Wireless Sensor Network - Fire Recovery Using adapted Dijkstra Algorithm for Firefighting (Geo - Dijkstra)

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Abstract – Fire disasters are considered the most important challenges in the real world where the risk of fire disasters directly affects human, material and environment. The damage of the fire is not affecting the individual only, but also it can be for the society direct or indirect. The impact of fire may be reflected on the activities of daily life such as factories, gas reservoirs, petroleum refineries, gas stations and power plants in addition to industrial facilities of various kinds. In all mentioned cases it is very necessary to respond very fast to crises. This paper, proposed an improvement for the normal Dijkstra algorithm (Geographical – Dijkstra) to be adapted with the fire crises. This adaptation focuses on the minimum arrival time for fighters and safest path for human and assets. Thus, the proposed adaptation fulfils the automatic and quick recovery of firefighting with less loss of human and assets.

The case study is about Elshagra gas depots company layout in Sudan. The validation of the adapted Dijkstra algorithm has been achieved by comparing the case of Elshagra gas deposit for firefighting in two cases. The first case is based on a node diagram (represents the companies) with road turns, and the other one is without considering the road turs. Two scenarios are used, in the simple one few numbers of nodes are used, and then the distance from the firefighting to fire location is measured. However, in complicated scenario a number of nodes are added, and the same distanced is measured. The simulation results are obtained using MATLAB. Firstly, the normal Dijkstra is used which selects the shortest path from firefighting to fire location. Secondly, the road turn is added to the adapted Dijkstra. It is very important to notice that the adapted algorithm has taken different path with similar total distance, but it has some sort of intelligence of choosing the path with a smaller number of roads turns and even if the number of road turns are equal it has the capability of choosing the path with road turns that enable the firefighting car to move faster. The shortest path between source and destination using normal Dijkstra. Firstly, to guide firefighting unit through shortest path to recover fired location(s), and the shortest path without road turn value is differing than short path with road turn value which clearly shown an effect of road turn and this adapted Dijkstra called GEO-Dijkstra which represent the geographical location.

Keywords Dijkstra; Wireless Sensor Network; Firefighting; Geographical – Dijkstra

1. INTRODUCTION

The fire indeed is one of the contributing main factors to fatalities, property damage, and economic disruption [1]. Fire has been a very big valuable gadget throughout long mankind's history; however, it can likewise bring grate disaster if not carefully used and controlled [2]. And exactly the fire is very big giant phenomena which can be controlled in its early stages, but this period does not take more than few seconds, there after its turns into a huge force where to be difficult to control and this exactly leads to loss in live and assets. WSN is subject to a high potential technology that has been successfully implemented and tested in real-time scenarios, as well as deployed practically in various applications[3].A strong example of a fire disaster is a Tejanyen Warehouse – In North China were injured more than 700 people, 114 people have been killed [4]. Fig. 1 shows the huge destroyer fire.

Fig. 1. Tejanyen Warehouse fire

Note that most of the big Companies have units to extinguish the fire and equipped vehicles for firefighting. Since fire has high score, it is necessary to have an alarm to quick access for the Premises when needed. The area of this system concentrates south Khartoum for the buildings (Domestic Market, Industrial Zone Savola, Yarmouk, Elshagra warehouse), Fig. 2 show the satellite image of these buildings.

Fig. 2. Satellite Map South Khartoum

One of these mentioned buildings in (Elshagra warehouse) is taken as sample for the proposed system, the lay out of the companies in Elshagra warehouse is detailed in Fig. 3, where there are a number of big petroleum companies shown in this figure.

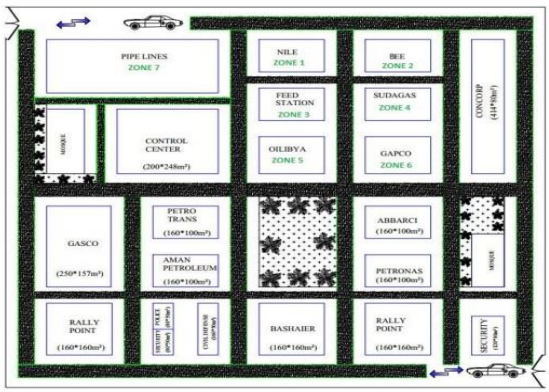

Fig. 3. Elshagra warehouse building

The proposed system takes Gapco, one of the companies in Elshagra warehouse as a sample, a number of 20 fire detection wireless sensors distributed in Gapco company building as seen in Fig. 4., when one of the sensors detecting fire, the alarm point to the fire location. In that time the name of the fired company will be clearly known.

