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Shortest Path Algorithms: State of the Art

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Abstract

This paper presents a review of algorithm for solving shortest path problem. Many methods or algorithms can be used to solve the shortest path problem in the graph, but there are many differences in each method or algorithm. Although the same expected goal is to find the shortest / minimum trajectory that is optimal and efficient. The main purpose is to find the shortest path but there is also another goal that is to find the optimal shortest path with a fast search time. It is very difficult to get both, the shortest or fastest path of the optimum course takes the maximum time and also by the arena that many ways it can be used to search the shortest path on the graph with the advantages and disadvantages of each.

However, to determine which is most effective requires an algorithm that can provide conclusions based on several parameters added, such as the length of each point distance, the condition of the path between points, as well as the density of traffic each point.

Keywords: algorithm shortest path, intelligent transportation system, transportation problem, graph, genetic algorithm, a* algorithm, dijkstra algorithm, bellman ford algorithm.

INTRODUCTION

People in doing travel activities have an impact on high economic growth. This can cause the level of congestion to increase due to the wrong route selection resulting in the buildup of vehicles on certain roads resulting in an ineffective travel.

To travel from one place to another can be done through different paths, but to determine the most effective path requires an algorithm that will perform calculations on all aspects of the parameters.

Many benefits can be obtained when knowing the shortest or fastest route in a travel route, as an example, can save travel time, power, less fuel consumption, and the density of vehicles on certain segments can decompose.

Another example is in a shipping company, to save the operating costs of the distribution of goods must be done efficiently so it is necessary to determine an effective route for the delivery of goods, it can be done with the Capacitated Vehicle Routing Problem (CVRP) [1].

To determine which paths are efficient and effective is part of the graph theory, the route skipped is illustrated by the points associated with the line, each connecting line having the respective weights that become parameters in determining the fastest route.

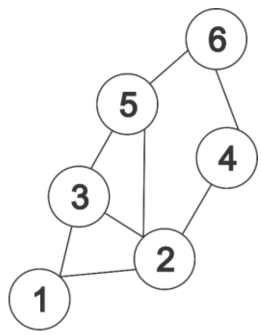

Figure 1: Graph Example

As in Figure 1, a graph that gives the option of taking the required route from point 1 to point 6, on the graph there are various routes available, such as route A from point 1-2-4-6, route B 1-3-5-6, route C 1-2-5-6, route D 1-2-3-5-6, route E 1-3-2-5-6. However, to determine which is most effective requires an algorithm that can provide conclusions based on several parameters added, such as the length of each point distance, the condition of the path between points, as well as the density of traffic each point.

In this paper, we will analyze the comparison of some algorithms used to determine the fastest route of a path and can be used as a reference to select the algorithm to be used in the future.

LITERATURE REVIEW

Genetic Algorithm

The numerical search tool used to find the maximum and minimum global of a function that is linear or non-linear is called the Genetic Algorithm [2].

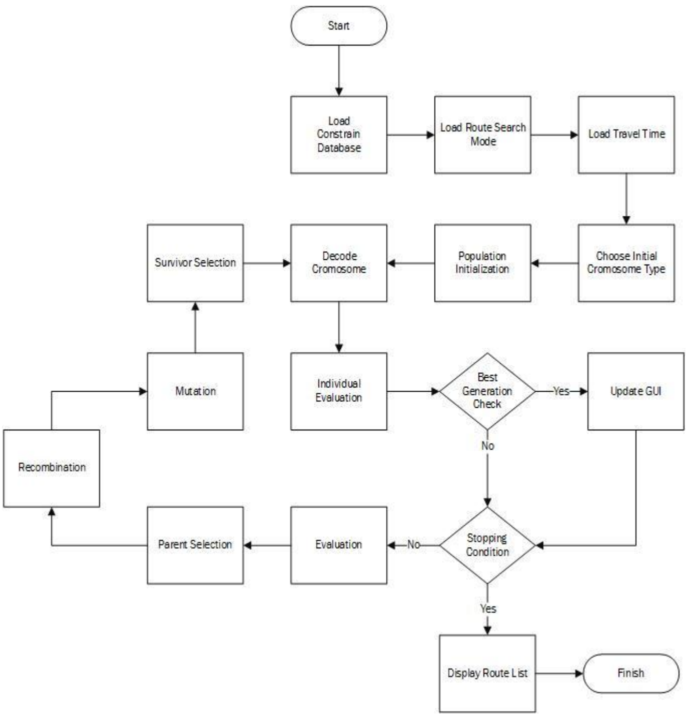

Figure 2: Genetic Algorithm Work Flow System [1]

