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Shortest Route Analysis for Road Accident Emergency using Dijkstra Algorithm and Fuzzy Logic

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Abstract— Victims of road traffic accidents face severe health problems on-site or after the event when they arrive at hospital lately in their emergency cycle. Road traffic accident has negative effect on the physical, social and emotional security of human lives which often lead to mortality, illness, pain, grief and even disability. This paper proposes a scheme that reduces the severity of road traffic accidents given its inevitable occurrence. The rational is to search for nearest hospitals to the accident location using Dijkstra algorithm and Fuzzy logic to recommend suitable hospitals out of list of nearest hospitals to timely attend to the emergency situation considering factors such as distance, severity of the accident, available facilities in the hospitals and other factors. The obtained results showed the practicability of the system to recommendation of quick solution to accident emergencies.

Keywords: Road Accident, Emergency, Analysis, Dijkstra, Fuzzy Logic, Algorithm

I. INTRODUCTION

Road traffic accident is a global problem where about 1.3 million people lose their lives, and about 20 to 50 million people injured [1]. These injuries and deaths have had huge influence on victims' families, employment, communities and states they belong. Road traffic accident is a health security threat because it increases the number of people seeking health services. The impact of such an overstretching of resources means that many road traffic accidents patients may face different health problems especially when they arrived at hospital lately in their illness cycle [2]. There are many factors that resulted to road accidents namely; driver distraction such as fiddling with technical devices, talking with passengers, eating while driving, dealing with children or pets in the back seat; driver impairment by tiredness, illness, driving while using alcohol or drugs, both legal and illegal; mechanical failure including flat tires or tires blowing out, brake failure, axle failure, steering mechanism failure; road conditions including substances on the road surface; making the roads slick; road damage including pot holes and speed exceeding safe conditions such as the speed for which the road is designed, the road condition, the weather, the speed of surrounding motorists [3].

Road traffic accident has negative effect on the health security, which could cause mortality, illness, pain, grief and disability; on the physical security or safety of the individuals and on the social interactions of victims and their families. However little attention is given to the problem, despite the fact that there is increase of road crashes from time to time especially in developing countries of the world. In order to reduce the severity of road traffic accidents given its inevitable occurrence, it is important to develop a scheme that can recommend nearest hospitals or health centers to the location of occurrence of an emergent road accident by considering factors such as distance, severity of the accident, available facilities in the hospitals or health centers. This is done using Dijkstra algorithm to get the nearest hospitals and Fuzzy logic to recommend the suitable hospital based on the considered parameters to attend to the road accident.

Dijkstra algorithm has been influential in path computation research. It is the most commonly used route finding algorithm for solving the shortest path [4]. Dijkstra algorithm is sometimes called the single-source shortest path because it solves the single-source shortest-path problem on a weighted, directed graph (G = V, E) where V is a set whose elements are called vertices (nodes, junctions, or intersections) and E is a set of ordered pairs of vertices called directed edges (arcs or road segments). To find a shortest path from a source s vertex or location to a destination location d, Dijkstra algorithm maintains a set S of vertices whose final shortest-path weights from the source s have already been determined. Knowing that w is the edge weight, the edge is an ordered pair (u, v) and assuming $w(u, v) \geq 0$ for each edge $(u, v) \in E$, the algorithm repeatedly selects the vertex $u \in V - S$ with the minimum shortest-path estimate, adds u to S, and relaxes all edges leaving u [5].

Fuzzy logic is an extension of multi-valued logic whose objective is approximate reasoning rather than exact solution. Unlike traditional crisp logic, such as binary logic where variables may only takes on truth values true and false represented by 1 and 0 respectively, the variables in fuzzy logic may have truth values that ranges between 0 and 1. Instead of describing absolute yes or no, the truth value, or membership in Fuzzy Logic explains a matter of degree. 0 shows completely false, while 1 expresses completely true, and any value within the range indicates the degree of truth. It runs on intricate mathematical models that provide a practical understanding of the overall system [6]. In this paper, the Mamdani fuzzy inference method was used as the inference engine.

