SkillCourt Autonomous Soccer Ball Reload Mechanism

Jose Perdomo, Adrian Sinanan, Tahsin Asgar, Rodrigo Arredondo, Sabri Tosunoglu

Department of Mechanical and Materials Engineering
Florida International University
10555 West Flagler Street
Miami, Florida 33174

jperd033@fiu.edu, asina001@fiu.edu, tasga001@fiu.edu, rarre001@fiu.edu, tosun@fiu.edu

ABSTRACT

In this paper, a reload mechanism for the autonomous SkillCourt ball launcher is proposed. SkillCourt is an up and coming soccer-training system used to develop player cognitive and decision-making skills using computer aided technology and automated feedback capabilities. By incorporating an autonomous ball delivery system, the goal is to improve the quality of training sessions. Furthermore, the project aims to improve the overall user experience, and allow multiple users to customize their own routines. This is accomplished by the reload mechanism's capability to track the user in motion, and interact with the SkillCourt software with little human interference.

Ball delivery systems are already common and widely used in sports such as tennis, football, and baseball. These devices have similar traits in means of function and purpose, but most lack autonomy and diversity in the complexity of delivery. For soccer, there are both advanced and basic mechanisms capable of various trick shots and passes currently available on the market. Unfortunately, most of these systems lack of autonomy and user based capabilities require human intervention. Not to mention the increasing costs of such systems may prevent households or academies from acquiring one.

For these reasons, the main objectives are reducing cost, improving motion capabilities of the ball delivery mechanism, independent loading and unloading of a ball, user tracking, and automatic delivery integration with the SkillCourt software The team built and tested a prototype based on a commercially available system. The system's main features of tracking, auto loading, and SkillCourt software) were implemented. Last, the continuous optimization and functionality of the system scrutinized.

Keywords

Autonomous Ball Launcher, SkillCourt, OpenCV-Player Tracking

1. INTRODUCTION

Ball delivery systems are already widely used for many types of sports across the globe. These devices have similar traits in means of function and purpose, but many lack user interaction capabilities and customizations. The main design will address movement capabilities of the ball delivery mechanism, independent loading and unloading of a ball, player motion tracking, and automatic delivery integration with the SkillCourt software. A prototype using concepts from commercially available launchers, as well as tracking software worked as expected.

2. Autonomous Ball Launcher

The industry of ball launching devices is very diverse and ranges across many sports, of which the biggest consumers are baseball and tennis. Currently, there are additional launchers for other sports such as soccer, volleyball, and football, although they lack intricacy and do not provide user feedback. These launchers have capabilities such as speed adjustment, trajectory customization, and a variety of unique shots and passes achieved through their respective systems. Some previous works considered are the Sidekick and First Pitch ball launching systems seen below in Figure 1.

Figure 1.Sidekick Ball Launcher

The user controls the ball's trajectory through the manipulation of the tire's speed and angular position of the mechanism.

Specifications will include structure of the launcher and its positional transition in the course of an operation. Though numerous systems are available, their higher cost limits athletes from affordable options. Consumers would desire a launcher that is affordable, provides a wide variety of features, and directly interacts with the user.

2.1 OpenCV- Player Tracking

OpenCV (Open Source Computer Vision Library) is an open source software library that is used in computer vision and learning applications. OpenCV supports Windows, Linux, MacOS, and Android operating systems, and interfaces with C, C++, Java, Python, or MATLAB. Additionally, this software library features algorithms used in face recognition, object identification, motion tracking, and three-dimensional object plotting, with potential for multiple subjects. OpenCV software brings a range of applications that are useful in the ball launcher's player tracking characteristic.

At Florida International University, an Electrical Engineering senior team featured this software in their American Football launcher, to track and estimate the position of a person attempting to catch the football. Their system consisted of two cameras that recorded the player's movements, while the software would track the player and rotate the ball launcher accordingly, seen below in Figure 4. Additionally, to estimate the distance between the ball launcher and the player, the concept of triangulation is used. This method allows for the accurate approximation of an objects distance and relative position using two or more points.

Figure 2. Autonomous Football Throwing Machine

2.2 Automatic Loading Machines

Automation for ball launchers does exist, but consists of a two-machine system where the balls are first collected by a loader and delivered to a launcher. These are prevalent in the tennis industry as tennis academies and training facilities use a large number of balls. If a person is to collect them individually, training sessions become interrupted and inefficient. For example, the Tennibot shown in Figure 5 is a patent pending robot that is able to identify tennis balls apart from different objects on the court.

