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Research Article

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Interactive Mapping of Ambulance Dispatch System using LeafletJS

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Abstract This project work solves the problem encountered in the dispatching of ambulance to civilians manually, using the University of Port Harcourt Teaching Hospital dispatch system as a case study. Some of the problem encountered when dispatching ambulance manually includes; Increase in ambulance tracking time as tracking is manual, high possibility of losing data since method of processing and documentation is paper trail, increasing loss of life since waiting time is longer especially when most of the ambulances are busy, wastage of dispatching resources, and longer time to retrieve data or information that has been store, among others. In respect to all these existing problems, the system is designed to manage a database for ambulance dispatching whose criteria meet the appropriate condition and policies of the University of Port Harcourt Teaching Hospital. This system have a form for tracking ambulance location and communicating necessary information and resources among civilians, dispatch operators and drivers. This system is user friendly and compatible with the existing manual systems. The methodology used for the system design is an Object-Oriented analysis and design methodology. The system was implemented using HTML, CSS and Java code. The result of this research is a fully functional web-based ambulance dispatch system that offers improved emergency medical service resources dispatching by best optimizing the response time of ambulances and makes tracking of ambulances more convenient.

Keywords Automated Dispatch System, Emergency Medical Services, Optimization, Emergency, Dispatching

Introduction

Our world is clearly moving in a digital direction at a breakneck pace; virtually everything, from sports to cars to education and healthcare, is becoming increasingly automated. It is significant to remember that nothing should be overlooked. The automation of things has evidently marked its stamp on different field around the world and one of these fields is the medical health sector. It application ranged from reading pulse electronically to predicting the health of patients using artificial intelligence. Among the impact of automation in the health sector is in the ambulance dispatch system. An ambulance is a special vehicle used to transport injured or ill patients to a hospital during emergencies. Simply put, they transport patients to treatment facilities in medically equipped vehicles. During the Siege of Malaga by the Catholic Monarchs against the Emirate of Granada in 1487, the Spanish forces used them for the first time as emergency transport. A typical ambulance looks like a van or a pickup truck, but they can be distinguished by their flashing warning lights and sirens, which give them special permission to ignore speed limits and other traffic laws in order to transport patients to designated hospitals as quickly as possible.

Ambulance dispatching is the process of tracking and assigning ambulance to locations they are required. It is a crucial part of the healthcare system, in charge of allocating and sending ambulances to patients who require medical attention. Patient outcomes, healthcare delivery efficiency, and cost can all be significantly impacted by the effectiveness and performance of these systems. The creation of various automated dispatch systems in recent years as a result of technological advancements has the potential to speed up response times, lower costs, and improve patient care. Although there is ongoing discussion about the effectiveness of these systems as well

as the most effective methods for designing and implementing them, adoption and implementation of these systems can be difficult.

Ordinarily, the response time of Emergency Medical Service (EMS) providers is used to gauge their performance, so the problem of ambulance dispatching arises from the need to optimize the waiting time between when a call for emergency response is been made and when the patient involved arrives at the hospital. The complexity of the problem emanates from the limited number ambulance available, increasing demand for dispatching, and the conflicting nature of some constraints imposed on the allocation process. The automated ambulance dispatch system is a web based application system that finds the most suitable and available ambulance (based on stipulated factors like the nearest to scene, traffic congestion etc.) to be dispatched with the most effective algorithm. This project was engaged not only to dispatch faster but to manage and optimize dispatching (example is so as large area can be covered with limited numbers of ambulance), leading to a maximal optimized scheduling of the ambulance system. This system does not only record call information but automate call sorting and prioritization process, allowing systems to function as algorithm-based decision support tools. The automated system will continuously monitor ambulance location, status of response parameters, priority of incidence and other resources by making response resource assignment recommendations itself by watching the physical movement of the resources across a computerized map system.

