Comparative Analysis Of A* And Basic Theta* Algorithm In Android-Based Pathfinding Games

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***Abstract*— Pathfinding games is a kind of mobile games which are included in Puzzle, Board Game, Game Show, Trivia, Card Games. Pathfinding games require a search techniques to get the fastest route, efficient, and shortest time. Searching techniques that can be used are A* (A Star) and Basic Theta* (Basic Theta Star) algorithm. A* algorithm was originally introduced by Peter Hart *et al*., A* algorithm calculate the cost using a heuristic function to prioritize the nodes (vertex) to be traversed, the cost is the distance it takes to walk from a node to anothernode. Basic Theta* algorithm is a variant of the A* made by Alex Nash et al. in 2007 because A* has the disadvantage that the results route is often not true shortest path because the routing path is limited by the grid, while the Basic Theta* change the limit of routing path becomes to all sides/angles. In this study will measure the performance of search methods which is better for square grids map on Android-based pathfinding games and used variable such as *completeness*, *time complexity*, and *optimality*. Input parameters for the simulation consists of a square-grids map with a starting point, goal point and unwalkable, and output consists of completeness, running time, path length, and nodes searched. The results of this study conclude that the A* and Basic Theta*algorithm has the same completeness criteria and has time complexity which is relatively same, the A* algorithm has the advantage of optimality in fewer number of nodes searched, whereas the Basic Theta*algorithm has the advantage of the optimality the shortest results.**

***Keywords*— Comparison Algorithm, Search Algorithm, A* (A Star), Basic Theta* (Basic Theta Star), Pathfinding Games,**

I. INTRODUCTION

Android is a platform that consists of the operating system, applications, middleware, developing tools, application store, vendor support from mobile industry, even the support from Open Systems community. This is an advantage not owned by other platforms (Mulyadi, 2010: 5). According to data published by Trinity Marketing (2011: 1), in 2011 the Android smartphone platform control total of 250 million devices, more than half of mobile devices number at that moment.

Based on statistics from StatisticBrain (2014), games application are on the top rank and mastered by 23% of the total apps downloaded from the app store on all mobile platforms. The data indicate that current smartphones are not only used as a communication tool, but also as entertainment.

There are some kind (genre)of mobile games, one of them is pathfinding games, a few example of pathfinding gamesare 8 Puzzle, Tower Based, Maze, Pac Man, Snake and so on. Pathfinding games included into the Puzzle and Board Games. According to data published by the Entertainment Software Association (2014: 5) in 2014 Puzzle, Board Game, Game Show, Trivia, Card Games is the second rank most commonly games played by users around the world in the amount of 31%. Pathfinding games have quite simple rules, that isto resolve the problem or to get the fastest route, efficient, and short time based on the form of map in the game by using search(searching)techniques. Several search techniques that can be used include the A* algorithm and the Basic Theta*algorithm.

A* algorithm (pronounced: A Star) which was developed in 1968 combines the concept of Dijkstra's algorithm and the Greedy Best First Search algorithm. A* algorithm calculate the cost using the heuristic function to prioritize the nodes (vertices) which will be passed in the map that are represented in the form of a graph, the cost is the distance it takes to walk from a node to another node. So A* has a good time efficiency because the expense of distance calculation is not required. This algorithm can provide a solution that is good enough for routes pathfinding, and commonly used in the making of a game application.

Basic Theta* (pronounced: Basic Theta Star) Algorithm is variant of the A* algorithm published in 2007 by Alex Nash, Kenny Daniel, Sven Koenig and Ariel Felner. Since the A* algorithm has the disadvantage that the results route is often not true shortest route because the grid path on A* is limited by the grid, then the algorithm Basic Theta* is made to find true shortest path to change the limit line by finding the edge on all sides/angles.

According to Russell and Norvig (in Suyanto 2011: 15), there are several criteria that can be used to measure the performance of search methods, that are*completeness* (ensure discovery of solution if a solution exists), *time complexity* (time required to get solution), and *optimality* (finding the best solution). The authors will compare the A* algorithm Basic Theta*for square grids map on the Android-based pathfinding

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games, using the criteria of *completeness*, *time complexity*, and *optimality* to measure the performance of the search algorithm.

