

Kicking, Snapping, and Throwing the Ball in Intercollegiate Robotic Football

Jeremy Wilson, Addison Hocter, Brian Recker, Eric Linn

ME Department

Ohio Northern University

Ada, OH 45810

Email: j-wilson.3@onu.edu

Abstract

The goal of this project is to improve multiple robots by introducing new designs. The robots that are being improved upon are the kicker, center, and the quarterback from last year's capstone. The rules are kept as similar to traditional football as possible, except the game is played by 8 robots on the field for each team. Each robot has a size, weight, and power constraint.

The current kicker is inconsistent in both distance and direction of kick. The directional inconsistency is primarily due to lack of rigidity in the kicking mechanism, as well as a highly variable football placement on the tee. The kicker performs inconsistently and inadequately in the distance of kick primarily due to the placement and type of the elastic band. The addition of an actual scale-size goal post for extra points and field goals requires a more precise kicking mechanism.

The kicker is being totally rebuilt. The chosen design uses elastic bands as the method for storing the mechanical energy used to power the motion of the kicking mechanism. The design uses an 18" leg as the kicking mechanism. Several feet and tee designs are being prototyped and tested to determine the most effective combination that produces the most reliable kick. A reliable kick is defined as how consistent the trajectory of the ball is after the kick. The leg is going to be made of 1" square aluminum 80-20-framing. The frame of the robot is going to be made out of the 80-20-framing with walls made of 0.25" HDPE plastic.

The center is only going to have the ball delivery system worked on. Currently, it does not have a way to keep the arm from rotating freely unless a rotation command is given. Also, if the ball is not placed correctly in the ball-holding mechanism, the center has a high risk of fumbling the football during the snap. To stop the arm from freely rotating, a solenoid with a rubber braking pad is going to be used to apply a frictional force to the arm. To reduce the error in placing the ball in the ball-holding mechanism, a back-stop is being incorporated to the current ball-holding mechanism.

When feasible, stock products will be purchased and used in assembling the robots. Otherwise, the pieces needed for assembly will be fabricated in-house. The metal and plastic will be cut in the shop. Several simple braces will be created in-house to save money. Prototyping for the foot and tee designs is being accomplished with the 3D printer.

Introduction

The first intercollegiate robotic football match was held in 2012 at Notre Dame University between the home team and Ohio Northern University. Since then, six matches have been held between the two teams. The ONU Robotic Football team has proven successful in past performances against Notre Dame but improvements can be made to create a more balanced and effective team. The current team lacks the ability to effectively pass the ball to its receivers. This task has proven difficult in robotic football and as a result the scoring system has been adjusted to encourage passing. The large point increase given for completing passes made it a desirable goal, but the passing skills of the previous ONU quarterback were too inaccurate, too inconsistent, and lack any form of automation. These deficiencies result in a passing game that was negatively influenced by operator and system error. Fielding the pass is also a difficult process for the ONU receivers as it relies solely on human interaction for positioning and route running. The lack of catching ability of the receivers reduces the completion percentage and increases the chances of a costly interception. The robots have become old and worn down since they were built 5 years ago.

The capstone group selected a few robots to work on over the course of the school year. The robots selected were the kicker, center, and quarterback. Each of these robots came with several issues that the group was looking to fix with either improvements or with completely new designs. The current kicker doesn't kick the ball far enough to complete an extra point kick with the new rules. The center has some extra motion in the snapping apparatus that could cause unnecessary damage. The quarterback was damaged at the end of last year and needed repaired. Improvements to these robots are looking to drastically improve the performance of the team.

Rules of Play

The game of Robotic football is similar to regular human football in how the game is played and scored, however, with remotely controlled mechatronic machines, additional new rules had to be introduced. The game is played between two teams, each consisting of eight players, and a minimum of five functioning players on the field. A violation in either of these rules results in a 1- point delay of game penalty. Since the robots are controlled remotely, human interaction during actual gameplay is prohibited except for when the balling is being placed on the Center before an offensive play or when the ball needs to be placed in the kicker on kick offs, punts, and field goals.

