Engineering a lacrosse training device for performance tracking

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Introduction

Lacrosse is a high-intensity sport that demands rapid decision-making and precise shot placement, making it ideal for performance analysis. Although response time (RT) plays a critical role in athletic performance, "there is an evident lack of reliable and valid sport-specific measurement tools applicable in the evaluation of RT in trained athletes" (Pojskic et al., 2019). This limitation is evident in lacrosse training, where performance is often assessed through subjective observation rather than quantifiable metrics. To address this gap, this project aimed to develop a training system capable of detecting ball entry location to calculate shot accuracy and tracking ball entry time in response to a visual cue to estimate player reaction time. By integrating ball detection with real-time data processing, the system was designed to provide athletes with measurable feedback on shooting precision and responsiveness to enhance skill development and overall performance in a game-like scenario.

Methods and Materials

Infrared (IR) break-beam sensors were selected to detect the lacrosse ball due to their compact size, cost efficiency, and reliable binary detection output. These sensors function by transmitting a continuous IR beam between a paired emitter and receiver; interruption of the beam by an object generates a digital signal that can be processed. A small prototype (Figure 1) was first designed to validate detection accuracy and code logic. An ESP32 microcontroller processed sensor inputs and controlled WS2812B individually addressable LED strips, which visually indicated the active target. The system was programmed using Arduino IDE to sequence target activation, monitor beam interruptions, and record performance data. An enclosure and printed circuit board (PCB) were designed in Autodesk Fusion to ensure all components could be safely housed and electrically connected within a compact layout (Figure 2).

Figure 1 (above): Prototype (10 × 10 in.) was designed in Autodesk Fusion and constructed using 3 mm plywood and 3D-printed holders.

Methods and Materials (continued)

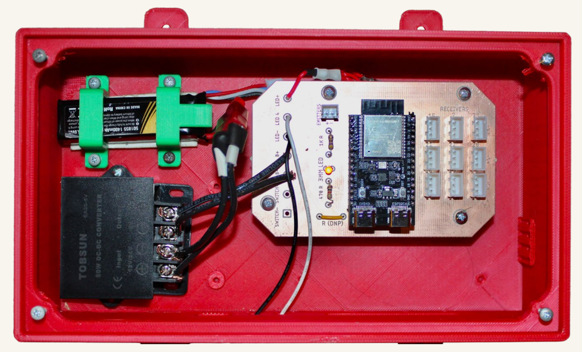


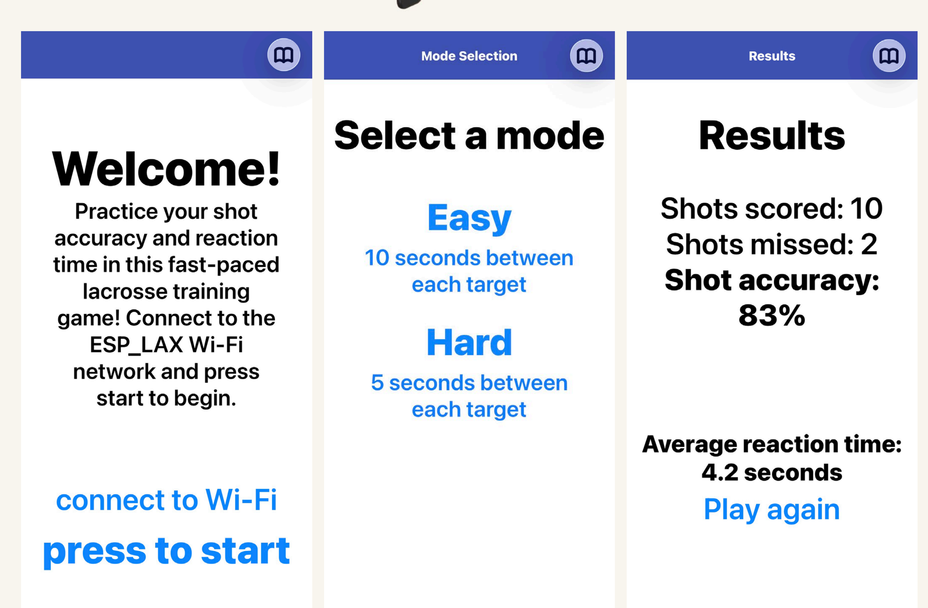
Figure 2 (left): Enclosure (8.3 × 4.6 × 2.7 in.) containing a lithium polymer (LiPo) battery for power, a buck converter for voltage regulation, an ESP32-C6 microcontroller for processing sensor inputs and Wi-Fi communication, and a PCB designed to integrate and organize electrical connections between components.

After prototype testing, multiple structural configurations were evaluated before finalizing the full-scale design. The completed system incorporated a commercial lacrosse goal cover with pre-cut openings positioned at optimal shot placements that was mounted to a 6 ft × 6 ft lacrosse goal. LED strips were cut into 9-inch segments and glued to the back of the goal cover to outline each target square. Sensors were mounted using wire racks, bungee cord, and 3D printed holders fastened to the top of the goal net to maintain beam alignment and structural stability under repeated impact.

Figure 3 (left): Player's view of goal with middle, right square illuminated in green to indicate a successful shot.

Figure 4 (left): Rear view of a single sensor module containing three paired IR emitters and receivers. The modules were mounted two inches behind each target opening to detect ball passage while remaining protected from direct ball impact.

Additionally, a mobile application for both Android and iOS devices was developed using MIT App Inventor. The app connected to the ESP32 via Wi-Fi and enabled users to select game modes, initiate training sessions, and view recorded performance metrics.



Figures 5–7 (above): Screenshots of welcome screen on the app, followed by mode selection and training session results.

Results

The training device was validated through outdoor testing in which a lacrosse ball was gently tossed through each target opening from approximately 2 feet away. Each target received 111–112 tosses, with care taken to ensure the ball passed cleanly through the designated area on each attempt. This process was repeated across all targets, allowing for systematic evaluation of IR sensor detection accuracy and reliability.

Accurate detections	False positives	False negatives	*N*	Event	Sample *p*	*z*-value	*p*-value
928	1	72	1000	928	0.928	−3.192	.999

Table 1 (above): The observed proportion of accurate sensor readings (0.928) indicated high reliability; however, a one-tailed one-sample proportion *z*-test showed no evidence that this value exceeded the hypothesized benchmark of 0.95, ($p = .999$).

LED indicators activated correctly for 6 targets, with 3 failing to consistently illuminate. This demonstrated partial but functional integration of the sensing, processing, and feedback system.

Conclusions

In response to the need for objective, sport-specific methods of measuring response time and performance in athletic training, this project produced a functional lacrosse training device capable of quantifying shot-accuracy. Although large-scale user testing was not completed, individual testing confirmed that the core system (including sensing, structural assembly, and app communication) operated reliably. Minor issues with LED consistency highlight areas for refinement, particularly in wiring, power supply, or component quality. Future work should include full-scale, team-based testing to evaluate the device in realistic training conditions and confirm its effectiveness in improving shooting performance.

References

Pojskic, H., Pagaduan, J., Uzicanin, E, Separovic, V., Spasic, M., Foretic, N., & Sekulic, D. (2019). Reliability, validity, and usefulness of a new response time test for agility-based sports: A simple vs. complex motor task. *Journal of Sports Science and Medicine*, *18*(4), 623–635. https://pmc.ncbi.nlm.nih.gov/articles/PMC6873124/