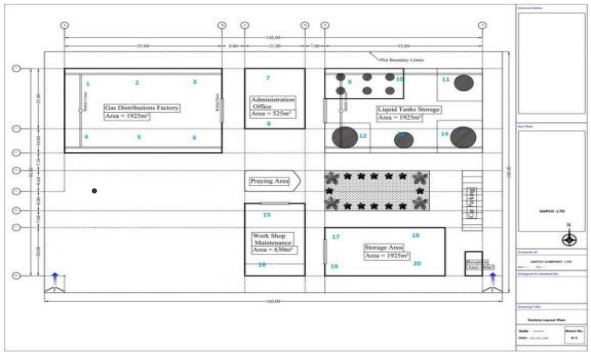

Fig. 4. Distribution of sensors in Gapco company

Technically the idea starts by sensing the signal coming from the sensors to define the fire location in a specific area in the company [5]. Then concentrate on how to reach the fire location.

This paper, survey previous studies to make a contribution using wireless sensor networks in early fire detection and find the short path (with minimum arrival time) for firefighting unit to reach fired area. The expected result of this paper gives strong justification that prove and verify our methodology with a clear contribution in adaptation of Dijkstra algorithm for firefighting with a very promising and realistic results which leads to the reduction of losses and provides a quick response to fire.

It's clear that from the related works, early detection is only the way to minimize the damages and casualties [6,7]. Different design present and evaluation of wireless sensor network for early detection of leakages gas/liquid and fast fire alarm system [8,9,10]. Also, some papers give a good idea for how to make the design of WSN [11], how to use GSM with WSN [12], how to use localization technique [13] , how to use machine learning [14,15] , and some different artificial intelligent ideas [16,17,18].Also in this paper Dijkstra's algorithm is the one that is considered to be the most classic and commonly used algorithm, Its produced result not only finds the shortest path from the start node to the end node but also finds the shortest path from the start node to every node in the graph [19]. More over shortest path algorithms are commonly applied to modern navigation systems [20]. One of the main related work papers representing the idea that starts by sensing the signal coming from the sensors to define the fire location in a specific area in the company., direction and size. Also, how to give guidance for the exit safe way for employee and people when there is a

fire. The result of this gives strong justification that prove and verify a clear contribution in Improved Dijkstra algorithm for firefighting like Forced-Dijkstra [21].

The importance and fire alarm and linking with the automatic firefighting Systems where the time element is one of the most important factors in the process of fighting and controlling the fire [5].

2. Problem Statement

The scope of this paper concentrates on how firefighting unit reach to the location of fire exactly peering in mind the minimum arrival time and considering the effect of road turn and the shortest path when executing normal Dijkstra algorithm.

3. Proposed Solutions

For the firefighting unit to reach the fired area and recover it from the fire, this done in the following scenarios, by using the block diagram for the building of Elshagra GAS depots. The details in the following Fig. 5, shows the layout of the companies and civil defense in factor of time units.

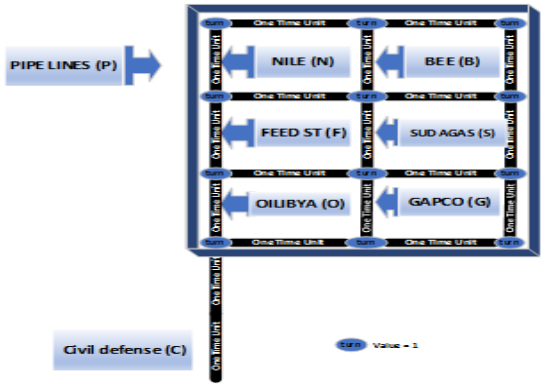

Fig. 5. Elshagra gas depots layout

The following Fig. 6, represent the node diagram from Elshagra gas depots layout pervious figure, the nodes detailed as (C = Civil defense, O = Oilibya, F = Feed St, N= Nile, B= Bee, S = Sudagas, G = Gapco, P = Pipelines) while the edge represent the distance in time unit, with road turn values. The edge and paths calculated from Elshagra gas depots layout with road turn value. The calculations of edge path cost between civil defence and Oilibya company as following path cost (2+1=3-time units). The calculations of edge path cost between Civil defense and Gapco company as following path cost (2+road turn+1+road turn+1= 6-time units). The movement from node to node telling the truth about the movement between companies with road turn values.

