Monte Carlo to Estimate USA Gymnastics Lineups with the Best Rate of Winning Medals

A Project Report for the UCSAS 2024 Data Challenge

Luke L Welsh

UCSAS 2024 Data Challenge

1/15/2023

Table of Contents

Introduction

Olympic qualifying countries must select only five athletes to participate in the Olympic games. This presents a difficult decision-making process for the countries because athletes achieve success in many ways. For this analysis, team success will be assessed through the lens of Olympic medals: gold, silver, and bronze for the top three placed finishers in each event. For men, there are eight different events with medals awarded: six coming from individual apparatus competition, one from individual all-around competition, and the final from the team all-around competition. For women, all is the same except there are only four apparatuses, leaving just six total events which provide medals.

Due to the complex nature of the competition, countries may find it difficult to select five athletes most strategically. Using Monte Carlo simulations, this project provides users with an analytically backed lineup of five gymnasts given their personal success criteria.

Once these five athletes have been chosen, countries are then able to select four of the five to participate in each apparatus for the qualifying round. Following this qualifying round, the top eight scores in each apparatus move to a final round competition, with the highest three scores receiving medals. Next, the 24 athletes with the highest combined scores across all apparatuses qualify for the individual all-around final, where they perform all apparatuses again, this time with the three highest combined scores receiving medals. Lastly, each team gets a score from the qualifying round. This score is calculated from the three highest individual scores in each apparatus. The teams with the eight highest scores move to the team all-around final round,

where they select three of their athletes to compete in each apparatus, with the scores all being added, and the three highest scoring teams receiving medals.

Given the complexity of this competition, different athletes will be expected to achieve success in different ways. The trouble comes in quantifying these differences. For example, if there is an athlete that is incredible in the floor exercise, but performs very poorly in every other apparatus, they will be able to help the team towards an individual floor exercise medal but will provide much less value in the individual all-around. This is where the decision for the lineup to select becomes very arduous.

Data Preparation

The data for this project begins with an in-depth record of scores from 39 recent world gymnastics events, including many World Challenge Cup events, as well as the 2022 and 2023 U.S. Championships. Each row represents a single athlete's score for one round of a competition. There is also information regarding the score breakdown, date of the event, gender of athlete, and the country with which they are competing.

Unfortunately, due to inconsistent recording, many of the athletes' names were recorded differently across various competitions. For example, sometimes an athlete's name may be reported as Sam, while other times it may be listed as Samuel. Secondly, some athletes represent different countries at different competitions. Lastly, there was one particular event in which many women were recorded to be men. These inconsistencies were addressed through a meticulous process of corrections as well as the addition of a new column entitled 'Name.'

Once clean, two different classes were created to seamlessly summarize the data. First, the *male/female_gymnast* class transformed any athlete's name into an object which contained a summary of the athlete's average score in each apparatus they competed in throughout the dataset, along with the standard error between each of those performances. This process demonstrated a very simple way in which to summarize all athletes down to a consistent format. A brief sidenote: if an athlete only competed in an apparatus once in the dataset, they are given the gender-wide average standard deviation for that apparatus.

The next class creates country objects, each having an attribute, *country.ath_perf*, which is a dictionary containing gymnast objects for all athletes that compete for that country. The process of creating country objects is simplified in Figure 1.

