Rule-based AI in sports games

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1 Introduction

This article serves as a comprehensive research guide for a project focused on sports AI and team management, specifically utilizing a rule-based system. We will focus on the details of the concepts, reasoning, and algorithms behind the project's development and present the conclusions drawn from it.

Our motivation for writing this article is to share our experience in researching sports AI, reducing the difficulty of locating the appropriate references, algorithms, and techniques essential for developing a functional and effective system. We hope this paper will assist readers in exploring and understanding the covered topics and encourage them to consult the attached references for further insights, as well as giving a broad idea on the path of developing a functional and interesting football AI.

2 Sports AI concept: Picking our basis

Generally speaking, most sports games that utilize artificial intelligence to create an engaging and accurate environment rely on neural networks to replicate real matches. This approach effectively recreates realistic situations without needing to generate them from scratch. Therefore, our initial focus in this research was deep learning AI:

2.1 Deep Learning AI and Neural Networks

Football, as many other sports, is based on the rapport of different players that cover various roles in the pitch, forming a team that seeks to score a goal. This concept although well known is incredibly difficult to replicate due to the great human factor that is involved. This human factor is responsible for the uniqueness of the plays, the fluency of the ball and in general all the pleasing characteristics that the game offers. It also is the reason why replicating it is primordial to keep the essence of both the individual and the group on the field.

Machine learning is a field that excels particularly in this area because of the great similarity to human based games that can be achieved through its usage. Through neural networks, we can make a certain AI learn and replicate human conducts in many fields, such as sports.

To fully understand this system, let us look at each individual concept that could fulfill the task of creating the AI that we are looking for:

- **Machine learning**: Machine learning is a field of study in artificial intelligence that allows an entity to learn from inputted data and generalize from it to answer to unseen questions, cases or challenges. Machine learning is based on mathematical

methods that acquire statistical answers to the specific questions proposed. This system usually relies on regression models to accurately generate cases.

- **Neural Network**: A neural network is a model inspired by biological neural networks in animal biology. In code, they are usually represented by directional graphs that serve as layers to process a certain input and return a predicted output. Usually, neural networks are fed with information that depending on the application that we are searching for, is used to create different responses that determine the conduct of our AI. These models can follow different patterns depending on the data we are dealing with, leading to linear regressions models, logistic regression models or other mathematics-based systems of training. For instance, we could feed a neural network with patterns of waves to replicate the movement of the ocean.

By understanding these concepts, we can easily see the lead that could create a suitable football AI that fulfills our requirements. Feeding the adequate regression model with the desired plays or situations could actually give us a very well-trained artificial intelligence that successfully replicates human players and satisfies our needs of creating a smooth, fluent and pleasant experience. However, it is also easy to see the main problem that this approach presents. On the one hand, we need to develop a suitable regression model that gives us the desired results, which although not impossible, is by no means an easy task. On the other hand, even if we could create an accurate enough model to train our artificial intelligence, we would still be lacking the necessary data to feed it with. The data used is an important aspect of machine learning, and choosing the correct source is critical to develop an acceptable artificial intelligence system.

Sadly, the previously mentioned concerns completely discarded this way of working for our project due to time constraints and resources, leading us to seek for a different path. However, the usage of machine learning is really encouraged for realistic outputs and having had a better understanding of the field, and a better situation, it would have led to a much more realistic outcome.

2.2 Rule-based AI system

Having discarded the machine learning approach our next instinct was to search for a simpler sports game. Being honest, most realistic sports simulations rely on huge databases and very thoroughly picked regressions in order to shape their NPCs. Replicating their behaviors without the right materials is completely impossible at this level.

In the light of these events developing a rule-based NPC system seemed the best approach given our needs and constraints.

A rule-based system in computer science can be addressed as a system in which application-specific knowledge is used to specify limits and general reasoning in order to solve the

problems presented. This could come in the form of an if-else chain to derive actions from certain conditions that the AI needs to fulfill towards a specific goal inside the limits of the domain. This concept can also be modified into a more declarative system in which the actions are not explicitly commanded, but rather intuitively constructed by the engine. However, we will not be exploring the latter.

