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Solving Hashiwokakero Puzzle Game with Hashi Solving Techniques and Depth First Search

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Abstrak

Hashiwokakero adalah permainan teka-teki logika yang melatih ketajaman otak dan sangat populer di Jepang. Makalah ini membahas bagaimana mencari solusi di permainan teka-teki menggunakan teknik-teknik pemecahan masalah Hashi yaitu Just Enough Neighbour, One Unsolved neighbor, Few Neighbours, Leftovers and Isolation. Teknik-teknik pemecahan masalah Hashi digunakan untuk mencari dan membangun jembatan-jembatan yang menghubungkan antar pulau kemudian Depth First Search (DFS) yang akan mencari dan membangun jembatan yang tidak dapat dilakukan oleh teknik-teknik pemecahan masalah Hashi. Hasilnya menunjukkan bahwa teknik-teknik pemecahan masalah Hashi dan DFS dapat menemukan solusi setiap sknario permainan teka- teki Hashi.

Kata kunci: *Hashiwokakero, Hashi Solving Techniques, dan Depth First Search*

Abstract

Hashiwokakero is a logic puzzle game that sharpen the brain and very popular in Japan. This paper discusses on how to find a solution in the Hashi puzzle game using Hashi Solving techniques, such as Just Enough Neighbor, One Unsolved neighbor, Few Neighbors, Leftovers and Isolation. Hashi Solving techniques are used to find and build bridges that can definitely be built across the island, while Depth First Search (DFS) will search and build bridges that have not been found by Hashi Solving techniques. The results have shown that Hashi Solving Techniques and DFS able to solve every Hashi puzzle scenario.

Keywords: *Hashiwokakero, Hashi Solving Techniques, and Depth First Search*

1. Introduction

Hashiwokakero or Hashi is a logic puzzle game created by Nikoli, a Japanese gaming company that specialized in the manufacture of logic game. The first Hashi appeared in a puzzle magazine Nikoli in September 1990. [1]. Besides it is fun, Hashi also test the logic and intelligence of people who play it. In UK, Hashi called "Bridges or Chopsticks", while in most of Europe, Hashi is known as "Ai-Ki-Ai"[1].

Research on Hashi game has already been done. Hashi game research conducted by Daniel Andersson and T.Morsink [2] [3]. The research which conducted by Daniel Andersson said that Hashi game is NP-Complete whereas T.Morsink did a research in making a solver for Hashi game using Sugar CSP. The result of T.Morsink research showed that Sugar CSP gives better results than the other solver techniques.

1.1 Hashiwokakero

Hashiwokakero game is played on a box. Inside this box, there are some circles (cells) which located on horizontally and vertically. These cells have known as the island. In each island, there is a number from 1 to 8. The goal of Hashi game is connecting all the islands by creating a bridge between the island and no island which isolated (or not connected with each other).

Rule in making bridge on Hashi game box as follows:

1. One bridge can be connected two islands that located on the same x coordinate

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(horizontal) or the same y coordinate (vertical)
2. The bridge should not be overlapping with other bridges
3. There may only have maximum 2 bridges between the same two islands

Number of bridges that connect to the island must be equal to the numbers written on the island.

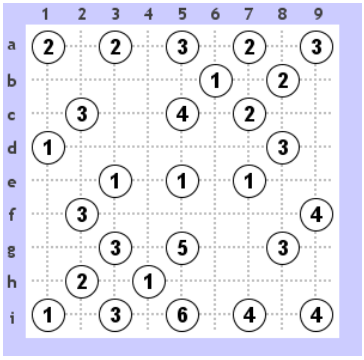

Figure 1. Example of Hashi game problem, Begin Condition [4]

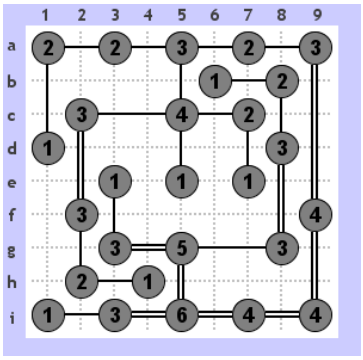

Figure 2. Example of Hashi Game Solution. Problem Solved [4]

Figure 1 shows the beginning condition of Hashi game problem that the problem could be varied in this game. For figure 2 is the end condition which is the solution for it will be solved with the rules that have been explained above before.