Regarding the actual robot, the machine cannot weigh more than 30 lbs., and powered by a DC power supply, which cannot exceed more than 24 volts. An accelerometer must be implemented on every robot that takes the field, and must provide 2 seconds of immobilization upon being tackled through an interrupt routine in the microcontroller. Regarding the physical build, there are no restrictions on the shape of the base plate, however, all players must fit within a 16 inch square, and a 24 inch tall box at the beginning of any play. Yet, these dimensions expand after the ball has been snapped by the quarterback.

The game is comprised of two 15-minute halves and a 10-minute halftime. The play clock for any offensive play is 25 seconds, which is indicated by the play clock, and starts when the referee spots the ball to initiate a play. Failure to start play after the play clock has expired is a 1 point delay of game penalty. The game clock stoppage occurs when there is a change in possession, dead-ball penalty, a score, or a time out is called. In addition, each team is allowed 2 time outs per half that last up to 1 minute, and the play clock will start from 25 after that 1 minute has expired. The game, surprisingly, can end in a tie, and no overtime will be played.

The scoring rules are very different than regular football as it reflects the difficulty in passing and catching the football. A touchdown is still worth 6 points, however, the point after is worth 2 points. If the ball is ran or passed in the PAT is then worth 1 point. A completed forward pass that is approximately 5 – 15 feet passed the line of scrimmage is worth 7 points, and anything further than 15 feet is worth 12 points. If a pass is intercepted within the 5-15 feet range of the line of scrimmage 2 points and possession of the ball is awarded to the defense, and anything after 15, 3 points and the ball would be the reward. A pass is caught or intercepted when a robot makes contact with the ball before it touches the ground. In other words, the wide receiver or safety need not actually catch the ball, but only hit the ball while it is in the air. Nevertheless, if the robot can catch the ball on either team, the robot can advance the ball.

The traditional rules of the game of football are upheld such as neutral zone infraction, pass interference, illegal contact beyond a certain distance from the line of scrimmage, roughing the passer, false start, and illegal motion on the offensive end. However, instead of yards beginning tack on based on a penalty, the distance the ball will move forward is measured in feet.

Previous Designs

The current kicker was designed 5 or 6 years ago when the rules for extra-point kicks were less strict. Extra points and field goals only required the ball to be kicked beyond the end zone for the kick to be good. The new rules specify that an extra point and field goal are good if they travel through the uprights of the scale-sized goal post. The current kicker is constructed out of HDPE plastic, as specified in the rules. It uses an elastic band to store the energy used for kicking the ball. The elastic band was attached to the top of the kicking leg and to the back of the robot. As the leg is pulled into position, the bands stretch and store the energy. A pin is used to hold the leg back in place until the kicker is in position. The pin is then pulled by a servo motor to release the leg. The tee on the kicker is two flat plates that the ball leans against to prevent it from rolling. The ball lies on its side when being kicked. This method was chosen because the ball must be no more than 3 inches above the ground, and the center of the base plate of the robot must be 3 inches above the ground as well. The kicking leg was made out of quarter-inch thick HDPE plastic. Bracing HDPE was placed at the leg on the axle to help reduce any swaying in the leg as it kicked.



