Ohio Northern Robotic Football Senior Design Project

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Introduction

The robotic football competition began as an alumni-sponsored senior design project at the University of Notre Dame. In the 2008 spring semester, two groups consisting of five members each were tasked with building two robots. They demonstrated the ability to complete the task within about 12 weeks, coming up with two forms of ball "throwing" robots that weighed about 40 pounds each. Pleased with the project's success, it was decided that it should be expanded to a full competition in 2009. Rules were developed for two eight-member teams to compete in a game of football in which the rules of the traditional sport served as a guideline, modified to robots' abilities. The two Notre Dame teams learned a great deal from their game, which set the stage for improvement in the 2010 game. This second match-up saw the first pass completions by the robots (a "completion" simply being the ball hitting the receiver) and improved maneuverability. The decision was made to expand the project to other universities in order to further the competition and technologies. Ohio Northern University was the logical choice for this due to the many existing ties between their faculty and Notre Dame's own.[1]

Due to Ohio Northern's difference in timing constraints and far less number of students available, it was decided that ONU would build three robots for their first year of involvement, to be implemented in one of Notre Dame's teams in the spring 2011 game. This team lost the game, but many valuable lessons were learned about ball handling, robot repair, and the importance of practice.[1] In 2012, ONU developed their own team to compete against the Fighting Irish. The first ever intercollegiate mechatronic football game was played on April 20, 2012 at Notre Dame. This game had many notable improvements in robot ability, including the first ever pass to be caught inside a receiver, by Notre Dame. Ultimately ONU lost 27-6 to the more experienced Notre Dame team.[2] Then, at the second meeting of the two teams on April 6, 2013, the Polar Bears presented vastly improved defense capabilities and a highly maneuverable running back to beat the Fighting Irish in a 49-37 shootout.[3] The Ohio Northern Robotics Club also attended the national ASEE conference in Atlanta this past summer to play an exhibition game against Notre Dame, in which it emerged victorious once again over the favored Notre Dame team.

For this year's competition, the ONU senior design team has been tasked with implementing six new concepts to further the technological aspect of the Polar Bear team. The first is a single power source to run all internal components. Currently, three different batteries are used to control the electronics inside the robots at various voltages. A single power source would simplify the circuits and provide for greater ability of the robots, such as swapping out the batteries when more power is needed. Secondly, Notre Dame currently supplies every robot's proprietary tackle sensor. The group will attempt to make the tackle sensor open sourced which will allow greater expansion of the game to other universities. The new tackle sensor will perform to the same standards as Notre Dame's current model which is a custom circuit board. The senior design team was also tasked with designing a robot that can find a ball on the field autonomously. This has huge implications for the future of robotic football. Even in the next couple years, this could lead to robots automatically being able to find and retrieve fumbles or kickoffs, let alone the possibility of an enhanced quarterback-receiver relationship. Another concept is a "tackle-tester," a device that could be brought to competition to quickly test whether all robots' tackle sensors are working correctly, bringing fairness and uniformity to the game, in the same way that a scale verifies that each robot is the correct weight. The final two ideas for Ohio Northern are two new robots: one that will run on 24 volts and one that can pick up a ball. The maximum voltage a robot can receive according to the rules of collegiate mechatronic football is 24 volts.[4] Currently 12 volts is the standard, as it is easy and feasible to obtain batteries and motors. A 24V robot will test the abilities of a robot with theoretically twice as much power. The robot to pick up the ball is another idea to further the technology of future mechatronic football teams. The rules state that if a robot can contain a live ball then it is allowed to advance the ball.[4] Picking up a fumble or kickoff would be a huge game advantage.

Competition

The robotic football competition has evolved into a game of eight on eight competition that takes place on a 94 feet long and 50 feet wide field. The end zones are 15 feet deep (outside of the 94 foot field length). The game is divided into two 15-minute halves and includes a 10-minute halftime where teams are allowed to make any necessary repairs or adjustments within the rules. Humans have limited interaction with the robots – they are only allowed to give the ball to the center or place the ball on the kicking tee. They cannot touch any other robot on the field of play. They are allowed to remove an injured robot from the field (and bring on its substitute). Although scoring a touchdown (6 pts.), a safety (2pts.), kicking an extra point (1 pt.), and kicking a field goal (3 pts.) are similar to that of American football there are a variety of other ways a team can score based off of the passing game. The first type of pass is the short pass, which is defined as a forward pass that travels between 5-15 feet to a receiver at least 2 feet beyond the line of scrimmage. When a short pass is completed 7 points are awarded and when it is intercepted the defense is awarded 2 points and possession of the ball. The second type of pass is the long pass, which is defined as a forward pass traveling more than 15 feet to a receiver at least 5 feet beyond the line of scrimmage. When a long pass is completed 12 points are awarded to the offense and when it is intercepted the defense is awarded 3 points and possession of the ball. The final type of pass is the screen pass, which is defined as a forward pass traveling more than 5 feet to a player that is within the first 2 feet of the line of scrimmage. When a screen pass is completed the offense is awarded 3 points and when the pass is intercepted the defense is awarded 1 point and possession of the ball. Live balls, such as kickoffs and fumbles, as well as receptions and interceptions are allowed to be advanced if the player is able to maintain control of the ball (i.e. "catch" it). The last way to affect scoring is by committing a penalty. Depending on what the penalty is, a team could be penalized by a one point reduction.

