Making a robot that actively tries to run into objects:

The SoccerBot (translated “Futbot”)

Group 2

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Executive Summary

Our project aims to create a robot that can act as the perfect goalie (within our technical limitations). By setting up a controlled field using only a skid steer model robot and a camera, we plan on configuring a robot capable of detecting players, soccer balls, and calculating the path to intercept the ball.

By configuring a simple field with a defined goal, an external camera on the robot as well as a camera monitoring the field of play, the robot will be able to process the feeds in tandem to calculate the speed, trajectory, and position of the ball at a given moment, and calculate the movements needed in order to prevent the ball from entering the defined goal area. Furthermore, our project has room to grow into not just a goalie, but into a robot capable of scoring a goal as well.

Problem Statement

From the period of 2000 to 2017, obesity prevalence in the United States rose by 11 percent, to an estimated 41 percent of Americans struggling with obesity [1]. While many alternatives to combat obesity, such as technological improvements in dietary plans and exercise equipment can help curve the problem for active Americans, keeping them entertained during the process has continued to be an ever-increasing dilemma.

Concurrently, video games such as *Rocket League*, *Mario Tennis*, and other similarly themed "sport-centric" games have seen an unprecedented spike in popularity. These games all feature single player models that can adapt the opponents AI to the difficulty level of the player at a given time, constantly giving them room to improve.

Our project aims to combine the single player, addictive aspects of these games with the activity level required to play a game such as soccer, manipulating our AI to reward the player while also creating enough difficulty to raise their overall activity level.

Relevance and Importance of the Project

As we move forward into the second quarter of the 21st century, improvement in the consumer market for robotics is estimated to explode. Using robotics such as these for exercise and entertainment is a new and rapidly growing field, and our project aims to capitalise on this crucial time period. We believe that the use of AI and robotics in gyms, homes, and training facilities will help the rising generation of athletes and gamers.

Conclusion

Over the course of our project, we aim to both determine the feasibility of incorporating simple robotic solutions into the athletics market, as well as discover a new method of combating childhood obesity through consumer entertainment products such as our Soccer Bot. By setting up a simple automation using consumer products such as web cameras and cheap skid steer model robots, we aim to make our Soccerbot both fun and affordable.

Literature review

Key Concepts, Theories, and Studies

Siregar [2] conducted a similar experiment in which a robot was created that could detect a ball using the onboard camera and plan its movement according to the ball's distance, position, and movement. They reported 100% accuracy in planned movement, though their measurements to obtain this figure were strictly observational. Multiple details such as locomotion type and ball interaction behaviour differ from our own design, but, regardless, several of the computer vision related principles that were found to be successful, such as pixel mapping, could prove useful as we seek to adapt and apply them to our own project.

Zhang [3] also discusses topics applicable to our own project design in their research paper regarding motion planning and obstacle avoidance. They constructed a simulation in which an agent would plan its motion using a genetic algorithm to train parameters for an artificial potential field (APF). Their paper contained much useful methodology for using an APF in a practical manner with grid-based motion planning. We may or may not use a genetic algorithm to train the optimal parameters, but the paper definitely presents an APF as a very viable option for motion planning in our own project. This is true especially as our use case naturally doesn't need us to overcome local minimums, a concept reinforced by other studies [4].

Key Debates and Controversies

One of the only debates we could find in robotic soccer literature was regarding the approach to getting to the ball whether it be by way of a more classical controls approach, APF paired with a genetic algorithm, or reinforcement learning. Even then, these are just different approaches to slightly different problems and may not be fully referable to as a "debate."

Gaps in Existing Knowledge

Overall, there seem to be multiple studies concerning motion planning and computer vision, especially in soccer-themed robotics. However, a gap our project may be able to fill lies in specific obstacle non-avoidance with computer vision based ball detection, especially as it relates to guarding a goal as a goalie. Specifically, we may be able to fill a gap by using reinforcement learning to adjust parameters of an APF as opposed to a genetic algorithm. In addition, we are only studying a single agent system while many studies deal with multi-agent systems.

Project design and methods

As our desire is to understand the feasibility and limitations of robotics in athletics environments, we will be direct in our research. We will design a robotic system capable of moving along a flat surface in two dimensions, with the sensors necessary to determine its own location relative to a ball and the goal.

Project design

The research will be primarily qualitative, as it is mostly based on whether the robot is succeeding in its goal or not, and our adjustments needed to make it succeed more frequently. This consists of descriptions of the iterations we go through in order to accomplish our goal. The quantitative portion of the research is success rates for each iteration of the system to maintain a record of quantifiable improvement throughout the project. Thus, we will be collecting our data ourselves through experimenting with the system and adjusting it to meet our goals.

Methods and Sources

Describe the tools, procedures, participants and sources of the research. When, where and how will you collect, select and analyze data?

Data collection will happen through repeated tests, using the following format:

- Place the robot at a constant start location (x,y) relative to the goal.
- Place the ball at a variable, but predetermined, location.
- Kick the ball towards the opening of the goal.
- Record the response of the robot in its attempt to intercept the ball, and determine the success of this attempt.
- Repeat a significant number of times in order to understand the current state of the robot, its failures and successes. Change the starting location of the ball regularly according to the predetermined set of locations.
- Make necessary changes to the system to improve response and increase success rate.

Data collection can happen at any sufficiently safe, flat, and consistent location to run the tests. Adjustments to the system can happen on site if necessary.

Practical Considerations

Our main limitation for our project is the platform on which we have to operate. Due to the increased cost of legged systems and difficulty of control, we have opted for the skid steer model. This will, however, prevent our robot from leaving the ground, which may be required in many cases in order to stop the projectile on its calculated course.

We may also run into issues with dual video feeds relaying conflicting / out of sync information to our calculation system. With the computer required to run multiple computer vision models concurrently, an outside compute module will be used and commands will be relayed to the robot. This relay over a distance as well as frame rate limitations [2] may also pose issues with latency and the required reaction time needed for quicker ball movements.

Implications and contributions to knowledge

Our proposed project is important and should be funded due to its three main contributions to the field of robotics:

- It will serve as a good, clean example of a mobile, vision-based system. There is value in complete examples that others may draw from. We experienced poor, incomplete research as we sought sources from which to draw design inspiration that limited our ability to draw conclusions and hindered us in deciding on a research direction. This can and will be remedied so that others considering research in this direction may have a more complete reference for doing so.

- It may explore a novel approach to well established techniques. It's not a major change, but tuning APF parameters with reinforcement learning, if we choose to do so, could provide yet-to-be-discovered advantages over using genetic algorithms for that purpose.

- It will be fun! However, we're not talking about in a "just watching" way that can traditionally be found in soccer playing robots. It will be fun in a "you play" way! All of the little children will line up for their turn to try to get the ball past the awesome soccer robot. It will bring joy and laughter in a way a robot that plays against other robots cannot. The name SoccerBot will become as commonplace in the mouth of the average person as robotic giants like Roomba. In other words, it could be a very marketable product.

References

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Research schedule

Research phase	Objectives	Deadline
Computer Vision 1	• Get camera and computer vision programs working correctly • Identify ball	6 weeks from due date
Computer Vision 2	• Determine where ball (and maybe people) is spatially in relation to robot and the goal	5 weeks from due date
Motion Planning 1	• Implement motion planning to block ball (APF?)	4 weeks from due date
Motion Planning 2	• Train an agent to optimise APF parameters(?)	3 weeks from due date
Motion Applied	• Apply planned motion to the system movement	2 weeks from due date
End Testing	• Final testing • Work out kinks	1 week from due date