LaserF: A Prototype Laser-Powered Soccer Training Tool Product

ECE 493: Product Design

Matthew L Bloom, Danny Campbell, Lelia Jennings, Jake Mann

Abstract

The smart fitness market is one with plenty of opportunity for innovation, and our product design team decided to investigate the market for sports training. Training tools are often restricted to amateur players due to cost and availability. LaserF is a product meant specifically for soccer to increase accessibility to these tools and performance for these players. By utilizing a grid of lasers, we can find the position and speed of shots, both useful metrics for those looking to improve their consistency, accuracy, and power. The product also provides a UI to visually represent this data. Each laser in the grid of 27 has a complementary circuit with a photoresistor used as the receiver and a trimmer potentiometer used to read and adjust output voltages when lasers are obscured by balls passing through the goal. The hope of the team is to improve accessibility to high-level sports by easing the training process for amateurs. Using similar technology, there is also room to expand into other sports. The software could also be expanded to provide more flexibility and customization for the training experience.

Introduction/Previous Work

The project focus was set to brainstorm and prototype a product in the "smart fitness" market. The work is based on the existing Hawk-Eye camera and computer vision system that is used in soccer as a goal-line technology. Instead of utilizing the precision required for that purpose, the final product focuses on a training tool for soccer players without access to this expensive technology. LaserF's system uses a grid of laser-receiver pairs to provide a precise localization of where the ball goes in the net as well as its speed. One can record this data over the course of a training session. Then, the user would utilize this so that they can focus on aiming their shots toward a certain part of the goal, for example, and evaluating how well they achieve that precision.

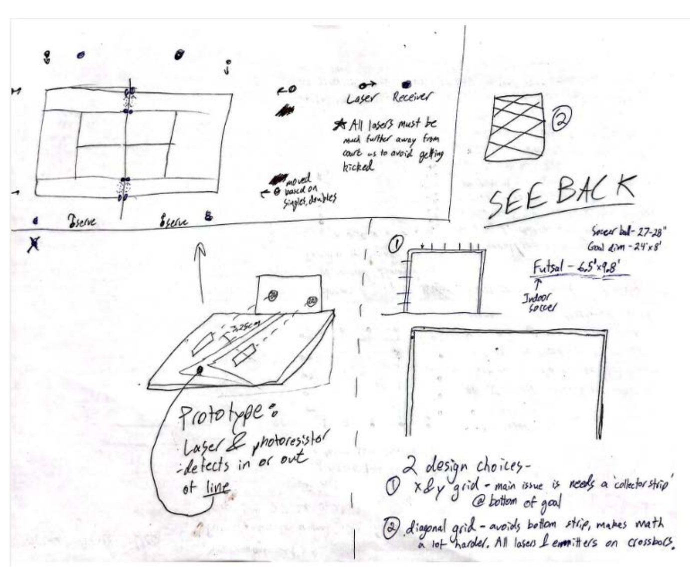

Fig. 1 Initial design idea sketches. The sketches on the left depict the team's original idea, which focused on a laser-powered alternative to the Hawk-Eye system used for line judging in tennis. Considering the difficulty of accurately making on-the-line calls and the potential danger to players of having a physical system on the court, the team pivoted to the soccer system, pictured on the right. Ideas for a standard vertical-horizontal "grid" or a system of diagonally aimed lasers were considered.

Acknowledgements

The product team was supported by advisors in the Pratt School of Engineering's departments of Electrical and Computer Engineering and Mechanical Engineering. Thank you to both Professor Tyler K. Bletsch of ECE and Dr. Rebecca Simmons of ME for the advice, expertise, and structure they provided to the team. Thank you to Patrick McGuire, the ME Senior Lab Adminstrator, and Kip Coonley, the ECE Lab Manager, for their assistance in selecting and obtaining supplies for the project. Construction was completed in Duke's Colab design space.