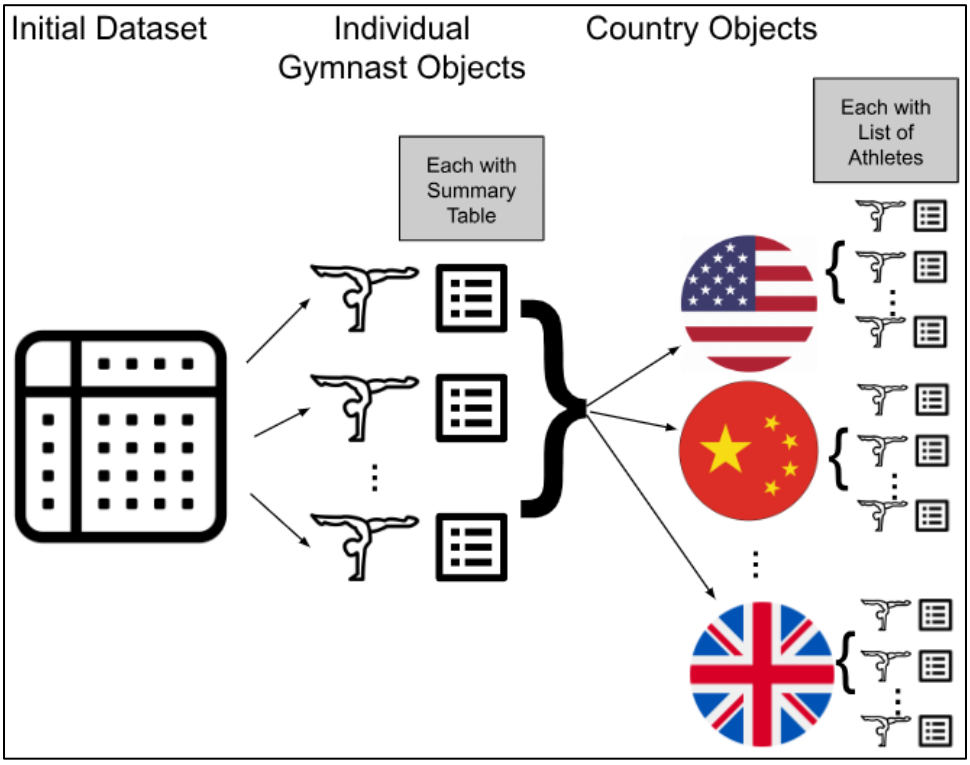

Figure 1: Visualization to describe organization of data through gymnast and country classes.

Olympic Qualification Round Set-up

The last step before beginning to simulate Olympic competitions is to determine which athletes will be competing. For each gender, 96 athletes can compete. 12 qualifying countries are each allowed five athletes. The next three teams in placement at the qualifying event each can qualify one athlete. The remaining 33 participants are determined through individual qualifying, which differs by gender.

Since the competitors in the qualifying round are not yet determined, predictions had to be made to decide which athletes would be competing. For the team qualification, an algorithm was created to select the five athletes that would be selected. This algorithm first checks if each athlete competed in at least three apparatuses, as well as if they had any performance in the top two for their country. Using all athletes that met these criteria, the five athletes that had the highest average score across apparatuses were selected to the Olympic team. Since only four athletes are allowed to compete in each apparatus per qualified team, this algorithm also selects the four athletes with the greatest average score in each apparatus. While this selection process may not be perfect, it serves to set a field that is generally similar to what will be present at the actual Olympics.

Some of the individual qualifiers have already been selected, so those individuals were automatically added. With the remaining open spots, the athletes with the best average scores by apparatus and overall were selected, based on the criteria of the spots.

Simulating the Olympic Games

Now with the field set, a series of functions was constructed to accurately simulate the Olympic games. For each athlete, 100 scores are simulated for each event for which they are eligible to compete in. These scores were simulated using a normal curve based off the athlete's average score and their standard deviation in that apparatus. Below, Figure 2 demonstrates how, for a more simplified group of only 4 athletes, different arrangements of placing may occur due to the randomness of these normal distributions.

Across all athletes, this simulation now contains 100 different qualifying rounds worth of scores. For each of these qualifying rounds, the finalists for each event type are selected, and 100 more final rounds are simulated in the same fashion as before. In total, this simulation represents 10,000 complete competitions, while recording the medal counts by country and event type.