Genetic algorithms can be used in the search for the shortest route because it has reliability in producing optimal output. Genetic algorithms are a form of stochastic search technique [19], the workings of genetic algorithms are based on the mechanism of biological evolution. Every living creature has its own unique genes, in which genes are part of a chromosome that will determine even affect the characteristics and properties of each individual.

The difference with other search path algorithms, genetic algorithms are based on evolutionary evolution, the initial phase of search in a genetic algorithm begins with a random set of compilations called populations, then a fitness function will be defined which will provide the standard of success of a population. After the fitness function is determined, next is the selection process of the population based on the standard of the fitness function, some methods of selection from the parent, such as Rank-based Fitness Assignment, Roulette Wheel Selection, Stochastic Universal Sampling, Local Selection, Truncation Selection, and Tournament Selection. Then the crossover stage where the cross between the chromosomes, and the last step is the phase of mutation where at this stage made changes to one or more chromosome values.

Greedy Algorithm

Greedy algorithm has a fast search speed than the A* algorithm because it only compares the distance from the original node to another node. But it makes this greedy algorithm has the best shortest path search optimization.

The greedy algorithm is a type of algorithm that performs the shortest path search using the problem solving approach by finding the maximum value while at each step. In most cases, the greedy algorithm will not produce the most optimal solution, nor does the greedy algorithm usually provides near-optimum solutions in a reasonably fast time, if when searching finds a node and the node has a very large value, greedy algorithm will still choose the node path because the mechanism of the greedy algorithm is unable to go back to the beginning so there is no choice but to take the path. It causes the search path becomes not optimal, even could happen worse thing is failing in search.

Dijkstra Algorithm

Dijkstra's algorithm is an algorithm used to solve single shortest path problems that have positive side values.

Dijkstra's algorithm aims to find the shortest path based on the smallest weight from one point to another. Suppose the point of drawing the location and line illustrates the path, the Dijkstra algorithm performs a calculation of all possible smallest weights of any point.

The Dijkstra algorithm is one of the most popular algorithms used to solve the shortest path problem, but the algorithm can only be used on graphs with no negative edge values. Dijkstra's algorithm for solving shortest path problems can be modified using several methods, one of which is a new method that provides effective results in determining the shortest path is the Modified Dijkstra Shortest Path (MDSP), based on research from S. Siva Kumar, et al. [7] proposed a new algorithm used to determine the shortest path called the Modified Dijkstra Shortest Path (MDSP) algorithm. In this algorithm to find a valid short path is better using some parameters than using a single parameter. The results of the analysis of the node gauge and time complexity can be known that the MDSP algorithm is efficient in determining the shortest path.

Reference [8] shows the problem of finding the shortest path from a particular node to another can be expressed as follows: The simple weighted Digraph G of n vertices is represented by n with n matrix D = [dij], where dij = length (or distance or weight) of edges directed from vertex i to node j: Dijkstra's algorithm assigns a label to each node of a given digraph, for each stage of the algorithm, the node has a permanent label and a temporary label. The algorithm starts by assigning the permanent label 0 to the starting point s, and the unlimited temporary label to the remaining n-1 node.

Bellman Ford algorithm

The Bellman Ford algorithm is very similar to Dijkstra's algorithm because the mechanism for finding the shortest route is to count each node that will point to the destination node, only difference is that Bellman Ford algorithm can calculate the path value which has negative weight, but Bellman Ford algorithm has more search time long compared to a Djikstra's algorithm. According to Nik Shahidah Afifi Bt. Md Taujuddin, et al.[11] The Bellman-Ford algorithm has a function for finding the shortest path in the graph that has a negative weight edges. The graph should be directed if there is a non-directional negative side that will immediately imply a negative weight cycle where this edge is traversed back and forth in each direction.