Figure 1: Old Kicker



Figure 2: Inside of Old Kicker

The current center is a robot in the shape of a cube. It has a tower on top of the cube with a flat arm connected to the top of the robot. This arm is connected to a servo motor that rotates it 180 degrees to snap the ball. The arm has a claw-like apparatus on the end of it that grips that ball. A servo motor is used to clamp onto the ball. The ball-clamping mechanism is made of a two-pronged clamp. The ball is placed between the prongs, and a command is given to clamp the ball. The ball must be placed in a fairly tight tolerance to acquire a good grip on the ball. If the clamp does not get a good hold on the ball, it can fall out during the snapping rotation. After rotating 180 degrees, the ball is around 11 inches from the back of the robot to give enough room for the quarterback or running back to line up for the snap. The motor that rotates the arm doesn't apply any braking force, so it is free to rotate when no command is given. This can cause it to swing away from the base of the robot when hit during play. As this robot is blocking every play, this happens quite frequently. If the center is unable to play, only half points will be awarded. This makes the center a very critical robot in the game. Reducing the amount of chances for it to get damaged is the main improvement the group is looking to make.

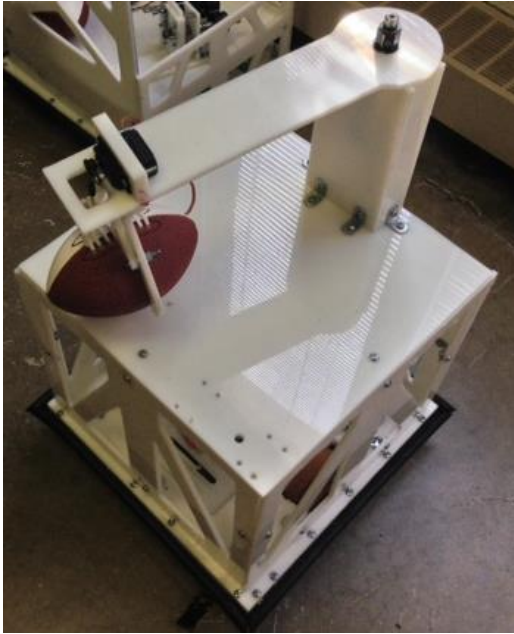


Figure 3: Old Center



Figure 4: Old Ball-Holding Mechanism

The quarterback was developed last year by the previous capstone group. That group developed a quarterback and receiver combination that track each other on the field. Each robot has a base that handles the locomotion and a top that rotates to keep the fronts facing each other. Tracking was accomplished with a CMUcam5 Pixy camera on each robot. The quarterback used a servo motor with a hard stop to perform this rotation. The quarterback throws the ball by using rubber wheels on both sides of the ball. These wheels are spun at several different velocities to account for the different throwing distances. The ball is pushed into the wheels, which propel the ball forward into the air. The quarterback had an issue with servo motor control during tracking, which caused it to break the motor used for rotation. After writing an improved control algorithm, last year's team loaded the incorrect code and again damaged the servo motor and burned the wiring. This is the state that the current capstone group inherited the quarterback. Based on the information left by the last group, a diagnosis was needed to find the issue and fix it.

Kicker

To account for the new rule, a new kicker was designed. Using 80-20 aluminum to create a frame with the HDPE plastic making up the walls. The design continues to use an elastic band system to store the energy for the kick. The elastic bands in the new design create around twice the amount of force for the same distance stretched as the current band. A roller is being used to reduce the friction and rubbing of the bands on the back of the robot. The current band has begun to exhibit tearing. The locking mechanism has also changed from a pin that is pulled by a servo motor to an electromagnet that is controlled by the Arduino. This change was added to account for the pin occasionally sticking, causing the robot to fail to kick the ball. The pin was also located on the inside of the robot, which caused a safety hazard if the leg were to come loose

while setting the pin in place. The electromagnet is located at the top of the robot so that it can be easily reached. The bottom of the robot has had a small slot cut out to allow the leg to swing lower than the base of the robot. This also allows the kicking tee to be placed below the base, which lets the tee in the new robot be more substantial. The more substantial tee will ensure the ball is placed the same for each kick, increasing the accuracy of the kick. The leg has also been changed to be made of the 80-20 aluminum. This makes the leg more rigid than the previous design. The thicker and sturdier leg will not sway. The foot used to strike the ball is made of 3D-printed plastic. It was designed to strike the ball such that the ball will leave the robot at a 45 degree angle to maximize the distance travelled by the ball.

