How Humans Search Varying-Knowledge Environments: Solving Imperfect Information Mazes

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Abstract. In our experiment, we studied the searching sequence of humans, i.e. how humans solve the game tree. We created a controlled environment of maze game to simulate the situation where the player is not allowed to observe the entire map freely. We use "fog-block" to cover the intersection of a maze. Thus, the maze becomes an "imperfect information maze." We give additional information to hint on the path that the player should choose. Then we observed the change in players' behavior. We found that hints affect searches making it best fit path towards hint.

Keywords: Knowledge, Game tree, Imperfect information, Gaze, Cognition.

1 Introduction

To solve a maze, various path-finding algorithms have been proposed [1]. In a computer, those algorithms manage sequence searches from memory. In general, the computer initially stores all the data of the maze's map which includes a path or wall or goal. The algorithm will explore mazes differently depending on search strategy. Figure 1 shows an area of search sequence between two different algorithms. 'S' is the start position and 'G' is the goal position. The colored area is the area involved in searching sequence to reach the goal position.

If the solver knows only the initial position, it evaluates neighbor nodes. Figure 1A shows how the algorithm starts searching under the given condition until the "path to goal" is found. A Dijkstra search [2] is used in this example. This algorithm repeats exploring all the unknown positions on the board, from the current position to neighbor nodes, until reaching the goal position.

If the solver knows both initial and goal position beforehand, A* algorithm is known as one of the algorithms to search more effectively [3]. Figure 1B demonstrates the A* algorithm. Search space is clearly reduced compared to Dijkstra search. Additional information enables more promising search methods as shown in our example. A question arises whether this information helps humans in searching or not.

It is known that gaze interactions can reflect human strategy [4]. It has been shown that the addition of information provided to the player affects gaze pattern [5,6,7,8,9,10]. However, in a perfect information maze, the information obtained from human eyes often involves too large area since each gaze can provide the information of several intersections and relative positions, it is difficult to tell which exact pieces of information motivate the player to search in their specific way.

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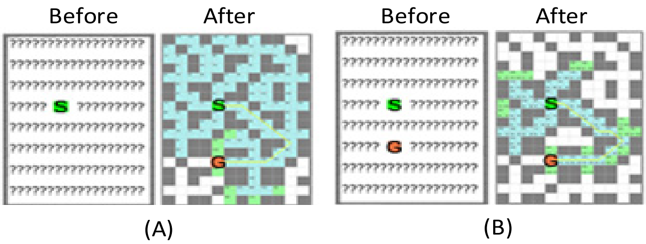

Fig. 1. Dijkstra search and A* search

2 Imperfect Information Maze

A form of game, where the player is not allowed to see the entire information provides a promising way to observe a player's thinking process, e.g. blindfold chess [11]. Figure 2 shows how a "fog-block" works in an imperfect information maze. We use the "fog-block" to cover an intersection of the maze. This environment enables to control the sequence of how a human explores the game tree.

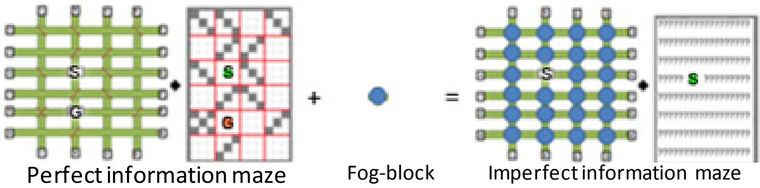

Fig. 2. Creating an imperfect information maze

We performed experiments on computer using Microsoft visual c#. Information obtained visually is limited to the interaction and interference of the "fog circle" controlled by user interface. To reveal information from under the "fog-block", user needs to move the mouse over the "fog-block" and click it. This setup reduces the ambiguity of how humans prioritize searches. Recognition process requires short-term memory [11], which affects gaze sequence due to memory capacity. In this experiment, the size of the maze problem is small and requires less memory.

3 Using Unsolvable Maze Problems for Motivation

When humans process reasoning, they need to search from the current position to each sibling position (leaf nodes) until they find a possible path to the desired outcome (winning position) in a game tree. Each maze can be modeled as a game tree because it has choices (branching nodes) and an answer (goal). Figure 3 shows how a maze can be represented in game tree format.

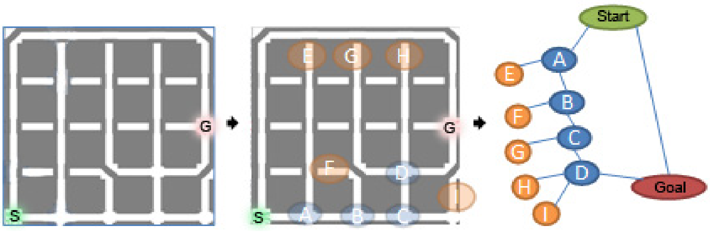

Fig. 3. Creating the game tree from a maze

There are three possibilities one can get during search through a maze, namely branching node (A,B,C,D), dead end (E,F,G,H,I) or goal position. Players will have to make a choice in the maze when they face a branching node. However, making choices in a maze problem is not as crucial of a decision as in a competitive game. Making the wrong choice in a maze will just make a player waste more time in solving it. He/she will eventually reach the goal in any maze problem. To configure the situation where the player cannot find the path to the desired outcome, we mixed a solvable maze with an unsolvable maze which includes no from start to goal. This engages the player to search through the maze like they would do in an adversarial game.

