

## The Problem

The assigned problem is to use a Monte Carlo simulation to model the board game Chutes and Ladders in order to make a recommendation for an average playing time to be printed on the box.

## The Variables

The dependent variable in this model is **playing time**, which will be determined by **number of players**, **age of players**, which will effectively determine the time length of each turn, and **number of turns**, which will be determined by the Monte Carlo simulation.

**Number of Players:** we will model expected playing time for games with two, three, and four players.

**Age of Players:** there will be two age categories (adult and child), which will be assigned different turn-times:

Adult = 10 seconds per turn

Child playing with Adult = 15 seconds per turn

Child playing with Child = 25 seconds per turn

For the sake of our calculations, it will be assumed that children in a group with any adults in it will take 15 seconds per turn, even if there are other children in the game as well.

**Number of Turns:** we will find this through a Monte Carlo simulation of the game, wherein we build a model for the game and the computer "plays" the game a couple thousand times and returns the average number of turns needed to finish the game.

## The Modeling Process

There are three rules to the game of Chutes and Ladders which we need to model: the spin (like a roll of a die), the board, and the finish.

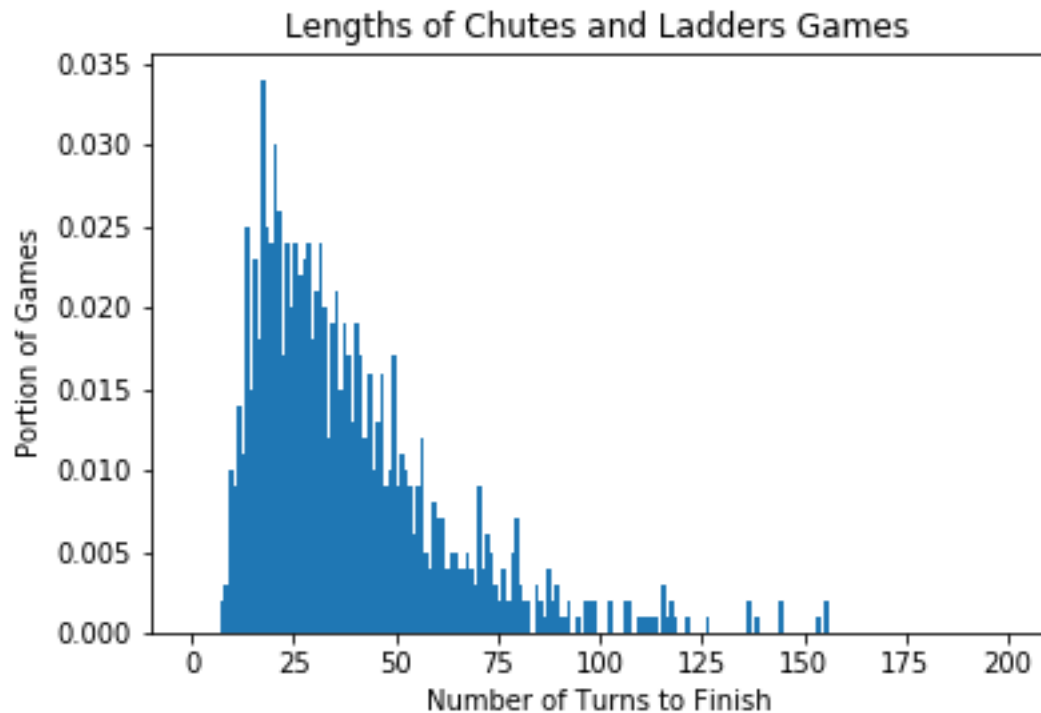
The roll is modeled by obtaining a random number between 1 and 6, the board is modeled by an array assigning the starting point of each chute or ladder to its end point, and the finish is modeled with an "if" statement, instructing the program to continue playing until the player rolls a move that gets them to the hundredth space and not over it.

```
from random import Random
import numpy as np
chutes_ladders = {1:38, 4:14, 9:31, 16:6, 21:42, 28:84, 36:44, 47:26,
                  49:11, 51:67, 56:53, 62:19, 64:60, 71:91, 80:100, 87:24,
                  93:73, 95:75, 98:78}
def play_game(rseed=None, max_roll = 6):
    position = 0
    turns = 0
    rand = Random(rseed)
    while position < 100:
        turns+=1
        roll = rand.randint(1, max_roll)
        if position + roll > 100:
            continue
        position+=roll
        position = chutes_ladders.get(position, position)
    return turns
```

This code yields the number of turns needed for a single player to finish a single game of Chutes and Ladders. This becomes a Monte Carlo simulation when we instruct the program to run the game a hundred thousand times and report to us the average number of turns needed to finish and the standard deviation from the average.

```
#Set up the parameters for the Monte Carlo Trial
number_of_games = 100000
outcome_sum = 0
outcome = np.zeros(number_of_games)
#Start the simulation
for n in range(number_of_games):
    outcome[n] = play_game()
#print(outcome) #this prints out all outcomes
print("The average outcome is ", np.average(outcome))
print("The standard deviation is ", np.std(outcome))
```

```
The average outcome is  39.2729
The standard deviation is  25.368229453195976
```



## Average Times

Thus, average number of turns needed for a single player to finish a game of Chutes and Ladders is about 39 turns. Applying this average to the various player combinations, we get the following average times:

### For Two Players

Players	Length of Game
2 Adults	13 minutes
1 Adult and 1 Child	16 minutes
2 Children	32 minutes

### For Three Players

Players	Length of Game
3 Adults	20 minutes
2 Adults and 1 Child	23 minutes
1 Adult and 2 Children	26 minutes
3 Children	49 minutes

**For Four Players**

Players	Length of Game
4 Adults	26 minutes
3 Adults and 1 Child	30 minutes
2 Adults and 2 Children	33 minutes
1 Adult and 3 Children	36 minutes
4 Children	65 minutes

**Conclusion and Recommendations**

On the box, the game states that it is for 2 to 4 players, ages 3+. Based on the results above, my first suggestion would be to change the age recommendation, because it is incredibly unlikely that two three-year-olds would have the patience to play a game that took, on average, over 30 minutes to play. Perhaps, with an extremely patient parent or baby-sitter, a three-year-old could be convinced to sit and play the game for 16 minutes with an adult, but even this is rather unlikely.

My recommendation for an "average play time" on the box would be 15 minutes for two players, 25 minutes for three players, and 35 minutes for four players. Perhaps a more marketable statement on a box would be that average play time is 15 minutes (assuming that most games of Chutes and Ladders are played with two people, and that typically at least one of these players is an adult), with an asterisk and a footnote that each additional player adds an average of 10 minutes to the play time. While potentially misleading, this would keep the averages simple and memorable, and packaging is part of advertising and therefore allowed to be a little misleading.