II. RELATED WORKS

Several studies have been reported in the research domain using a range of techniques and methods, but there are still areas that need further attention especially in health security, recommendation and management. The author in [7] proposed shortest route optimization for road accident emergencies in order to reduce the average loss of lives. They dealt with the problem of finding shortest paths in traversing some locations within the Kumasi Metropolis in the Ashanti Region of Ghana. Dijkstra algorithm was adopted in constructing the minimum spanning tree considering the dual carriage ways in the road network of Kumasi Metropolis within the shortest possible time for emergency services. The authors analyzed the distance needed to be covered but necessity may arise to consider suitable hospital to treat patients. The comparative analysis and implementation of Dijkstra shortest path algorithm for emergency response and logistic planning is introduced in [8]. The author was motivated to solve the transportation problem by determining the optimal path for emergencies, get to facility location and ensure effective vehicle routing from source to destination at minimum cost. Dijkstra algorithm was implemented using double bucket dynamic data on a web-based, Geographical Information System (GIS). Shortest distance analysis was carried out but cases of inefficient treatments from selected hospitals ensued.

In [9], an emergency rescue dispatch system for road vehicles for instant notification of road accident and post-crash analysis is proposed. The objective was to enhance the reporting of vehicle crashes and provide post-crash analysis. The approach used involves pinpointing the exact location of the crash using GPS and sending the data to an emergency rescue authority using GSM text service. Also motion sensors and record of event in images were used to carry out post-crash analysis which reduced the time it takes for emergency rescue to arrive at the crash location. The approach is good for the detection and mitigation of frequent points of accidents but failed to sample available parametric facilities in the hospitals for efficient medical services. The author in [10] discussed traffic accident analysis to identify accident spots on road network by analyzing collected police record data. GIS was used to plan and manipulate the transportation system and equally analyze nearby hospital. Optimal route to the nearest hospital was achieved but only the usual accident locations were accepted for analysis.

In the work of [11], an accident detection and reporting system is developed as a life-saving system by sending timely accident information to emergency service. GPS receiver was used to monitor the speed of a vehicle and detect occurrence of accident as well as notification of the location and time of the accident from the GPS data processed by microcontroller via the GSM network to alert emergency service center. A device-oriented information system using GSM was achieved but monitoring events used speed as the only parameter without any algorithmic computation. Khan *et al*. [12] also developed accident detection and smart rescue system using android smartphone with real-time location tracking. The aim was to reduce the response time of emergency services in traffic accidents. Onboard sensors of a smartphone was used to detect vehicular accidents and report it to the nearest emergency responder available. A complete tracking system was developed for accident emergency victims without providing the platform for ensuring patient medical treatment by recommending nearest and suitable hospitals.

The authors in [13] simulated the movement of emergency vehicle using shortest path method so as to reduce the response time of an emergency vehicle. Dijkstra algorithm was used to simulate the automatic movement of an emergency vehicle system. Shortest path from source to destination was provided by the proposed technique but no relationship to medical attention. Ojekudo and Akpan [14] also applied Dijkstra algorithm to shortest route problem for businesses and industries so as enhance quick delivery of goods and service by selecting the optimal path. Their method provided alternative paths for selecting shortest route to transport goods from source to destination. In [15], a vehicle accident detection and messaging system is developed using GPS and GSM. The objective was to provide an optimum solution to traffic hazard. An alarm application that uses accelerator and force sensor was developed to achieve their objective. The system detects was able to crash signal using existing hardware platforms but failed lacks real computation scheme for accident treatment.