4 Experimental Setup

Two graduate students consented to participate in this experiment. We had them play 7 maze problems with a computer. During play, we captured their eye movement with using Tobii X60 & X120 Eye Trackers [8]. The objective of the maze problem is to find if there is at least one path from start to goal. We let the player play 3 different types of maze as shown in Figure 4. Figure 4A and Figure 4B are perfect information and imperfect information mazes, respectively. Figure 4C shows imperfect information with the goal position already revealed at the beginning.

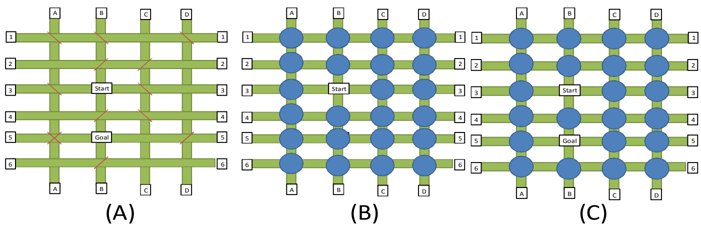

Fig. 4. Configurations in maze experiment

After playing the maze, each player was requested to answer a questionnaire. We provide the perfect information maze to the test subjects. We ask the player to pick the best intersection of the maze, considering that this hint will guide other players when they are playing the imperfect information maze with/without goal information.

5 Discussion and Concluding Remarks

We represent all maze positions as nodes in a game tree. In this way, we can recognize the position of each player's focus while solving the maze.

In a perfection information maze, the sequence of the gaze points does not fit to the exact maze position. Because it is easy to recognize obstacles in range of central vision without looking directly at them or the player simply did not pay attention to them. However, there are clear gaze patterns obtained from the player as follows:

1. The player starts looking at start and goal position as the first priority.
2. The player retrieves the straight line path from start to goal, with consideration to obstacles in each maze position as shown in Figure 5. The line represents a scan path.
3. The player attempts to construct a solution on that straight line from start to goal.

Fig. 5. Noticeable straight line, towards hint, of eye gaze sequence

In the imperfect information maze we have shown that gaze point corresponds to the cursor position. It is useful to recognize gaze point from the cursor position. In this setup, the player explores though the sibling nodes continuously. If a dead end is found, he will backtrack to the previous branching node. This search pattern is similar to Depth-First Search.

In the imperfect information maze with goal hint, the player often starts exploring the nodes from the goal position, rather than from start position. The process is similar to the perfect information maze. When the player is faced with a maze with no goal, the player tends to show less confidence when solving this problem. He/she always double-checks the path over again. The answers from the questionnaire showed that the hint guides the player to the shortest path between the start and the goal. Players comment that the straight line towards the hint guides the player when making a decision at branching nodes.

In conclusion, we found that the hint shapes the searching sequence. This straight line guides the player to make a certain decision at branching nodes. The searching sequence becomes a best fit path to the straight line toward hint.

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References

1. Kumari, S.M., Geethanjali, N.: A survey on shortest path routing algorithms for public transport travel. Global Journal of Computer Science and Technology 9(5), 73–75 (2010)
2. Dijkstra, E.W.: A note on two problems in connexion with graphs. Numerischemathematik 1(1), 269–271 (1959)
3. Dechter, R., Pearl, J.: Generalized best-first search strategies and the optimality of A*. Journal of the ACM (JACM) 32(3), 505–536 (1985)
4. Meijering, B., van Rijin, H., Taatgen, N.A., Verbrugge, R.: What eye movements can tell about theory of mind in a strategic game. PLoS one 7(9) (2012)
5. Sennersten, C.: Eye movements in am action game tutorial. Unpublished master's thesis, Lund University, Lund, Sweden (2004)
6. Gedeon, T.D., Zhu, D., Mendis, B.S.U.: Eye gaze assistance for a game-like interactive task. International Journal of Computer Games Technology 3 (2008)
7. Gowases, T., Bednarik, R., Tukiainen, M.: Gaze vs. mouse in games: The effects on user experience. In: Proceeding to International Conference on Computers in Education, pp. 773–777 (2008)
8. Sennersten, C., Alfredson, J., Castor, M., Hedström, J., Lindahl, B., Lindley, C., Svensson, E.: Verification of an Experimental Platform Integrating a Tobii Eytracking System with the Hifi Game Engine. In: Command and Control Systems, Swedish Defence Research Agency, pp. 5–15 (2007)
9. Jennett, C., Cox, A.L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., Walton, A.: Measuring and defining the experience of immersion in games. International journal of human-computer studies 66(9), 641–661 (2008)
10. Qian, Q., Shinomori, K., Song, M.: The functional role of implicit memory on gaze-evoked attention orienting. In: IEEE International Conference on Information and Automation (ICIA), pp. 148–153. IEEE (2010)
11. Campitelli, G., Gobet, F.: The mind's eye in blindfold chess. European Journal of Cognitive Psychology 17(1), 23–45 (2005)
12. Hollingworth, A., Richard, A.M., Luck, S.J.: Understanding the function of visual short-term memory: Transsaccadic memory, object correspondence, and gaze correction. Journal of Experimental Psychology: General 137(1), 163–181 (2008)