A Algorithm*

One of the most effective ways to break the shortest path in a 2-dimensional grid is to combine the advantages of the Dijkstra algorithm and the first search algorithm or also called the A star algorithm [5]. The A * algorithm for performing searches calculates all existing node values and stores them and then compares them to existing data. So making the fastest trajectory search using the A* algorithm has an optimum path finding result. But since the A* algorithm does a search for all existing nodes and then continues to compare the results obtained between each node doing a search using the A* algorithm takes a long time. The A* algorithm is used in cases that are more concerned with the optimal search results than long data search calculations.

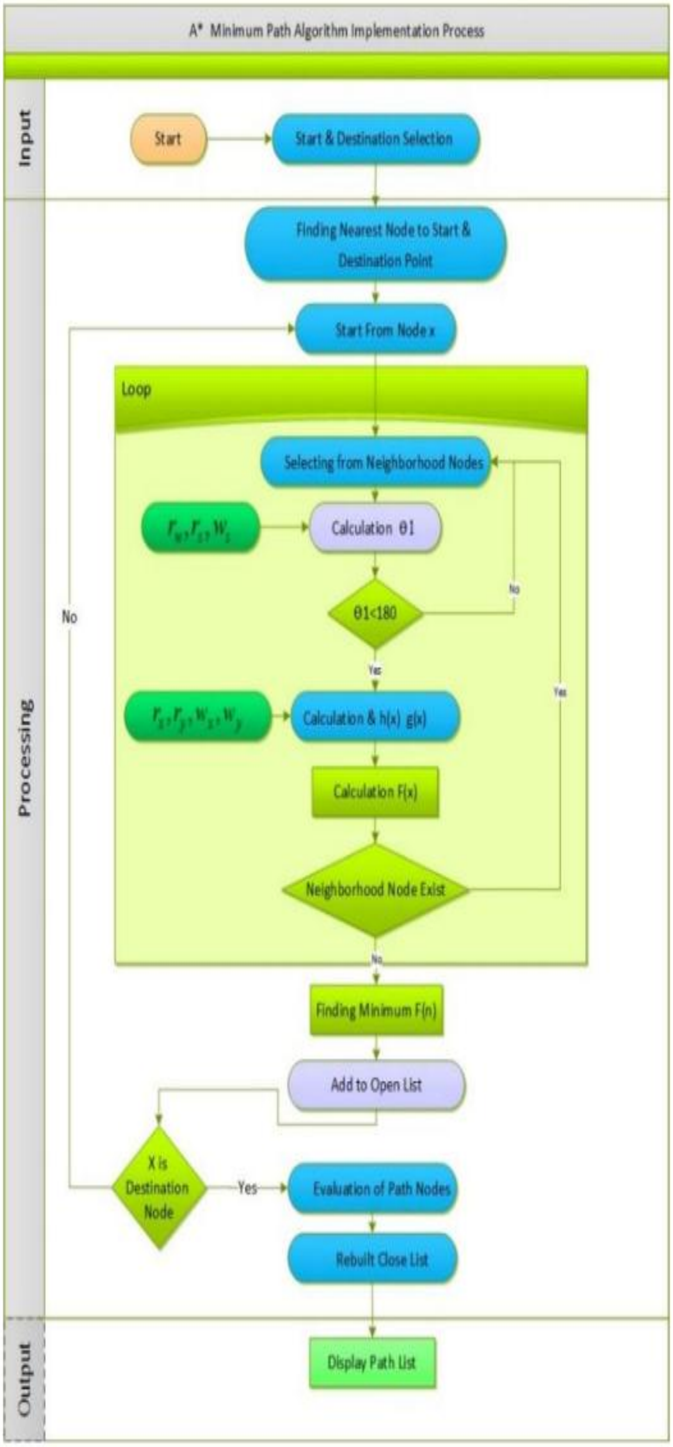

Figure 3: An Example Implementation steps of A* algorithm [10]

Even the A * algorithm when compared to the Dijkstra algorithm has better search results, a journal article from Shrawan Kr. Sharma, et al. Consider [9] A* algorithm is more effective and efficient to determine the shortest path than the Dijkstra algorithm when using one directional or Bidirectional methods.