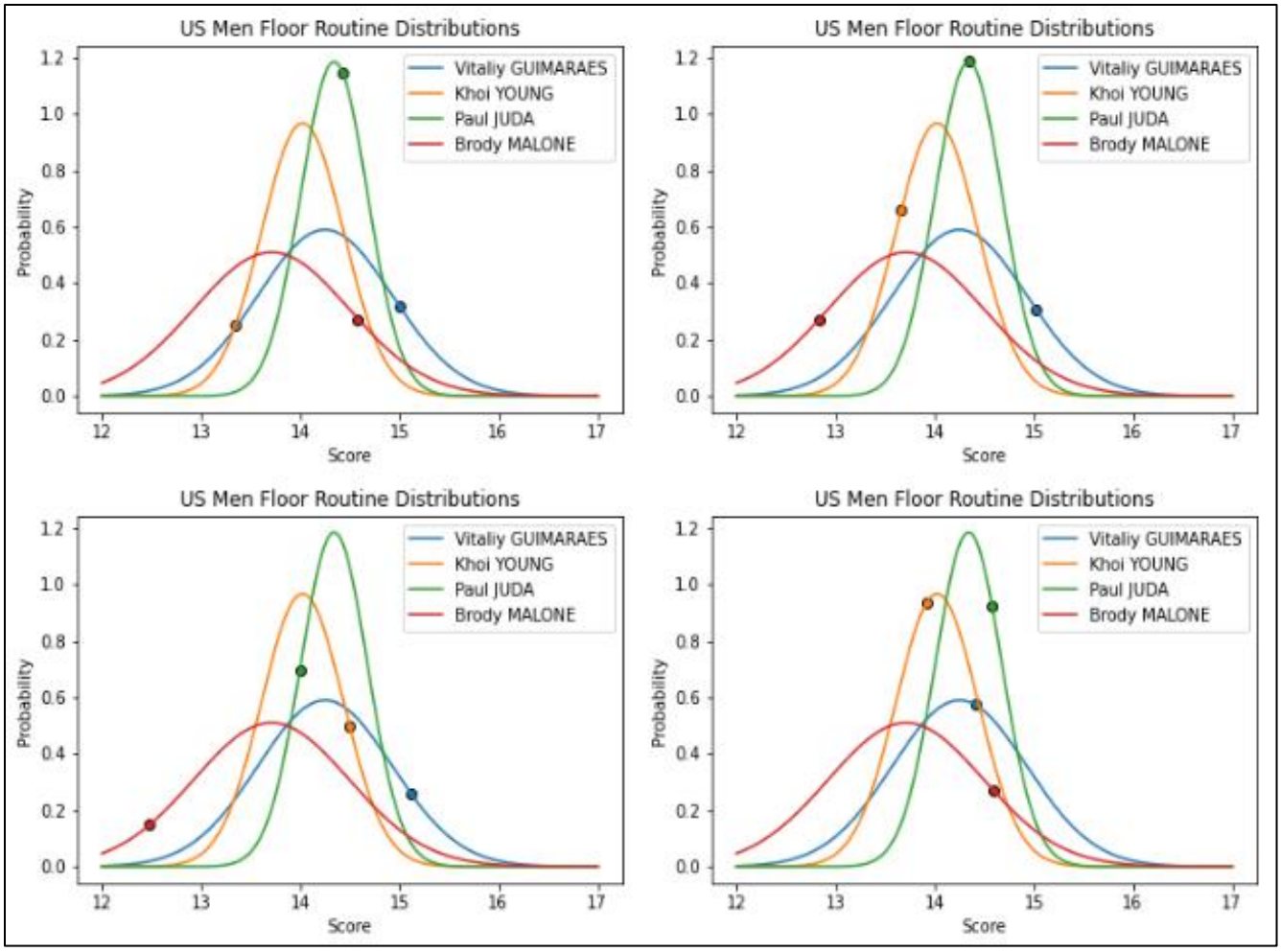

Figure 2: In different simulations, athletes will be placed differently due to the randomness in their distributions. In two simulations, Khoi Young (yellow) has the lowest score, and in the other two, Brody Malone (red) has the lowest score.

Comparison of Different American Lineups

With a simulation ready, it is now easy to calculate the medal winning rate of any USA lineup. By simply entering any lineup of five USA athletes, the simulation calculates and returns

the number of medals that this lineup would win over the course of the 10,000 aforementioned simulations.

To find the optimal lineup, the simulation had to be run for every possible five-person lineup that the country could create. Due to the exponentially increasing nature of combinations, using all of the athletes for combinations would be far too computationally expensive. As such, the total pool of athletes that simulations were run for was limited to only those who pass the following criteria. To start, the top five all-around gymnasts for the country were found, and their average scores per apparatus were recorded. For a male athlete to be included in the simulations, they had to meet the following criteria. In at least one apparatus, their performance had to be equal to or better than the best score in that apparatus from the previously described group. Since there are a lot less women in the dataset, the female athletes had to be at least as good as the third best athlete among the top five all-around.

As previously mentioned, the "best" lineup may differ depending on what the country believes the goals of the competition are. Fortunately, the simulations allow for direct comparison between lineups and allow us to set a criterion and be returned with the best lineup. Through some testing, different criteria may result in different outcomes. Figures 3.1 and 3.2 display the suggested lineups for five different classifiers calculating success.

Male Competition Recommendation					
Total Medals	Vitaliy GUIMARAES	Brody MALONE	Paul JUDA	Khoi YOUNG	Donnell WHITTENBURG
Weighted by Type of Medal	Vitaliy GUIMARAES	Brody MALONE	Asher HONG	Khoi YOUNG	Donnell WHITTENBURG
Higher Weight for Team Medal	Vitaliy GUIMARAES	Brody MALONE	Paul JUDA	Khoi YOUNG	Donnell WHITTENBURG
Higher Weight for Team & Indv. AA Medal	Vitaliy GUIMARAES	Brody MALONE	Paul JUDA	Khoi YOUNG	Alex DIAB
Higher Weight for Type of Medal, Team & Indv. AA Medal	Vitaliy GUIMARAES	Brody MALONE	Paul JUDA	Khoi YOUNG	Donnell WHITTENBURG

Figure 3.1: Recommended USA Men five-person lineup according to different specifications of success.