II. PROBLEM FORMULATION

2.1. Problem Formulation

Based on background, the authors formulate the problem as follows:

How is the results of performance comparison between A*and Basic Theta*algorithmfor square grids mapin the Android-based pathfinding games using criteria: completeness, time complexity, and optimality?

2.1.1. Limitations

Limitation the problem as follows:

a. Pathfinding algorithms used are A* and Basic Theta*algorithm.
b. A simulation pathfinding games is made for Android mobile platform.
c. A simulation pathfinding games is named"Finding The Bones Benchmark".
d. Heuristic function used is Euclidean Distance (Straight Line Distance) because Basic Theta* has consistently only using that heuristic function.
e. Method of comparison algorithmsused is the simulation method.
f. Input parameter is square grids map with a starting point, goal point and the unwalkable. Map used will have size based on the level of the game, the maximum sizeof square grids used is 100x100 grids.
g. Output parameters generated in the form of a table which consists of: completeness (found a solution or not), running time (time required to find solution), path length (distance or length of the solution obtained), and nodes searched (the number of nodes or grid traced),
h. The output will be used as a performance comparison search techniques with criteria: completeness, time complexity, and optimality.
i. Tools used are the Android SDK, Eclipse IDE, and IBM Worklight with HTML5 and JavaScript programming languages.

2.1.2. Purpose and Benefits

The purpose of this study is to determine the characteristics and performance of the algorithm which is is better between A* and Basic Theta*algorithm for square grids map in the Android-based pathfinding gamesusing criteria: *completeness*, *time complexity*, and *optimality*.

Benefits

The expected benefits of the authors of this study are as follows:

a. Knows that the simulation method can be used as method of comparison algorithms.
b. Knows which is better pathfinding algorithm for square grids map in the pathfinding games.
c. Know the performance of A* and Basic Theta*algorithm based on criteria: *completeness*, *time complexity*, and *optimality*for square grids map in the Android-based pathfinding games.

III. RESEARCH METHODOLOGY

3.1. Data Collection Method

In this paper the authors conducted a study using two types of data, as follows:

3.1.1. Primary Data

Data collection was done through experimentation, observe, analyze, and record each experimentation simulation results of the algorithm used for the comparison.

3.1.2. Secondary Data

Data collected through the study of literature and a review of previous research related to the research conducted by the authors. The data and the results of previous research is very important thing needed in this research. The results of these studies are used as a basis and reference in the analysis and comparison the A*and Basic Theta*algorithm.

Reference that the authors use is printed books, and electronic media such as ebooks and the internet. While the sources of research literature in the form of journals, thesis, and other type of publications. The research results were used as the main reference by the authors is the publication by Alex Nash, Kenny Daniel, Sven Koenig and Ariel Felner in 2007 entitled Theta*: Any-angle path planning on grids, published in Proceedings of the AAAI Conference on Artificial Intelligence page 1177-1183.

3.2. Simulation Method

In this study, the authors use simulation method as comparison algorithmmethod by doing simulation against the algorithm to be used. The simulation method consists of several stages which consist of:

a. Problem Formulation
b. Conceptual Model
c. Input Output Data
d. Modeling
e. Simulation
f. Verification and Validation
g. Experimentation
h. Output Analysis

IV. RESULT

The main problem in pathfinding games is needed the better search (searching) techniques to solve the problem or get the fastest route search solution, efficient, and short time based on the form of map or maps in the game. Several search techniques that can be used include the A* and Basic Theta*algorithm. To determine the characteristics and better search techniques, can be done with a search technique performance comparison using criteria: *completeness* (guarantee discovery solution if a solution exists), *time complexity* (time required), and *optimality* (finding the best solution).

1.1. Conceptual Model

In the simulation of the algorithmcomparison, there are several provisions that are used in game applications Finding The Bones Benchmark is applied to the simulation, namely:

1.1.1. Map for pathfinding games in the form of square grids. This is because the square grids have a simple graph structure and can be represented as an array of two-dimensional, and is widely used in the board game type. Size of map are differentiated based on the level of the game, ie maps at level 1 5x5 grid,level 2 sized 10x10 grid, and so on.