Furthermore, Bagchi *et al*. [16] introduced an ambulance service using modified Dijkstra algorithm with the aim of ensuring quicker reach to the emergency destination upon the request for an ambulance service. A predefined set of data about the ambulance services were collected analyzed to determine the shortest route to reach emergency location. The authors in [17] applied GIS in determining road emergency medical service location for identifying the best emergency system location to accident black spots and response time. However, suitable medical service to an emergency was not implemented in their scheme. Road network analysis for timber transportation from harvesting site to mills was presented by [18]. A GIS-based news route approach was used to determine the shortest path from logging site to destination using ArcGIS software. As a result, a path with minimum links and length as well as maximum vehicle speed was established. In addition to the use of GIS, the authors in [19] worked on GIS based network analysis for the identification of shortest route access to emergency medical facilities. Modelling the shortest path in order for an ambulance to travel through a road network was established using GIS technology. Close proximity of hospitals to the accident location is achieved but did not consider the facility criteria. Ni *et al*. [20] introduced shortest path analysis using Dijkstra algorithm in emergency response system. The objective was to ensure routing and re-routing of vehicles from various key locations including hospitals, fire and police department to the event scene and from the event scene to hospitals or other locations. Dijkstra Algorithm along with GIS were used on-site while a web application was used off-site to manage emergency information. However, the method suffers cases of traffic congestion. Meghanathan [21] discussed Dijkstra algorithm and Bellman-Ford algorithm for finding the shortest path in a graph. He concluded that the time complexity of Dijkstra algorithm is O ($|E|*log\ |V|$) while the time complexity of the Bellman-Ford algorithm is O ($|V||E|$). On the otherhand, accident emergency response and routing system using genetic algorithm is develop in the work of [22]. The author provided a software package for emergency analysis through the implementation of algorithm to estimate optimal route in cases of emergency. The authors in [23] proposed an automatic accident detection and notification with smartphones to eliminate the delay between accident occurrence and first responder dispatch. An in-vehicle automatic accident detection and notification system was developed. The technologies adopted provide situational awareness to first responders without a focus on distance reduction and shortest route analysis to accident location.

Sahar and Sadoullah [24] considered the dynamic shortest path problem, motivated by its applications in dynamic minimum cost flows in transformation problem. In their work, the shortest path problem is seen to be equal to time-expanded network through the application of Label Correcting Algorithm for solving this problem and the time complexity of the algorithm is $O(|nT||mT|)$. They applied conventional method on the time-expanded network but the huge network size proves difficult for realistic problems without any benefit during network expansion. The authors in [25] developed an emergency response management and information system to improve emergency recovery through solving the routing problem when a critical situation occur using GIS technology. Their work provided efficient route for speedy transportation of a patient when an emergency occur. GIS technology was also used by [26] to identify accident hot spots so as to investigate high rate accident locations and safety deficient areas. Their idea facilitates spatial data sharing with transportation agencies. Sommer [27] investigated shortest path query processing in networks both from a theoretical and a practical point of view. A simple and general method based on Voronoi duals to efficiently support the shortest path queries in undirected graphs with very low pre-processing overheads and competitive query times, at the cost of exactness was used. This method is a good alternative to existing exact methods designed for transportation networks.

III. PROPOSED METHOD

Our proposed method involves the use of Dijkstra algorithm to implement search strategy for the nearest hospitals to an accident emergency location and when the list of the closest hospitals are derived, we adapted a fuzzy logic algorithm to search through the list based on the following parameters namely; severity of accident, distance, availability of staff, availability of medical equipment, workdays for weekly medical service, working hours for daily medical service and staff skill that were later used for data collection. In this proposed method, the direction and time taken to reach destination (hospitals) were also analyzed using computational rigorous techniques and adopted technologies as used in [12]. The adopted technologies include smartphone installed on Android operating system, a Linux-kernel open-source operating system, Android Studio as the primary Android Integrated Development Environment (IDE) and Android Google Map API, a service in the Google Play Service Library that allows access to Google Maps server automatically, displaying map, downloading data, and map gesture response.

A. Use Case Diagram

The use case model of the proposed system is presented in figure 1 as follows:

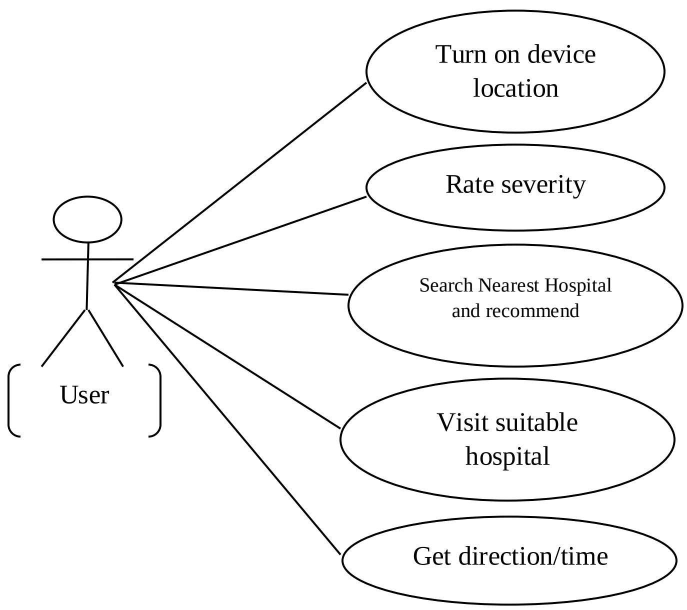

Figure 1: Use Case Diagram

B. Algorithmic Analysis

Dijkstra algorithm was adapted to get the hospitals with the shortest distance to an accident location while fuzzy logic technique was used to predict the suitable hospitals that can attend to an accident emergency on the basis of fatality. The formal analysis of Dijkstra algorithm is presented as follows:

Given a graph G, distance, $d_j, j = \{1, 2, 3, \dots, m\}$ and S, as the source of the graph.
Initialize the single-source (G, S) where S, is the source of the graph also denotes the accident location.

$$S \leftarrow \{H_i d_j\} \quad (1)$$

Where $H_i, i = \{1, 2, 3, \dots, n\}$ represent the available hospitals

Initialize the priority queue Q as:

$$Q \leftarrow H_i \tag{2}$$

$$\text{while} \quad Q \neq \emptyset, \text{do} \tag{3}$$

$$u \leftarrow Min(d_j, (Q)) \tag{4}$$

$$S \leftarrow \{u;\ H_i\} \tag{5}$$

where u is the shortest distance and H_i is the associated Hospital.
The rated hospital nearest to the accident location is therefore given in equation (6) as:

$$\text{Nearest Hospital } (NH) = \{u, H_i\} \tag{6}$$

For hospital suitability prediction, the input fuzzification process of the fuzzy logic technique is presented as follows:

$$f(x{:}\,a,b,c) = \begin{cases} 0 & for\ x < a \\ \frac{x-a}{b-a} & for\ a \le x \le b \\ \frac{C-x}{C-b} & for\ b \le x \le c \\ 0 & for\ c \le x \end{cases} \tag{7}$$

where x is the membership function, a, is the start point, b, the peak and c, the end point of the input parameters acc_fat, med_stff, fctl, wd, wh and stf_skl respectively.

For defuzzification, centroid method was used as follows;

$$Z* = \frac{\int u\beta(H_i).H_i dz}{\int u\beta(H_i) dz} \tag{8}$$

where Z is the center of each symmetric membership function computed for each hospital. The hospital with the highest value of Z computed serves as the suitable hospital (SH) that can attend to the accident based on fatality. This is computed as follows:

$$SH = \max(\{f(Z) : Z = 1,2,3, \dots, n\}) \tag{9}$$

where n is the upper bound of available hospitals

C. Data Collection

A well-structured questionnaire was designed to collect on-site data from the available hospitals and health centers within Akoko township, a university town in Ondo State, Nigeria. Data were collected on the availability of staff, availability of medical equipment, workdays for weekly medical service, working hours for daily medical service and staff skill along with their directions. A sample of the data collected is shown in table 1 with data presentation alongside their ratings used as linguistic variables namely; Very High (VH), High (H), Average (AVG), Low (L) and Very Low (VL) is presented in table 2 as follows:

TABLE 1: DATA SAMPLE COLLECTED FROM THE HOSPITALS/HEALTH CENTERS.

S/N	**Hospital**	**Facility (%)**	**Latitude, Longitude**
1	State Specialist Hospital	95	7.528323592028, 5.764550714825
2	Inland Medical Centre	90	7.530265264979, 5.764664581741
3	General Hospital Iwaro Oka	80	7.443788010024, 5.753925188337
4	AAUA Health Centre	75	7.4803741, 5.7389567
5	Ile-Ayo Medical Centre	60	7.506113209801, 5.754567285071
6	Caregiver Hospital	55	7.523475797391, 5.757021354686
7	Dr Balogun Clinic	50	7.458202510138, 5.737868417556
8	Orisuniye Clinic	50	7.446341104741, 5.764833138688
9	Aduloju Memorial Hospital	48	7.456891226747, 5.740152400676
10	Ireti Clinic	45	7.44013649113, 5.762788982177
11	St Lawrence Clinic	40	7.442317892367, 5.763584910853
12	Reva Clinic	30	7.4799768, 5.7388312
13	Comprehensive Health Centre	20	7.4803741, 5.7451742