This arrangement comes really handy when dealing with sports games or simulations because it very much represents the concept of a sport itself, which is indeed a rule-based system: an action that needs to be fulfilled while following a set of arbitrary rules created by the programmer, or in the case of a sport, the founder. The parallelism of these two is an indicator towards the suitability of this approach when dealing with these kinds of challenges.

Taking this into account, our team decided to run on this idea to develop the application that would showcase our AI implementation.

Moreover, to further enhance the rule-based AI system, we incorporated additional features:

- **Dynamic Adjustments:** The AI can dynamically adjust its strategies based on the flow of the game, making it more adaptable and realistic. This also allows us to update each player's movement individually making it a much smoother experience.
- **Scenario Analysis:** The system includes modules for analyzing different game scenarios, with indicators such as zones, or areas where the ball is to optimize the team decision making.
- **Behavioral Patterns:** By studying human players, we developed behavioral patterns that the AI can mimic, enhancing the realism of the simulation and adding real plays and football patterns. (Refer to Figure 0)

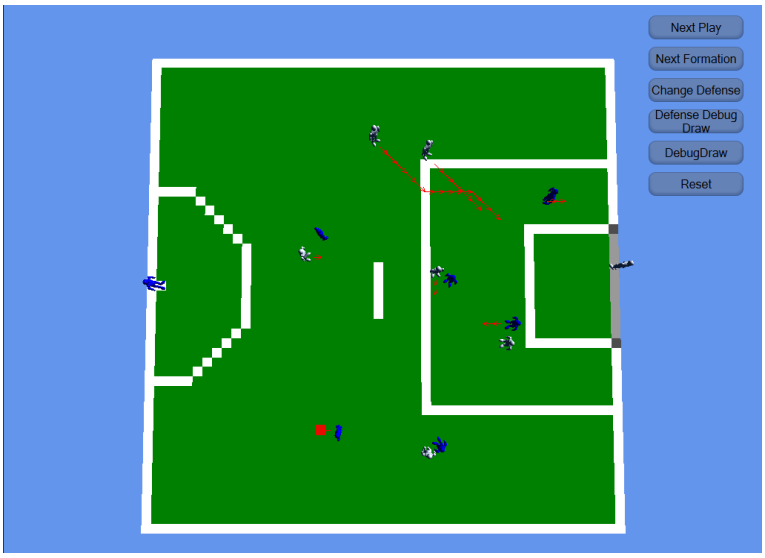


Figure 0: showcase of different behaviors

3 Application of the concept: How do we layer the project?

Having chosen a system to follow, our team decided to create a layered system in which rules would act hierarchically to determine the importance of certain actions in comparison to others, thus, building an internal system of preferences when dealing with different situations. In this way, the AI would have clear specifications in case of having an impasse due to mixed signals or corner cases. These layers are no more than theoretical separation of the individual components of the program, but it is crucial to determine the usage of each of them to really address the way in which the system works, and successfully depict the idea that we followed.

3.1 First Layer: Teams

Although it may not be considered a layer or a rule itself it is the main distinction between agents that fuels our project, the confrontation between an attacking and a defending team in a certain situation.

The attacking team would need to follow specific rules in order to successfully score a goal against an opponent that refuses to give up. Opposingly, the defending team would need to respond to the chosen attack system and answer accordingly to stop it. Refer to Figure 1.

