

# Shock Prediction in Mario Kart 8 Deluxe with Bayesian Method

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In the paper, we use Bayesian method to study the prediction of opposite team shock usage in competitive Mario Kart 8 Deluxe clan war. Using the simplified item distribution, we revealed the luck-dependent property of Mario Kart 8 Deluxe.

## INTRODUCTION

Mario Kart 8 Deluxe, hereinafter referred to as MK8D, is an unorthodox racing game published by Nintendo on May 29, 2014, about two months after the release of Nintendo's most current console Nintendo Switch, one of the newest member of the most popular franchise in terms of racing game [1, 2]. Although being an upgraded version of the original game Mario Kart 8 on Wii U released by Nintendo earlier in 2014, MK8D sold very well. According to the "Financial Results Explanatory Material 2nd Quarter of Fiscal Year Ending March 2022" from Nintendo [3], MK8D has sold more than 38.74 million copies, outsold the previously most popular racing game, Mario Kart Wii with 37.38 million copies [4], making MK8D the best-selling race game [5], and even one of the best-selling video games of all time[6].



FIG. 1. Lighting, commonly referred to as shock, is the most powerful and difficult to get item in MK8D. Picture retrieved from Mariowiki[7].

While being a perfect party game for families and friends, MK8D is also a competitive esports game. Competitive mario kart is popular in both the western community and japanese community with more than 17000 players currently registered on mariokartcentral [8], one of the largest mario kart website in the world. Usually, the following forms of matches are used for hosting competitive MK8D tournaments: FFA (Free For All), 2v2(6 teams of 2 players each team), 3v3(4 teams of 3 players each team), 4v4 (3 teams of 4 players each team), and 6v6, which is the default setting for clan war and the most common setting for clan based tournaments. Unlike common esports games, such as starcraft, CS:GO, DOTA, FIFA, etc., MK8D is not only skill-based, but also luck-based. While driving fast and making correct decisions are important, the sheer luck of getting the correct item at the correct time may change an entire game. This duality makes MK8D both attractive and frustrating at the same time. Currently, tournaments like MKU, Mario Kart Worlds, and many other matches are being played by people all over the world. There is also an unofficial ladder, named MK8DX Lounge [9] offering players ranked matches to allow more competitive experience.



FIG. 2. From left to right, the item Boo(ghost), Star, Bullet Bill, and the NPC Lakitu are shown.

An MK8D game can at most have 12 players simultaneously in the same online lobby competing with each other. Each people is allowed to have 2 items at the same time. With a total number of 22 types of items, various items using strategies are developed. Shock, with official name Lighting, shown in FIG 1, is undoubtfully the strongest and most impactful item in this entire game. Upon activation, shock is able to hit every player on the track, except the player who used the shock, and any other players who is in the "dodge state". Everyone got hit by the shock will lose both items he/she possess, stay in a "minimized state" for certain amount of time based on the place when getting shocked, lose three coins, and potentially fall off track if hit by shock above a gap or near the edge. Hence a well-used

shock is able to instantly change the situation of the match, which also makes dodging shocks extremely important as well. A dodge state can be achieved by either using a dodge item, including a star, a boo (ghost), and a bullet bill, shown in FIG 2. or during the invincible period while being saved by Lakitu, as shown in FIG. 3. Players who dodged shock will be able to easily catch up or hit other players who got hit by the shock, and drastically change result of the match. A famous example is Mario Kart World Cup 2021, where team France (FR) was able to dodge shock from team Japan (JPN), and even land a second shock of their own, thus win the game, and defeat team Japan for the first time in years[10].



FIG. 3. JPN player くさあん intentionally driving off the track to be saved by Lakitu and hence dodge the shock and keep his items during Mario Kart World Cup 2019, match between Japan (JPN) and Canada (CAN) [11].

Hence in competitive MK8D, it is important to figure out the optimal timing to enter a dodge state, in order to dodge shock from the opponent team, minimize the damage, and potentially obtain advantage even from the opponent shock.