TABLE 2: SHOWS A SAMPLE OF THE DATA PRESENTED ON THE BASIS OF SOME PARAMETERS

S/N	Hospital	Facility (%)	Staff Skill	Workdays	Working Hours	Latitude, Longitude
1	State Specialist Hospital	95	VH	VH	VH	7.528323592028, 5.764550714825
2	Inland Medical Centre	90	VH	VH	VH	7.530265264979, 5.764664581741
3	General Hospital Iwaro Oka	85	H	VH	VH	7.443788010024, 5.753925188337
4	AAUA Health Centre	70	H	H	H	7.4803741, 5.7389567
5	Ile-Ayo Medical Centre	65	H	H	AVG	7.506113209801, 5.754567285071
6	Caregiver Hospital	55	H	AVG	AVG	7.523475797391, 5.757021354686
7	Dr Balogun Clinic	50	AVG	H	H	7.458202510138, 5.737868417556
8	Orisuniye Clinic	50	AVG	AVG	AVG	7.446341104741, 5.764833138688
9	Aduloju Memorial Hospital	48	L	H	H	7.456891226747, 5.740152400676
10	Ireti Clinic	43	L	VH	VH	7.44013649113, 5.762788982177
11	St Lawrence Clinic	40	L	VH	H	7.442317892367, 5.763584910853
12	Reva Clinic	30	VL	VH	VH	7.4799768, 5.7388312
13	Comprehensive Health Centre	20	VL	VH	H	7.4803741, 5.7451742

D. System Flowchart

The flow of the proposed system is presented in figure 3 as follows:

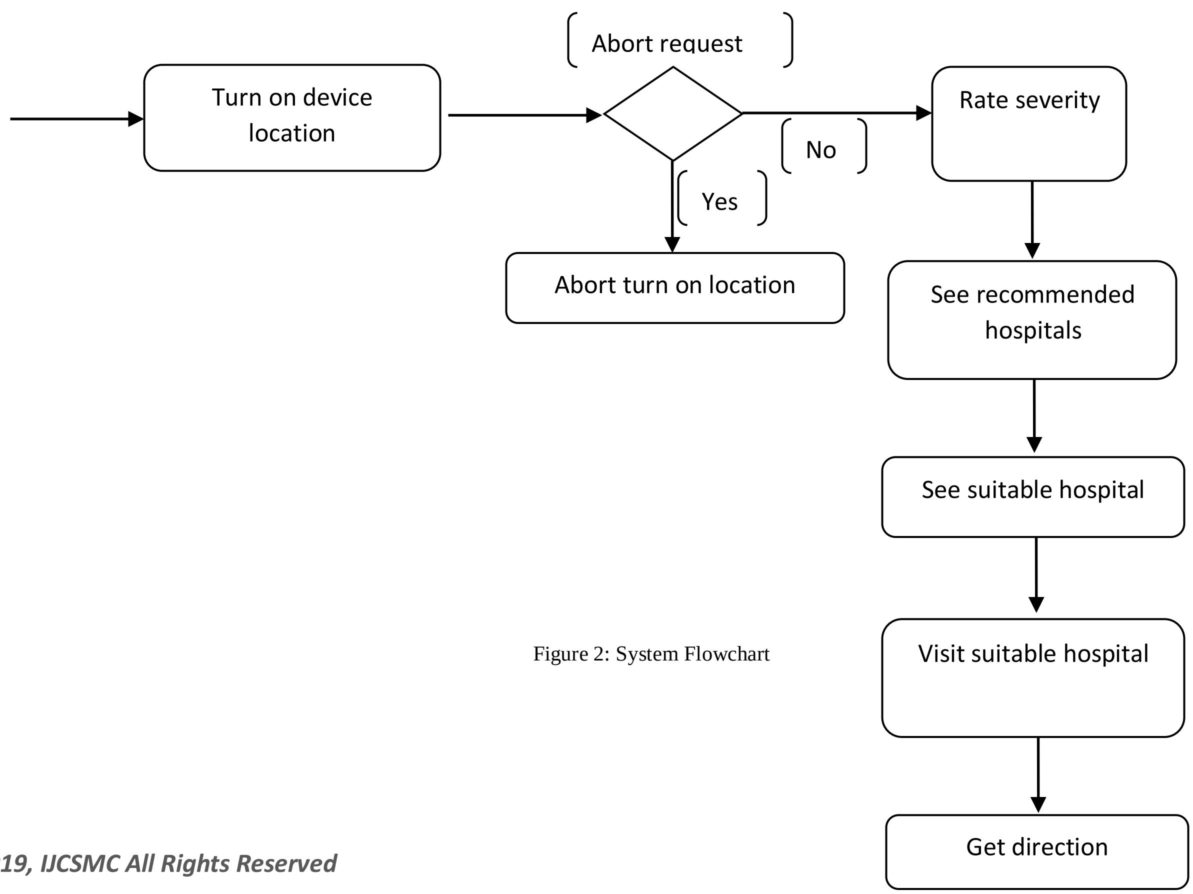

Figure 2: System Flowchart

IV. IMPLEMENTATION INTERFACES

The proposed system tagged "FindNearbyHospital" was developed with Java programming language using Android Studio as IDE. This prototype application is developed for android operating system having a minimum API 17, and target API 23. The application is fully working and implemented on Android Smartphone. The implementation interfaces are presented as follows:

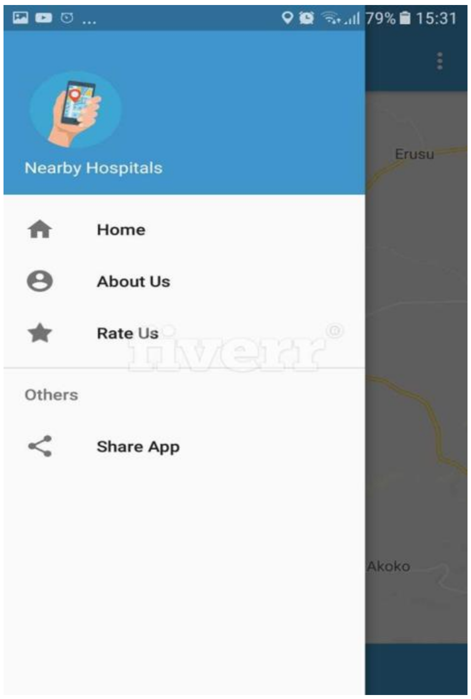

Figure 3: Home Screen of the App "FindNearByHospital"

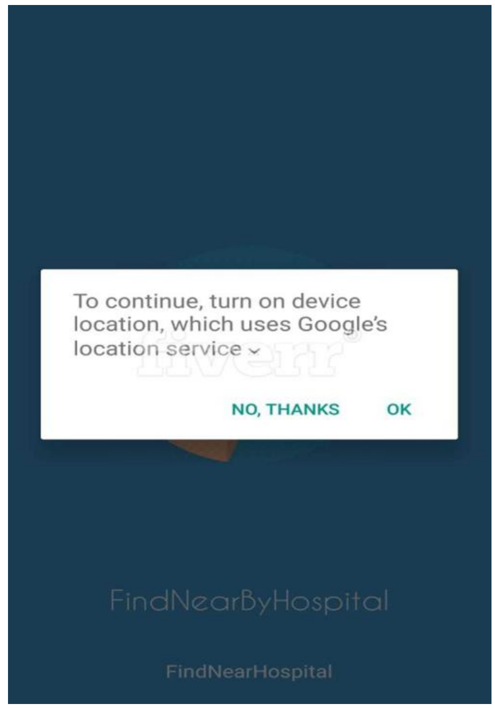

Figure 4: Location Lunch Screen

Figure 4 shows the lunch screen of FindNearByHospital, users must turn on device location and have internet access to be able to use the application.