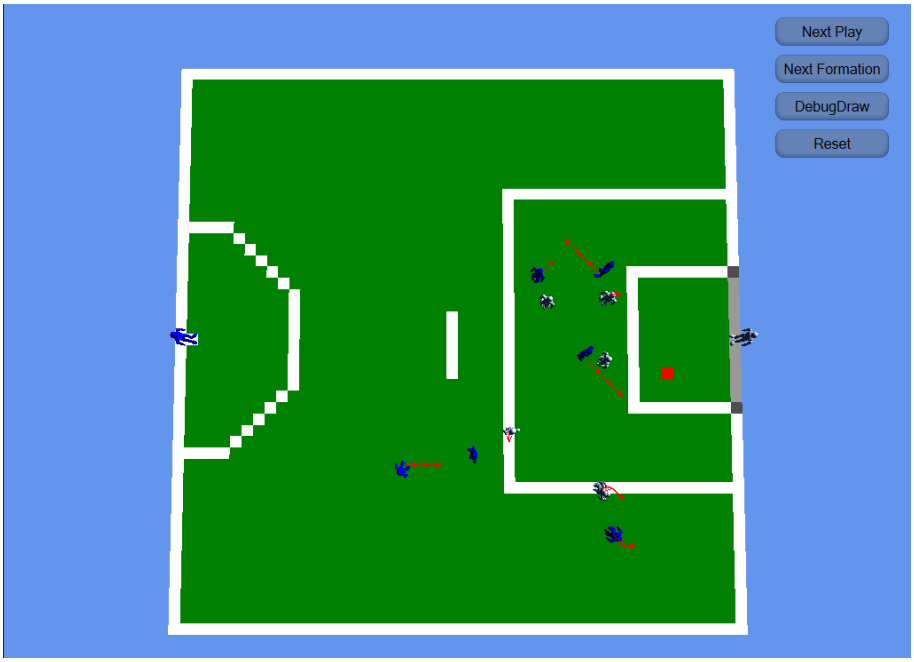


Figure 1: an attacking team playing against a defending team in an organized way.

3.2 Second Layer: Action zone

In most simulations the action set of an agent is easily limited. Geometry, visibility or environmental factors can, and most likely will take a big part in the decision making of each individual. However, in a football pitch we face a great challenge in this regard: the only factors that actually matter are the decisions of other agents.

While working in this project this has come to be the biggest challenge that our research has faced. The way in which agents move and react to others while cohesively working with their teammates is by no means an easy task to address. Experience tells us that when these kinds of problems arise, the wisest choice is usually to split them: divide and conquer. And so, we did.

Basically, we limited the choices of each player by assigning them to a certain zone in which their actions would again be limited by other smaller rules. This system is like a weighted map or an influence map, in the sense that it determines the moving path of the agent by assigning weights related to tags (football positions in this case). With this system we could limit the movement and visibility of both the attacking (Refer to Figure 2) and defending (Refer to Figure 3) team in different ways, while still having a pretty wide range of action that allowed the individuals to connect with each other and act as a group.

