Artificial Intelligence in the Field of Botball

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Abstract

Artificial Intelligence (AI) offers transformative potential for the Botball tournament, an educational robotics program that challenges students to design, build, and program autonomous robots. This paper explores the integration of AI into Botball, with a detailed case study of our team's neural network project. By training a neural network to guide a robot in a simulated environment, we demonstrate how AI can enhance robotic autonomy, improve competitive performance, and foster innovation. We also discuss the implications for educational robotics and future research, addressing both opportunities and ethical challenges. Our work aims to contribute to the advancement of AI in robotics education.

I. Introduction

Artificial Intelligence (AI) has evolved from a theoretical concept to a practical tool that powers autonomous systems across industries. In robotics, AI enables machines to perceive their environments, learn from experience, and make decisions autonomously, revolutionizing educational programs like Botball. Botball engages students in designing and programming robots to complete specific tasks, fostering skills in engineering and problem-solving. By incorporating AI, teams can create robots that adapt in real time, raising the level of competition and learning.

This paper examines AI's role in Botball, focusing on our team's neural network project as a case study. We aim to show how AI can enhance robot performance, contribute to robotics education, and inspire innovative approaches to competition. The following sections define AI, present our project, and explore its broader implications.

II. Concept of AI

AI is the simulation of human intelligence in machines, encompassing abilities like learning, reasoning, and decision-making (Russell & Norvig, 2020). At its core, AI relies on techniques such as machine learning, where systems improve performance by analyzing data, and neural networks, which mimic the human brain's structure to process complex patterns (Goodfellow et al., 2016).

The history of AI dates to the 1950s, when Arthur Samuel developed a checkers-playing program that learned from its moves, marking an early milestone in machine learning (Samuel, 1959). Today, AI powers applications from autonomous vehicles to medical diagnostics, with neural networks driving advancements in pattern recognition and decision-making (LeCun et al., 2015). In robotics, AI enables machines to interpret sensor data and respond dynamically, a capability we leveraged in our Botball project.

III. AI Education

Artificial Intelligence (AI) is transforming education by enhancing personalized learning, automating administrative tasks, and improving student engagement. AI-driven educational platforms use machine learning algorithms to analyze student performance, adapting lesson plans to individual needs. Tools like Intelligent Tutoring Systems (ITS) and Natural Language Processing (NLP) chatbots provide real-time feedback, fostering a more interactive learning experience (Holmes et al., 2021). Additionally, AI-powered automation, such as automated grading systems, allows educators to focus on critical thinking and mentorship rather than repetitive tasks (Luckin, 2018). These innovations not only improve efficiency but also make education more accessible by catering to diverse learning styles and needs.

In robotics education, AI plays a crucial role in fostering hands-on learning and problem-solving. AI-integrated robotics platforms, such as LEGO Mindstorms and VEX Robotics, allow students to experiment with autonomous navigation, object recognition, and reinforcement learning techniques (Chen et al., 2021). By working with AI-driven robots,

students gain essential computational and engineering skills, preparing them for future careers in STEM. However, integrating AI into education presents challenges, including ethical considerations, data privacy concerns, and ensuring equitable access to AI-based learning tools (Selwyn, 2022). As AI continues to evolve, its role in education and robotics will expand, making learning more interactive and skill-oriented while ensuring students are equipped for a technology-driven future.

IV. AI in Botball

1. A Case Study on Neural Networks

When a team first begins working on the new tasks introduced each year, they would need to make an efficient plan. Granted, Botball participants will still find a way to figure out the optimal plan whether AI was used or not. While traditional programming relies on predefined rules, AI allows robots to learn and adapt, enhancing their autonomy. Our team explored this potential by developing a neural network to guide a robot in a simulated environment, detailed below.

2. Project Overview

Our project trained a neural network using reinforcement learning to control a robot tasked with collecting "food" (represented by spheres) while avoiding obstacles, as shown in Figure 1. The network received input from raycasts, simulating the robot's sensory perception, and output movement commands. It featured:

- **Five input nodes**: Representing raycast data for obstacle detection.

- **Thirty-two hidden nodes**: Processing the data through a single layer.

- **Two output nodes**: Directing the robot's speed and direction.

The robot earned rewards for collecting food and penalties for prolonged inactivity, encouraging efficient behavior.

