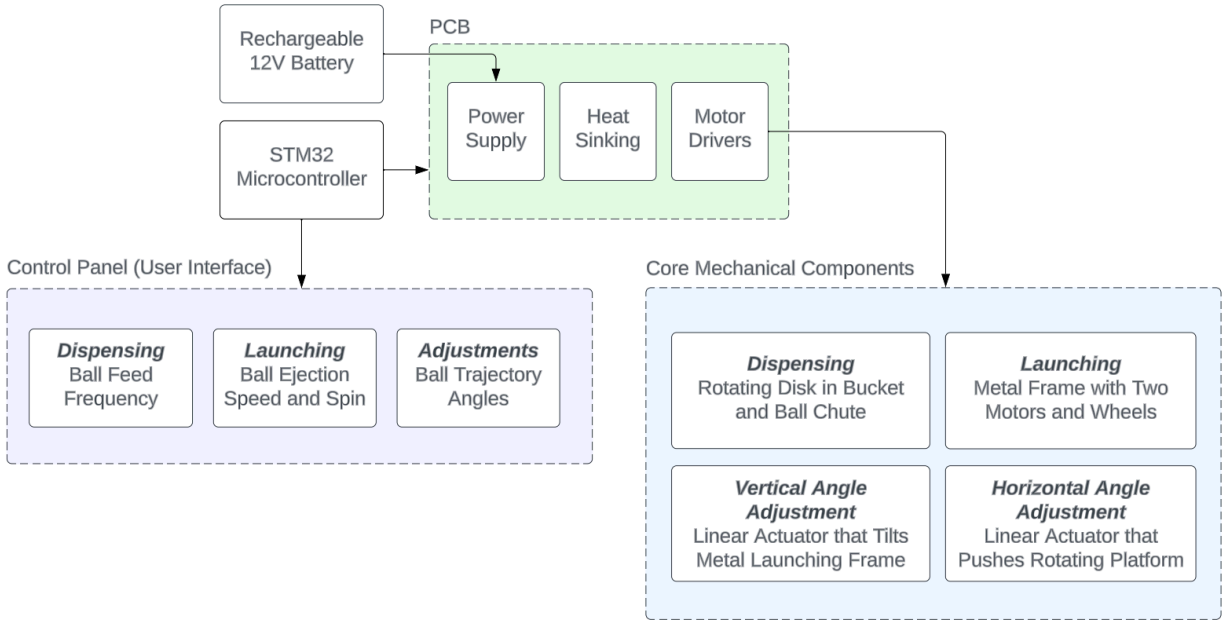
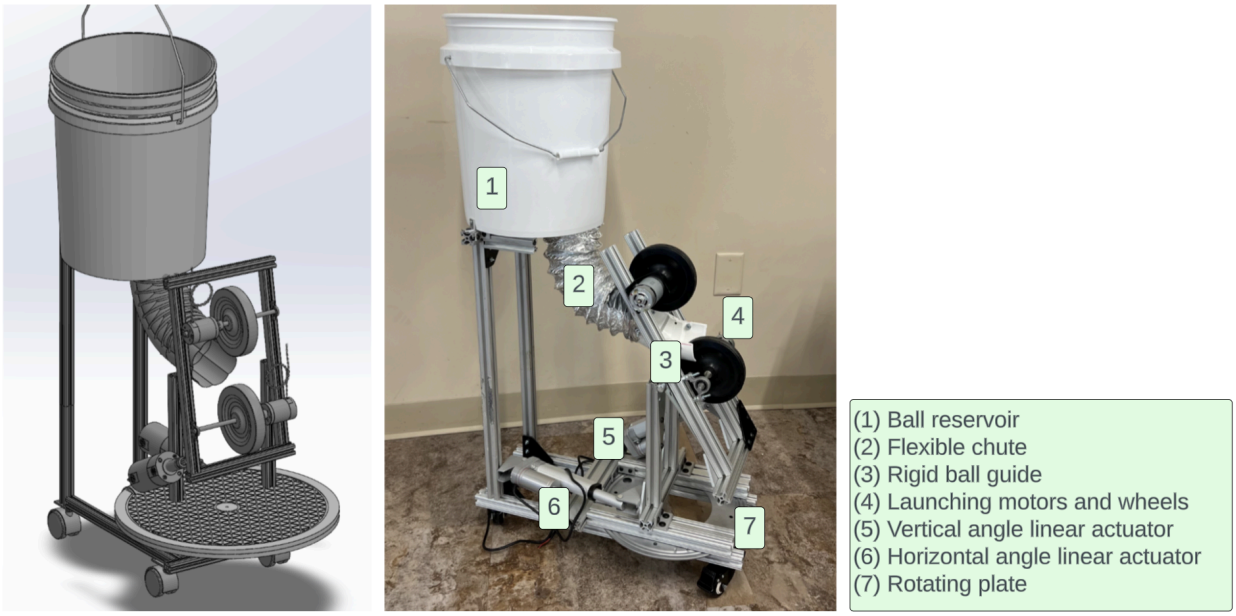