1.1.2. Map is assumed for the game so it does not need the depictions of real/actual map, so unwalkableon the map will be randomlygenerated by the game application Finding The BonesBenchmark. Meaning of randomly generated is a node for unwalkable created by random coordinate points. Unwalkablevalued '1' on the map while the walkable path valued '0'.

1.1.3. Map is assumed for the game so it does not need the depictions of real/actual map, so that the starting point and goal point at each level of the game was randomly generated by the simulation programpathfinding games.

The conceptual model can be described as follows:

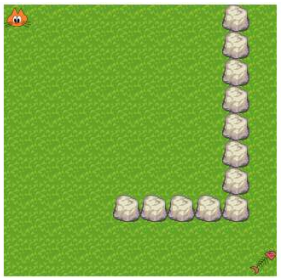


Figure 1 - Conceptual Model Application Benchmark Finding The Bones

Figure 1 is a map in the form of size 10x10 square grids with unwalkable, the starting point and goal point was randomly generated by the game application Finding The Bones Benchmark. Starting point at coordinates '0.0' portrayed with a cat and goal point at coordinates' 9,9'portrayed with fish bones that will be addressed by a cat. Obstruction (unwalkable) depicted in the form of rocks and roads are passable (walkable) depicted in a grassy street. Map in the figure above is represented by a two-dimensional array of the following:

```
world = [[0, 0, 0, 0, 0, 0, 0, 0, 0, 0],
         [0, 0, 0, 0, 0, 0, 0, 0, 0, 0],
         [0, 0, 0, 0, 0, 0, 0, 0, 0, 0],
         [0, 0, 0, 0, 0, 0, 0, 0, 0, 0],
         [0, 0, 0, 0, 0, 0, 0, 1, 0, 0],
         [0, 0, 0, 0, 0, 0, 0, 1, 0, 0],
         [0, 0, 0, 0, 0, 0, 0, 1, 0, 0],
         [0, 0, 0, 0, 0, 0, 0, 1, 0, 0],
         [1, 1, 1, 1, 1, 1, 1, 1, 0, 0],
         [0, 0, 0, 0, 0, 0, 0, 0, 0, 0]];
```

Specification:

- Value '1' indicates if the world [x] [y] in the map square grid is an obstacle that can not be passed (unwalkable).
- Value '0' indicates if the world [x] [y] in the map is a square grid of roads are passable.

1.2. Input Output Data

1.2.1. Input

Input (input) are attributes or variables that are used by both algorithms A* and Basic Theta* pathfinding algorithm in simulation of comparison in game applications Finding The Bones Benchmark. Inputs used are:

a. Map is represented in the array (array) of two-dimensional. Array is a collection of vertices (nodes) that has the attribute points x and y coordinates. In the array there are obstacles (unwalkable), which is a hindrance to the grid value '1', while the grid of roads are passable (walkable) value '0'.

b. Starting point is a variable that describes the coordinates of the initial position of an object.

c. Goal is a variable point in the form of point coordinates that describe the position of the goal to be achieved from the initial position of an object.

1.2.2. Output

The output of the simulation results based on the main problem in the pathfinding games, namely:

a. Completeness,ie if thepathfinding algorithm used in the simulation game applications Finding The Bones Benchmark can find the route (path) in the map. Completeness of the pathfinding algorithm in this simulation will be worth *True* or *False*.

b. Running time, ie the time required by pathfinding algorithm to find a route that is used as the final solution. Running time of the pathfinding algorithm in this simulation has units of milliseconds (ms/millisecond).

c. Path length, ie the distance or length of the route is generated by a pathfinding algorithm from the starting point to the goal point.

d. Nodes searched, ie the number of vertices/nodes (grid) which is traced by the pathfinding algorithm to find a final solution.