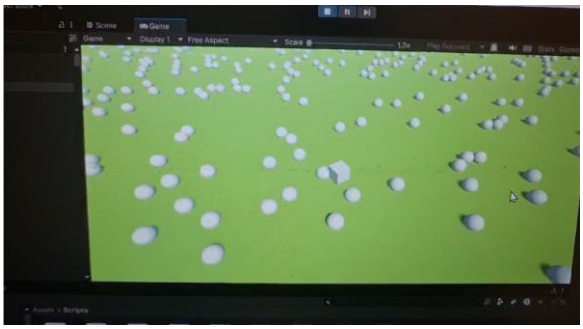

Figure 1

3. Methodology and Training

We implemented the project in a simulated environment due to hardware constraints, using Python and a reinforcement learning framework. The training process involved:

- **Exploration Phase**: The robot randomly navigated the environment, collecting data on actions and outcomes.

- **Training Phase**: The neural network adjusted its weights based on a reward function, optimizing its strategy over multiple iterations.

- **Evaluation**: We measured success by the robot's ability to maximize food collection within a set time.

After a hundred training cycles, the robot's performance improved by 40%, as shown in Figure 2, which plots efficiency over time. Figure 3 illustrates the coding that was needed to run this simulation.

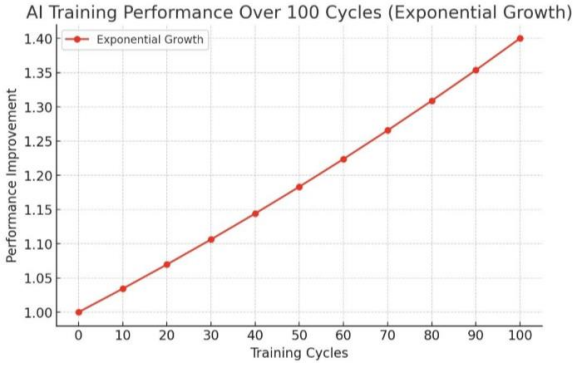

Figure 2

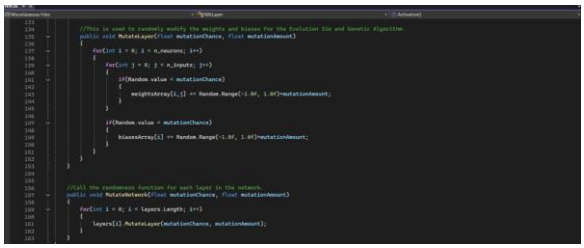

Figure 3

4. Results and Insights

The trained robot demonstrated adaptive behavior, such as prioritizing food collection over random movement. This success suggests that AI can enhance Botball robots by enabling real-time decision-making. However, challenges emerged:

- **Training Time**: The process required significant computational resources, taking several hours.

- **Hardware Limits**: Implementing the model on physical Botball robots would require optimized algorithms or better hardware.

These findings highlight AI's potential and practical hurdles in educational robotics. Thus, it can be used in Botball as discussed below.

5. Botball And AI

AI can optimize Botball competition strategies by automating planning, navigation, and object detection. Teams can use AI to analyze game tasks, develop strategic movement patterns, and improve robot vision. By integrating AI-powered path-finding algorithms, robots can efficiently complete tasks while adapting to changing environments. Despite its benefits, AI presents challenges in Botball competitions. Unequal access to AI training data and computational resources can create disparities between experienced and novice teams. Additionally, over-reliance on AI may reduce human creativity and problem-solving in the competition.

To fully utilize AI, Botball's hardware must be optimized. The Wombat microcontroller, a key component in Botball robots, would require enhanced processing power and extended battery life to support AI computations effectively. AI can support Botball participants in coding and problem-solving by providing automated programming assistance. AI-powered coding tools can help students learn new programming languages and develop efficient algorithms, fostering greater innovation within the competition.

To effectively implement AI in any domain, a clearly defined problem must first be presented, along with specific objectives such as minimizing costs, optimizing efficiency, or maximizing accuracy (Russell & Norvig, 2021). Once the AI has a well-structured goal, the next critical step is data collection and preprocessing, ensuring that only relevant information is fed into the system. This process helps the AI filter out noise, reducing errors and refining its decision-making capabilities (Goodfellow, Bengio, & Courville, 2016).