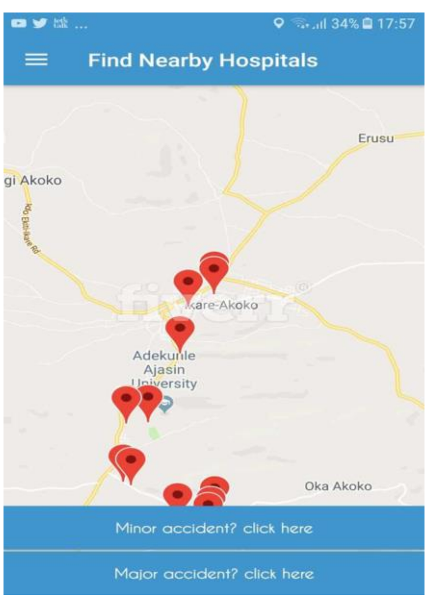

Figure 5: Rate accident's severity

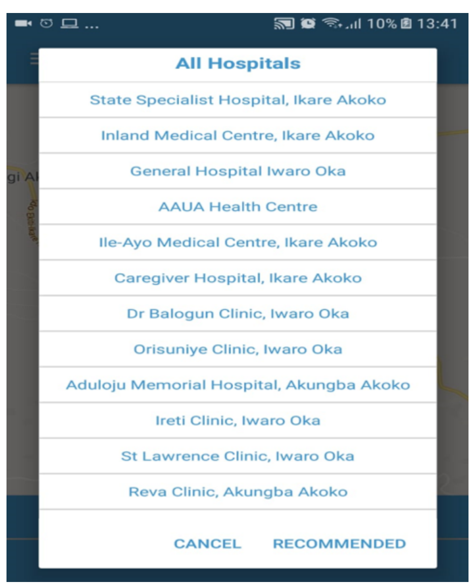

Figure 6: Available Hospitals for Minor Accidents

Figure 5 shows the rate accident severity screen, users specify the fatality of the accident so that suitable hospital can be recommended while figure 6 indicates the available hospitals for minor accident within the vicinity based on the minor severity of the accident

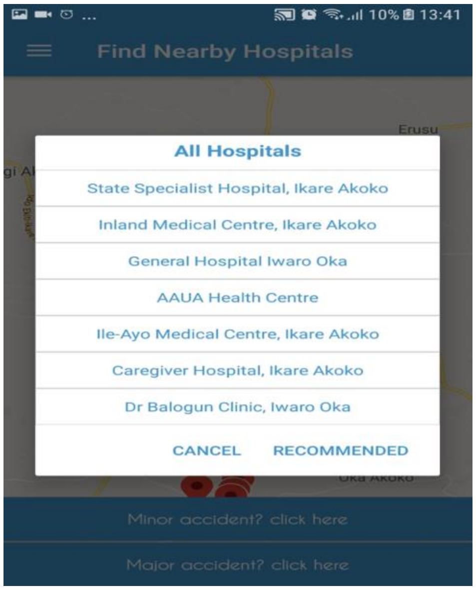

Figure 7: Available hospitals for major accidents

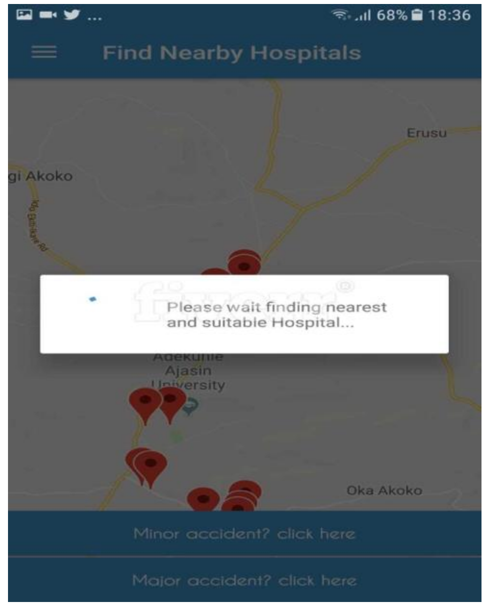

Figure 8: Searching for nearest suitable hospital

In figure 7, the available hospitals for major accident within the vicinity are searched based on the major severity of the accident. Then the users are prompted to search for the nearest hospital suitable to treat injured accident victims in both cases of minor and major accidents. This process is performed by the Dijkstra Algorithm that continuously searches for the closest hospitals based on distance as shown in figure 8. On the selection of the closest hospitals, the users will again search for the most suitable hospitals based on the parameters set out to collect data such hospital facilities, number of medical personnel, staff skills and the hospital distance. This is shown in figure 9. The recommendation of this hospitals is done through the use of Fuzzy logic algorithm that search through the list of hospitals and selects the most suitable one for the accident scenario. In addition, figure 10 indicates the direction to the hospital and calculates the time it will take to get to the recommended hospitals.

