Investigations of Learning Algorithms for Robotic Foosball

For the Mazilu Engineering Research Fellowship, I am proposing the creation of a robotic foosball table. Foosball is a tabletop game involving two to four players attempting to hit a ball into each opponent's goal. Each team has four sets of players, goalies, defenders, midfielders, and strikers, connected by a rod that can be moved from side to side or rotated. The simplicity of the players' motion is such that a robot could effectively perform this task using linear and rotational actuators. However, the movement of the players is only one small part of the game. The complexity of foosball arises mainly because the ball moves quickly and unpredictably. The ball can cross the entire length of the table in under a second, and due to the players on the field and the ball's interactions with the walls, it is tough to predict where the ball will go. In addition, there is much strategy involved in the game. Through faking out an opponent, passing between teams, and complex shots like angle shots and bank shots, nearly infinite complexity arises from this theoretically simple game.

This project, which combines sensing, controls, and machine intelligence, is worth pursuing because there are many different avenues of research to explore. For example, to track the ball's movement accurately while leaving enough time to position the players, the system needs to quickly convert visual data into the ball's location while dealing with obstructions caused by the players and people leaning over the table. By taking inspiration from the human brain and tracking only what changes between video frames, machine intelligence researchers significantly reduced the amount of data needed to determine the ball's position (Cohen, 2022). This approach provided a considerable increase in processing speed and is one example of the many possibilities for computer vision research in this project. Outside of image processing, there is considerable potential for applying machine learning (ML) to the system. For example, the system has many low-level actions that it can perform, such as moving the players and hitting the ball. To develop a higher-level strategy, the machine can learn from observing human games or playing against itself in simulation to arrive at an optimal strategy. This is a perfect application for reinforcement learning, genetic algorithms, and other techniques in ML. Finally, since this is a physical system with high demands for speed and precision, there will be a significant emphasis on controls with the potential to use cutting edge techniques in non-linear control and state estimation, optimal control, and adaptive control (Janssen et al., 2012).

This project is not without precedent, with teams from Brigham Young University (BYU) and the École Polytechnique Fédérale de Lausanne (EPFL) creating robotic foosball tables. However, differences in the design and construction of their systems allowed them to focus on different aspects of the game. For example, the team from BYU placed the camera above the table, introducing obstructions and other factors that meant that they had to emphasize computer vision and state estimation (Hollingshead, 2019). The EPFL team, on the other hand, focused on the design of their actuators so that they could move quicker and be more precise (Oberhaus, 2016). From these examples, one can see that this project offers many avenues for exploration.

Outside of research, it can also support multiple different Thayer classes. For example, ENGS 147 Mechatronics is an ideal candidate for the use of this project. This course focuses on the fusion of electronics, mechanical systems, and embedded controls in applications such as robotics. Professor Ray, the instructor of 147, proposed that this system would be an excellent option to explore the software side of robotics and mechatronics and could present an option to explore during the class. Additionally, students in ENGS 108 Applied Machine Learning could use the table to apply techniques developed in the real world. For example, the students could compete to create the best artificial intelligence to control the system. Finally, because people are supposed to play with the project, it has the potential to inspire future engineers. By interacting with the project, children, undergraduates, and adults will see the potential of engineering to tackle interesting problems and its application to many different domains.

Work on the project will start with the creation of the physical hardware. This involves designing the mechanisms for actuation, supports for the camera, and any other necessary changes to the table and will be finished by the end of this spring to culminate my Presidential Scholars research. Then, the project's focus will shift to electronics, combining the vision and actuation systems so that one piece of hardware can control the entire system. This will begin during the spring and extend into the early part of the summer. Finally, the rest of the project will focus on software for the system, involving the design of controllers for the motors, image processing, trajectory prediction, and strategy development. Additionally, this stage will involve the development of machine intelligence that will integrate all these tasks into one system, ultimately making up most of the project and serving as the focus of my senior honors thesis, which I will present next spring. Project advisor Professor Laura Ray will help by providing years of expertise in designing and implementing robotic systems, as well as guiding me in tackling any inevitable issues or questions. Additionally, she will share potential areas to investigate further as she is up to date with new research occurring in this field.

Finally, I would like to thank Saguaro Technology and Jamie Mazilu Brown for establishing this research fellowship, for it presents students with the opportunity to dive deep into an engineering research project. The skills I will develop, from research and investigation of literature to hardware and software design, will be crucial in pursuing graduate school and a career in engineering research.

References

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