Mysteries of 2048

By Ethan Oh and Chiong Jun Yan (1O2)

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1. Introduction

2048 was created by *Gabriel Cirulli* using Java just over a weekend. He just wanted to create a game for fun and play but did not anticipate that just a week after the game's release, there were about 4 million views. *Gabriel* was inspired by the game called *The Game of Threes.* Here is how you play a game of *2048*: so we swipe to the direction that we want to move the tiles to, then, when two tiles with the same number meet, they merge into one number on a spot which is the sum of both the numbers merged.

2. Objective and Research Questions

2.1 Objective

The objective of our project is to find out the most efficient strategy to complete a game of 2048 in the least number of swipes. This is a single player game and thus people compete to find out who can complete the game in the least number of swipes. Therefore, our sole objective of this project is to find out the most efficient strategy to complete the game in the least number of swipes.

2.2 Research Questions

1. Does the **starting position** determine the outcome?
2. Does **repeating a set of swipes** continuously allow us to solve 2048 most efficiently?
3. Does **cornering the biggest number** affect the outcome?

3. Literature Review

Here are some successful strategies that we have found:

1. **Build Into A Corner**

This strategy lets you **build toward a singular tile** without moving it around and disrupting your ability to merge it with other large tiles when the time comes. The key, however, is to understand that this limits your movements. In my case, that means I should only be **swiping to the direction of my corner** -- that is, left and upward -- to merge tiles. Never pull in the opposite direction of your largest tile -- meaning down for an upper left or right tile and up for lower left or right tile -- unless you absolutely have to.

2. **Always Make Moves Where Multiple Tiles Merge First**

If you come across an instance where you can **merge multiple stacks of cards at once**, take it. The more space you keep open on the board, the better flexibility you have when bringing in new cards. With single moves you're replacing a card you stacked with a new one. When multiple cards can be combined, you're not only bringing one new card onto the board, but you're **getting rid of more than one**.

4. Terminology

Firstly, when we say the word “swipe”, it means a move which brings all numbers of the grid to the direction of the swipe. This means that if we have a 2 blocks of ‘2’ side by side, when we swipe to the right as shown in the figure below, the tiles will both merge to the left and form a ‘4’ tile at the spot under the ‘8’ tile.

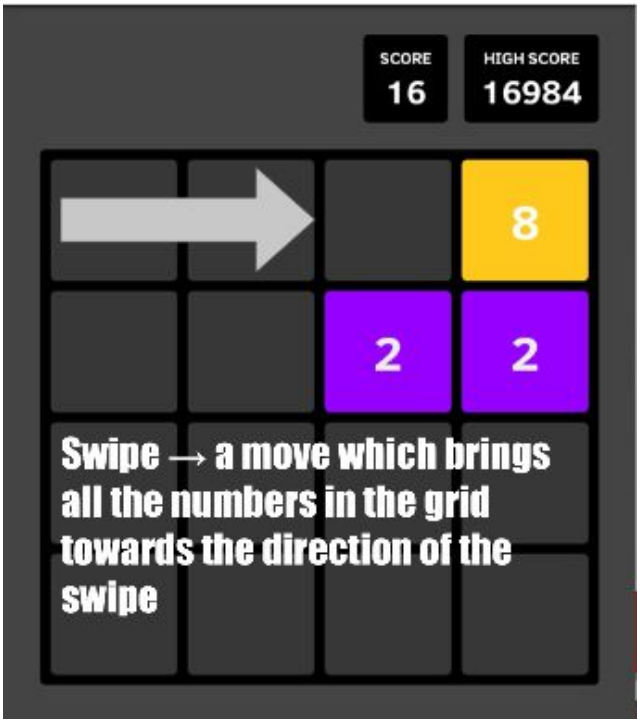


Fig 1a: Definition of Swipe

Secondly, “merge” is another term we would use throughout the whole written report. When we say “a tile ‘merges’ with another”, we mean that the tile when swiped in a direction will create the sum of both numbers side by side, top, left, right and bottom. Let’s say we have 2 blocks of ‘4’ that are side by side to each other, when we swipe to the right as shown in the diagram below, both blocks of ‘4’ will merge and form a block of ‘8’ at the right corner of the board.