FIG. 4. FR player Valer got 1st place after dodging two shocks, first one from JPN, second one from FR, helping his team won the grand final of Mario Kart World Cup 2021, team Japan (JPN) vs team France (FR), thus ends the years of dominance of JPN in MK8D [10].

## BAYESNET MODEL

We use Bayesian approach to answer these questions, which is one of the most basic, yet most sophisticated theory in statistics. The Bayes theorem allows us to calculate the posterior probability based on certain observations, according to Eq. 1

$$\Pr(H|D) = \frac{\Pr(D|H)\Pr(H)}{\Pr(D)}, \quad (1)$$

where  $\Pr(H|D)$  is the posterior probability, also called conditional probability, of hypothesis  $H$  based on observation data  $D$ . We then use python package [pgmpy](#) [12] is used for the building the BayesNetwork and calculation of the

probabilities.

To begin with, we consider only one team, and build our BayesNetwork as FIG. 5. Here we start with the event of getting a dodge item D, the event of getting a shock item S, the event of being in a position advantage, PA, which is defined later. These three together determine the event of using the dodge UD. The event of using the shock, US, is determined by S, UD, and PA, and going off track to dodge the shock OT is determined by the decision US, and the result of dodging shock is determined by US, UD, and OT, with UD and OT allowing the player to be in a dodge state. Here we ignored the part that shock user is also immune to the shock.

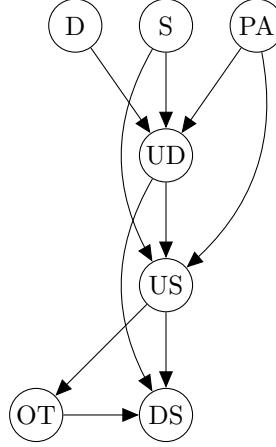


FIG. 5. BayesNetwork of one team in MK8D.

Here we define PA, position advantage. This is a factor based on the property of the track currently being played. While there are 48 different tracks in MK8D, we can roughly classify them into three different types:

1. Running track: Very few shortcuts or good positions, such as glider sections for shocks,  $\text{Pr}(\text{PA}=1) = 0.1$ .
2. Mid track: Some good shortcuts and positions for shocks,  $\text{Pr}(\text{PA}=1) = 0.25$ .
3. Bagging track: Lots of shortcuts and positions for using shocks to damage enemy,  $\text{Pr}(\text{PA}=1) = 0.5$ .

With the preliminary model providing us some insights, we further design a more complicated BayesNetwork FIG. 6 involving both teams, as well as including the skill levels,  $S_{k_i}$  of both teams, which determine whether a player makes mistakes or play normally. In addition to add another team, we also let both team decide the position advantage of team 1,  $\text{PA}_1$  together, and simplify team 2 network, as we only consider the situation where team 1 get shock and use shock. Team 2 using dodge  $\text{UD}_2$  and going off track  $\text{OT}_2$  will also be based on observing team one using dodge  $\text{UD}_1$ , and the result of team 2 dodging shock is determined by team 1 using shock  $\text{US}_1$ ,  $\text{UD}_2$ , and  $\text{OT}_2$ .

The original item distribution [13, 14] is simplified to the following, shown in FIG. I

item	$\text{Pr}(I)$
Mushroom	0.7
Star	0.25
Shock	0.05

TABLE I. Simplified item distribution, a mushroom can be used and the player will be accelerated for a short period of time, not able to provide a dodge state.

## RESULT

For model 1, FIG 5, we use the simplified item distribution, and we only consider one item instead of two. According to TABLE. I we can set  $\text{Pr}(D)$  the probability of having a dodge: star in hand ( $D=1$ ) to be 0.25, and the probability of having a shock in hand ( $S=1$ ) to be 0.05. Position advantage is situational, and it depends on the actual situation

of the game process and the skills of players in both teams. For simplicity, we can just set  $\Pr(\text{PA}) = 0.1$ , which means that there is a 10% chance of a team finding a Position Advantage (PA=1). With our settings, we can see that the probability of having a dodge item when shock used is observed is about 0.252, slightly higher than the item distribution probability. When a dodge is used, it indicates that a shock exists with probability 0.0848, about 70% higher than the original rate 0.05. Settings can be printed by running the code [bayes-model-1.py](#).