References

Hawk-Eye Innovations. (n.d.). Retrieved December 4, 2022, from https://www.hawkeyeinnovations.com/

Design, Methods, and Prototyping

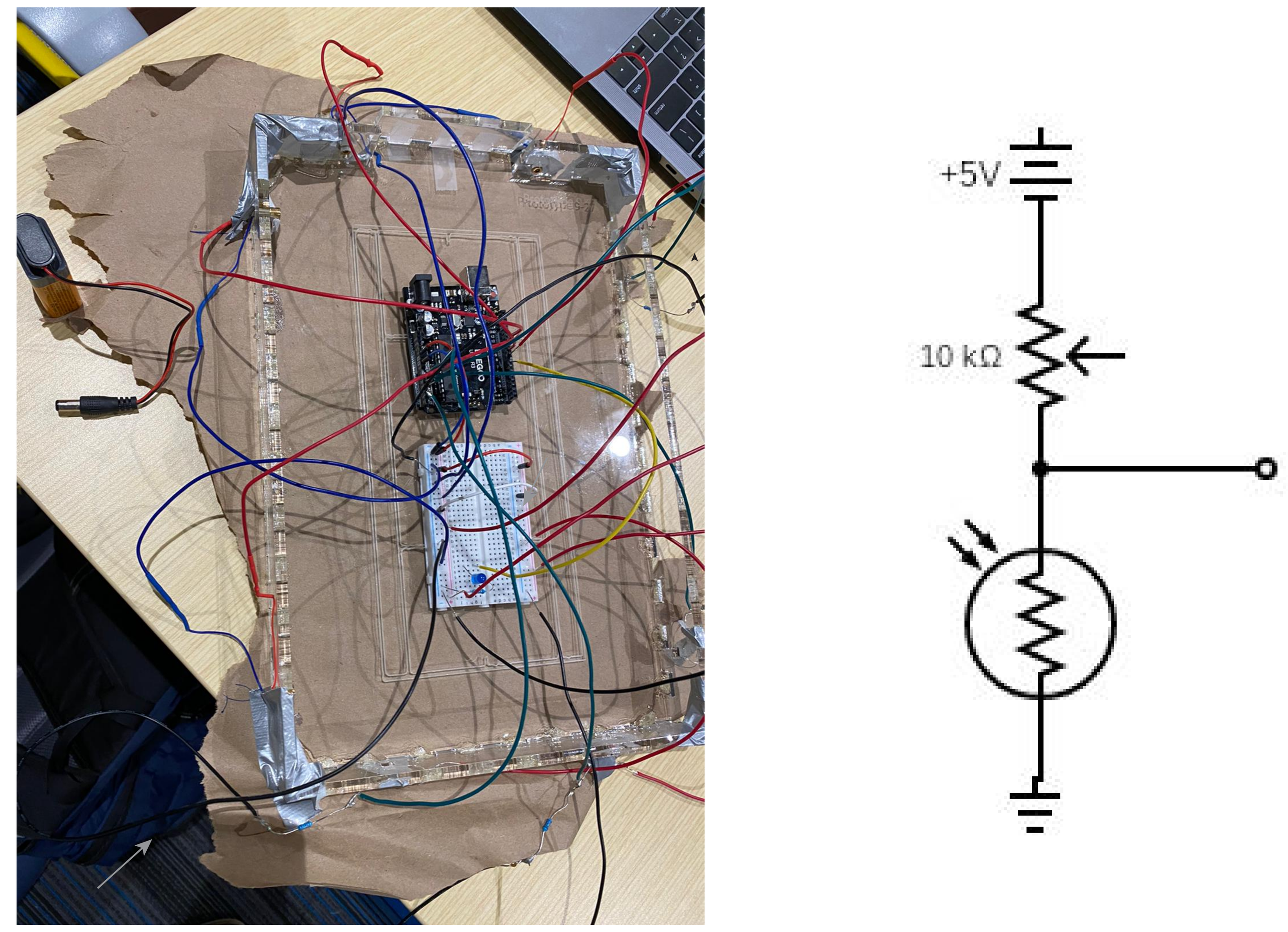

Fig. 2 Initial tennis prototype and circuit. Left, the team's first prototype for tennis line judging. Right, the circuit used for sensing at each photoreceiver in the final laser grid. The voltage divider across the potentiometer and the photoresistor is adjustable in order to tune the output voltage to digitally read output voltages with a 2V threshold based on ambient light.. When the ball goes through the goal and obscures the receiver, the voltage is above 2V, and then returns to below 2V when the receiver is uncovered and exposed to the laser diode's beam.