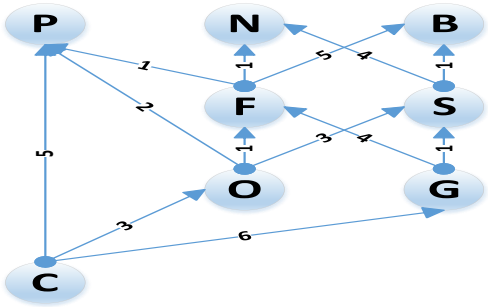

Fig. 6. node diagram with road turn value

In the following Fig. 7, also represent the node diagram from Elshagra gas depots layout pervious, the edge and paths calculated from Elshagra gas depots layout without road turn value. The calculations of edge path cost between civil defense and Oilibya company as following path cost (2+1=3-time units). The calculations of edge path cost between civil defense and Gapco company as following path cost equal (2+0+1+0+1= 4-time units). The movement from node to node telling the truth about the movement between companies without road turn values.

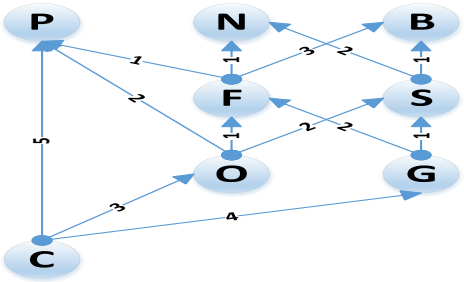

Fig. 7. node diagram without road turn value

By using above two nodes diagram figures it's easy to obtain the cost table with and without road turn to obtain the cost table in time units as shown in the following table (1).

Table 1. Elshagra gas depots cost table (ROAD TURN VALUE=1)

Source TO destination node	Number of roads turns	Cost without road turn	Cost with road turn value
Feed St → Nile	0	1	1
Feed St → Bee	2	3	5
Feed St → Pipe	0	1	1
Sudagas → Nile	2	2	4
Sudagas → Bee	0	1	1
Oilibya → Feed St	0	1	1
Oilibya → Sudagas	2	2	4
Oilibya → Pipe	0	2	2
Gapco → Feed St	2	2	4
Gapco → Sudagas	0	1	1
Civil Def → Oilibya	0	3	3
Civil Def → Gapco	2	4	6
Civil Def → Pipe	0	5	5

From the cost table its easily to program a MATLAB code to find the shortest path between two nodes or exactly between civil defense (source) and any one of the companies (destination) to recover it from fire when there is a fire alarm. The result will be in a red arrow from source to destination. For this solution, we have the following different scenarios that obtained in the following simulation results section. simulation result

4. Simulation Results

When the fire occurs in Elshagra GAS depots, and the real time fast fire alarm system inform firefighting units (in-campus and off-campus (neighboring)) units about the location, size and fire direction as well as the shortest path to the fired companies this enables the firefighting units start moving to the target company to recover it from fire.

4.1 Shortest Path To Fired Company

By using the shortest path which has been determined by the improvised Dijkstra. The following scenarios discus simple and complicated examples to find the shortest path in Elshagra location with road turn value and without road turn value.

4.2 Optimized Path To Fired Company

In the following sub sections efforts concentrate on applying scenarios for clarify the shortest path between two nodes that not in direct path, as simple design and complicated design due to number of nodes and road turns, where the less number is simple scenario and a greater number of nodes and road turns represent the complicated scenario. In the following here the existence of both simple and complicated scenario to test the algorithm capabilities for choosing the optimum path considering the number of roads turns as well as the distance.

4.2.1 Simple Scenario Without Road Turn Value

The result that shown below in Fig. 8, (a) is a normal Dijkstra algorithm to find the shortest path between FIRE FIGHTING UNIT and BEE company using matlab code, the cost of edge without putting road turn value in mind. While same Fig. 8, (b) represents the result simulated in the real map.

