


Analysis of the Monte Carlo Method in Simulation of Snake and Ladder Game Using R Programming

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Article Info	ABSTRACT
<p>Keywords: Monte Carlo, Simulation, Snakes and Ladders, R Programming, Probabilistic Modeling.</p>	<p>This study applies the Monte Carlo method to simulate the classic board game "Snakes and Ladders" using the R programming language. The research aims to explore how randomness and probability influence the number of moves needed to complete the game and to provide a statistical overview of game outcomes. A simulation of 10,000 iterations was conducted, where each iteration represents one complete game play, starting from position 1 and ending exactly at position 100. The results show that players require an average of 51.41 moves to finish the game, with a minimum of 8 and a maximum of 394 moves. These results illustrate the highly variable nature of the game due to random dice rolls and the presence of snakes and ladders that can significantly alter a player's position. Visualization techniques such as histograms, density plots, boxplots, and line graphs were used to represent the distribution and variability of moves. The findings demonstrate the effectiveness of Monte Carlo simulations in analyzing stochastic systems, where outcomes are driven by random variables. This research contributes to the understanding of probabilistic modeling and can serve as a simple yet insightful example of applying computational methods to real-world scenarios.</p>
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INTRODUCTION

Games are an important part of human life, not only as a means of entertainment, but also as a medium of learning and simulation to understand complex concepts in mathematics and statistics (Wati et al., 2024). One of the games that is quite popular and often used as an example in probability studies is the snake and ladder game. The game has a simple mechanic, but it contains an element of high probability as the player's movement is determined by the outcome of the dice roll (Sukarsa et al., 2023). This random element makes the snake and ladder game relevant to be studied in the context of stochastic simulation in order to understand the distribution of the possible number of steps or turns needed to reach the finish line (Fitriani et al., 2023).

To study complex systems that involve an element of uncertainty, the Monte Carlo method is one of the most widely used techniques (Dalimunthe, 2021). Monte Carlo is a simulation method based on random repetition that allows researchers to estimate the

outcome of a process that cannot be determined analytically (Syahbana et al., 2023). In the context of snake and ladder games, this method can be used to simulate thousands to millions of game scenarios to observe the probabilistic patterns of the player's journey in the game (Constantin et al., 2023).

The Monte Carlo method relies heavily on a random process that is performed over and over again to produce a probability distribution of an event (Desi et al., 2024). In game simulations, this process reflects the player's turn to roll the dice, make progress, or retreat due to ladders or snakes. Thus, the Monte Carlo approach can be used to predict the expected number of turns to complete the game, determine the highest probability of winning based on the starting position, and evaluate the effects of the board configuration (Signoret et al., 2021).

The R programming language is a very suitable tool for use in the context of Monte Carlo simulation because of its ability to handle statistical computation, data visualization, and the availability of specialized libraries such as `sample()`, `replicate()`, and `ggplot2` that support the creation of simulations and graphs (Kabacoff, 2022). In addition, R has advantages in documentation and a broad user community, thus supporting reproducibility and data openness in academic research (Wali et al., 2023).

Several previous studies have used the Monte Carlo method for simulation of simple to complex games, such as monopoly games, blackjack, and strategy wars. However, studies on snake and ladder games as objects of scientific simulation are still limited. In fact, with this approach, many aspects of the game can be analyzed, such as the variation in results based on the number of players, the role of the board configuration, as well as the analysis of the expected time of completion of the game.

In this simulation, the author will create a model of a snake and ladder game with a standard board configuration, one player, and one dice. The simulation will be run using the Monte Carlo method thousands of times to generate a frequency distribution of the number of turns needed until the player reaches the 100th square. The output of the simulation will be analyzed in the form of descriptive statistics and distribution graphs, as well as compared with theoretical expectations if possible.

Based on the above background, the purpose of this study is to analyze the effectiveness of the Monte Carlo method in simulating snake and ladder games using the R programming language, as well as to observe the pattern of probability and distribution of the number of turns needed to complete the game. The results of this simulation are expected to provide an in-depth understanding of the application of the Monte Carlo method in the context of games and encourage its use in simulation-based learning.

METHODS

This study uses a quantitative approach through Monte Carlo simulation to analyze the number of steps needed by players to complete the snake and ladder game. The simulation was carried out using the R programming language by defining the position of the ladder and the snake as a start–end pair in the form of a list. The main function `main_ular_tangga()` simulates the game from the starting position (1) to the end (100), where in each move, the

player rolls the dice randomly and adjusts its position if it hits a ladder or a snake. To obtain a representative probabilistic distribution, 10,000 simulations were performed using the replicate() function. The result of each game in the form of the number of moves needed is stored in the outcome variable.