Once identified, the loader will then gather up to seventy tennis balls autonomously, or via remote control. After the collection process is complete, the balls can be loaded back into the launcher using a bucket, net loading system, or manually. This concept can be applied to soccer training by integrating a similar mechanism that will collect balls provided by the user, and then directly load the balls into the launcher.

Figure 3. Tennibot

2.3 Mobility and Tracking

The chief focus of the product is its ability to track a player in motion and accurately launch the ball. The machine is capable of determining the distance and pinpointing a players' position based on their movement while at the same time, delivering an accurate pass. This is possible due to the working range and mobility capabilities of the launcher.

The Launcher is able to rotate in terms of roll, pitch and yaw. For yaw, or oscillating around the vertical axis, the launcher is capable of rotating ±60 degrees from its initial position. As for roll and pitch, or rotating along the z-axis and x-axis respectively, the launcher can rotate 45degrees tilt in either direction. In addition to its maneuverability, the launcher has been fitted with a self-locking mechanism. This allows for five different types of preset soccer strikes and passes for a variance in play.

2.4 Reloading

The Ball Collection and reloading of the Ball Launcher is capable of storing up to five size No.5 soccer balls at any given time. This area of storage will then transfer the balls into the shooting segment automatically delivering a ball. The Ball Launcher will then fire a shot every 7 seconds in order to maintain a lively and continuous workout. In addition to a workout, with consumer use in mind, the reloading mechanism would be easily assembled and attached to the main component of the launcher and easily detach as needed.

2.5 SkillCourt Integration

SkillCourt is the main software selected to communicate with the ball launcher. SkillCourt provides a user feedback and timing system that encourages the trainer to improve reaction times and practice their skills.

Training drills can be used to integrate the launcher, reloading, and collection systems, with SkillCourt to time and test player's performance. The software allows the user to communicate with the launcher to begin a drill, and the collection device to complete the drill, while providing various stats such as ball velocity and time of completion.

3. Design Components

The flow chart below illustrates the hardware used on the design. As shown on Figure 6, the main components are the Arduino UNO, and a stepper actuator. Other items used are a variety of sensors and LED technology. Once fitted to the frame, these allow for a simple but effective system. Using the Arduino, a continuous reloading process is created.

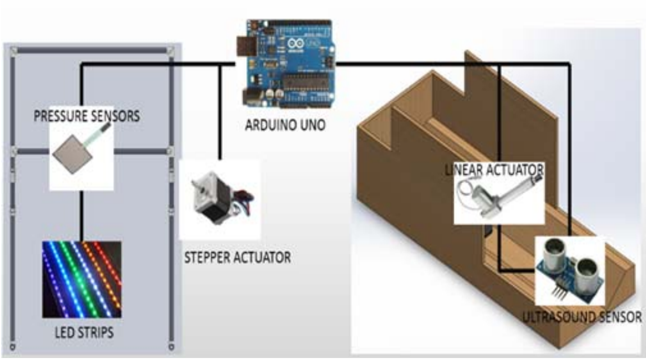

Figure 6. Triangulation Diagram

3.1. OpenCV Motion Tracking System

As previously stated, OpenCV, an open source vision software, will be used for the main tracking and distance measuring algorithms. OpenCV works with several programming languages. Some of these include C, C++, and Python, which are the most common, and user friendly. A recent FIU EE senior team project based on motion tracking and distance measuring used this software. In their project, OpenCV interacts with two webcams to track the movement of a person. Likewise, using an Arduino, a servo motor rotates to aim the ball launcher.

Similarly, the SkillCourt ball launcher employs an Arduino and a single servo to achieve the third degree of freedom (i.e. yaw rotation) needed by the ball launcher. In order to calculate the position of a target, the triangulation method is used. As shown in Figure 7 below, there are two cameras on the same axis, at a fixed distance-from each other. Using the angle provided OpenCV draws a line drawn from each camera to the object being tracked, thus creating a triangle from which a distance relative to the launcher is obtained.

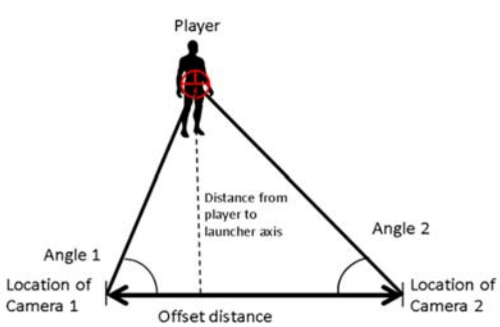

Figure 7. Triangulation Diagram

There is, however, an issue with the triangulation method, in regards to the distance approximation and accuracy range that it can provide. The accuracy of long distance measurements depends highly on the quality of the cameras used. As the object being tracked moves away from the cameras, the depth of field increases and the cameras struggle to focus on the object. Although high-end cameras are more efficient, it increases the cost of the system significantly.