Figure 1. Pickleball Training Machine System Architecture



(a) (b)

Figure 2. Pickleball Training Machine Mechanical Design

In terms of mechanical design, it will be important to select durable and stable materials because the motors will be spinning at high speeds to launch balls above 40 mph. When designing the PCB, careful consideration must be taken when routing the power and handling heat distribution. Understanding how to regulate current and voltage appropriately will ensure that the machine components maintain their integrity. Additionally, the circuit layout will be comprehensively tested with an oscilloscope, an electronic measurement tool, on a breadboard and simulated in KiCad, the electronic design software that will be used. The embedded system will be developed in parallel with the PCB to ensure that the functions controlling the motors and linear actuators perform as expected.

Throughout the development of the prototype, videos of the ball launches will be taken and analyzed to see how the ball speeds and trajectories compare to the project specifications. The results of these tests will influence what adjustments need to be made to either the components or the control systems to align more closely with user needs. Because the machine will be battery-powered, power consumption data will be collected throughout development and components will be chosen to improve energy efficiency. Additionally, the team will receive user feedback from the prototype and integrate any changes.

STS Project Proposal

Although pickleball was founded in 1965, its recent surge in popularity can be attributed in part to the COVID-19 pandemic when there was a need for physical activity but at a safe distance (Meyersohn, 2023). In the years following, the demand for pickleball courts has increased and groups in the D.C. metropolitan area have taken different approaches to create more pickleball courts. The region includes D.C., Montgomery County, Prince George's County, Arlington County, Fairfax County, Alexandria, and Falls Church ("§ 2–1105. "Washington

metropolitan region" defined," n.d.). In public spaces, the application of pickleball court lines onto tennis and basketball courts, like what has been done at the Jefferson Field courts in D.C., has sparked several complaints from tennis and basketball players and residents in the area who find the sport too loud. Within the private sector, businesses like Dill Dinkers, an indoor pickleball court chain with a location in Montgomery County, Maryland, have repurposed old indoor trampoline parks and warehouses into an indoor pickleball court space (Kenney, 2023). This study aims to understand the social factors influencing the design process of recreational spaces.

Regarding the development of pickleball courts in the D.C. metropolitan region, the current discourse is limited to determining the objective functionality of a design rather than the interplay of different social factors. For instance, articles highlight the space efficiency of new court construction and the convenience of the location of the pickleball courts added (Spears, 2023). This incomplete assessment overlooks broader sociotechnical factors at play for the designers including how the tensions these spaces have created with user groups, such as tennis and basketball players who previously used these spaces, impact development. I argue that the adoption of pickleball courts within recreational spaces is a socially constructed process driven by user perspectives and relationships between relevant social groups. While the technical functionality of courts is important, there are more social factors at play. Accounting for these different perspectives explains why some attempts to expand the number of pickleball courts, such as painting lines on existing courts or mandating playing schedules for public courts, have led to park vandalism and protests in the D.C. region.

