An Improved Dijkstra Algorithm for Firefighting

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ABSTRACT -- In this paper, briefly the efforts going toward a mathematical calculation to validate a new-Dijkstra algorithm from the original normal Dijkstra algorithm [1] as an improvised Dijkstra. The result of this improvised Dijkstra was used to find the shortest path for firefighting unit to reach the location of the fire exactly. The idea depends on the influence of turns on the path, while there are two equal paths', the more number of turns take more time to pass through it and the less number turns takes less time to pass through it. To apply this scenario practically we take a small real area in south Khartoum.

The result gives strong justification that proves and verifies our methodology with a clear contribution in Improved Dijkstra algorithm for firefighting like Geo-Dijkstra. Furthermore, an evaluation of the above-mentioned algorithms has been done showing very promising and realistic results.

1 INTRODUCTION

Automatic and intelligent fire detection system is important for early detection and promptly extinguishing fire [2]. Fire is a danger leads to quick destroying of assets and human lives. Moreover, it can propagate in fast manner according to several factors such as wind direction, fired contents (gas, fuel), etc. The fire is giant phenomena which can be controlled in its early stages but this period does not take except few seconds, thereafter it turns into a formidable force that is difficult to control. With the scientific progress, man found himself before requirements that imposing obligation upon him to consider the velocity of fire discovery where the scientific progression has been exploited in the field of communications and information transfer towards developing means of fire alarm and linking these means with

Automatic Firefighting System. where the time element is one of the most important factors in the process of fighting and controlling the fire. The clear problem related to identification of fire source to find the best path for firefighting unit to reach the fire location through the shortest path. In this paper, we take an area south Khartoum Sudan as seen in Wikimapia map in the following Figure (1), for making an improved in normal Dijkstra algorithm using mathematical calculations.

Figure (1) Area South Khartoum Example for Validation Geo-Dijkstra Algorithm

The idea starts by sensing the signal coming from the sensors to define the fire location, direction and size. Then concentrate on how to reach the fire location for firefighting unit when there is a fire.

2 Related Work

In glance literature reviews based on scientific papers. Helps in reading and analyzing the gap help in preparing this paper with strong and good ideas. Then help in result comparison that gives a clear contribution in this paper. Briefly The following table (1) summaries literature reviews.

Table (1) Related Work

NO OF PAPER'S	1[3]	2 [4]	3 [5]	4 [6]	5 [7]	6 [8]	7 [9]	8 [10]	9 [11]	10 [12]
ISSUE DATE	2012	2013	2014				2015		2016	
TECHNICALLY USED	SAFETY ASSESSMENT	USING WSN FOR DESIGN AND IMPLEMENT A SYSTEM FOR FIRE PREVENTION AND REDUCTIONS								
Lesson LEARNED	REDUCE THE FIRE DISASTERS									
OUT PUT	FIRE PROOF MATERIALS	ALARM, MONITORING, SMS								
Research GAPs	SHORTEST PATH FOR FIREFIGHTING UNIT TO REACH FIRE LOCATION.									

3 METHODOLOGY

The Idea behind the improvised algorithm, was concentrated in calculating the effects of turns. Where if there are more turns more time to pass through the way, and if there are less turns less time to pass through the way. By putting the turn values in mind, we can reach fired location exactly on time. And due to this guided location through the turns our improvised Dijkstra was born.

3.1 The Hypothesis for Validation of Improvised-Dijkstra Algorithm: -

As an illustrative example for validation Geo-Dijkstra algorithm, that find the shortest path between two nodes we take a small real area in south Khartoum as shown in the above Wikimapia plan Figure (1). and, it's clear that we have two ways between two nodes, the red one is passing through three turns while the green one passes through one turn.

A practical test was done by moving a car through the two paths', in a time that there is no cars congestion to calculate the time of internal red path and the time of external green path as the result shown in the following Figure (2). It is clear that the green path takes less time than the red path because of turn numbers which effect the time to be more. And another meaning also direct long path effect the time to be less.

In this paper scope, there is no car congestion and its suitable to use this scenario of validation for Geo-Dijkstra algorithm bearing in mind the case of full congestion change the result and the internal red path become the best and take less time than external green path. For detailed proof please refer to the following which explains the details of the proof based on mathematical rules with an illustrative calculation.

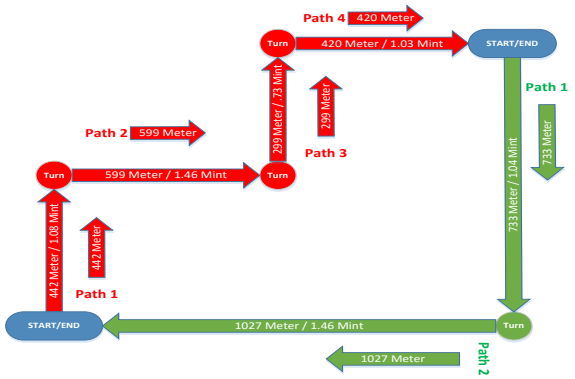

Figure (2) Block Diagram for Above Wikimedia Plan

The above figure is a block diagram for the Wikimapia map Figure (1) and the distance/time relationship was calculated clearly as shown in table (2) below, where the time is calculated by moving a car through the paths as was used before in this paper.