Female Competition Recommendation					
Total Medals	Simone BILES	Shilese JONES	Sunisa LEE	Jade CAREY	Konnor MCCLAIN
Weighted by Type of Medal	Simone BILES	Shilese JONES	Sunisa LEE	Jade CAREY	Konnor MCCLAIN
Higher Weight for Team Medal	Simone BILES	Shilese JONES	Sunisa LEE	Jade CAREY	Konnor MCCLAIN
Higher Weight for Team & Indv. AA Medal	Simone BILES	Shilese JONES	Sunisa LEE	Jade CAREY	Konnor MCCLAIN
Higher Weight for Type of Medal, Team & Indv. AA Medal	Simone BILES	Shilese JONES	Sunisa LEE	Jade CAREY	Konnor MCCLAIN

Figure 3.2: Recommended USA Women five-person lineup according to different specifications of success.

In the above tables, the decision for which five female athletes to send to the Olympics is unanimous: Simone Biles, Shilese Jones, Sunisa Lee, Jade Carey, and Konnor McClain. However, for the men, the decision is not quite as blatant. Depending on the preferences of those making the decision, an argument could be made for some different lineups.

These criteria for the different rows are as follows:

- Total Medals - total of:
    - # of apparatus medals +
    - # of individual all-around medals +
    - 1 if the team achieved a team all-around medal

- Weighted by Type of Medal - Same as total medals, but
    - gold medals are weighted to be worth 3x as much as bronze
    - silver medals are weighted to be worth 2x as much as bronze
- Higher Weight for Team Medal - total of:
    - # of apparatus medals +
    - # of individual all-around medals +
    - 5 if the team achieved a team all-around medal
- Higher Weight for Team Medal & Indv. AA Medal - total of:
    - # of apparatus medals +
    - 3 * # of individual all-around medals +
    - 5 if the team achieved a team all-around medal
- Higher Weight for Type of Medal, Team Medal & Indv. AA Medal -
    - combination of Type of Medal and Team & Indv. AA Medal

Future Directions for Improvement

There are a couple aspects in which this estimation could be further developed.

- First, the pool of competitors in the qualifying stage of the simulations could be more accurately predicted:
    - For predicting the five athletes from each team, this could be done by applying the simulations for different lineups for all the teams, not just the United States. Looking back, this algorithm selected Vitaliy Guimaraes, Curran Phillips, Khoi Young, Paul Juda, and Brody Malone when applied to the US men. Comparing

this the selected athletes at the end, four of these five are featured in almost all of the suggested lineups. For the US women, all are the same.

    - As for the individual qualifiers, the qualifications were not quite followed to a tee. For example, instead of selecting an athlete that I predict to qualify at each of the Continental Championships, I simply chose the 4 top remaining athletes based on their all-around score. Additionally, many of these individuals will qualify by the time that the country needs to select their lineup, meaning that the process could be updated and run again with that new information. Lastly, I did not address the rule maximizing the number of eligible gymnasts for a non-qualified country.
- Additionally, more USA athletes could be included in the potential simulations. While I believe that my filtering did not eliminate any athletes that would be part of a lineup resulting in the maximum success (by any measure), there is a chance that this is not the case. Simulating with more athletes would result in a more complete analysis that I could not perform due to lack of compute power.
- Another improvement could be made in the prediction of all athletes' Olympic score distributions for each apparatus. In this analysis, this step was done by simply taking the average score across the entire dataset for each athlete-apparatus combination. However, there could potentially be time trends pointing to athletes which are consistently improving, or correlations between performances in different apparatuses at the same competition or the same apparatus in different rounds. For example, a strong vault score in the first round may often lead to a higher-than-average vault score for that athlete in additional rounds of the contest.

- Lastly, analysis of the final lineup-medal summary table could be done to quantify how valuable each gymnast on the top lineups is. For example, one could compare the selected women's team to the same team but with Simone Biles replaced by the next best option. This analysis would be able to quantify how many medals, on average, Simone Biles adds to the team in comparison to the next best replacement.

References

Qualified Women

Qualified Men

Selecting Tripartite Qualifier Reddit Conversation

Images Used:

Dataset Icon

Gymnast Icon

Summary Table Icon

United States Flag

Chinese Flag

United Kingdom Flag