The use of the existing system of ambulance dispatching in the University of Port Harcourt Teaching Hospital (UPTH), which is a paper-trail method is a very tedious and time-consuming operation. This manual method of allocation is a dangerous approach prone to errors and extended waiting time which can be fatal, therefore, an automated computerized method should be adopted in ambulance allocation because of the risk of life associated. Also, the increase in the number of reported emergencies(due to population growth) has surpassed the manipulation of the existing system that was used for ambulance dispatching and this has caused a lot of issues with includes the delay of dispatching ambulance, since it was very difficult to track the location of any dispatch ambulance. It was also very difficult to keep record of ambulance available or in duty.

With all the issues mentioned, solutions are needed to be made so this research work aims to develop an interactive mapping ambulance dispatch system for the University of Pert Harcourt Teaching Hospital using the LeafletJS which will address the problem of the waiting time between dispatching and ambulance tracking.

Literature Review

Ambulance dispatching is an essential part of emergency medical services (EMS) that ensures prompt and efficient response to medical emergencies. It involves receiving calls for help, assessing the nature and severity of the emergency, and dispatching the appropriate resources, such as ambulances and paramedics, to the scene thereby dispatchers play a critical role in saving lives by quickly assessing the situation and dispatching the right resources to the scene. They also provide pre-arrival instructions to the caller, such as how to perform Cardiopulmonary Resuscitation (CPR) or control bleeding, which can increase the chances of survival for the patient. Ambulance dispatching and management are therefore critical issues in hospital administration. Most first generation (in terms of relative date of establishment) hospital in developing countries have an ambulance dispatching unit built years ago when the average population were small compared to the current influx. The upsurge in population is such that the demand for emergency dispatch service increased which in turn has an adverse effect on the performance and throughput of the dispatch system such as the increase difficulty in tracking and dispatch ambulance and the increase in the waiting/response time between dispatching.

Currently in Nigeria, ambulance services are executed by individual hospitals (public and private) as well as organizations and agencies (Adebowale 2021) while the most developed of them all is the Lagos State Ambulance Service. There are about 20 ambulance points (stations) for the Lagos State Ambulance Services (LASAMBUS), one in each of the 20 local government areas in the state so at maximum efficiency—that is, each station having an ambulance as designed—about a million Lagos residents will depend on each ambulance for emergency transportation (Awoyemi 2019). This number is grossly inadequate to meet the population's needs, and it is even more disturbing to note that at any point in time, fewer than 10 ambulances are generally at full working capacity. The allocation of ambulance can thus be seen as a competitive process with strict guidelines set by various institutions to steer the process.

The dispatch system would be built to triangulate to patient /callers location, and then optimize the shortest path an ambulance can take to quickly reach patient/caller while avoiding various constraints like traffic and the distance from the hospital to the caller's location. A web-based system called automated ambulance dispatch system (AADS) would be able to locate the caller and obtain a satellite road network in order to efficiently monitor the road network conditions along the caller's route. The system is managed by an operator/dispatcher, who is also in charge of answering incoming calls for processing. There are quite a couple of systems that perform some similar functions of that of the AADS. The most famous system that has similar characteristics is the "911" system used in the United States. The 911 is the emergency number developed for the people of the United States. This three-digit number has been termed the "ultimate emergency number' for the people of the United States. The line is used for emergency purposes only. The dialing of this number links the caller to any emergency dispatch unit, which processes the emergency and handles it. This system was formed in 1967 by the president of the law enforcement and administration of justice in the United States. It is although noted that the number is strictly for emergency and any individual who calls the number, as a form of prank would face criminal judgment. Therefore, the 9-1-1 dispatchers although do not use the manual method of dispatch but rather a computerized system of dispatch to record emergencies and also sends the information through either radio or messages on a pager to the dispatched who goes to attend to the emergency. The advantage of this system however is that it also tracks and collects a caller phone number to the location at which the person is being situated so as to make the dispatcher able to view the status of all available emergency units and also effectively respond to calls effectively.