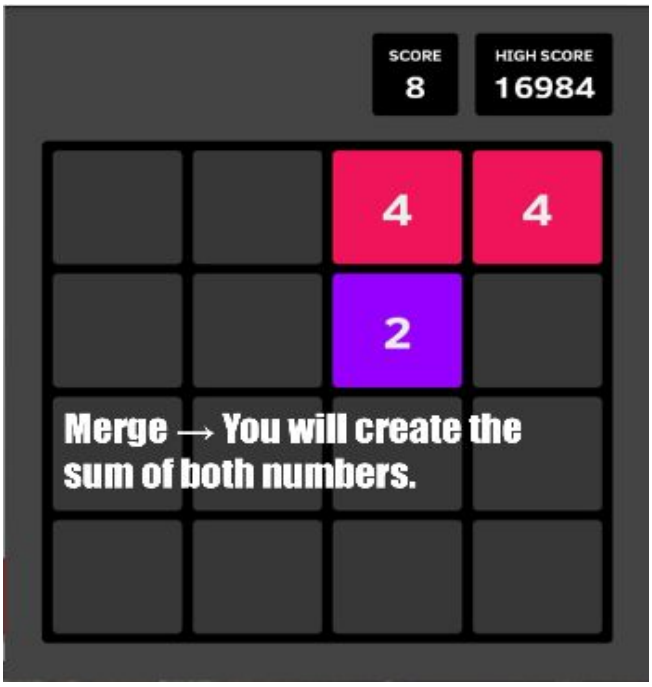


Fig 1b: Definition of Merge

Thirdly, we will define an empty box on the board as a spot.

5. How is *2048* played?

2048 is a game about numbers and space. You have a limited number of free spots, and each move introduces another tile of either 2 or 4 into the grid randomly. When you combine two same numbers, they combine into a new tile with the value of their sum, thus simultaneously progressing a little further toward your goal of making a 2048. The game is completed when you combine 2s to form 4s to form 8s to form 16s and so on until the number 2048 is met.

6. Methodology

We first played 20 games for each variable based on the research question, then we record the highest number reached and the score for each and every game that we have played. Then, out of the 20 tabulations, we compare the different strategies with two criteria. The first criterion that we look for is the highest number reached. The second criterion is the number of swipes. The most efficient strategy is one which can achieve the highest number while having the lowest score. Lower scores translate into lesser number of swipes. This is because for each time you swipe, the score would increase. Therefore, through this method, we can find out which strategy allows us to reach the highest number in the least number of swipes.

7. Limitations of Our Project

The ‘2’s and ‘4’s that will appear on an empty spot on the board after every swipe will be randomised. Due to our inadequate coding experience, we are unable to code a customised *2048* where the ‘2’s and ‘4’s appear at the same spot. Therefore, we used the scores to determine the most efficient strategy.

8. Findings

8.1 Findings for Research Question 1

A	B	C	D	E	F	G
	Attempt Number	1	2	3	4	5
	Final score					
1)	**Starting Position**					
	Top	5146 (512)	2888 (256)	3072 (256)	1492 (256)	5416 (512)
	Left	**4616 (512)**	3296 (256)	2232 (256)	2848 (256)	2696 (256)
	Right	4856 (512)	**2376 (256)**	2944 (256)	1576 (128)	2920 (256)
	Bottom	2575 (256)	**4652 (512)**	3016 (256)	**888 (64)**	2932 (256)

Fig 2a: First 5 Tabulations (Starting Position)

Highest number reached
1024 (Top)
512 (Left)
512 (Right)
1024 (Bottom)

Fig 2b: Highest Number Reached (Starting Position)

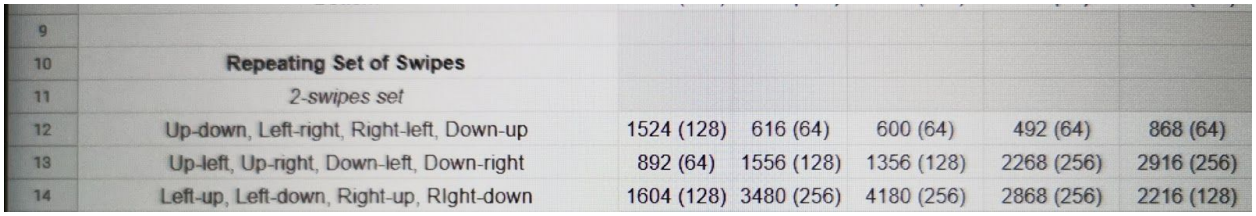
For the first research question, we wanted to find out how the starting position affects the end result. Thus, we played 20 games for each of the starting positions. We started the game by playing from the top, the bottom, the left and the right respectively. Then, we compared the four variables to see which one was the most efficient. From our tabulations, we eliminated the ‘Left’ and ‘Right’ starting positions as they both achieved the highest number of 512 while the ‘Top’ and ‘Bottom’ starting positions achieved the highest number of 1024. We then eliminated the ‘Bottom’ starting position as it reached 1024 with a score of 9520 whereas the ‘Top’ starting position reached the same number with a lower score of 7036. This means that the ‘Top’ starting position is more efficient because it reached 1024 in a lesser number of swipes. This suggests that starting from the top allowed us to get the highest number with the least number of swipes.