Table 1: Comparison of A * and Dijkstra [9]

Algorithm	Condition	Length	Time	Operation
A star	One-Direction	38	3.8190	553
Dijkstra	One-Direction	38	14.8760	1933
A star	Bi-direction	38	0.5920	348
Dijkstra	Bi-direction	38	8.2140	1618

Ant Colony algorithm

Colonies of ants can find the shortest path between the nest and the source of food based on the footprints on the trajectory that has been skipped. The more ants that pass through a path the clearer the footprints are. This leads to the passage of ants in small quantities increasingly decreasing the density of ants that pass through, or even will not be skipped at all. Conversely, the passage of ants in the number of the longer the more will be the density of ants that pass through it or even all the ants pass through the path, the more ants that pass through the path the more ants follow, the fewer ants that pass through the path, the pheromones that are left less and even disappear. From here, then the shortest path is selected between the nest and the source of food. Artificial ants used in ACO run a stochastic line construction that iteratively adds an arc to a partial travel plan using probabilities generated from pheromone pathways, which dynamically change. Applying the concept of a vehicle so as to share information and thus cooperative behavior between vehicles of the same type [18].

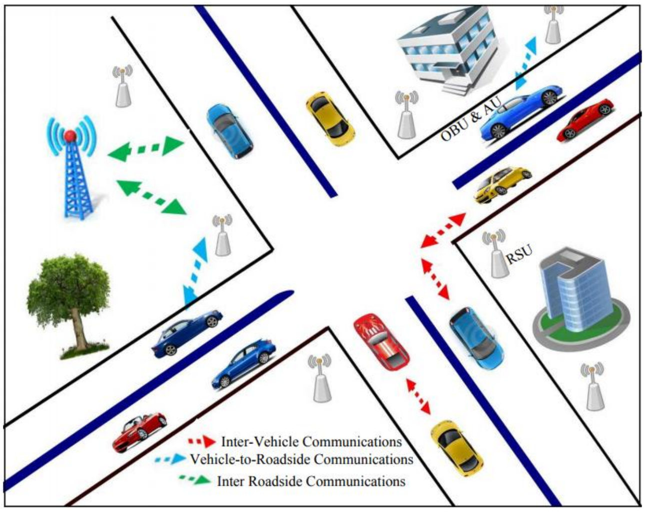

Figure 4: A typical VANET Scenario Using Ant Colony Algorithm [12]

Floyd Warshall algorithm

Floyd-Warshall's algorithm can be used to calculate the shortest distance solution for all pairs of points on a directed and weighted graph. This algorithm takes longer to determine the fastest path compared to Dijkstra's algorithm for the same problem, but has a more flexible result, because it can solve graphics that have the weight value of the positive and negative numbers. In figure 5 can be seen that formation of Clusters and locating centralized vehicles with Floyd Warshall Algorithm in the urban road.

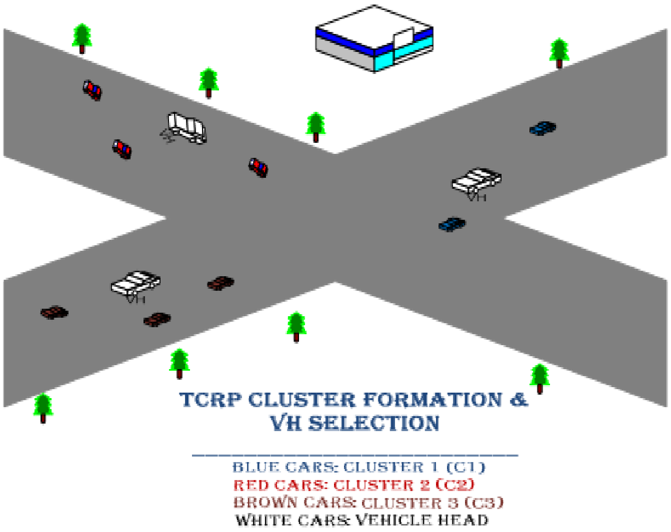

Figure 5: Formation of Clusters and locating centralized vehicles [15]