1.3. Modelling

In comparison algorithm simulation pathfinding on game applications Finding The Bones Benchmark testing was performed several times with different scenarios based on the level of the game, and for each scenario performed 3 times a simulation loop. Here is an example scenario for this simulation level 1:

Table1 - Scenario Level 1

Parameter	Variabel
• Map Size	• 5x5 *grid*
• Array Map with Unwalkable and Walkable	• Random
• Starting Point	• Random
• Goal Point	• Random

Scenario level 1 simulation of pathfinding algorithm comparison on game applications Finding The Bones Benchmark assumed map in the game has an area of 5x5 grid with values obstacles (unwalkable) and roads are passable be randomly generated by the game application Finding The Bones Benchmark, Starting point and goal points placed randomly on the map game with coordinates (x, y). outputs or results generated simulation consisting of completeness, running time, path length, and nodes searched,

Following is size of map for each level scenarios:

1. Scenario level 1 = 5x5 *grid*

2. Scenario level 2 = 10x10 *grid*
3. Scenario level 3 = 25x25 *grid*
4. Scenario level 4 = 50x50 *grid*
5. Scenario level 5 = 75x75 *grid*
6. Scenario level 6 = 100x100 *grid*

1.4. Simulation

To perform a simulation of pathfinding algorithm comparisonin Android based pathfinding games needed the uses both algorithms to be tested. Generally, the following steps to create game applications Finding The Bones benchmark that will be used as a tool for simulation of pathfinding algorithm comparison and Here is a flowchart of simulation:

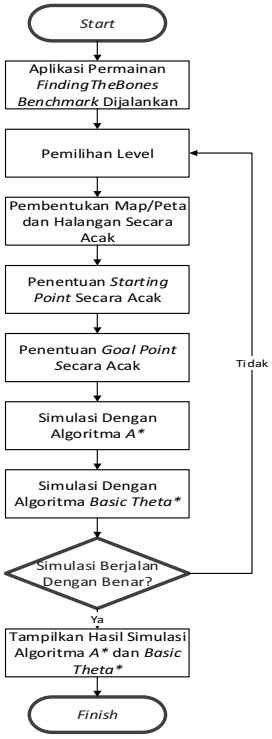


Figure 2-Simulation Flowchart

1.5. Verification & Validation

This stage is a stage to perform verification and validation of the previous stages. In this stage, corrections or repairs if something goes wrong at each stage of the simulation method. Verification is done by testing game applications Finding The Bones Benchmark Benchmark is run in accordance with the flowchart of simulation that has been made before on simulation stage. While validation is done by testing game applications Finding The Bones Benchmark Benchmark whether in accordance with the provisions of the stages of conceptual models, input data output, and modeling,

1.6. Experimentation

After the game applications Finding The Bones Benchmark be deployed and be installed on the smartphone Android, the game application is run to perform the simulation of pathfinding algorithm comparison algorithm A* and algorithm Basic Theta* under the terms, concepts, models, and flowchart simulation has been described previously.

1.7. Output Analysis

The results of this simulation in the form of video recording and screen capture of game applications Finding The Bones Benchmark for each level of the game (scenario). From the simulation results, the authors make record parameter output is generated in the form of tables.

a. Level 1 Scenario Simulation Results

Here is a screen capture app game Finding The Bones Benchmark levels for the simulation scenario 1:

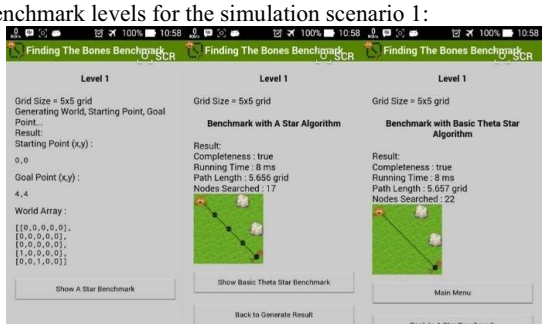


Figure 3 -Screen Capture Scenario 1 Experimentation-1

Figure 9 is a screen capture resulting from the experiment to the level-1 simulation scenario 1, the results generated applications Finding The Bones Benchmark is the starting point at coordinates (0,0), and the goal point at coordinates (4.4). Simulation results using algorithm A* produces completeness : true, running time : 8 ms, path length : 5.656 grid, and nodes searched : 17 grid, The simulation results using the algorithm Basic Theta* generate completeness : true, running time : 8 ms, path length : 5.657 grid, and nodes searched : 22 grid,