The London ambulance service (LAS) is a service that is in charge of responding to Calls of medical emergencies in London. The emergency number related to this service is the "999". The system serves over 7000 people in the city of London, England. It was implemented in 1992, known by the name "LASCAD" (London ambulance dispatch computer aided dispatch). The aim of the system was to improve efficiency and control resources efficiently decrease personal requirements. The system consists of a computer-aided dispatch, computer map display, and automatic vehicle location system. The system worked satisfactorily and staffs were able to sort out any problems. However, as the number of calls increased, major problems became clear. The system was often failing to terminate duplicate calls, on some occasions more than one ambulance would attend a scene. SAMU ("Service d'Aide Medicale d'Urgence") is an EMS unit based in France. It was initiated in Paris in 1956. Since that date, it has developed a new concept of emergency transportation, which excludes speed as the best way for saving life threatened by danger. Indeed, this EMS System is based upon the same principles that are used everywhere, but there are some practical differences which are characteristic of the service in France. One example is the medicalization (physician-staffing), which permits excluding speed in transportation M. Clara et al. (2012). The most incipient models, regarding ambulance location is the Location Set Covering Model (LSCM), proposed by Toregas et al. (1971) and Maximal Covering Location Problem (MCLP), introduced by Church et ReVelle (1974). While LSCM aims to minimize the number of vehicles needed to cover all demand points, MCLP tries to maximize population coverage by means of a given limited number of ambulances (Ormeu et al. 2017).

Bork et al. (2006) indulged in the surveillance of ambulance dispatch data as a tool for early warning. Early detection of disease outbreaks is essential for authorities to initiate and conduct an appropriate response. A need for an outbreak detection that monitored data predating laboratory confirmations was identified, which prompted the establishment of a novel symptom surveillance system. The surveillance system monitors approximately 80% of the Danish population by applying an outbreak detection algorithm to ambulance dispatch data. The system also monitors both regional and national activity and has a built-in, switch-on capacity for implementing symptom surveillance reporting in case of an alert. In an evaluation with outbreak scenarios it was found that decreasing the outbreak detection sensitivity from a prediction limit of 95% to one of 99% moderately reduced the time to detection, but considerably diminished the number of false alerts. The system was able to detect an increased activity of influenza-like illness in December 2003 in a timely fashion. The system has now been implemented in the national disease surveillance programme.

Vítor and Mylopoulos (2013) wrote on designing an adaptive computer-aided ambulance dispatch system with Zanshin. There has being a growing interest in systems that can adapt their behavior to deal with deviations

between their performance and their requirements at run-time. Such adaptive systems usually need to support some form of a feedback loop that monitors the system's output for problems and carries out adaptation actions when necessary. Being an important feature, adaptively needs to be considered in early stages of development. Therefore, adopting a requirements engineering perspective, they proposed an approach and a framework (both called Zanshin) for the engineering of adaptive systems based on a feedback loop architecture. As part of their framework's evaluation, the research have applied the Zanshin approach to the design of an adaptive computer-aided ambulance dispatch system, whose requirements were based on a well-known case study from the literature. In the paper, they reported on the application of Zanshin for the design of an adaptive computer-aided ambulance dispatch system, presenting elements of the design, as well as the results from simulations of run-time scenarios.

Värbrand and Granberg (2016) researched on decision support tools for ambulance dispatch and relocation. In this paper, the development of decision support tools for dynamic ambulance relocation and automatic ambulance dispatching was described. The ambulance dispatch problem is to choose which ambulance to send to a patient. The dynamic ambulance relocation problem occurs in the operational control of ambulances. The objective is to find new locations for some of the ambulances, to increase the preparedness in the area of responsibility. Preparedness is a way of evaluating the ability to serve potential patients with ambulances now and in the future. Computational tests using a simulation model show that the tools are beneficial in reducing the waiting periods for the patients.