REVIEW AND DISCUSSIONS

A In determining the shortest path information in a route can use various algorithms or methods to facilitate decision-making. Many methods or algorithms can be used to solve the shortest path problem in the graph, but there are many differences in each method or algorithm although the same expected goal is to find the shortest / minimum trajectory that is optimal and efficient. Although the main purpose is to find the shortest path, but there is also another goal that is to find the shortest path optimal with a fast search time. It is very difficult to get both. The shortest path of the optimum course takes the maximum time also by the arena that many ways that can be used to search the shortest path on the graph with the advantages and disadvantages of each. The choice of method is based on conformity with the main objective in the shortest path search method as seen in table 2.

Table 2: Algorithms Review

Algorithm	Author	Title	Method	Purpose	Main Parameter
Floyd-Warshall's algorithm	Zahid khan, et al. [15]	A Novel Triple Cluster based Routing Protocol (TCRP) for VANETs	Floyd-Warshall's algorithm	Floyd Warshall algorithm is used to select a centralized vehicle. The Floyd-Warshall algorithm falls into all the shortest shortest category categories of graph theory, which calculate the shortest distance from all vehicles.	– Average distance – Variance In Velocity
Ant Colony algorithm	Chinmoy Ghorai , et al [12]	A Multi-Objective Data Dissemination Protocol for Intelligent Transportation Systems	Ant Colony Optimization (ACO)	To identify the optimal paths for Vehicular Ad-hoc Networks (VANETs)	– Signal to Noise Ratio, – Throughput, – End-to-End Delay Hop-count – Packet Loss
	Imad SABBANI, et al. [13]	A Multi-agent Based on Ant Colony Model for Urban Traffic Management	Ant Colony Optimization (ACO)	To manage roadway network congestion over time and space by developing the current urban traffic vehicles path routing methods.	– position, – speed, – distance with the adjacent vehicles, – acceleration, – consumption
	X. Wang, et al. [14]	Application of ant colony optimized routing algorithm based on evolving graph model in vanets	Ant Colony Optimization-Evolving Graph (ECO-EG)	Presented a traffic adaptive algorithm named ACO-EG to calculate the most optimal route	– End-to-end delay – Routing reply ratio – Route discovery time and delivery ratio.

Algorithm	Author	Title	Method	Purpose	Main Parameter
Genetic Algorithm	Rasyid Kurniawan, et al. [1]	Genetic Algorithm for Capacitated Vehicle Routing Problem with Considering Traffic Density	Recombination and mutation methods	Route selection with faster travel time even though the distance traveled further in the search process	– Traffic density
	Shijin Wang, et al [3]	A Genetic Algorithm for Energy Minimization Vehicle Routing Problem	A branch and-cut algorithm	Focusing on route selection so as to minimize energy on heterogeneous vehicles	– Heterogenous vehicle
	Sripriya. J, M.Tech, et al[4]	A Hybrid Genetic Algorithm For Vehicle Routing Problem With Time Windows	Hybrid Genetic Algorithm	Efficient solutions for Vehicle Routing Problem with Time Windows. With the aim to reduce the number of vehicles as well as the total distance at the same time	– Start Position – Finish Position – Rute – Road Condition
	Mitsuo Gent, et al [19]	Genetic Algorithms for Solving Shortest Path Problems	Priority-based coding method	The most difficult task and the critical task to expand the genetic algorithm is how to encode paths that exist on the graph to the chromosome. proposed a method that potentially represents all possible paths in the graph ie Priority-based coding method	– Node size – Variety of network optimization problems
A* Algorithm	Ma Changxi, et al [5]	Study on the hazardous blocked synthetic value and the optimization route of hazardous material transportation network based on A-star algorithm	A* algorithm	The A-star algorithm is used to find the single shortest route on the path of distributing hazardous materials by using the definition of safety-unblocked synthetic value and hazardous blocked synthetic value as its value parameter	– Safety unblocked synthetic value – Hazardous blocked synthetic value