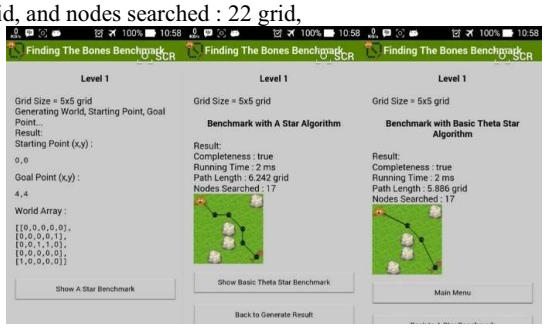
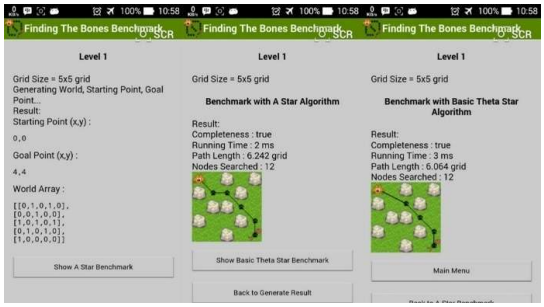


Figure 4 - Screen Capture Scenario 1 Experimentation-2

Figure 10 is a screen capture resulting from the experiment to the level-2 simulation scenario 1, the results generated applications Finding The Bones Benchmark is the starting point at coordinates (0,0), and the goal point at coordinates (4.4). Simulation results using algorithm A* produces completeness : true, running time : 2 ms, path length : 6.242 grid, and nodes searched : 17 grid, The simulation results using the algorithm Basic Theta* generate completeness : true, running time : 2 ms, path length : 5.886 grid, and nodes searched : 17 grid,



Gambar 5 - Screen Capture Scenario 1 Experimentation-3

Figure 11 is a screen capture of the experiment produced a 3rd-level simulation scenario 1, the results generated applications Finding The Bones Benchmark is the starting point at coordinates (0,0), and the goal point at coordinates (4.4). Simulation results using algorithm A* produces completeness : true, running time : 2 ms, path length : 6.242 grid, and nodes searched : 12 grid, The simulation results using the algorithm Basic Theta* generate completeness : true, running time : 3 ms, path length : 6.046 grid, and nodes searched : 12 grid,

From the results of experiments that have been conducted on the simulation scenario 3x level 1 as shown in the screen capture, then obtained the data output is as follows:

Table 2 - Results of Scenario Level 1

Output	Experimentation -1		Experimentation-2		Experimentation-3		Average	
	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*
Completeness (boolean)	true	true	true	true	true	true	true	true
Running Time (ms)	8	8	2	2	2	3	4	4,333
Path Length (grid)	5,656	5,657	6,242	5,886	6,242	6,064	6,047	5,869
Nodes Searched (grid)	17	22	17	17	12	12	15,333	17

b. Level 2 Scenario Simulation Results

From the results of experiments that have been conducted on the simulation scenario 3x level 2 as shown in the screen capture, then obtained the data output is as follows:

Table 3 - Results of Scenario Level 2

Output	Experimentation-1		Experimentation-2		Experimentation-3		Average	
	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*
Completeness (boolean)	true	true	true	true	true	true	true	true
Running Time (ms)	3	6	5	7	3	6	3,667	6,333
Path Length (grid)	14,07	11,084	12,484	12,892	11,898	11,898	12,817	11,958
Nodes Searched (grid)	29	29	34	37	31	36	31,333	34

c. Level 3 Scenario Simulation Results

From the results of experiments that have been performed on simulated scenarios 3x level 3 as shown in the screen capture, then obtained the data output is as follows:

Table4 - Results of Scenario Level 3

Output	Experimentation-1		Experimentation-2		Experimentation-3		Average	
	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*
Completeness (boolean)	true	true	true	true	true	true	true	true
Running Time (ms)	12	7	19	11	8	8	13	8,667
Path Length (grid)	28,038	27,397	29,038	28,735	30,624	31,011	29,233	29,047
Nodes Searched (grid)	79	74	87	94	76	81	80,667	83

d. Level 4 Scenario Simulation Results

From the results of experiments that have been conducted on the simulation scenario 3x level 4 as shown in the screen capture, then obtained the data output is as follows:

Table5 - Results of Scenario Level 4

Output	Experimentation-1		Experimentation-2		Experimentation-3		Average	
	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*
Completeness (boolean)	true	true	true	true	true	true	true	true
Running Time (ms)	134	38	16	15	19	24	56,333	25,667
Path Length (grid)	46,764	45,893	45,178	44,216	54,834	53,941	48,925	48,016
Nodes Searched (grid)	124	133	129	131	144	160	132,333	141,333

e. Level 5 Scenario Simulation Results

From the results of experiments that have been conducted on the simulation scenario 3x level 5 as shown in the screen capture, then obtained the data output is as follows:

Table6 - Results of Scenario Level 5

Output	Experimentation-1		Experimentation-2		Experimentation-3		Average	
	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*
Completeness (boolean)	true	true	true	true	true	true	true	true
Running Time (ms)	48	42	53	45	57	66	52,667	51
Path Length (grid)	82,7	81,17	93,77	91,678	83,528	85,239	86,666	86,029
Nodes Searched (grid)	223	224	237	237	228	229	229,333	230

f. Level 6 Scenario Simulation Results

From the results of experiments that have been conducted on the simulation scenario 3x level 6 as shown in the screen capture, then obtained the data output is as follows:

Table7 - Results of Scenario Level 6

Output	Experimentation-1		Experimentation-2		Experimentation-3		Average	
	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*	A*	Basic Theta*
Completeness (boolean)	true	true	true	true	true	true	true	true
Running Time (ms)	112	105	78	87	89	99	93	97
Path Length (grid)	117,566	116,243	112,254	109,322	115,152	114,912	114,990	113,492
Nodes Searched (grid)	303	304	284	296	310	320	299	306,667

1.8. Performance Comparison Methods Search Results

Once the results of the data output at each level of the game scenario experiment is obtained, then the results of the output is used to do performance comparison search algorithm with the following criteria: *completeness* (guarantee discovery solution if a solution exists), *time complexity* (time required), and *optimality* (finding the best solution),

The following performance criteria table search algorithm based on the output after the simulation on game applications Finding The Bones Benchmark levels by as much as 6 scenarios with each 3 times experiment total of 18 experimentations, namely:

Table8 - Performance Criteria Search Algorithm

Criteria	Experimentation Result		Explanation
	Algoritma A*	Algoritma Basic Theta*	
Completeness			
True	18	18	Both algorithms can find solutions for each experiment ie a total of 18 experimentations.
False	0	0	
Time Complexity			
Running Time	8	7	1. Running timealgorithm A* is faster than the algorithm Basic Theta* 8 times experiment with an average of 37,111 ms of each experimentation. 2. Running timealgorithm Basic Theta* algorithm is faster than A*7 times experiment with an average of 32,167 ms of each experimentation. 3. While bothalgorithms requireds running time 3 times the same experiment.
Optimality			
Path Length	4	13	1. Algorithm A*found shorter route than the algorithm Basic Theta* 4 times experiment with an average of 49,779 grid each experiment, 2. Algorithm Basic Theta*found shorter route than the algorithm A*with the experiment 13 times on average every 49,068 grid each experimentations, 3. While both algorithms found the distance or the same length as much as 1 time experimentation.
Nodes Searched	13	1	1. Algorithm A*perform asearch nodes is less than the algorithm Basic Theta* as much as 13 times experimentations with each experiment as much as 131.333 grid, 2. Algorithm Basic Theta*perform a searched the nodes is less than the algorithm A* as much as 1 times experimentations with each experiment as much as 135.333 grid, 3. While both algorithms perform a searched the nodes with the same number 4 times experimentations.

V. CONCLUSION

Results of performance comparison algorithm A* with Basic Theta*for square grids map inthe Android-basedpathfinding games using simulation method as a method of comparison algorithm which consists of a phase *problem formulation*, *conceptual models*, *input data output*, *modeling*, *simulation*, *verification and validation*, *experimentation*, and *output analysis* with the criteria *completeness*,*time complexity*,

and *optimality* shows that the A* and Basic Theta*algorithm has criteria for completeness of the same and has a time complexity which is relatively same, the A*algorithm has the advantage of optimality on the fewer number of search nodes (nodes searched), while the Basic Theta*algorithm has the advantage of optimality shortest route

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