8.2 Findings for Research Question 2

For the second research question, we wanted to find out whether repeating a set of swipes allows us to reach 2048 more effectively. We went to tabulate by researching with sets of 2-swipes, 3-swipes and 4-swipe sets. Firstly, we grouped the tested variables based on their type. For example,

Up-down, Left-right, Right-left and Down-up are grouped together because they swipe in opposite directions. Then, we tried out the 2-swipes sets.

8.2.1 Findings for 2-swipes Sets



9						
10	**Repeating Set of Swipes**					
11	*2-swipes set*					
12	Up-down, Left-right, Right-left, Down-up	1524 (128)	616 (64)	600 (64)	492 (64)	868 (64)
13	Up-left, Up-right, Down-left, Down-right	892 (64)	1556 (128)	1356 (128)	2268 (256)	2916 (256)
14	Left-up, Left-down, Right-up, RIght-down	1604 (128)	3480 (256)	4180 (256)	2868 (256)	2216 (128)

Fig 3a: First 5 Tabulations (2-swipes sets)

Highest number reached
128 (Up-down, Left-right, Right-left, Down-up)
256 (Up-left, Up-right, Down-left, Down-right)
512 (Left-up, Left-down, Right-up, Right-down)

Fig 3b: Highest Number Reached (2-swipes sets)

For the 2-swipes sets, we first eliminated the groups of ‘Up-down, Left-right, Right-left, Down-up’ and ‘Up-left, Up-right, Down-left, Down-right’. We first eliminated ‘Up-down, Left-right, Right-left, Down-up’ due to the fact that the highest number reached is only 128. Then, we eliminated the group of ‘Up-left, Up-right, Down-left, Down-right’ because it only reached the highest number of 256 while the group of ‘Left-up, Left-down, Right-up, Right-down’ reached the highest number of 512.

8.2.2 Findings for 3-swipes Sets

16	III	3-swipes set					
17		Up-left-up, Up-right-up, Up-down-up	1020 (64)	1148 (128)	1032 (128)	884 (64)	1288 (128)
18		Left-up-left, Left-right-left, Left-down-left	1408 (128)	468 (64)	1400 (128)	708 (128)	496 (64)
19		Up-left-left, Up-right-right, Up-down-down	3768 (256)	720 (64)	664 (64)	1512 (128)	1164 (128)
20		Up-up-left, Up-up-right	2220 (256)	940 (128)	920 (128)	3024 (256)	3216 (256)
21		Up-left-right, Up-left-down	1468 (128)	1056 (64)	1324 (128)	1532 (128)	3016 (256)
22		Up-right-left, Up-right-down	712 (128)	1220 (128)	1972 (128)	884 (128)	612 (64)
23		Up-down-left, Up-down-right	1076 (128)	2144 (256)	1368 (128)	1604 (128)	892 (64)
24		Left-up-up, Left-up-right, Left-up-down	1572 (128)	1528 (128)	3664 (256)	2048 (128)	1612 (128)
25		Left-left-up, Left-left-down	2932 (256)	3340 (256)	2004 (128)	5788 (512)	2452 (256)
26		Left-right-up, Left-right-down	1992 (128)	1188 (128)	968 (128)	1164 (32)	2580 (256)
27		Left-down-up, Left-down-right, Left-down-down	3168 (256)	2872 (256)	2436 (256)	1504 (128)	1652 (128)

Fig 4a: First 5 Tabulations (3-swipes sets)

Highest number reached
128 (Up-left-up, Up-right-up, Up-down-up)
128 (Up-left-left, Up-right-right, Up-down-down)
256 (Up-up-left, Up-up-right)
256 (Up-left-right, Up-left-down)
128 (Up-right-left, Up-right-down)
256 (Up-down-left, Up-down-right)
256 (Left-up-up, Left-up-right, Left-up-down)
512 (Left-left-up, Left-left-down)
256 (Left-right-up, Left-right-down)
256 (Left-down-up, Left-down-right, Left-down-down)

Fig 4b: Highest Number Reached (3-swipes sets)

For the three-swipes sets, we eliminated all the groups except for the group of ‘Left-left-up, Left-left-down’ which reached the highest score of 512. The other groups only managed to hit the highest numbers of either 128 or 256.