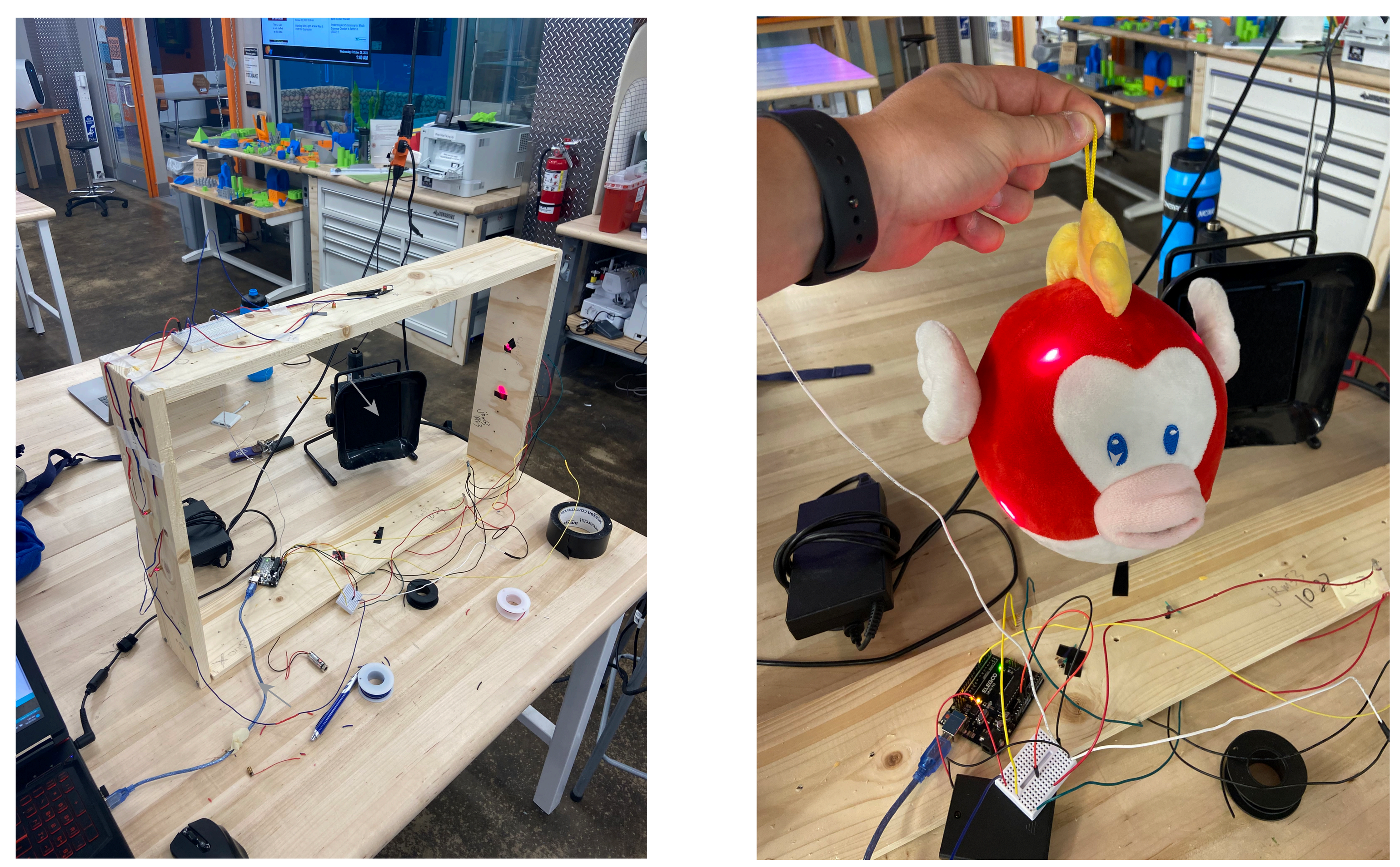

Fig. 3 First soccer prototype views. Left is the full view of the 2 x 2 grid of laser-photoresistor pairs. The wood was cut with a ShopBot to create mounts for the lasers and receivers. Right, a close-up demonstration of a "ball" obscuring multiple lasers at once. The final grid is set up so that at least 3 lasers are "hit," and the position is extrapolated through a weighted average of the positions of the obscured sensors.