1.2 Hashi Solving Techniques

Hashi Solving Techniques are some specific techniques that are used for finding Hashi game solution. Based on Indigopuzzles, the nest way in finding Hashi game solution is to work on the problem in Hashi game one by one. Hashi Solving Techniques, which are published by Indigopuzzles [4], can be used to find Hashi game solution, there are:
1. Just Enough Neighbor Technique
2. One Unsolved Neighbor Technique
3. Few Neighbors Technique
4. Leftovers Technique
5. Isolation Technique

1.3 Depth First Search

Searching using Depth First Search (DFS) is done from the initial node in depth until the very last (dead-end) or until found. In other words, a branch node or a child who first visited. As an illustration can be seen in Figure 3 [5] [6].

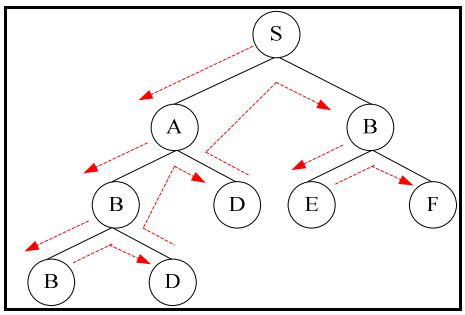

Figure 3. Depth First Search [5]

The searching process conducted by visiting a branch until meet final node as shown in Figure 3. If the desired goal is not reached then the search continues to the previous branch, down to the bottom if there are still branches and so on to achieve the goal. This operation is known as backtracking.

DFS also has the advantage which is fast reaching the depth of the search space. If it is known that the solution to the problem will be a long path then DFS will not waste the time to do a large number of the state of 'shallow' in the problem graph / tree. DFS is more efficient for the search space with many branches because it does not need to evaluate all nodes at a certain level on the open list. Moreover, DFS requires relatively little memory because only the nodes on the current path are stored.

2. Finding Hashi Solution Using Hashi Solving Techniques

2.1 Just Enough Neighbor Technique

This technique is a technique that is used to connect an island with its neighbors when the number of bridges owned by the island is same as the number of bridges, so it can be built to a neighbor. In Figure 4, island (4) in i9 need 4 bridge and by being in the corner, the island has no choice other than connecting the bridge with island F9 and i7, with each 2 bridges.

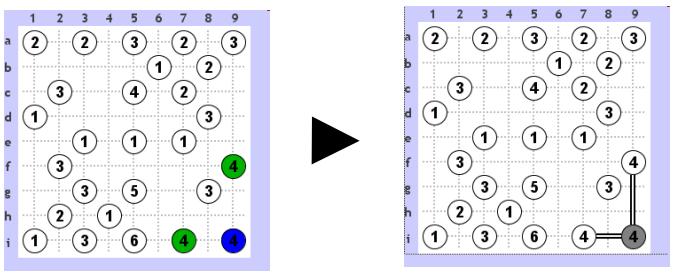

Figure 4. Just Enough Neighbours Technique [4]

2.2 One Unsolved Neighbor Technique

This technique is a technique that is used to connect an island with its neighbors when there is only one neighbor island near the island with the rest of the weight of one. In Figure 5, the island (1) h4 only needs 1 bridge and because there is no other island that can be achieved, the island h4 can only be connected with the island (2) on h2.

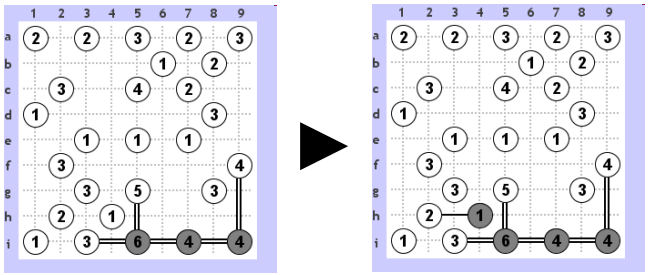

Figure 5. One Unsolved Neighbours Technique [4]

2.3 Few Neighbor Techniques

This technique is based on rules that "there may only have 2 bridges between islands". In Figure 6, the island (3) on g3 can only reach two other islands. And because the e3 island has only a number 1, and g3 build one bridge to island e3 and 2 bridges to the island g5.