Some permutations were not tested as they overlap with the tested permutations when the grid is flipped upside down. However, this will not affect the tabulations as the ‘2’s and ‘4’s appear randomly.

8.2.3 Findings for 4-swipe Sets

Variables	1st Attempt	2nd Attempt	3rd Attempt	4th Attempt	5th Attempt
Clockwise, Counter-clockwise	1344 (64)	1520 (128)	3060 (256)	2956 (256)	1424 (128)

Fig 5a: First 5 Tabulations (4-swipes sets)

Highest number reached
256 (Clockwise, Counter-clockwise)

Fig 5b: Highest Number Reached (4-swipes sets)

For the four-swipes sets, we got the highest number of 256 with a score of 1984.

8.2.4 Conclusion

Thus, from these results, we could determine the best sets of swipes for each category. For the 2-swipes sets, we can conclude that the best choice is the group of ‘Left-up, Left-down, Right-up, Right-down’ as they reached the highest number of 512. For the 3-swipes sets, we can conclude that the best choice is the group of ‘Left-left-up, Left-left down’ as it reached the highest number of 512.

8.3 Findings for Research Question 3

For the third research question, we are trying to find out whether cornering the biggest number will help to achieve 2048 in the least number of swipes. Here is a table of our tabulations:

Variables	1st Attempt	2nd Attempt	3rd Attempt	4th Attempt	5th Attempt
Cornering the Biggest Number	1604 (128)	1556 (128)	3480 (256)	2268 (256)	2916 (256)

Fig 6: First 5 Tabulations (Cornering the Biggest Number)

By cornering the biggest number, we can achieve the highest number of 512 with the lowest score of 5356.

8.4 Findings for Extension

For the extension, we used all the best methods from the starting position, the repeat of sets of swipes and the cornering of the biggest number on a bigger grid, the 5 x 5 grid. Here are our tabulations:

1)	**Starting Position**					
	Top	6448 (512)	3488 (256)	7856 (512)	**5556 (512)**	11816 (512)
2)	**Set of Swipes**					
I	*2-swipes sets*					
	Left-up, Left-down, Right-up, RIght-down	3488 (256)	3616 (256)	4144 (256)	3320 (256)	12084 (1024
II	*3-swipes sets*					
	Left-left-up, Left-left-down	5100 (256)	5876 (512)	1204 (128)	**11160 (1024)**	**1072 (128)**
III	*4-swipes sets*					
	Clockwise, Counter-clockwise	3008 (256)	3496 (256)	2800 (256)	4608 (256)	3264 (256)
3)	**Cornering the Biggest Number**	6476 (512)	7332 (512)	10928 (1024)	6076 (512)	7984 (512)

Fig 7: First 5 Tabulations (Extension)

For the ‘Top’ starting position, we got the highest number of 2048 with a score of 19772. For the 2-swipes sets, we got the highest number of 1024 with a score of 12084. For the 3-swipes sets, we got the highest number of 1024 with a score of 11160. For the 4-swipes sets, we got the highest number of 512 with a score of 4980. Lastly, for the cornering of the largest number, we got the highest number of 2048 with a score of 17956. Thus, we can conclude that starting at the top and cornering the biggest number are both efficient solutions. Just like the normal 4 x 4 grid, these methods allow you to achieve 2048 within the least number of swipes.

8.5 Overall Conclusion

All in all, for all the tabulations that we have tested, we can conclude that the most efficient way to achieve 2048 in the least number of swipes is to combine the strategies of starting at the top and cornering the biggest number. This allows us to reach higher numbers with a lower score. Thus, a combination of both strategies would result in a method that would be the most efficient strategy to achieve 2048 in the least number of swipes, answering our objective for this project.

9. References

1. Source: Adapted from Statt, Nick (March 22, 2014) *2048 starts easy; gets hard. Here's how to make it easy again* Retrieved from https://www.cnet.com/news/2048-starts-easy-gets-hard-heres-how-to-make-it-easy-again/ on 1 April 2019
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