Since the current SkillCourt training system does not utilize an extensive field area, the limit of the tracking device has been set to 20 yards. Therefore, using this distance measuring method is suitable for prototype purposes. As an alternative to using cameras, measuring distance via lasers can be very effective on stationary objects at long distances. However, with moving objects the time of flight of the laser can slow down the distance reading. These lasers provide many benefits but are far more expensive than the two-camera method as Laser distance measuring devices range in the hundredths. Consequently, the motion tracking and distance measuring with OpenCV is a more feasible option.

3.2. Reloading Mechanism

Referring to the images below, Figures 8a and 8b depict the first iteration of the reloading system. In this design, there are two concepts from the SkillCourt ball launcher project adapted to the system. First, the receiving mechanism is composed of a wall curved in the shape of a wave that elevates a ball to a catching net. The ball then drops down to a rail that will hold and guide it to the next-section. Here, the transition of the ball from the loader, to the launcher system is controlled. As the ball rolls into position in the launcher, a piston then pushes it into the mechanism’s flywheels propelling the ball to the target.

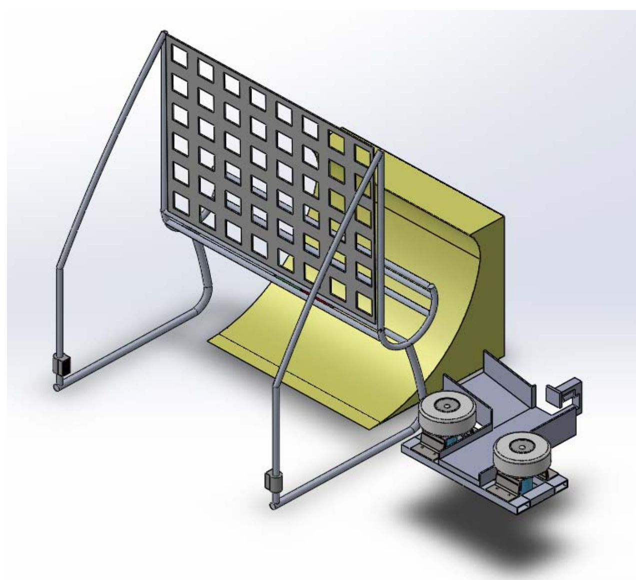

Figure 8a. Conceptual Design of SkillCourt Launcher System.

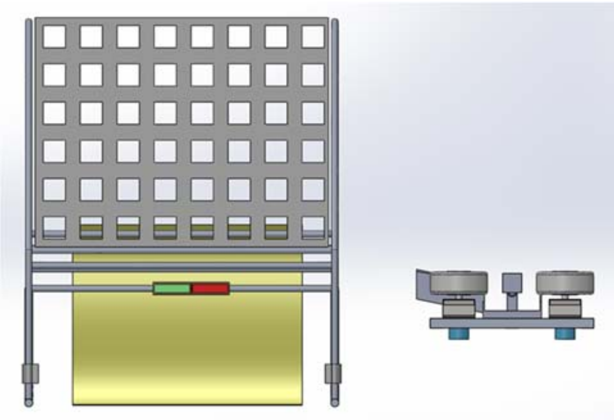

Figure 8b. Conceptual Design of SkillCourt Launcher System.

In addition to the previous systems, there will be sensors controlling and giving feedback to the player. When the ball goes in, an LED display lights up showing the player a green light if the ball properly reaches the rail. Similarly, a red light lights up if the ball does not reach the rail. In addition, there are other sensors and servos controlling the system. One of these is a pressure sensor, which activates an actuator when a ball is in the correct position before propelling it. Aiming to further improve the process and lower the cost of manufacturability, other changes are as follow:

- The connection between the launcher and the ramp was improved
- Actual placement for the linear actuator was changed
- Different sensor locations and orientations were tested in order to ensure optimal ball detection
- Cost efficient materials
- Easy assembly for consumer usage

The reloading mechanism has gone through several trial and error stages in order to position the ball correctly in the launcher. **Figure 9** represents the first iteration of a link between the net and the launcher system. This component is necessary in order to facilitate the ball's transition from the net to the launcher's linear actuator. Without it, the ball could be stuck in the rail, fall off the net, or transition to the wrong position.