Table (2) Distance and Time Value for Figure (2)

Path	Following path sequences	Distance/ meter	Time/ mint
Green path	Path1+turn+path2	1760	2.50
Red path	Path1+turn+path2 +turn+path3+turn +path4	1760	4.30

As we see in above table, also the distance between the source and destination are equal for both of the green and red paths, the more turns add more time for the red path and also the time is less for the green path because it has only one turn. Also, the long direct distance adds less time because mechanically the car speed became high in long direct distances, and that's due to the use of the fastest gear (4 and 5) if compared to the use of the slowest gear (1 and 2) while the car is entering and leaving the turn.

4 SIMULATION RESULTS

4.1 Validation of Geo-Dijkstra Algorithm Based on The Effect of Turns Using Mathematical Calculations.

By referring to the previous Figure (2) mentioned before in the methodology section, the following calculations results give approximately the increase of the cost of the near turns if compared to the far turns. This scenario has been physically applied so as to show the trip by car from location A which is near to AL zakat Building to location B near to Alsahafa Locality (Alsahafa-Khartoum). As can be seen for the map the distance between location A and B are equal using both of the red and green path's.

As can be seen from the figure above that the two different paths are equal from distance point of view, firstly the green path that includes one turn through the way from location B to location A, secondly the red path which includes three turns from location A to location B. The following mathematical calculations telling and simulate the fact, to prove the effect of turns on the arrival time for two equal distances one with turns more than the other (as has been shown by Figure (2) a mathematical calculation has been done for the real car trip from location A to location B (Red Path) and from location B to location A (Green Path).

For the green path, take the speed value form one turn

Where,

Average Speed = $\frac{DistanceTraveled}{timeoftravel}$

Green Path Speed (one turn path) = $\frac{1027+733}{1.04+1.46} = \frac{1760}{2.5}$ = 704 m/mint

Hypothesis: time required for the Green path with one turn to pass through 1000 meter.

Green Path (one turn) $\frac{1000meter}{704meter/mint}$ = 1.4 mint

Green Path Speed (without turns) = $\frac{1027}{1.04}$ = 987.5 m/mint (by considering the longer trip from the above calculation)

Hypothesis: time required for the Green path without turns to pass through 1000 meter.

Green Path (without turn) $\frac{1000meter}{987.5meter/mint}$ = 1.0126 mint

Then, value of turn = G-Path with one turn – G-Path without turn

Turn value = 1.4 – 1.0126 = 0.3874 mint

For the red path, by using above law and calculate the average to find the speed through three turns.

Red Path Speed (three turn path) =

$\frac{442+599}{1.08+1.46} = \frac{1041}{2.54}$ = 409.84 m/mint

$\frac{599+299}{1.08+0.73} = \frac{898}{2.19}$ = 410.04 m/mint

$\frac{299+420}{0.73+1.03} = \frac{719}{1.76}$ = 408.59 m/mint

Red Path Speed Medium

$\frac{409.84+410.04+408.59}{3} = \frac{1228.43}{3}$ = 409 m/mint

Hypothesis: time required for the Red path with three turns to pass through 1000 meter.

Red Path $\frac{1000meter}{409meter/mint}$ = 2.4 mint

Hypothesis: time required for the Red path without turn to pass through 1000 meter.

In the best-case the time required for the Red path without turns to pass through 1000 meter.

$\frac{1000\ meter}{987.5\ meter/mint}$ = 1.0126 mint

Then, value of turn = R-Path with three turn – R-Path without turn

2.44 – 1.0126 = 1.3874 mint as three nearest turns value

One turn value = $\frac{1.3874}{3}$ = 0.462 mint.

In short, based on the above mathematical calculations, it's clearly observed that more turn more time consumed between the two locations. Furthermore, it seems that by sense the far turns consume less time than the adjacent turns.

4.2 Validation of geo-Dijkstra algorithm graph and relations result: -

By referring to Figure (2) above, and using its data in a matlab code for the validation of improvised Dijkstra named (geo-Dijkstra) algorithm. Then applied that values to be coded for finding the shortest path between the two-path's due to time unit cost, and this is shown in the following result Figure (3).