On offense, at least four robots must be aligned within a foot of the line of scrimmage when the ball is snapped. These four players are allowed to motion laterally along the line of scrimmage, and all are allowed to release downfield at the snap of the ball. All players on offense are eligible to catch and advance the football, including linemen. The center is allowed to have an arm that can reach outside of the 24” height and 16”x16” base limits. This arm is used exclusively to transfer the ball to other players. The quarterback also is allowed some exceptions to the rules in addition to its permitted extra weight. Teams can elect to have the quarterback start the play with the ball (instead of having the center snap it). If a team chooses to do so, all scoring is reduced by one point.[4]

Defensively, exactly three robots must be lined up within one foot of the line of scrimmage. These three players can only deflect passes. An interception would only be counted if the robot was able to retain the ball. The remaining five players must line up at least ten feet back from the line scrimmage until play begins, at which time a full rush is allowed. Both offensive and defensive pass interference can be penalized and is based upon the referee’s judgment if significant contact was made to impede either players’ movement.[4]

Problem Definition

Based off of the rulebook all robots must adhere to several constraints based on size and function. The maximum weight allowed is 30 lbs. The only exceptions are the quarterback and kicker, which are allowed a maximum weight of 45 lbs. All robots must fit in a 16” square base and be no taller than 24” except for the kicker who is allowed a 16”x24” base plate. Another important sizing constraint is that if a robot has an arm it must not extend more than 18” from the joint it is connected to. Each robot must have an LED light (run by the tackle sensor) that indicates when a player is tackled. A tackle is defined by a significant collision between two robots in excess of 2 g’s, as measured by the tackle sensor (accelerometer).

In addition to the constraints all the robots must follow, each of the six proposed tasks comes with its own constraints. The two new robots being built both are going to run on the single power source. This means only one battery will be used to supply power to all the necessary components. Since the 24V robot will be upgrading its battery, all of that robot’s drive components must be able to handle the extra battery voltage. The robot picking up the ball, as stated in the rules, must have its arm start from inside the robot and keep the ball undamaged. Additionally in order to advance the ball, the ball must be held inside the robot. The system used to automatically locate the ball will also be implemented into this robot. For this to happen all the components must be able to fit inside the frame of the robot and be protected during impacts.

Because the rules currently state all robots must use Notre Dame’s tackle sensors, the performance of the new tackle sensor is very important. It must be reliable and able to be integrated with the existing parts. The sensor must also be durable. The tackle tester will help show ONU’s new tackle sensor performs similarly to Notre Dame’s current model. Therefore the tackle tester must deliver consistent impacts. The tackle tester should also be transportable, so it can be taken to competition and ensure an even playing field.

For each objective, three criteria were developed that were considered the most important. For the tackle tester, a system that could provide consistent results, be cost efficient, and portable were all important. For the tackle sensor, the criteria were that it be cost efficient, that it be durable enough to use in competition, and that it could be interfaced with existing robots. For the robot to pick up the ball, it was important that it could consistently pick the ball up, that it could pick up the ball regardless of orientation, and that it be cost efficient. For the single power source the criteria were that it is cost efficient, that it could be easily implemented, and that it wouldn't increase the speed at which the battery dies. For the 24V robot the three most important criteria were that it would respond well to controls (quickly), that it was easy to handle, and that it was cost efficient. Finally for the robot to find the ball it was important that it could reliably find the ball, that it could find the ball as fast as possible, and that it can be integrated into a robot.

Proposed Designs

In order to convert the previous three power source system to a new single power source, a voltage regulator will be used that can encompass the Arduino and the tackle sensor. This will be incorporated into both new robots. The old, three battery power source and the new single power source are shown in Figure 1.