If any of above, issues were to present themselves, manual feeding would be required. In order to reduce the load of friction for the ball, the edges of the link were made into curves that would follow the contour of the ball. With portability and consumers in mind, the ramp is also equipped with an interlocking connection in which it would "snap" into place as well as come apart for effortless assembly and transportation. Last, at the far end of the mechanism, there is a series of four circular protrusions, where the sensors that communicate with the loading mechanism are located. In essence, once the ball goes over the sensors, the actuator moves into position for the ball to line up properly into the slot.

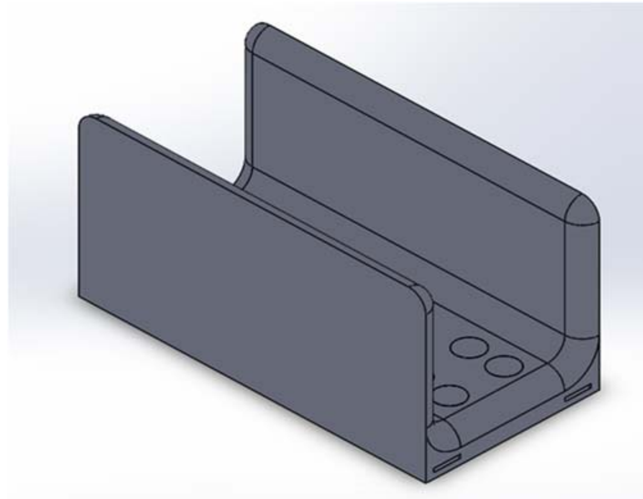

Figure 9. First iteration of reloading mechanism.

A simpler design was necessary due to time constraints, and the high cost of materials needed. Not to mention the challenging manufacturability of the component with the tools at our disposal. Considering these issues, a different approach was taken in which the functionality of the original design is implemented on the next iteration. Illustrated in **Figure 10**, in order to further reduce cost and ease manufacturability, the second iteration consists of flexible wood components and plastic.

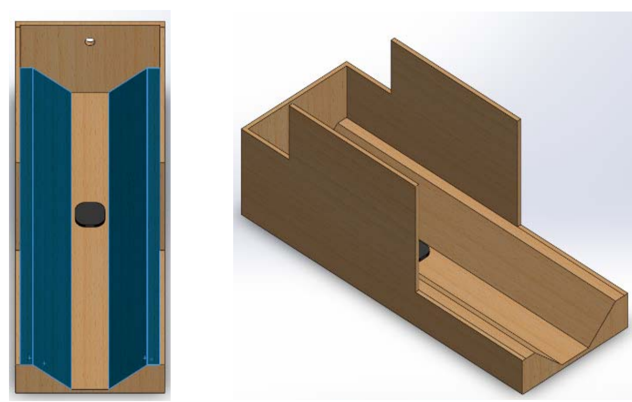

Figure 10. Top and Side Views of Reloading Mechanism

As seen in the images above, a single pressure sensor located on the ramp, notifies the launcher when a ball is ready in position before launch. When the ball triggers the pressure sensor, a linear actuator activates. This component is located behind the hole on the vertical wall shown on the image above. As the actuator moves, it pushes the balls into the launcher with a set time delay, feeding the launcher continuously. In order to guaranty the balls move along the path effortlessly, an inclined plane in the launching area is used to provide a path of less resistance for the balls to follow.

3.3. SkillCourt Software

Last, all of the aforementioned systems operate with the Skill Court software to establish full integration, in addition to data collection and user feedback. Compartments for the basic box unit and vertical collection system protect the relatively small wireless computers. These compartments are encased in a high impact resistant box, to ensure little to no damage to the computers during training sessions. Likewise, all other electrical components are positioned on various parts of the support stand capable of absorbing the impact force of a soccer ball.

Similarly, for the vertical collection system, the LED light strips can be re-positioned anywhere along the net, along the length of the half cylinder ramp, or along the supporting stand of the system. Next, velocity and acceleration sensors track ball characteristics in the data collection process in order to compare user performance over subsequent training sessions. Similar to the Skill wireless computers, these sensors require to be enclosed or be able to endure high impact forces. Obviously, there are many components that must be considered and be able to sustain any impact that could occur on any soccer field or training facility.