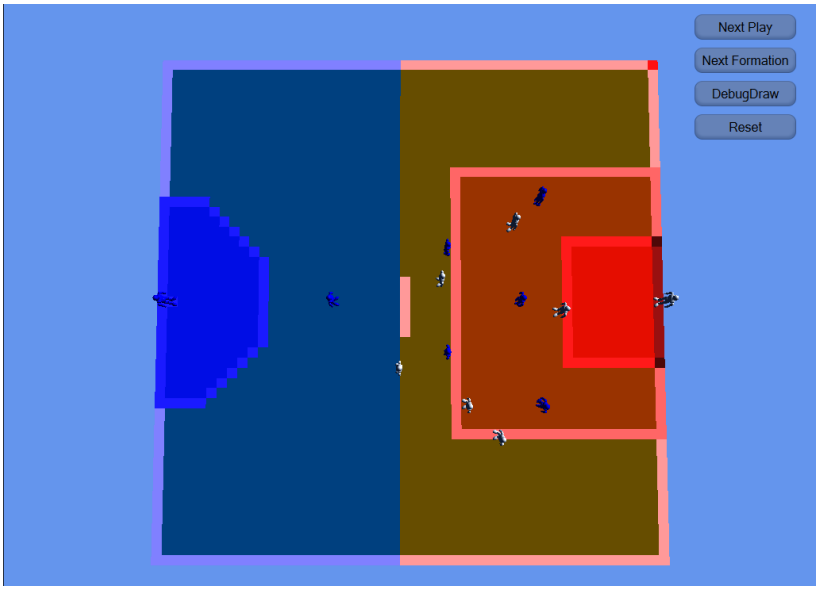


Figure 2: weighted map for the attacking team

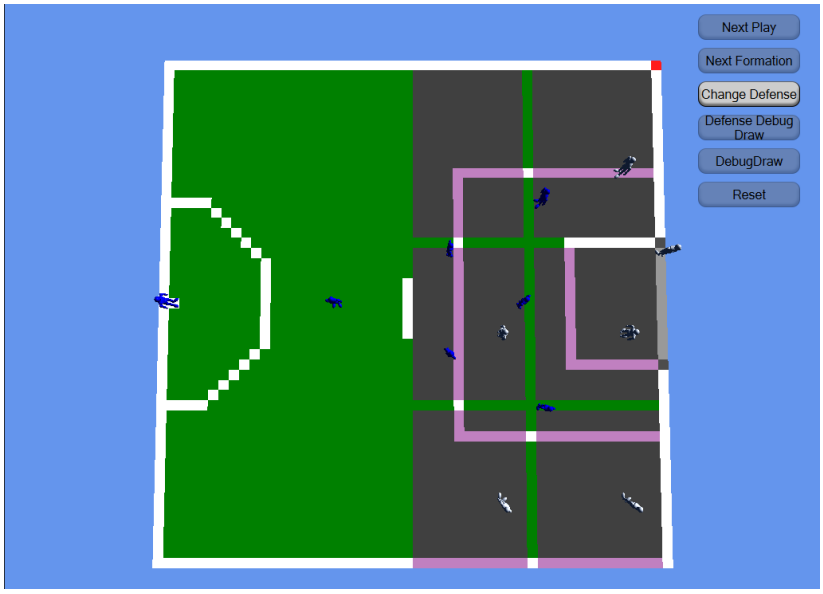


Figure 3: zone map for defending team (when static defense is on)

3.3 Third Layer: Tactics and plays

Having already set the boundaries of each agent inside the domain in which we wanted to act we needed to continue following the principles of football. This part of the research is abnormal in the sense that it does not search for techniques to program or algorithms to output a certain outcome, instead it serves to explore the possibilities that a real team could have in a football match following different formations and tactics. Although it may seem trivial, we must remember that we are trying to successfully replicate a situation between two teams that follow the rules of the game, thus this point is crucial to give a smooth experience that we can further analyze.

Following this idea, we decided to implement different attacking formations that the players would need to respect, and defending techniques in order to counter them:

Table 1 Formations of the attacking team

Player Formation	Positions
Just attack	3 strikers, 2 midfielders, 1 defender
Neutral playmaking	2 strikers, 2 midfielders, 2 defenders
Just defense	1 striker, 2 midfielders, 3 defenders
Extremal balance	3 strikers, 0 midfielders, 3 defenders
All to defense	1 striker, 1 midfielder, 4 defenders

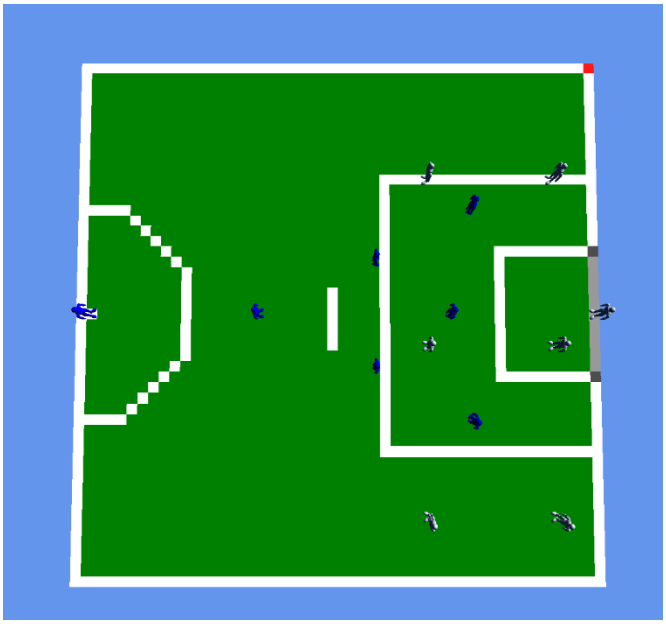


Figure 4: Just Attack Formation (example)