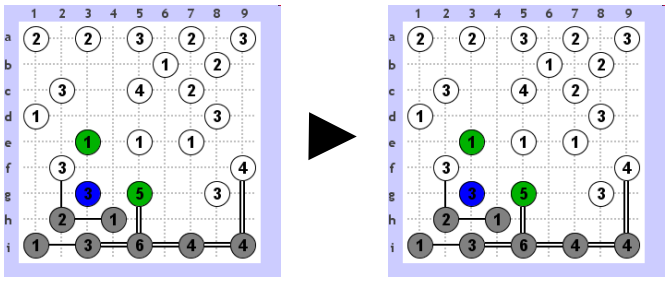

Figure 6. Few Neighbours Technique [4]

2.4 Leftover Techniques

This technique is a technique that is used to connect an island with its neighbors if the island has a weight of N and the number of neighboring islands is N, with (N-1) neighbors have a weight / remaining weight = 1, then build a bridge from the island with neighbors who do not have a remaining weight of 1. In Figure 7, the island (4) on C5, need 2 other bridges. One on it neighbor is the island (1) on e5 which can only receive 1 bridge. Therefore, at least one bridge on the island C5 should lead to the other islands; it is island (2) at C7.

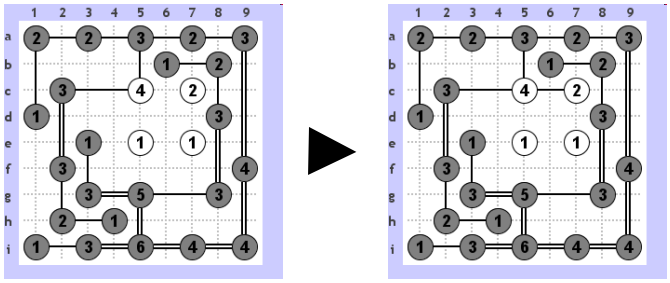

Figure 7. Leftovers Technique [4]

2.5 Isolation Techniques

This technique is the most important technique to solve Hashi puzzle. This technique uses the rule that each island should be able to reach other islands. Look at the island (1) on e5 in Figure 8 which will only have 1 bridge follows.

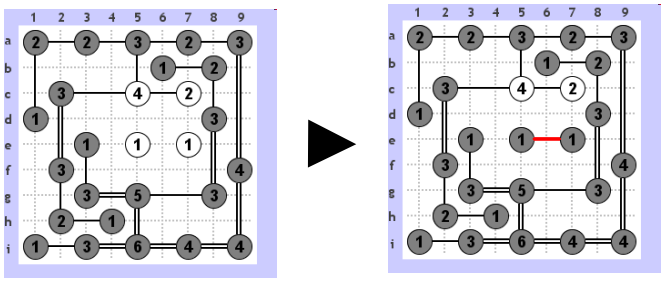

Figure 8. Isolation Technique [4]

In figure 8, if the island e5 is connected to the island next to his right, then the two islands will become isolated. Therefore, e5 islands must be connected with the island upper it, C5.

3. Solution Searching using Depth First Search

Depth First Search (DFS) is used to complete the rest of the bridge that has not been built. DFS algorithm will develop only one possible direction of the bridge that can be built on an island into a new state of the original position. Furthermore, algorithm DFS will advance the searching to the next island and develop a possible direction of the bridge on the island without violating the rules of Hashi game.

If there is no bridge that can be developed on a track because it violates the rules of Hashi, the DFS method will return to the previous path and take the direction of another bridge. This situation continued until the last bridge on the island is developed.