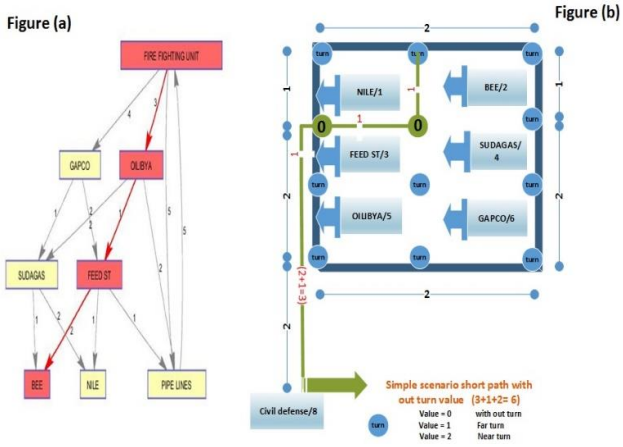

Fig. 8. (a, b) short path without road turn value

As can be noticed from the above figure, if real map compared with the matlab code result it gives accurate movement from source (Firefighting Unit) to destination (BEE). Where the result takes the shortest path from (FIREFIGHTING Unit to OILIBYA to FEED ST to BEE). and the total cost

through this path = 6-time unit without road turn value. And if we simulate in real map with green line, it will show typical movement with same cost value which also equal 6-time unit.

4.2.2 Simple Scenario With Road Turn Value:

The result shown below in Fig. 9, (a) we suggest to call it GEO-Dijkstra algorithm where the path of shortest path in scenario1 without road turn, was changed to a clear different path when using road turn values. While Fig. 9, (b) represents the result simulated in real map showing the new path and the previous path from senario1 just for proving both have different paths.

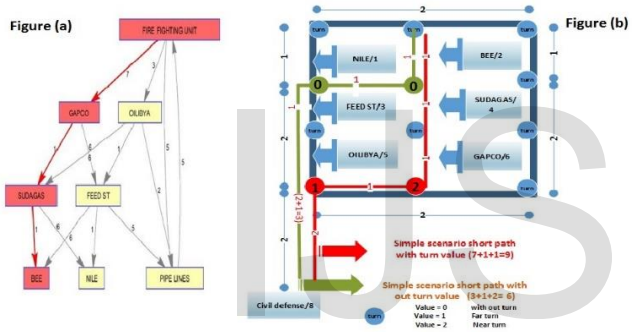

Fig. 9. (a, b) short path with road turn value

Where in above figure, the result takes the shortest path from (FIREFIGHTING Unit to GAPCO to SUDAGAS to BEE) and the total cost through this new path is also 9-time unit with road turn value. And if we simulate in real map Figure (b) we see the difference between both with road turn value (Red Path) and without road turn value (Green Path) and its clearly different ways, the cost is changed from 6 to 9, because we add to the path the value of road turns.

4.2.3 Complicated Scenario Without Road Turn Value:

To ensure the correct functionality of the proposed algorithm (GEO-Dijkstra), it is urgently need to study deep in the behavior of the normal Dijkstra algorithm and compare it with proposed algorithm which deal with the cost of road turns. The result shown below in Fig. 10 is a normal Dijkstra algorithm to find the shortest path between FIRE FIGHTING UNIT and CONCORP company in a complicated scenario using matlab code, the cost of edge without putting road turn value in mind.

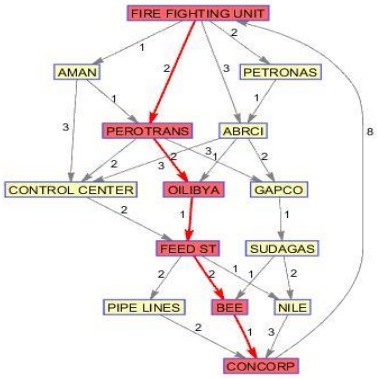

Fig. 10. complicated scenario without road turn

While Fig. 11 below represents the result simulated in real physical map. If we compare the output of the matlab code in the two figures it gives accurate movement from source (Firefighting Unit) to destination (CONCORP). While result takes the shortest path from (FIREFIGHTING Unit to PETROTRANS to OILIBYA to FEED ST to BEE to CONCORP.), and the total cost through this path is 8-time unit without road turn value. Notice this output of the improvised algorithm is typically the same as the output of the normal Dijkstra algorithm.