4. Integration of Global Design Elements

When discussing designs and their impact on the user and the environment, it is important to consider the components that went into the system and how they could affect people across the world. The materials chosen to construct the ball launcher have a significant effect on cost and environmental concerns. Ideally, cheap products and materials that minimize or eliminate any negative impact on the environment are to be used. Keeping this in mind, cheaper plastics such as PVC or clear extruded acrylic are considered. Eco-friendly plastics and cheaper metals such as aluminum are compared for their stress capabilities and economic uses. Ultimately, designing a launcher that does not produce, or greatly reduces various forms of harmful and toxic emissions is imperative. Likewise, safety concerns for children and adults are also taken into consideration. Furthermore, the mechanism can be easily transportable and will adhere itself to being able to fit in most car trunks or truck beds, as well as movement across a field. Lastly, casings made for the launcher ensure longevity in different types of weather.

Manufacturability of parts is a major influence in costs of the product across the globe. By first using premade products like the Soccer Wave ramp and Soccer Wave Jr nets, the ability to rebound the ball in the opposite direction and vertically while maintaining energy is far simpler rather than designing a new one. For the ball collector, aluminum was abandoned due to its difficulty to manufacture intricate parts thus increasing the production and shipping costs across the world. As previously stated, the main goal of the entire SkillCourt ball launching and collecting system is to make it economically feasible for anyone across the globe, ranging from individual families, to youth academies, and professionals. In addition, user feedback will become available with a wide range of options that will interact with the Skill Court program.

4.1. Feasibility Assessment and Future Improvements

When assessing the overall feasibility of this design, one can ensure that it is indeed achievable. Beginning with its manufacturability, the parts are relatively simple to produce as many other products have used similar components. Along with being easily manufactured, the materials used can be made from low-cost plastics and metals making it light weight and economical. Parts such as the swivel wheels or the smooth tires can be found for a viable and economical price for the system. The amount of moving parts needed in ball launching is limited, as only three degrees of freedom will be required.

Cost and strength of the various parts are of the utmost importance, both affecting one another continuously and dire to the durability of the complete device. For the respective rebounders, their economic costs are strongly considered since the products are directly incorporated as previously described. It is far more likely that the net-based rebounder will be used rather than the plastic encased ramp, as it will be portable, cheaper, and multipurpose. There are drawbacks and positives for both the ramp and net rebounder, but the latter will be chosen as the more likely means of changing direction of the ball while maintaining momentum. Cost considerations of the ramp rebounder will range up to $200, while the net rebounder is a reasonable $60-$100.

To continue, the vertical collection system and net attached to it must be able to withstand the force of an incoming soccer ball up to a range of 70 mph and not tip over, thus ensuring continuous play and little need for reset. Likewise, the material portion of the vertical system must be sturdy enough to not be damaged by an incoming projectile while also ensuring the safety of the software. If the lighting systems and computer compartments will be located on the vertical collection stem or supports, design considerations for the vertical collector will be altered slightly with additional material needed. This system is the wildcard for the structure as metalworking may cost a considerable amount. On the other hand, supplementary materials can be considered for the collector, such as fiberglass for its price and compressive strengths, or other types of plastic that are durable. Prices could range from a cheap $100 up to $400, which would be detrimental to the global design of the system.

Finally, the net used will be likely those used for baseball and football practices, these nets are loose and their main goal being to completely stop a ball's momentum. By attaching this type of net system to the vertical collector, balls can continuously be reloaded into the ball launching system. It is likely the net will be locked by a set of wires and lines that will be attached to the vertical collector. There are some stress and vibration concerns that must be considered, as the net must be tied down in several areas, this additional system would cost $50-200 depending on quality and size.

Similarly, weather conditions that the product will be exposed to may also affect the structural capability of the various components. Wet areas may cause erosion of the metallic components, while windy conditions may tip over the vertical collector. Some additions to consider combating these environments are coverings for the metallic parts like the collector and rebounder, but also stronger ropes and tightening tools.

5. Conclusion

The result of the task in regards to the reloading mechanism for the Autonomous Launcher is not only to work together with teammates from very diverse backgrounds and ideals, but also to create a unique design concept that could possibly lead to a change in the way launchers are used in a variety of sports. The main goals were to develop a simple autonomous reloading mechanism for a launcher that is cost effective for consumers to purchase and manufacturers to make, while portability to take it anywhere for a quick setup were met satisfactorily. The team approached every aspect of those main ideas to develop an effective solution to those problems. However, further research is necessary in regards to maneuverability to achieve a wider range of motion for the launcher to track the user.

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