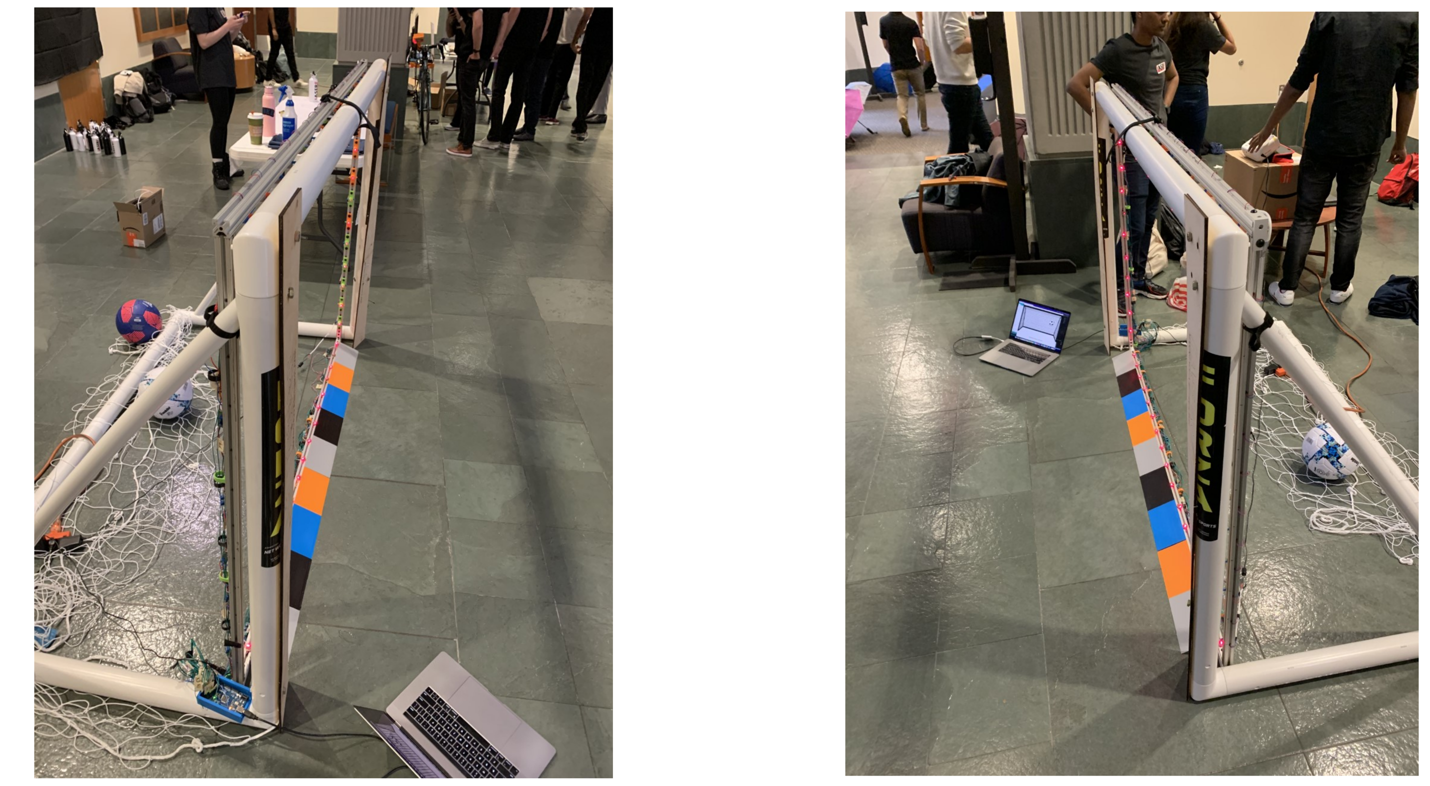

Fig. 4 Final prototype mounted to goal. Left side, view from the left of the completed laser grid attached to a soccer goal. Along the top and the right upright there are 27 total adjustable 3D-printed mounts for the laser diodes. On the right is the view from the right side, with a view of the mounted complementary photoresistors. Each photoresistor has a circuit as depicted in Figure 2 attached for sensing.