Figure 5: All to defense formation (example)

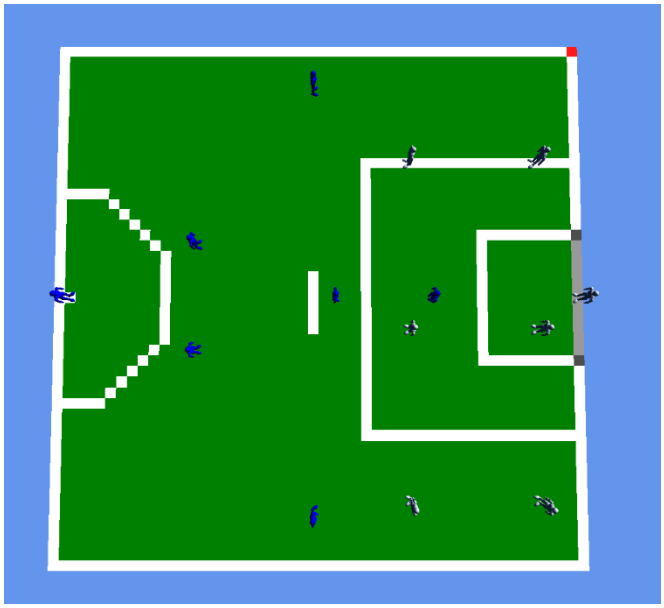
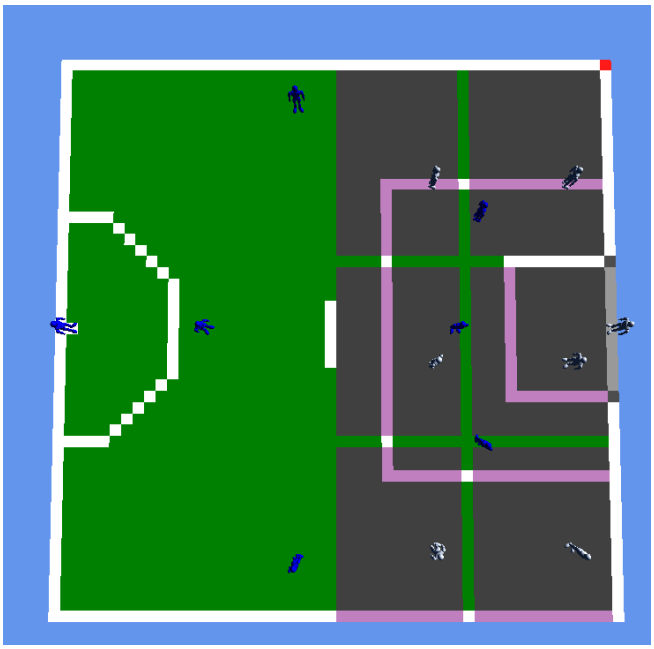


Table 2 Formations of the defending team

Player Formation	Tactic
Man to man defense	Each defender gets a man to guard
Man to zone defense	Each defender guards a strategical zone

Figure 6 : Man to zone defense (example)



