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An Analysis of the Impact of Front Row Attackers in Division I Women's Volleyball using Markov Chain Processes

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Abstract

This study investigates the impact of front row attackers on the outcomes of a National Collegiate Athletic Association (NCAA) Division I women's volleyball match using Markov chain techniques. The goal is to compare consistency, efficiency, and overall quality of performance in each of the three front row attackers: outside, middle, and opposite hitters. By assessing the skill levels of these players both over full seasons and a single match, we are able to create transition matrices containing probability that the ball will move from each individual state to another, including states that represent scoring points. These transition matrices are then used to inform Markov models built to reflect points and sets of volleyball, which include stipulations to uphold the integrity of the rules of the game such as only allowing three touches per side.

Evaluation of Attackers

In some preliminary exploratory data analysis performed on the data taken from all 14 teams in the Big Ten Conference in 2023, we can see the distribution of attacks and attacking percentage between the three types of hitters: outside, middle and opposite. Hitting percentage is measured by subtracting the number of errors from the number of kills and dividing by the total number of attacks. Negative hitting percentages stem from a higher number of errors than kills or successful attacks.

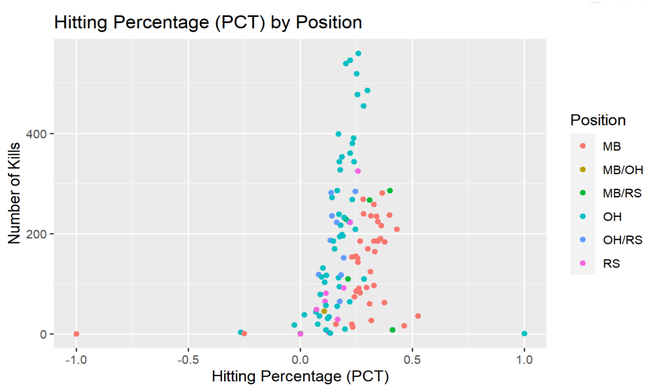
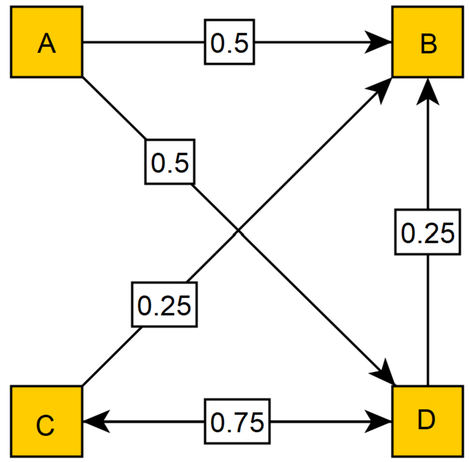


Figure 1. Hitting percentages in comparison to their number of successful attacks grouped by position.

In Figure 1 above, we can see that outside hitters have the highest quantity of kills, but middle hitters have the greater quality of attacks. This lower attacking percentage for outside attackers is often due to their high frequency of errors. Middles likely accrue less errors due to their position on the court, which is further from the boundaries of the court than the other two attackers. Opposite attackers, also referred to as right-side hitters, fall somewhere in between outsides and middles. Hitters who fluctuate between a right-side attacker and either a middle or an outside tend to follow the same trends as their position that isn't right-side. For example, a middle-opposite switch hitter is comparable to a middle blocker and an outside-opposite switch hitter is comparable to an outside hitter.



Let A represent a serve by the home team. Notice, the ball cannot return to the serve and thus this state in a single point.

Let B represent a point for either team being scored. Notice that all states get absorbed into this state.

Let C represent a player from the home team. Notice that a serve cannot go to this player as the ball must cross the net on a serve.

Let D represent a player from the away team.

Figure 2. Graph of a Markov Chain using volleyball logic with arbitrary probability values

Markov Chains

A Markov chain is defined as a special type of discrete-time stochastic process which is a description of the relation between the events or characteristics observed at discrete points in time denoted as *t*. There are many different kinds of states and paths between states in a Markov process, but the main states demonstrated in this research include transient, recurrent, and absorbing states. Transient states are those which are able to reach other states but not themselves be reached, like state A in Figure 2. Absorbing states are reachable by other states but cannot itself reach out to others, such as state B above. Lastly, recurrent states are those that are able to reach and be reached by other states, like states C and D. If two states share a path such that both are able to reach and be reached by one another, they are said to be communicating as states C and D are with one another.

$$\begin{bmatrix} 0 & 0.50 & 0 & 0.50 \\ 0 & 0 & 0 & 0 \\ 0 & 0.25 & 0 & 0.75 \\ 0 & 0.25 & 0.75 & 0 \end{bmatrix}$$

Figure 3. Corresponding transition matrix to the Markov chain demonstrated in Figure 2.