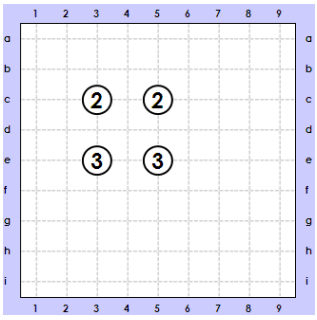

Figure 9. Example of Hashi Game Problem

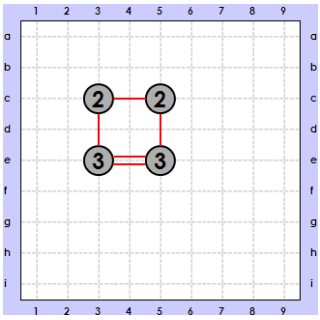

Figure 11. Hashi Solution that has been found using DFS

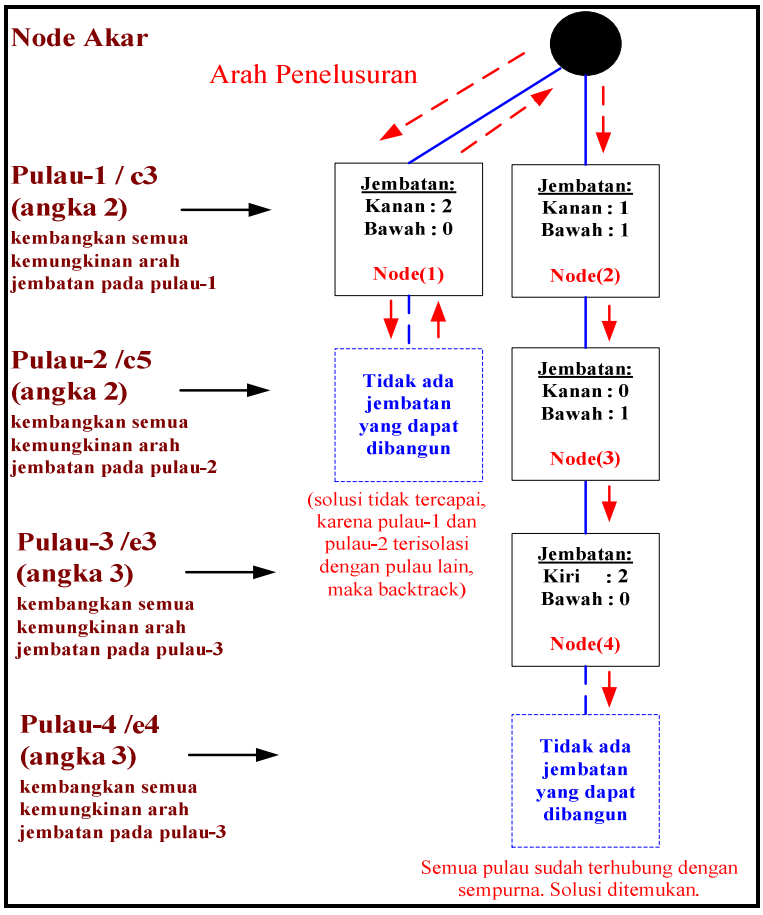

Figure 10. DFS Searching Solution

DFS algorithm process can be described briefly as follows:

1. Search began in the island-1.
2. Develop a possibility at the bridge to the right or bottom of the island-1. Place the possibility direction of this valid the bridge into a new node at level-1, suppose Node (1).
3. Search continues on node (1). Develop a longer one possible direction of the bridge to the right or bottom of the island-2. Place the likely direction of this valid the bridge into the new node at level-2, suppose Node (2).
4. Continue the same search on the next node, in-depth at subsequent levels.
5. If there is a node that cannot build the bridge because it violates the rules of Hashi, then search again (backtrack) to the parent node and get up again to another bridge that is different from the existing child node. Continue the searching to a new child node.
6. The same search is continued on subsequent nodes, until we find a solution.

For example, suppose the Hashi game problems example to be solved as shown in Figure 9, then tracing solutions with DFS tree can be seen in the figure 10 below. The searching with DFS based on the Figure 9 as shown in Figure 10. Hashi solution has been found by DFS could be seen in Figure 11

4. Analysis and Result

4.1 Analysis of Solution Searching by using Hashi Solving Techniques

In this section presents an analysis about Hashi game solution searching only using Hashi solving techniques. Tests carried out with Hashi problem that taken randomly from Hashi book written by "Saito Yamamoto" and "Nikoli". Hashi game problems randomly have drawn total 60 problems with different difficulty levels [7]. The level difficulty devided into three levels of difficulty. There are "Easy", "Medium", and "Hard" each of them takes 20 problems. The criteria of the difficulty in Hashi game is based on the book written by "Saito Yamamoto" and "Nikoli" [7].

After we have done the testing using the 60 problems, the result is found. Based on the Table 1 shows hashi solving technique solved the problems in 70% of total problem at easy level.

Table 1. Solution Searching Result by using Hashi Solving Techniques

No.	Level	Total Problem	The amount of problem that was successfully completed with Hashi Solving Techniques	Percentage
1.	Easy	20	14	70%
2.	Medium	20	0	0%
3.	Hard	20	0	0%

4.2 Analysis of Solution Searching by using Hashi Solving Techniques and Depth First Search

In this section presents an analysis about Hashi game solution searching using Hashi solving techniques and DFS. Testing will be carried out using the same problems that we have taken when we do the testing for only using Hashi solving techniques its own.