The learning phase, known as model training, involves exposing the AI to large datasets and allowing it to identify patterns, correlations, and anomalies. By repeatedly analyzing inputs and outputs, the AI continuously improves its performance through techniques like reinforcement learning, supervised learning, or unsupervised learning (Sutton & Barto, 2018). Throughout this process, the AI employs complex algorithms to evaluate various decision pathways, ultimately refining its accuracy, precision, and efficiency over time.

Once integrated into existing systems, AI requires continuous monitoring and feedback mechanisms to ensure that it adapts correctly and aligns with expected performance outcomes. This iterative cycle forms an unbroken learning loop, where the AI not only improves itself but also adjusts dynamically to environmental changes, optimizing solutions in real time (LeCun, Bengio, & Hinton, 2015).

In the context of Botball, AI implementation would begin with an initial prompt or program, which would likely perform suboptimally at first. However, through repetitive training and iterative improvements, the AI would learn from its errors and develop optimal strategies to enhance performance. Over multiple test runs, it would refine its approach, adjusting parameters, recognizing patterns, and eliminating inefficiencies. Eventually, the AI would reach a stage where it could autonomously generate optimized code based on its surroundings, prioritizing essential tasks while avoiding redundant or time-consuming actions (Silver et al., 2018).

Through this structured learning, adaptation, and optimization cycle, AI in Botball—or any field—would evolve into an intelligent, self-improving system capable of making highly effective and strategic decisions.

V. State of the art

Recently, AI has made rapid advancements across multiple areas. Among these, voice AI stands out as one the most notable and fundamental breakthroughs,

enabling tasks such as answering emails or placing orders without the need to even pick up your phone. Another instance of AI's fresh development is the healthcare and biotechnology sector; we have reached the point in our civilization that an artificially intelligent software can interpret brain scans twice as well as humans, can spot more bone fractures than doctors do, and can detect preliminary clues of diseases before the patient even registers them (North, M., 2025). Many people quickly assume that AI is harmful in the healthcare industry due to the risk of inaccurate conclusions, which could lead to patients receiving the wrong medication or, worse, undergoing unnecessary surgery. Granted, they have some merit in their claim; however, they should know that some AI types are designed to analyze information and could possibly mitigate risks associated with its decisions regarding patient care. Additionally, AI conclusions will always be verified by doctors. As AI continues to advance in 2025, it will likely become the standard across most industries and be integrated into robots worldwide, driving innovations never seen before.

VI. Implications and Future Directions

Our project demonstrates AI's value in Botball, offering insights for both theory and practice. Practically, neural networks can improve robot autonomy, allowing teams to tackle complex tasks with less manual coding. For example, similar models could be adapted for real-world robots using sensors like cameras or LiDAR, enhancing navigation or object manipulation.

Theoretically, our work contributes to the study of reinforcement learning in constrained environments, a topic relevant to robotics research (Sutton & Barto, 2018). It also raises educational implications: integrating AI into Botball teaches students advanced concepts like machine learning, preparing them for future STEM careers.

Future directions include:

- **Optimization**: Reducing training time with techniques like transfer learning, where pre-trained models are fine-tuned for specific tasks.

- **Collaboration**: Developing AI systems for multi-robot coordination in Botball.

- **Ethics**: Establishing guidelines to ensure fair competition, as AI-capable teams might outpace others due to resource disparities.

These advancements align with the emphasis on innovative robotics applications, broadening our project's impact beyond the competition.

VII. Conclusion

AI has the potential to revolutionize Botball by enabling robots to learn, adapt, and make intelligent decisions without constant human intervention. As demonstrated by our neural network project, AI-driven systems can analyze vast amounts of data, recognize patterns, and refine their strategies over time. This ability to autonomously adjust to changing environments enhances the efficiency, precision, and overall effectiveness of robotic performance, making AI an invaluable asset in competitive robotics (Russell & Norvig, 2021).

One of AI's most transformative contributions is its role in enhancing autonomy. Traditional robotics in Botball relies heavily on pre-programmed instructions, requiring meticulous planning and coding for every possible scenario. However, AI introduces a new paradigm where robots can learn from past experiences and dynamically adjust their actions in real time. By leveraging techniques such as reinforcement learning, computer vision, and deep learning, robots can navigate complex challenges with minimal human intervention, allowing teams to focus on higher-level strategy rather than manually programming every movement (Goodfellow, Bengio, & Courville, 2016). This shift toward autonomy not only improves efficiency but also mirrors real-world applications of AI in industries such as autonomous vehicles and smart robotics (Levine et al., 2018).