Data analysis was carried out descriptively by calculating the average, minimum, and maximum values of all simulation results. Data visualization uses histograms, plot density, boxplots, and line graphs to show the distribution and tendency of game patterns. The set.seed(123) function is used to ensure the reproducibility of the simulation results. The study did not involve human subjects so it did not require ethical approval, and all simulation parameters were explicitly specified in the code. With this approach, the simulation results can be used as a basis for analyzing other random games and strategies in a probabilistic context.

Table 1. Stair Position

Yes	Starting Position	Final Position
1	3	22
2	5	8
3	11	26
4	20	29
5	27	56
6	21	82
7	43	77
8	50	91
9	72	84

Table 2. Snake Position

Yes	Starting Position	Final Position
1	17	4
2	19	7
3	21	9
4	54	34
5	62	18
6	64	60
7	87	24
8	93	73
9	95	75
10	98	79

Based on tables 1 and 2 above, it shows the position of ladders and snakes in the game of snakes and ladders. The Stair Position Table displays the start and end points that lead the player up to a higher position when landing on the ladder box. In contrast, the Snake Position Table shows the starting and ending positions that make the player drop to a lower position when landing on the snake's head. This information is important for understanding the

dynamics of the game and how certain positions can speed up or slow down the player's progress towards square 100.

RESULTS AND DISCUSSION

Average, Minimum Steps, and Maximum Analysis

From the results of 10,000 simulations of snake and ladder games carried out with the Monte Carlo approach, it was obtained that the average number of steps needed to reach the 100th square was 51.41 steps. This means, in general, players can complete the game in the range of 50s of steps. However, there are extreme variations, where the minimum steps recorded are only 8 moves, signaling the existence of an ideal scenario where the player greatly benefits from the stair position. In contrast, the maximum move reaches 394 moves, which indicates that players can be severely harmed by repeated snake exposure, especially in positions near the end of the board. These results reflect that the game of snake and ladder relies heavily on a combination of random factors of the dice and the position of the snake/ladder that can speed up or hinder the course of the game.

Frequency Distribution Number of Steps

The distribution of the number of steps is displayed in the form of a histogram and density plot, which describes the pattern of frequency of occurrence of the number of steps during the simulation. The histogram shows that most games are completed in the range of 45 to 60 steps, with the peak of the distribution being around 51 steps, according to their average values. The density plot describes the shape of the curve resembling a normal distribution that tends to be symmetrical, despite the presence of an elongated right tail. This long tail indicates the existence of several simulations with a very high number of steps due to repeated obstacles from the unfavorable position of the snake. This distribution confirms that although most games run efficiently, there is a potential for very long games due to the cumulative effects of snake positioning.

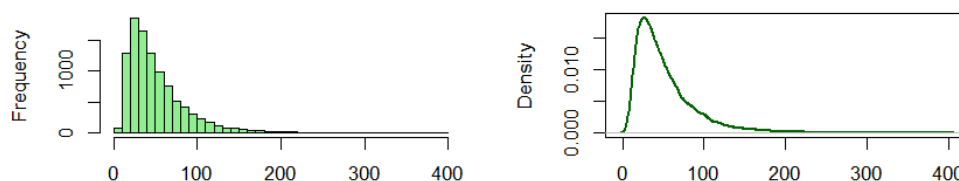


Figure 1. Frequency Distribution Number of Steps Histogram Form and Density Plot

Data Spread Analysis and Outliers

The spread of the number of steps is visualized using a boxplot, which provides information about the distribution of quartiles, medians, as well as the presence of outliers. From the graph, it can be seen that the median value is around 51 steps, while the first quartile (Q1) and third quartile (Q3) are in the range of 47 to 55 steps. This shows a fairly dense distribution of data in the middle. However, there were a number of extreme outliers that appeared well above Q3, even up to 394 steps. This outlier shows that although the game tends to finish within the normal range, there is a chance that the game will last for a very long time. This is mainly due to snakes being strategically positioned near the finish line, such

as boxes 98, 95, and 93, which can get players trapped in a fall-and-build cycle before successfully completing the game.

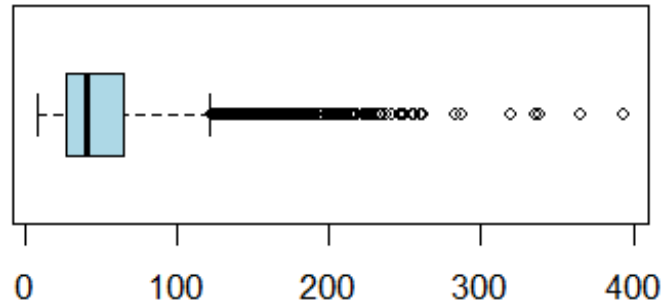


Figure 2. The spread of the number of steps is visualized using the boxplot

Step Patterns Based on Simulations and Global Averages

In a linear visualization showing the number of steps in each of the 10,000 simulations, it can be seen that there are fairly wide random fluctuations. Nevertheless, the red horizontal line showing the global average of 51.41 moves seems to be the center of concentration of these values. Although the data is spread from 8 to 394 steps, most of the simulations are huddled together around the mean line. This shows that the simulation has a good level of stability and consistency, and is able to realistically capture the probabilistic phenomena of the snake and ladder game. In addition, the fluctuations seen in the graphics show that each simulation is completely unique, which corresponds to the nature of a dice-based game full of uncertainty and luck.