Methods

The data collected for the rest of this project was found by viewing the 2023 Division I Women's Volleyball Championship match between the Texas Longhorns and Nebraska Cornhuskers. This data was gathered by dividing the court into 12 zones (6 per side) and recording ball movement between them. It was then stored in a matrix that informed a Markov simulation model, using the probabilities in the matrix to determine ball movement between zones. A sample matrix reflecting the given values in the diagram above is presented in Figure 3. The Markov model created uses the rules of volleyball to simulate a point made up of valid rallies and strings them together to simulate a game to the desired number of points. Alterations were made between simulations to show possibilities for improvement and simulations were run to 10,000 points for a greater sample size.

Results

Two different kinds of adjustments were made to the attacking percentages (PCT) of Nebraska, the losing team in all three sets. The first kind substituted the PCT of the main player of each attacking position with their season PCT to determine the impact of each player's skill being increased a reasonable amount. For example, Harper Murray was the team's leading outside attacker all season and in this championship game, so for plot 2 in Figure 4, her PCT of 0.125 in this game was replaced with her season PCT of 0.237.

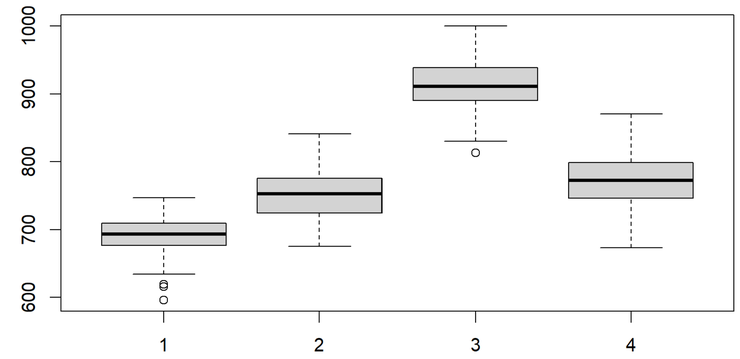


Figure 4. Side-by-side boxplots of hitters' effects on the outcome of the game (baseline, outside, middle, and opposite).

The second kind of adjustment increased all three attackers' PCT by increments of 0.05. As we can see in comparing Figures 4 and 5, increasing the middle attacker's PCT to their season average has a similar effect to increasing all three attackers' PCT by 15%.

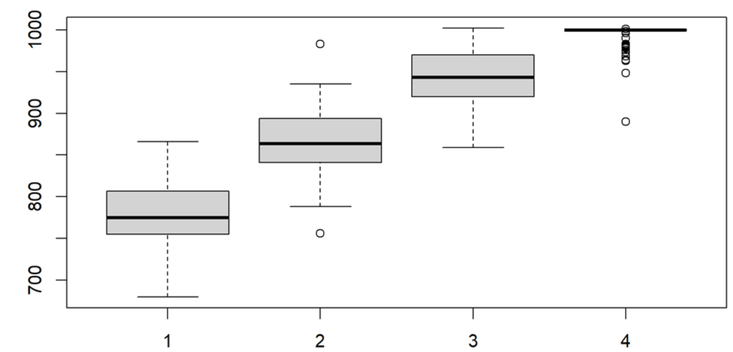


Figure 5. Side-by-side boxplots of each incremental adjustment in numerical order (5, 10, 15, and 20%).

Conclusion

The goal of this study was to use the findings to make recommendations for coaches recruiting hitters to their collegiate teams and even aid in how they practice and prepare for matches. From these results, we gather that middle and opposite attackers should be granted a higher frequency of attack attempts, rather than being reserved for blocking purposes. Middles were the most consistent attackers, accruing less errors than their counterparts. One off the most efficient sets proved to be a middle hitting a tight slide attack, which is set just above the net to zone 2 in the front right corner of the court rather than the middle hitter's base zone in the middle of the front row (i.e. zone 3). Outside attackers are fed the ball most frequently but have such a high rate of errors that this strategy can often be inefficient. For future research, I would recommend taking a second look into back row attackers especially with the rising popularity of pipe attacks, which come from the middle back zone of the court (i.e. zone 6).

References

[1] NCAA. Women's volleyball statistics. Retrieved from https://www.ncaa.com/stats/volleyball women/d1

[2] Winston, Wayne L. "Chapter 17. Markov Chains." Operations Research: Applications and Algorithms, Duxbury Press, Belmont, California, 2003, pp. 923–933.