To analyze the transforming recreational landscape, I will draw upon SCOT, an STS framework developed by Trevor J. Pinch and Wiebe E. Bijker that suggests how the development

of technology is shaped by the interactions, interpretations, and interests of various social groups. SCOT also highlights the idea of stabilization, or when relevant social groups agree upon one design that satisfies the needs of each group (Pinch & Bijker, 1984). I will assess the various social groups involved in transforming recreational spaces, including pickleball players, tennis players, local government authorities, and community members. Additionally, I will explore how the influence of these groups contributes to a given design. To conduct this analysis, I will review urban planning documents, news articles that have interviews with stakeholders involved in the development of pickleball facilities, and community engagement forums.

Conclusion

The technical project deliverable will be an affordable pickleball machine prototype with adjustable launch settings and full-court coverage. This machine will launch balls up to 40 miles per hour with topspin, backspin, and horizontal and vertical oscillation. A custom PCB will be designed for power regulation and heat dissipation. The STS research paper will leverage the SCOT framework to examine how social factors influence the initiatives that expand access to pickleball spaces in the Washington D.C. metropolitan region. The insights into the interactions and perspectives of various social groups will serve as a guide for designing a pickleball machine that not only offers a high-quality training experience on recreational courts but also caters to the changing needs of stakeholders. This approach will address the overarching sociotechnical challenge of ensuring that the benefits of playing pickleball are accessible to a wider audience, ultimately enhancing the mental and physical wellbeing of its players.

References

§ 2–1105. "Washington metropolitan region" defined. | d. C. Law library. (n.d.). Retrieved October 27, 2023, from https://code.dccouncil.us/us/dc/council/code/sections/2-1105

DeMelo, J. (2022, September 3). Why is pickleball so popular? *The New York Times*. https://www.nytimes.com/2022/09/03/well/move/pickleball-popular-sport.html

Eather, N., Wade, L., Pankowiak, A., & Eime, R. (2023). The impact of sports participation on mental health and social outcomes in adults: A systematic review and the 'Mental Health through Sport' conceptual model. *Systematic Reviews*, *12*(1), 102. https://doi.org/10.1186/s13643-023-02264-8

Furlihong 680pbh pickleball starter kit. (n.d.). Retrieved October 27, 2023, from https://www.amazon.com/Furlihong-Pickleball-Including-Recycling-Pickleballs/dp/B0BPXSKPP2

Kenney, E. (2023, August 19). Pickleball, the fastest growing sport in the country, is moving indoors. *NPR*. https://www.npr.org/2023/08/19/1194077043/pickleball-indoors-malls-noise-tennis-courts

Lobster pickle two ball machine. (n.d.). PickleballCentral.Com. Retrieved October 27, 2023, from https://pickleballcentral.com/lobster-pickle-two-ball-machine-el0p2/

Mackie, B. (2023, September 28). *Best pickleball machine in 2023—Top 8 compared*. Pickleheads. Retrieved October 27, 2023, from https://www.pickleheads.com/pickleball-gear/pickleball-machine

Meyersohn, N. (2023, March 11). *Pickleball is America's fastest-growing sport. These people hate it | CNN Business*. CNN.

https://www.cnn.com/2023/03/11/business/pickleball-sports-noise-complaints-tennis-ctpr/index.html

Pickleball courts. (2013, June 27). https://usapickleball.org/what-is-pickleball/court-diagram/

Pickleball tutor plus ultra. (n.d.). PickleballCentral.Com. Retrieved October 27, 2023, from https://pickleballcentral.com/pickleball-tutor-plus-ultra/

Pinch, T. J., & Bijker, W. E. (1984). The social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science*, *14*(3), 399–441. http://www.jstor.org/stable/285355

Ryu, J., Yang, H., Kim, A. C. H., Kim, K. M., & Heo, J. (2018). Understanding pickleball as a new leisure pursuit among older adults. *Educational Gerontology*, *44*(2–3), 128–138. https://doi.org/10.1080/03601277.2018.1424507

Spears, H. (2023, September 13). *Pickleball on the National Mall? Yes, it's actually happening. - Washingtonian*. https://www.washingtonian.com/2023/09/13/pickleball-on-the-national-mall-yes-its-actually-happening/

The physics of tennis | ball spin in flight. (n.d.). Retrieved October 27, 2023, from http://ffden-2.phys.uaf.edu/webproj/211_fall_2014/Max_Hesser-Knoll/max_hesserknoll/Slide3.htm