By referring to the above mathematical calculations which proves that the effect of turns leads to delay in arrival, moreover, the cost of the near turns is larger than the cost of the far turn. in this section to make it simply for human calculation a hypothesis for. The cost of the near turn is considered to have the value of 2 while the cost for far turns is taking the value 1

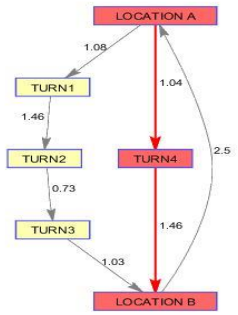

Figure (3) Shortest Path Between the Two-Path's Due to Time Unit Cost

As this effort proved by calculations above, also the matlab code result figure (3) above prove that the short path is the path passing one turn in a 2.50 Mint, where the other path passing through three turn take 4.30 Mint and the time difference is shown also clearly in the following matlab graph result Figure (4) below. This figure has been drawn according to the data of the following table, while the data for the graph was taken form the following table (3).

Table (3) Green and Red Path Movement Points

Green Path		Red Path	
x-axis Distance in Meter	y-axis time in Mint	x-axis Distance in Meter	y-axis time in Mint
0	0	0	0
100	0.25625	100	0.31875
200	0.2925	200	0.4595
300	0.44875	300	0.72825
400	0.605	400	1.175
500	0.76125	500	1.44375
600	0.9175	600	1.5345
700	1.19375	700	1.80325
800	1.35	800	2.072
900	1.39875	900	2.34075
1000	1.555	1000	2.7875
1100	1.71125	1100	3.05625
1200	1.8675	1200	3.147
1300	2.02375	1300	3.59375
1400	2.18	1400	3.8625
1500	2.33625	1500	3.80129
1600	2.4625	1600	3.95325
1700	2.49625	1700	4.20534
1760	2.5	1760	4.3

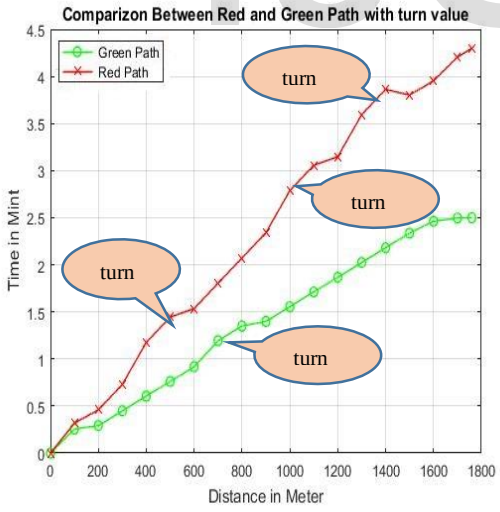

Figure (4) Comparison Between Red Path and Green Path with Turn Value

For the purpose of validating the proposed algorithm (Geo-Dijkstra) considering the effect of turns as simple as possible in above figure in the same distance the green path has one turn taking less time for passing between the two nodes, while the red path has three turn and as we see in the figure more time for passing between the two nodes. then the Figure clearly shows the time difference between green path and red path Table (3) data plotting graph compare between red and green path with turn value.

For more details, if there is no turn in both red and green paths the time for passing by the two ways is equal and less in time than both time taken by red path and green path,

this shown clearly compared with the graph simulate the movement of green path with one turn and the red path with three turns in the following Figure (5).

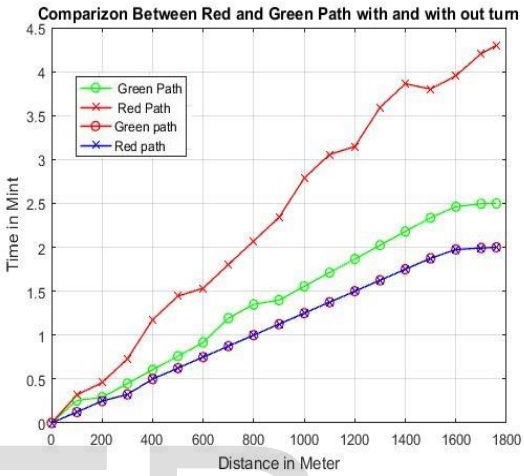

Figure (5) Both Relations with and Without Turns

In the above figure, you can clearly see the difference between green path that have one turn and red path that has three turns and both compared assumption of having no turns. From the figure, it's clear that more turn more time and less turn mean less time, where in above figure the upper red line represent path with three turns, then the green path that represent path with one turn and the last typical lines represent both red and green path without turn and this yields less time than both above with one and three turns.

5 CONCLUSION

In this system, the original Dijkstra has been improved to achieve the goal of fast arrival of the firefighting units via the shortest path considering the mechanical movement. It is very important to notice that the proposed algorithm (geo-Dijkstra) has some sort of intelligence of choosing the path with less number of turns and even if the number of turns are equal it has the capability of choosing the path with turns that enable the firefighting car to move faster (i.e. taking less arrival time) which leads to reduction of the effect of fire on lives and assets due to the importance of quicker response time (i.e. 2 minutes late may lead to pig lost).

Finding the shortest path between two nodes using Dijkstra. Firstly, to guide Firefighting Unit through shortest path to recover fired location(s), and the shortest path without turn value is different than short path with turn value which clearly show an effect of turn and this improved Dijkstra called GEO-Dijkstra

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