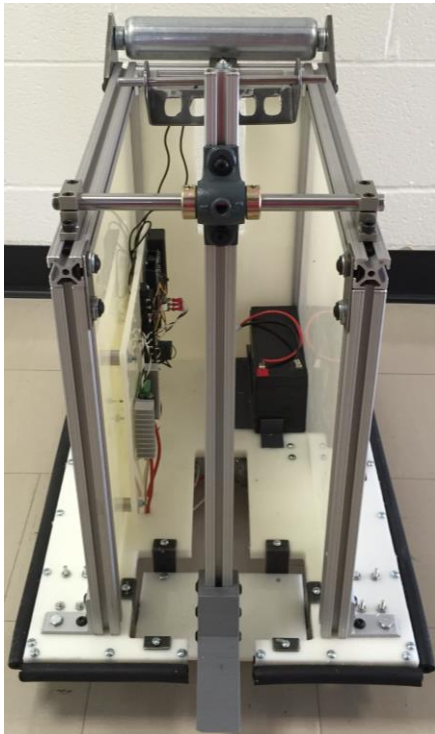


Figure 5: New Kicker

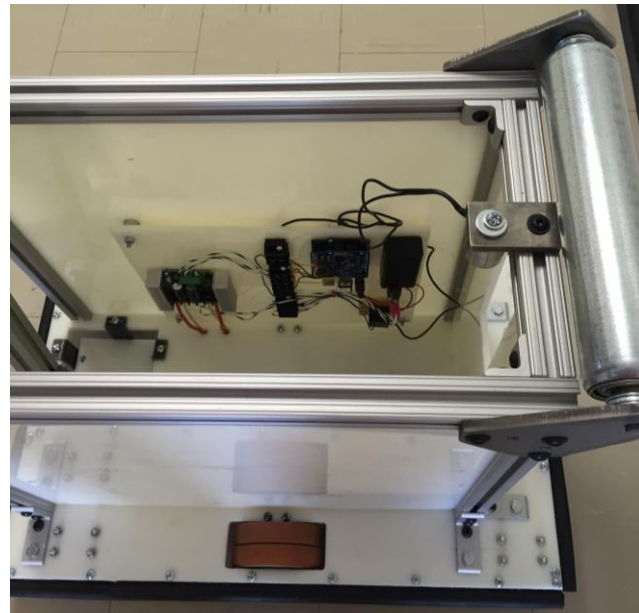


Figure 6: Inside of New Kicker

Center

Only improvements were designed for the center. A whole new robot is not being created. To prevent the arm from freely rotating, a solenoid is being used to apply a frictional force to the arm to prevent any extra rotation. When the solenoid is energized, the frictional force is removed from the arm to allow the intended rotation to occur. The solenoid is energized whenever a command to rotate is given. The solenoid will be attached to a spring that will apply the actual frictional force to the arm. The spring will be depressed by the energized solenoid, removing the force. Another design change to the center is to add a backstop to the ball-clamping mechanism. This will allow the user to place the ball correctly each play, without wasting any time. It will prevent the ball from being fumbled at the start of the play.

