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EECS 372

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**Penalty Kicks: Progress Report #2**

Firstly, a bulleted summary of my meetings with Prof. W. and Bryan Head is due:

1. My original proposal was a model of a specific instance of a game in which randomness and interactions were involved; it was decided that such a situation does not necessitate an agent-based model, which is more apt for a situation which involves many agents, over many games, developing a pattern which can be modeled.

2. Thus, it was decided that, as my model was sufficient to be a part of an agent-based model, I would create numerous instances of my original model and find a behavioral pattern across those instances.

3. Bryan proposed an idea to see a learning pattern of players as they move on from opponent to opponent and seek an optimal strategy of producing kicks and saves in certain directions.

4. Prof. W. proposed that I look closer at the El Farol Bar model, which describes agents that learn adaptively, similar to how one would assume a player would learn in this situation.

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As discussed in person with Prof. W. and Bryan, and as described in my last progress report, my main goal for this week was to create a three-dimensional model for a game of penalty kicks, and research more into possible behaviors of my agents, including their learning strategies and shooting and saving techniques. After an accumulation of studies, I have concluded that:

a. There are only a few relevant shooting or saving ‘techniques’ to be modeled. There are no complicated physical techniques when it comes to acting on a ball which will travel 12 yards. No such techniques are implemented on a regular basis by a professional. Also, many (note: MANY) studies show that chances of success for the kicker significantly decrease when he takes into account any behavior of the goalkeeper prior to his kick. Lastly, a kicked ball travels the 12 yards for 0.3 seconds on average, which is less than the goalkeeper’s reaction time in addition to his movement time; the goalkeeper, then, cannot practically react to the kicker’s actions.

b. Such findings very much support Palacios-Huerta’s hypothesis that the set of strategies and solutions involved in a penalty kick is a real-life manifestation of a Nash equilibrium, where no player has anything to gain by changing only his own strategy. Interestingly, the set of solutions involved in the El Farol Bar model also constitute a state of Nash equilibrium. Perhaps I can hope to have my model replace the El Farol model as a classic example of it, since in Palacios-Huerta’s words, “to the best of our knowledge, [our results] represent the first time that the fundamental notion of Nash equilibrium in mixed strategies is supported with real data.” Palacios-Huerta proves his hypothesis by firstly establishing that the rules of penalty kicks are consistent with the criteria of a game which involves the equilibrium, and through a thorough mathematical analysis which shows that the predictions of the theory of Nash equilibrium mixed strategy play – specifically that “(i) winning probabilities are statistically identical across strategies, and (ii) players’ choices are independent draws from a random process” – are very much consistent with his analysis of penalty kicks. Palacios-Huerta further claims that the second prediction “has *never* found support in any empirical tests,” until possibly now.

c. The height of a kick, as predicted, is essential to the kicker’s success rate, and I’m glad to have decided to work on a three-dimensional model. It is now included as a characteristic of a kick, and to be modeled is a decision algorithm for choosing the height of one’s kick.

And from these studies, I have formed a few more questions:

1. I have the data which analyzes the success rates of kicks based on their horizontal directions, but not on their vertical directions. Could I possibly find the optimal percentage of balls shot to the upper half of the goal through my model?

2. Palacios-Huerta worries that, since penalty kicks are awarded far apart from each other, perhaps the length of time passed in between those kicks account for the perceived randomness of choice in their directions, since it would make forgetting about their last kicks easier for the players. I hope to answer this question. In my model so far I have set a percentage of kicks sent to the player’s natural direction, therefore completely assuming the second prediction of mixed strategy Nash equilibrium plays. If each player’s kick is modeled to not be based on such chances, but instead the agent learns over time and forms a sequence to follow based on its experience, could each choice in that sequence be independent from the previous one? (A graph would be very useful to show the statistical chances of a certain agent’s choice being dependent on his last one. And *it would be*, except could it mimic a random sequence?) In other words, could my agents learn to form a random sequence of strategies through experience only, something that has so rarely been proven in empirical studies?

In essence, my model is still the same as the last updated version, except it has been adapted to fit three dimensions. All behaviors, rules, and outputs remain the same. My goal for next week is to implement as many of my findings as outlined here. To reiterate, these include: the behavior of a kick in relation to its height, the learning strategies of each agent, and separate modes to implement a chance-based model and a model based on enumerated sequences of strategies.

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Matt Le Tissier is striker who famously played for Southampton Football Club from 1986 to 2002, and at the age of 44 is still active, playing for a small club in Guernsey in the Channel Islands. Among many things, he is known for having successfully converted 48 penalty kicks out of 49 attempts throughout his career at Southampton, yielding a rate of 98%. Such statistics are practically unheard of from any other player; the average success rate of top professional players who specialize in penalty kicks is around 80%. Perhaps one may think he just has a great shot, but many others are better known for their shooting abilities. Perhaps one may think he has a secret strategy to follow. But I have written so far that the best strategy for this game is still randomness and unpredictability; it is to decide independently from any outside input or a set strategy. I conclude my second progress report with an apt quote from the man. It is non-mathematical, but it can definitely supplement as evidence to Palacios-Huerta’s analysis. Le Tissier seems unaware that he may have a chance at becoming an accomplished game theorist, as well. When asked by a BBC reporter if he had any tips to offer to other penalty takers, he had this to say:

*“I don’t think I could offer them any advice. It’s a personal thing and not something you can teach. I don’t think there was any secret to my success. Self belief and confidence were the biggest thing. I believed that when I stepped up to take them, I was going to score. It was an easy chance for a goal. Being a goalscorer and loving hitting the back of the net, I just didn’t want to waste that opportunity.”*