Algorithm	Author	Title	Method	Purpose	Main Parameter
	Shrawan Kr. Sharma, et al. [9]	Shortest Path Searching for Road Network using A* Algorithm	one directional or Bidirectional methods	Used to find the shortest route with the fastest calculation time	– Characteristic of traffic restriction network
	S. M. Ayazi, et al. [10]	Modified A* Algorithm Implementation In The Routing Optimized For Use In Geospatial Information Systems	A* Algorithm	Using A* algorithms for the optimal method to find the shortest path with shortest time condition to be reviewed	– Start selection – Destination selection – Nearest node
Dijkstra Algorithm	Mayur Parulekar, et al . [6]	Automatic Vehicle Navigation using Dijkstra's Algorithm	Dijkstra algorithm	To get an effective route the parameters used are information from the starting point of the trip until the destination will be sent and received at the control center, The intergrated controller execute the altered Dijkstra's Algorithm and finds the shortest path from source to end point.	– Information from the starting point of the trip until the destination
	S. Sivakumar, et al. [7]	Modified Dijkstra's Shortest Path Algorithm	Modified Dijkstra's Shortest Path Algorithm (MDSP)	To find a valid short path is better using some parameters than using a single parameter	– Cost – Modified weighs
	Ojekudo, Nathaniel Akpofure, et al. [8]	Anapplication of Dijkstra's Algorithm to shortest route problem	Dijkstra algorithm	To finding the shortest route motivated by the need to minimize the distance and time of transporting goods from the company's production plant to seven different dealers in the road network given by the data	– Distance between nodes or location
Bellman-Ford algorithm	Nik Shahidah Afifi Bt. Md Taujuddin, et al. [11]	Findings On A Least Hop(S) Path Using Bellman-Ford Algorithm	Bellman-Ford algorithm	Solving most multiple constrained routing problems arise in the network	– Start Position – Route – Destination

Algorithm	Author	Title	Method	Purpose	Main Parameter
Greedy Algorithm	Jianing Min, et al. [16]	A Two-Phase Greedy Strategy in One to Many PDVRP	Two-Phase Greedy Strategy (TPGS)	To schedule vehicle routes with the lowest cost.	– Numbers of tasks – Start (pickup) point of task – Last (delivery) point of task – Distance
	Fu-Sheng Chang a, et al. [17]	Greedy-search-based multi-objective genetic algorithm for emergency logistics scheduling	Greedy-search-based multi-objective genetic algorithm (GSMOGA)	Used to set the schedule based on the number of depots and the number of requests. the resulting output can be used to determine the availability of resources at each point of demand as well as the number of points of supply	– Population – Generation – Selection – Crossover – Crossover – Ranking – Mutation – Mutation – Stop criterion

CONCLUSION

Each algorithm has its own functions and advantages, to use them tailored to the needs of the system itself. For example, on the shortest path search using A* and Greedy algorithms, both can provide search results on the shortest path, but have differences in the length of time to search. Greedy algorithm has a fast search time than A* but makes the level of optimization is low, unlike algorithm A* which has a high optimization because it searches on all nodes before making a decision so it has a longer search time.

So before choosing an algorithm must be able to determine whether it takes a fast search time or a high percentage optimal. For future research is expected to make GA become more adaptive so that in determining the value of evolution operator can be adjusted to the state of the population during the search process.

To improve the effectiveness of the A* algorithm can be used from the direction of restriction, by eliminating the moving node in the opposite direction with the restriction and then the scrolling speed rises. In the next study, we can determine the angle size of the proposed approach and method and the floating point value for various routes.

For further research it is expected that the application of GSMOGA algorithm can be applied also to traffic related information, including collapse of bridges, road closures, weather, and earthquakes, and other disasters. Then, speed up computing time can use cloud service.

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