After we have done the testing using the 60 problems, the result is found. Based on the table 1 shows hashi solving technique and DFS solved the problems in 100% of total problem at easy level; 90% at medium and hard level.

Table 2. Solution Searching Result by using Hashi Solving Techniques and Depth First Search

No	Level	Total Problem	The amount of problem that was successfully completed with Hashi Solving Techniques and DFS	Percentage
1.	Easy	20	20	100
2.	Medium	20	18	90%
3.	Hard	20	18	90%

4.3 Analysis of Solution Searching by using Hashi Solving Techniques and using Hashi Solving Techniques and Depth First Search

In this section present an analysis about Hashi game solution searching only using Hashi solving techniques and using Hashi solving techniques and DFS.

Table 3 Comparison Result between Hashi Solving Techniques and with Hashi Solving Techniques and Depth First Search

No	Level	Total Problems	Solution Searching Techniques		Persentation	
			Hashi Solving Techniques	Hashi Solving Techniques and DFS	Hashi Solving Techniques	Hashi Solving Techniques and DFS
1.	Easy	20	14	20	70%	100%
2.	Medium	20	0	18	0%	90%
3.	Hard	20	0	18	0%	90%

From the table above can be seen that the DFS technique is really helpful in finding a solution to solve Hashi game. Of the 60 total of Hashi game problem, Hashi Solving techniques can only complete 14 questions of Hashi game problems in Easy difficulty level, and also provides appropriate solutions. Compared using two techniques such as: Hashi solving techniques and DFS techniques, from 60 questions that have been tested and using the same questions which tested on the first test results, Hashi game can solve 20 Easy problems, 18 Medium problems and 18 Hard problems.

The percentage rate of success that can be achieved when using theHashi solving technique only reached 70% Easy difficulty, 0% for Medium difficulty and 0% "Hard" difficulty. So, if we accumulate overall, with 60 test questions, Hashi solving techniques's success rate is only reached 23.33%, while for the combination of Hashi solving techniques and DFS obtained 100% success rate percentage in Easy difficulty, 90% in Medium difficulty and 90% in Hard difficulty. So, when we accumulate them as a whole, with a test of 60 questions, the using combination of Hashi solving techniques and DFS percentage success rate is 93.33%.

The difference is quite high in percentage stated where DFS is really helpful in finding a solution in the Hashi game. In Hashi game with levels of Easy difficulty, Hashi solving techniques still can find solution in precisely because the problems is not too complicated. But when entering the Medium and Hard difficulty levels, Hashi solving techniques have difficulty in finding the solution because there is a bridge that cannot be found. In the second test, two techniques were used and we got the success rate of 93.33%. The bridge, which was not found by Hashi solving techniques, is found using DFS. DFS helps to find the bridges that cannot be found by Hashi Solving techniques.

5. Conclusion

The conclusions that can be drawn from this research are as follows:

1. Hashi game problems in Easy difficulty can be solved by Hashi solving techniques by its own whether in order to solved Hashi game problems in Medium and Hard difficulty it is used both Hashi solving techniques and Depth First Search (DFS).
2. DFS can help to search Hashi game solution when there are not an island that can't be found using Hashi solving techniques.
3. The combination of Hashi solving techniques and DFS can help to find Hashi game solution searching better. It is proved based on the testing result that success rate is 93,33% when using both techniques better than when we using only Hashi solving techniques.

References

[1] Nikoli. 2001. Hashiwokakero I. Nikoli Co., Ltd, Japan. http://www.nikoli.co.jp/. Last access: 15 Februari 2011.

[2] Morsink T. Hashiwokakero. 2009. Available on: http://www.liacs.nl/assets/Bachelorscripties/2009-11TimoMorsink.pdf. Last access: 20 Februari 2011.

[3] Anderson Daniel. Hashiwokakero is NP-complete. 2009; 109(19). Available on: http://www.daimi.au.dk/~koda/hashiwokakero.pdf. Last access: 20 Februari 2011.

[4] http://www.indigopuzzles.com/ipuz/help.action?helpId=hashi/index. last access: 15 Februari 2011.
[5] Desiani Anita, Muhammad Arhami. Konsep Kecerdasan Buatan. 1st Edition. Yogyakarta: ANDI 2006.
[6] Kusumadewi S. Artificial Intelligence (Teknik dan Aplikasinya). 2nd Edition. Graha Ilmu. 2002
[7] Yamamoto Saito. 2008. Hashi. Drs. Suharsono. Mitra Media.