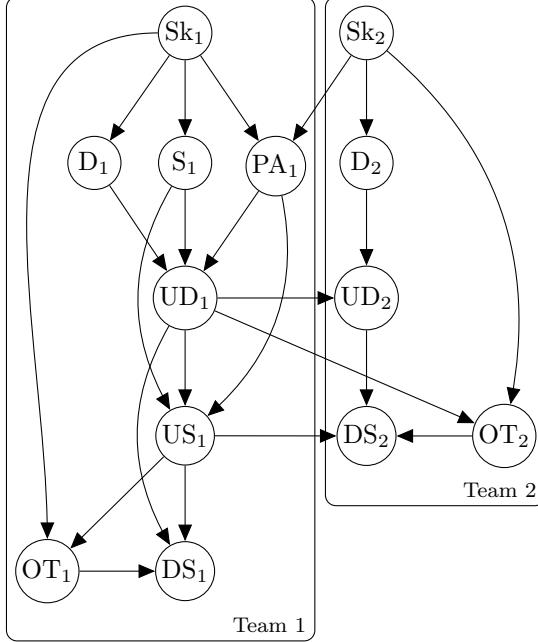


FIG. 6. BayesNetwork of two teams in MK8D.

For the updated 2-team model in FIG. 6, we set the skill of team 1  $\text{Sk}_1$  to be 0.7, so team 1 is able to make right decision with probability 70%, and we calculated the probability of team 2 dodging the shock  $\text{DS}_2$  while team 1 use shock:  $\text{US}_1 = 1$ . Surprisingly, while the skill of team 2 increase, the probability of them dodging shock actually decrease, due to the setting that a less skilled team is more likely to use their dodges and fall off track randomly, hence enter the dodge state unintentionally. Results shown in TABLE II, detailed settings included in file [bayes-model-2.py](#).

Team 2 Skill	$\Pr(\text{D}_2 \mid \text{US}_1)$	$\Pr(\text{DS}_2 \mid \text{US}_1)$	$\Pr(\text{DS}_2 \mid \text{US}_1, \text{D}_2)$	$\Pr(\text{DS}_2 \mid \text{US}_1, \text{D}_2, \neg \text{OT}_2)$
$\text{Sk}_2 = 0.5$	0.200	0.232	0.582	0.519
$\text{Sk}_2 = 0.6$	0.210	0.230	0.579	0.518
$\text{Sk}_2 = 0.7$	0.220	0.227	0.575	0.518
$\text{Sk}_2 = 0.8$	0.230	0.225	0.572	0.517
$\text{Sk}_2 = 0.9$	0.240	0.222	0.569	0.517

TABLE II. probability of team 2 dodge shocking with different skill levels.

## CONCLUSION

We have built both the 1-team and 2-team BayesNetwork model of shock obtaining, using, and dodging in MK8D. The model is simple, and unfortunately shows the fact that MK8D is heavily luck-dependent, and miss play will actually get rewarded. Future study may include considering two item slots as the real game, analyzing the positions of players based on the minimap, and dynamically adjust the probabilities of items each player is getting as they dependent on the relative distance between the player and the 1st place player. Include decision making process, as shown in FIG 7 Include all the items for a much more complicated model, with analysis of getting hit, hence modify the probabilities of using star. And include the influence of player skills more, such as ability to dodge attacks so to

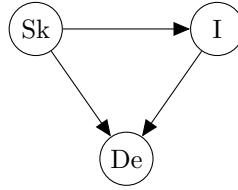


FIG. 7. skill

reduce star use, hence when star is used by good players, it shows a greater possibility of their team having shocks, while used by a bad player it may be getting hit, trying to go a shortcut unnecessarily, or even just due to mistakes. Even more advanced studies includes using AI to automatically analyze videos of games, generate data and calculate the probability of certain events and hence develop better strategies.

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