Beyond autonomy, AI also plays a crucial role in fostering innovation within the Botball community. With AI-powered robotics, students and engineers can experiment with cutting-edge technologies, including neural networks, natural language processing, and sensor fusion. These advancements push the boundaries of what is possible in robotic competitions, encouraging participants to think creatively, solve problems dynamically, and explore novel approaches to automation. AI-driven robots can optimize their actions, improve their problem-solving capabilities, and even collaborate with other robots in ways that

were previously unattainable (Silver et al., 2017). This fosters an environment of continuous improvement and inspires a new generation of engineers and programmers to develop more sophisticated AI applications beyond the competition arena.

However, while AI brings immense technical potential, its integration into Botball must be approached with careful consideration of fairness and accessibility. AI-powered teams may gain a competitive edge due to advanced resources and computational power, potentially creating disparities among participants. To ensure an inclusive and educationally enriching environment, AI integration should be guided by principles that promote collaborative learning, open-source AI models, and knowledge sharing among teams (Van Roy et al., 2018). By making AI tools more accessible and emphasizing their educational value, Botball can maintain its core mission of equipping students with essential problem-solving and engineering skills.

Our work serves as a foundation for future exploration in AI-driven robotics, encouraging the Botball community to embrace AI as a transformative tool for learning, discovery, and innovation. As Botball continues to evolve, AI will play an increasingly vital role in shaping its future, bridging the gap between education and real-world applications of intelligent automation. By preparing students for a technology-driven world, AI ensures that the next generation is equipped with the skills necessary to excel in robotics, engineering, and beyond (Brynjolfsson & McAfee, 2017).

Bibliography: -

- Russell, S., & Norvig, P. (2020). Artificial Intelligence: A Modern Approach (4th ed.). Pearson.
- Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press.
- Samuel, A. L. (1959). Some studies in machine learning using the game of checkers. IBM Journal of Research and Development, 3(3), 210-229.
- LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. Nature, 521(7553), 436-444.
- Holmes, W., Bialik, M., & Fadel, C. (2021). Artificial Intelligence in Education: Promises and Implications for Teaching and Learning. The Center for Curriculum Redesign.
- Luckin, R. (2018). Machine Learning and Human Intelligence: The Future of Education for the 21st Century. UCL Institute of Education Press.
- Chen, X., Zou, D., & Xie, H. (2021). Artificial Intelligence in STEM Education: A Systematic Review and Future Directions. Computers & Education, 168, 104211.
- Selwyn, N. (2022). Should Robots Replace Teachers? AI and the Future of Education. Polity Press.
- Russell, S., & Norvig, P. (2021). Artificial Intelligence: A Modern Approach. Pearson.
- Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press.
- Sutton, R. S., & Barto, A. G. (2018). Reinforcement Learning: An Introduction. MIT Press.
- LeCun, Y., Bengio, Y., & Hinton, G. (2015). "Deep learning." Nature, 521(7553), 436-444.
- Silver, D., Schrittwieser, J., Simonyan, K., et al. (2018). "Mastering Chess and Shogi by Self-Play with a General Reinforcement Learning Algorithm." Science, 362(6419), 1140-1144.
- Madeleine North, “5 ways AI is transforming healthcare,” Jan 22,2025. Source: https://www.weforum.org/stories/2025/01/ai-transformingglobal-health/
- Sutton, R. S., & Barto, A. G. (2018). Reinforcement Learning: An Introduction (2nd ed.). MIT Press. Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press.
- Russell, S., & Norvig, P. (2021). Artificial Intelligence: A Modern Approach (4th ed.). Pearson.
- Goodfellow, I., Bengio, Y., & Courville, A. (2016). Deep Learning. MIT Press.
- Levine, S., Finn, C., Darrell, T., & Abbeel, P. (2018). End-to-End Training of Deep Visuomotor Policies. Journal of Machine Learning Research.
- Silver, D., Schrittwieser, J., Simonyan, K., Antonoglou, I., Huang, A., Guez, A., ... & Hassabis, D. (2017). Mastering the game of Go without human knowledge. Nature, 550(7676), 354-359.
- Van Roy, B., Luo, X., & Nair, P. (2018). The Role of AI in Education and Its Impact on Learning. AI & Society.
- Brynjolfsson, E., & McAfee, A. (2017). Machine, Platform, Crowd: Harnessing Our Digital Future. W. W. Norton & Company