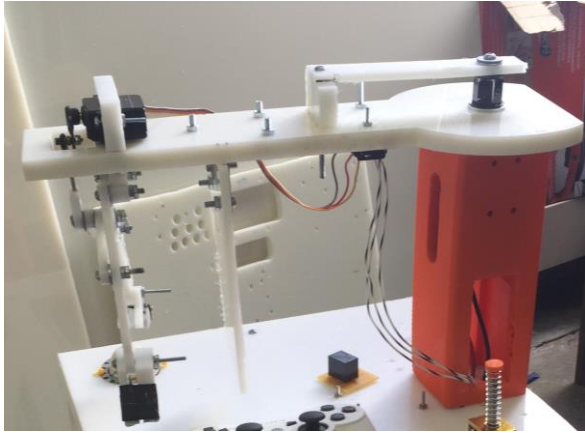


Figure 7: New Ball-Holding Mechanism



Figure 8: Solenoid



Figure 9: Front of Claw

Quarterback

The quarterback was rewired so that a diagnosis could be made to determine what should be fixed. It was initially thought that the motor was unable to apply enough of a braking torque to prevent the top from rotating all the way into the hard stop. It was found that the motor was able to provide enough torque to stop the motor before the hard stop. The software that was embedded on the Arduino was not commanding any braking torque. It was just commanding the motor to stop, without providing any force. With this in mind, new software was developed to control the tracking of the receiver. Fuzzy logic and PID control systems were created and simulated using MathWorks products. It was determined after simulation testing that a PID controller would perform better for this application. A testing apparatus seen in Figure 1 was constructed to physically test the control algorithm prior to testing on the actual robot. The specific type of motor used has its own closed loop controller which does not provide position feedback to the microcontroller (Arduino MEGA). This makes motor control difficult and is likely why the previous year's team had the issues they did. To make control easier, the motor unit was modified for position feedback to the microcontroller. The performance was still not acceptable so the motor unit was modified for continuous rotation. Modifying for continuous rotation allows for a more direct control over motor voltage. With the continuous rotation modification complete, the system performed with acceptable behavior on the testing apparatus. The new control algorithm makes the system capable of leading a receiver if the receiver is travelling across the field. This is to allow for passing on the move instead of the traditional system, which has the receiver drive forward several feet and stop. Although the quarterback will be programmed to have limited rotation, mechanical hard-stops will be installed to ensure that the robot is not damaged from over-rotating.