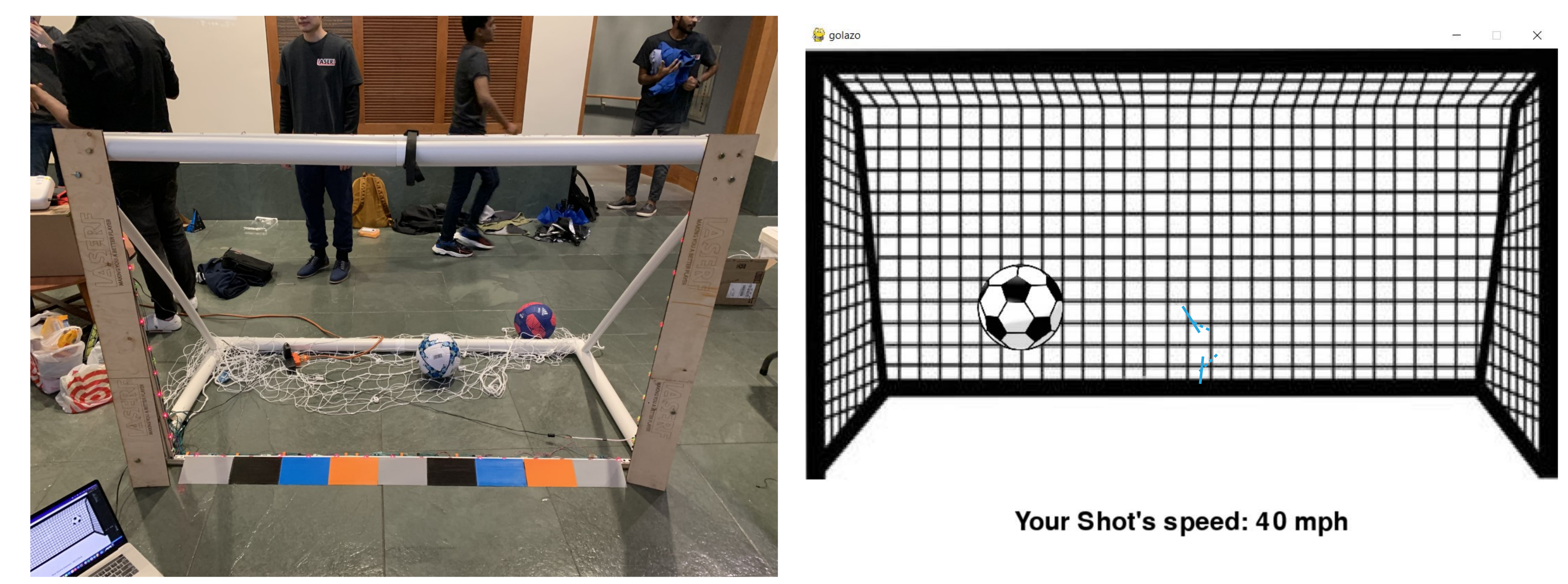

Fig. 5 Final prototype front view and UI. Left image, front view of the final prototype. The 3D-printed ramps along the bottom are meant to protect the bottom array of photoresistors. The wood panels protect the lasers and receivers on the sides. On the right, the graphical UI that displays the position of the ball after it goes through the goal. Unfortunately, the speed calculation was not functional for our final demonstration. The UI was created using Pygame, a Python library for making games and GUIs.

Conclusion and Future Work

The completed final prototype was reliably successful in localizing shots on goal. Speed calculation was not fully working for the final demonstration, but from earlier testing the results indicated errors of less than 10%. In the future, we would want to develop a more robust UI and UX. Some possible features would be the ability to record a "session" of shots while training and provide statistics. Flexibility is also a concern due to the use of trimmer potentiometers, so digital potentiometers could be an alternative. We also encountered some structural and wiring issues to be resolved.