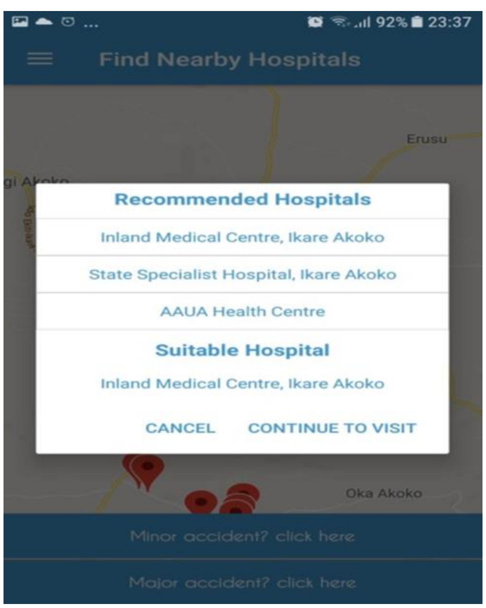

Figure 9: Recommendation of Suitable Hospitals

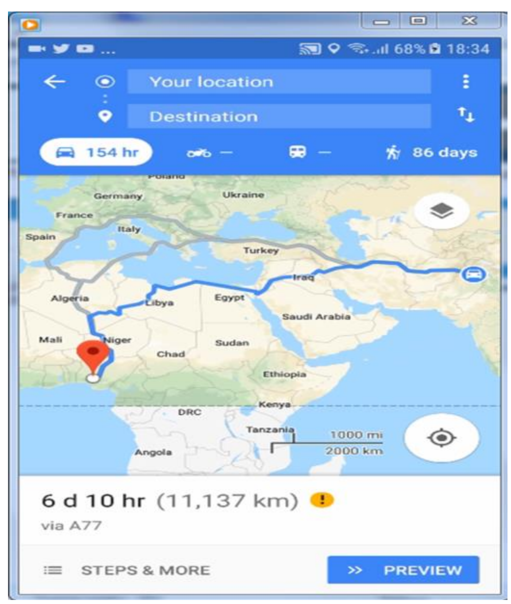

Figure 10: Direction and Time to get to the suitable hospital recommended

Table 3 shows the comparison of the results of the existing works with the result of the current work in respect to functionalities and features considered.

Features/Functionalities	**James (2013)**	**Kumar (2014)**	**Bagchi *et al.* (2016)**	**Eneh and Arinze (2017)**	**Edward (2017)**	**Current Work**
Recommend suitable hospital	✗	✗	✗	✗	✗	✓
Hospital facilities	✗	✗	✗	✓	✗	✓
Fatality	✗	✗	✗	✗	✗	✓
Distance	✓	✓	✓	✓	✓	✓
Algorithm Deployed	GPS	GIS	GPS	Dijkstra Algorithm	Dijkstra Algorithm	Fuzzy Logic and Dijkstra Algorithm

Key:

✗ ➔ Not Used
✓ ➔ Used

V. CONCLUSION

In this research, an android-based mobile application for analyzing shortest route to hospitals and recommending suitable hospitals for accident emergencies is developed. The proposed system uses Dijkstra algorithm to calculate the shortest distance from accident site to the nearest hospitals and Fuzzy logic to recommend the suitable hospital that can attend to the accident. With real time location tracking, the system will drastically increase the survival rate of an accident victim by providing timely emergency aid. The system is flexible to other emergencies such as fire outbreak, robberies/theft and other medical emergencies. Locations of nearest hospitals was computationally analyzed using Google map in real time.

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