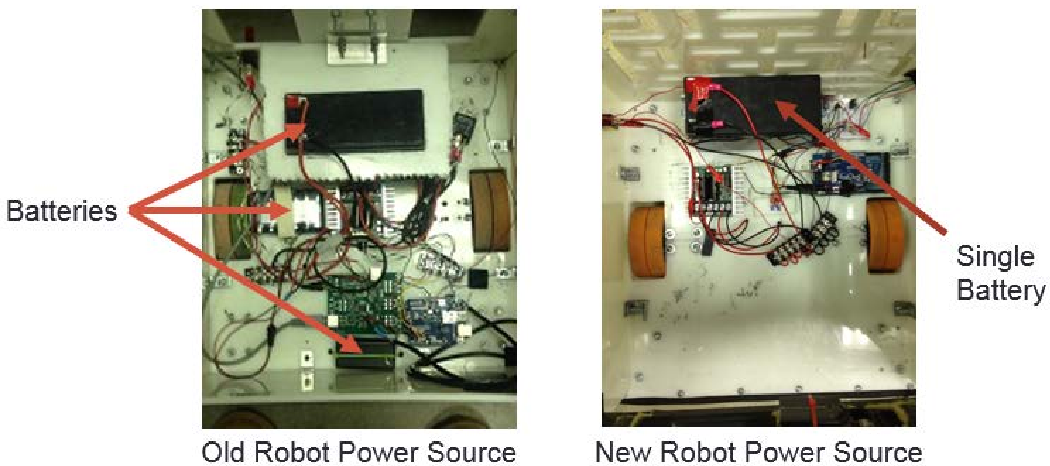

Figure 1: Old and New Power Source Systems

The 24 volt robot will have its drivetrain components upgraded in order to compensate for the higher voltage battery. The 24 volt battery itself will consist of two 12 volt batteries connected in series and the drivetrain will have two new motors running on a chain and sprocket system. This system is shown in Figure 2.

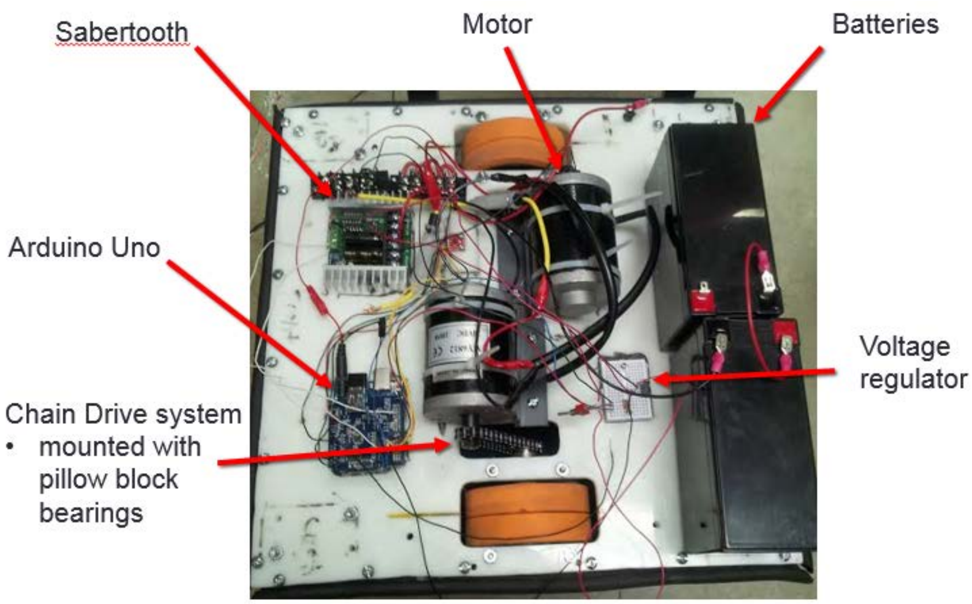

Figure 2: 24 Volt Robot's Components

The other new robot to pick up the ball will continue to use the current 12 volt battery but will have a rotating arm attached to the front of the robot. The innards of the robot are shown in the picture to the right in Figure 1. A design of the arm secured to the robot is showed in Figure 3 below:

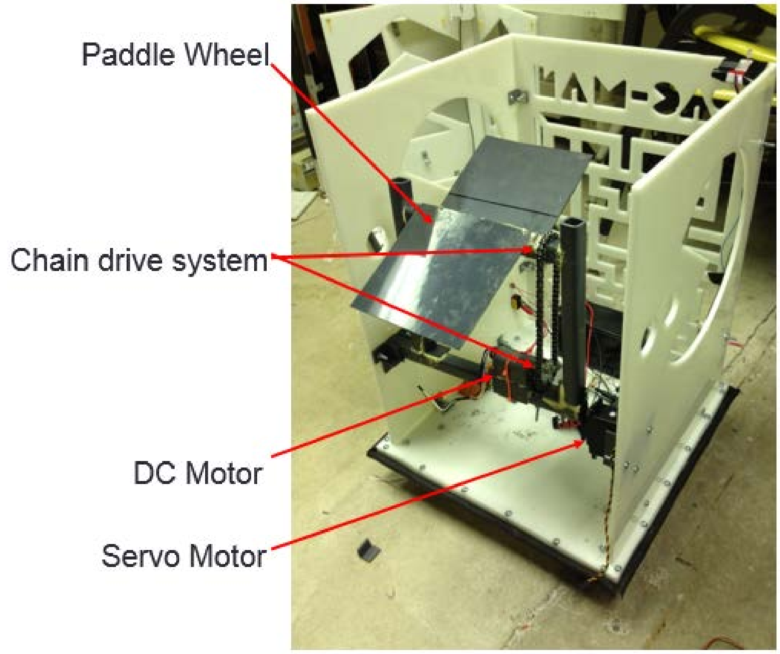

Figure 3: Robot to Pick Up a Football

this arm will come down over the ball and have another motor power a propeller-style mechanism to "sweep" the ball into the robot. A chain and sprocket system will also be used for

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this motor in order to keep both motors inside the robot. Additionally on this robot will be the system to autonomously locate the ball on an open field. To do this a CMUcam will be used along with the more advanced Arduino Mega (instead of the Arduino Uno R3). The more advanced Arduino is needed because it offers additional serial communication ports. The Arduino Uno R3 only has one port which is currently being used. The CMUcam will divide the field into multiple section and scan each one. The system will then use shape and color recognition to identify the football.

The proposed design for the tackle tester is a swing weight type system. The swing weight will impact a sled on which the robots will be placed. The sled includes a section to place compensating weights to eliminate any discrepancies in the weights of various robots. This will simplify the system because the swing weight will be drawn back to the same angle each time instead of altering the angle based on the robot's weight. Having the swing weight hit the sled also eliminates the possibility of damaging the robots. The design of the tackle tester is shown below in Figure 4.

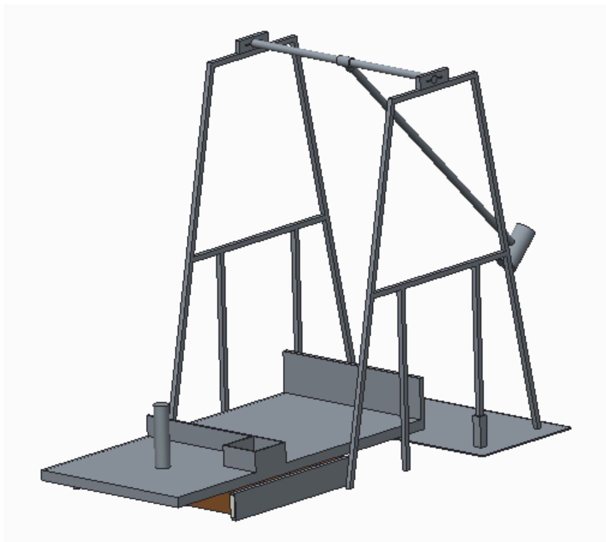

Figure 4: Tackle Tester System

This swing weight will test the consistency of the team's new tackle sensor. The new tackle sensor is comprised of three components; the existing Arduino, an accelerometer, and an LED light. With the proper coding this new tackle sensor will perform to the exact same standards as the existing Notre Dame tackle sensor.

Conclusions and Future Work

With the developments provided by the Senior Capstone Design Team, various components can be implemented in the existing robots at Ohio Northern University. One change could be reducing the current three power source system with the new single power source system for the entire team, not just the two robots to be built. This will reduce the number of spare batteries needed. Another change could be implementing the new tackle sensor into all of Ohio Northern's robots. Going forward the robot to pick up the ball could have its functionality integrated into other robots, so multiple players would be able to pick up the ball during competition.

Bibliography

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[3] "ONU 49 - ND 37." Ohio Northern University. N.p., 8 Apr. 2013. Web. 04 Feb. 2014. <http://www.onu.edu/features/48993>.

[4] Rules of Collegiate Mechatronic Football; University of Notre Dame; created 3/15/2010