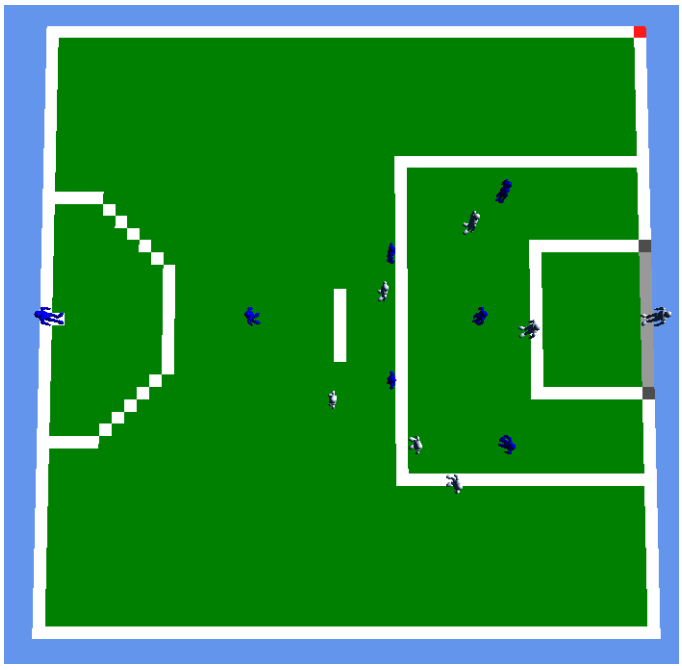


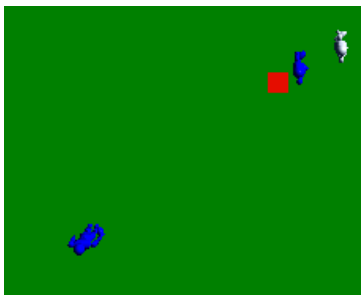
Figure 7: Man to man defense (example)

3.4 Final Layer: Individual layer

At the end of the hierarchy, we have the individual layer, which represents the tree of actions that each individual player can take in order to contribute to their goal. These actions will vary depending on the situation in which each team is and the previous layers, which means that depending on the zone, the tactics chosen by each team and the position of the player and the teammates the individual might choose differently to ensure that the most optimal path is taken. (Refer to figures 8, 9 and 10)

Inside this layer also lays the foundation of the movement (pathfinding, in this case), based on which players will decide where to move to make an assist, shoot the ball, make a pass… A* is a great algorithm in this case for optimal and fast computation. When combined with techniques such as goal bounding or JSPS it could be even faster, creating more dynamic and fluent plays.

Figure 8: a player passing the ball as a decision



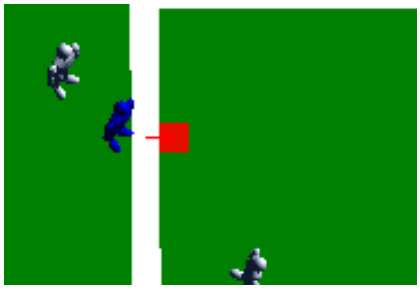
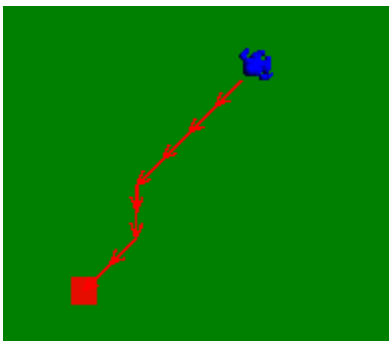


Figure 9: a player “dribbling” the defender

Figure 10: a player using A* to go for the ball



4 Conclusion

In this project, we explored the development of an AI for football team management. By examining different approaches, we determined that a rule-based system best suited our needs due to constraints in resources and time. Our layered system effectively prioritized actions, creating a cohesive and realistic football simulation.

The rule-based system, while simpler than deep learning models, provided a robust framework for developing the AI. It allowed us to manage complexity through hierarchical rules and zone-based actions, ensuring that the AI could make intelligent decisions within the constraints of the game.

Future Work: To further enhance the realism and effectiveness of the AI, future work could focus on:

- **Integrating Machine Learning:** Incorporating machine learning techniques when more data and resources become available could improve the AI's adaptability and performance.
- **Advanced Tactical Analysis:** Developing more sophisticated tactical analysis tools to allow the AI to better understand and counter opposing strategies.

In conclusion, our project demonstrates the potential of rule-based AI in sports simulations. With further development and integration of advanced techniques, such systems can significantly enhance the realism and enjoyment of sports video games and simulations.

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