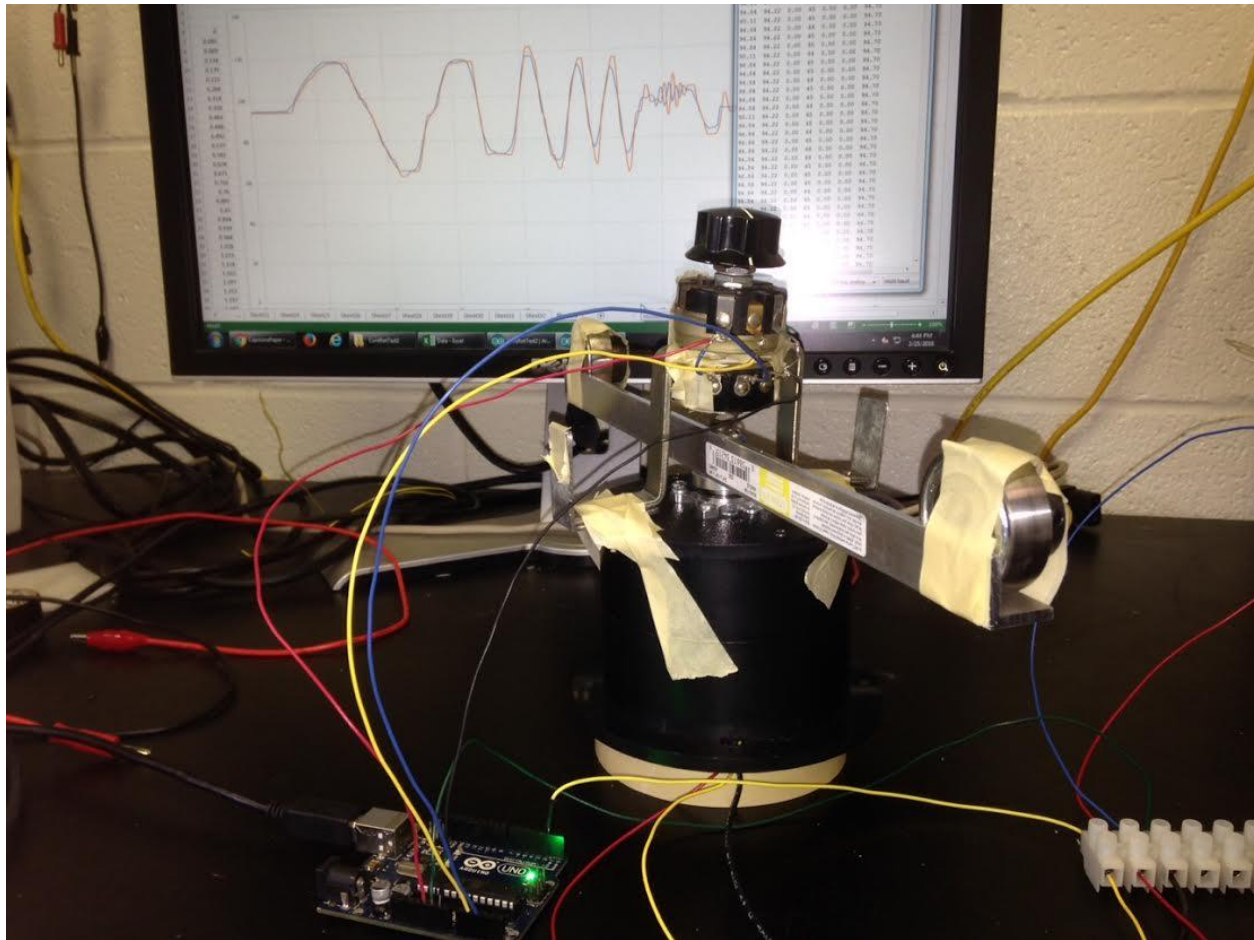


Figure 10: Pan Control Test Apparatus

Investigative Work

After the kicker, center, and quarterback are finished, a 24 volt motor robot is going to be designed and constructed for next year's competition. The 24V robot that was created a few years ago had problems with coding, so, instead of fixing the coding, the robot was cannibalized for parts, and the base plate received unnecessary drill holes. Currently a new base plate and side walls have been created for the new 24V robot. Also, the driving wheels and supporting casters have been mounted to the base plate, as shown in the pictures below.



Figure 11: Underside of 24V Robot



Figure 12: Frame of 24V Robot

Conclusions

With the kicker and center construction complete, testing can begin. The kicker will be tested by making a mock goal post and kicking the ball through it. The kicker will be tested at various distances to find the max field goal distance. The foot and tee designs may be tweaked to improve the trajectory of the ball. At least 25 test kicks will be done to ensure the kicker can repeat the extra-point kick with a high accuracy. The center will clamp onto the ball and snap it multiple times to test that the backstop and claw will hold with ball without fumbling during the snap. The solenoid brake will be tested by crashing other robots into it and seeing how much movement occurs in the arm. This will simulate an actual game where other robots will be attempting to push the center back into the quarterback. The quarterback will continue to be tested and worked on to improve the PID controller. After the controller has been implemented correctly, testing will take place with the quarterback and receiver. The quarterback will attempt to pass the ball to the receiver under a variety of conditions. These conditions include the having the receiver drive forward several feet and stop and having the receiver drive in a straight-line perpendicular to the quarterback. This testing must all occur before April 15th, the day of the game. After the game, any small improvements found during the game will be implemented in the kicker, center, and quarterback. Then the 24V robot will be investigated in earnest. With a month remaining in the semester, the 24V robot will be fully assembled and the control algorithm will be tested.

Bibliography

- [1] J. Yoder and L. DiBerardino, Interviewees, *Communications with Advisors*. [Interview]. September 2015.
- [2] H. LeBlanc, Interviewees, *PID Control and Coding in C++*. [Interview]. February 2016.
- [3] T. Hertenstein, N. Rosenbaum, Z. Myers, J. Chenault, K. Ross, "Ohio Northern Robotic Football Senior Design Project," Ohio Northern University, Ada, Ohio, 2015.