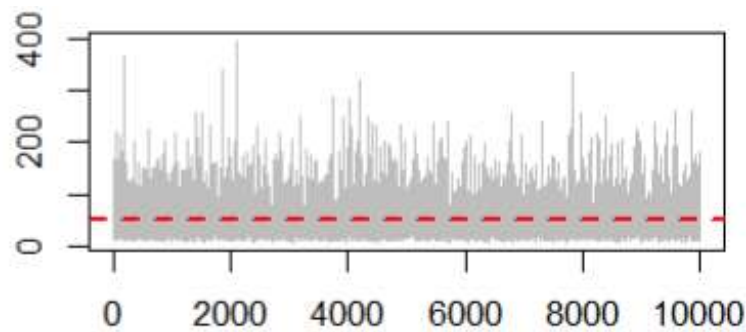


Figure 3. Line-Shaped Visualization

CONCLUSION

Based on the results of Monte Carlo's simulation on a game of snakes and ladders using R Programming, it can be concluded that this method is effective for modeling and analyzing the variability of the number of steps required to reach the 100th square. Of the 10,000 simulations conducted, an average of 51.41 steps with a minimum of 8 steps and a maximum of 394 were obtained, indicating high uncertainty due to random interaction between dice and the position of ladders and snakes. Monte Carlo not only provides an average estimate of the game's performance, but also provides a realistic picture of the distribution and spread of

the results, so this method can be a very useful tool in understanding the probabilities and behavior of stochastic systems.

REFERENCES

- Constantin, M. A., Schuurman, N. K., & Vermunt, J. K. (2023). A general Monte Carlo method for sample size analysis in the context of network models. *Psychological Methods*.
- Dalimunthe, N. A. (2021). *Simulasi Prediksi Permintaan Kue Kacang Di Cv. Fawas Jaya Medan Menggunakan Metode Monte Carlo*. Universitas Medan Area.
- Desi, E., Aliyah, S., Lubis, C. P., Nst, M. A. E., & Tahel, F. (2024). Simulasi Monte Carlo Dalam Memprediksikan Tingkat Lonjakan Pendaftaran Vaksin Booster Pada Puskesmas Martubung. *Jurnal Teknologi Informasi Dan Ilmu Komputer*, 11(3), 579–586.
- Fitriani, L., Tresnawati, D., & Pamungkas, M. I. I. S. (2023). Multiplayer Game Guessing Sunda's Proverb Using Socket. Io And Node. Js. *JUITA: Jurnal Informatika*, 11(2), 231–240.
- Kabacoff, R. (2022). *R in action: data analysis and graphics with R and Tidyverse*. Simon and Schuster.
- Signoret, J.-P., Leroy, A., Signoret, J.-P., & Leroy, A. (2021). Monte Carlo Simulation. *Reliability Assessment of Safety and Production Systems: Analysis, Modelling, Calculations and Case Studies*, 547–586.
- Sukarsa, I. M., Bayupati, I. P. A., Ananda, G. O. D., Buana, P. W., & Wisswani, N. W. (2023). An Efficient Synchronization Model in Random Word Educational Games with Multiplayer Platforms. *Journal of Advances in Information Technology*, 14(5).
- Syahbana, H., Akbar, M. F., Syahputra, M., & Efriyanti, L. (2023). Pemodelan Decision Modeling on Clothing Model Selection of Female Students of UIN Bukittinggi. *SMART: Jurnal Teknologi Informasi Dan Komputer*, 2(2), 93–108.
- Wali, M., Nengsih, T. A., Hts, D. I. G., Choirina, P., Awaludin, A. A. R., Yusuf, M., Aminuddin, F. H., Purwandari, N., & Baradja, A. (2023). *Pengantar 15 Bahasa Pemrograman Terbaik Di Masa Depan (Referensi & Coding Untuk Pemula)*. PT. Sonpedia Publishing Indonesia.
- Wati, D. C., Judijanto, L., Apriyanto, A., Sepriano, S., & Maryana, M. (2024). *Media & Teknologi Pembelajaran Matematika*. PT. Sonpedia Publishing Indonesia.