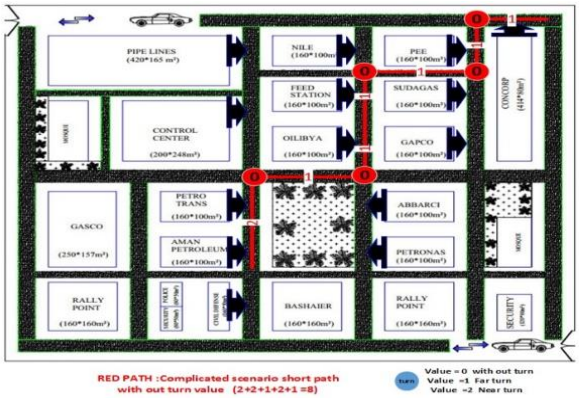

Fig. 11, simulate in real map without road turn

4.2.4 Complicated scenario with road turn value:

The result shown below in Fig. 12 we suggest to call it GEO-Dijkstra algorithm where the path taken after adding the value of road turn is changed due to road turn values. In another meaning the result shown below is a GEO-Dijkstra algorithm to find the shortest path between FIRE FIGHTING UNIT and CONCORP company in a complicated scenario using matlab code, the cost of edge with putting road turn value in mind.

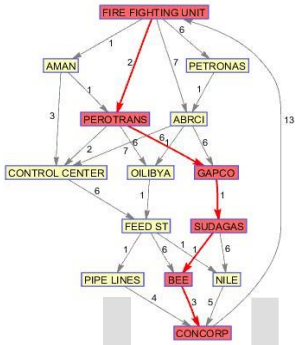

Fig. 12 simulate in real map without road turn

While Fig. 12 below represents the result simulated in real physical map. Form the above two figures, if we compare the output of the matlab code with the real map it gives accurate movement from source (Firefighting Unit) to destination (CONCORP).

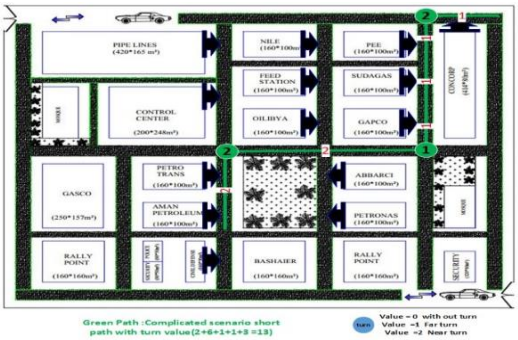

Fig. 12 simulate in real map with road turn

Where in above the result takes the shortest path from (FIREFIGHTING Unit to PETROTRANS to GAPCO to SUDAGAS to BEE to CONCORP.), and the total cost through this path is 13-time unit with road turn value. The real map simulation shows the movement from FIREFIGHTING UNIT to CONCORP company with the value of road turn. It is very important to notice that the proposed algorithm has taken different path with similar total distance, but it has some sort of intelligence of choosing the path with a smaller number of roads turns and even if the number of road turns are equal it has the capability of choosing the path with road turns that enable the firefighting car to move faster (i.e., taking less arrival time).

5. Conclusion

In this paper, a cost-effective and autonomous solution for intelligent fire alarm system using WSN has been presented. The aim of the proposed system is the fast recovery of fire. Also in this system, the original normal Dijkstra has been adapted 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 adaptation of Dijkstra algorithm (geo-Dijkstra) has some sort of intelligence of choosing the path with a smaller number of road turns and even if the number of road turns are equal it has the capability of choosing the path with road turns that enable the firefighting car to move faster (i.e., taking less arrival time) which leads reduction of the effect of fire in lives and assets due to the importance of quicker response time (i.e., 2 minutes late may lead to huge loss).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 road turn value is differing than short path with road turn value which clearly show an effect of road turn and this improvised Dijkstra called GEO-Dijkstra.

6. The Future Work

In the future work a fire safety plan will be a strategy that is implemented in a facility that provides information about what to do to prevent fires, and how to respond should one occur. Also, carefully the Physical Testing of the Implementation should occur by using additional sensors for example GAS leakage valve sensor where sensing and if GAS leaking closes the valve. When the fire occurs and there is need for help form external firefighting unit using any interconnection network technology to monitor the fired location in

real time to be easily shown by all branches of the civil defense and even authorities.

One of the main important and help on fast control of fire, Built-in Data base to guide fire-fighting unit for using suitable fighting component according to the stored assets inside the fired locations.

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