Khalique et al. (2017) developed an automatic ambulance dispatch system via one-click smartphone application. Emergencies such as accidents require immediate medical attention where patients need to be transported from the place of incident to hospital. In such situations, emergency systems are crucial in saving precious lives. The importance of taking a patient to hospital can be judged by the fact that if the arrival of an ambulance is delayed due to any problem, it can worsen the patient medical state and even cause death. The delays can occur due to time consumed for dialing emergency numbers and carrying out conversation for guiding the address to the place of incident to the ambulance dispatch service provider representative. The immense need of automation of ambulance dispatch system is necessary for solving this problem. The research work provides a comprehensive system that tackles this problem of manual ambulance dispatching by replacing it with Automatic Ambulance Dispatch System AADS. The AADS comprises of android based application where the user (victim or the caretaker of the victim) have to press a simple “help” button on the AADS android application to signal and buzz any ambulance near the place of incident along with the victim’s geographical location just on one click. The objective of the research is to minimize the time consumed for the arrival of ambulance through automation.

Material and Methods

System Design

This system allocates and mobilize a suitable ambulance within minutes, transmit the information to the selected ambulance, track and monitor actual performance plus position. A message should be generated if there is no ambulance available for a selected minutes. The operating procedures in the proposed system are as follow:

- **Service center**, as shown in Figure 1, receives the messages for emergency medical services from a case reporter and the corresponding locations uploaded to the system will activate the route planning subsystem to proactively access latitude/longitude coordinates of the scene of a case reported from the case management subsystem for computing of time for available ambulances arriving at the scene and sorting of ambulances by time and Computing of time for an ambulance driving from the scene to available hospitals and sorting of hospitals by time, both of which are the basis of dispatching an ambulance by the service center. After the ambulance to be dispatched is selected, the ambulance should receive and verify the command of dispatching from the service center via the webpage and further latitude/longitude coordinates of the scent of a case reported (the hospital) for pre-arrival routing planning at Stage 1 (post-arrival routing planning at Stage 2). The operating procedure will be completed with the ambulance arriving at the hospital and changed service status updated to and received by the webpage.

- **Ambulance**, as shown in Figure 2, shows the location of a case reported and the corresponding which receives and verifies the command for one task issued by the service center. The ambulance arriving at the scene also receives the location of a hospital and the route from the scene to the hospital transmitted by the service center. The operating procedure will be completed with the ambulance arriving at the hospital and changed service status updated to and received by the webpage.

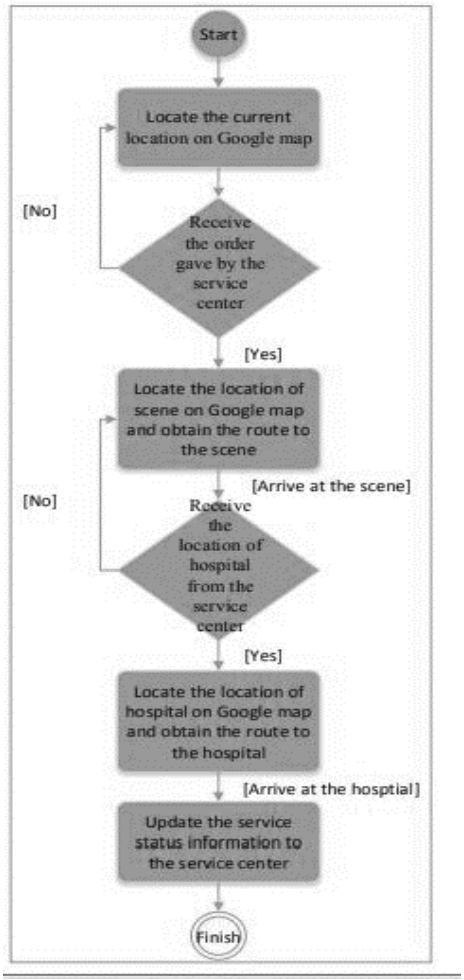

Figure 1: Flow chart for ambulance dispatching for operating procedure at an ambulance

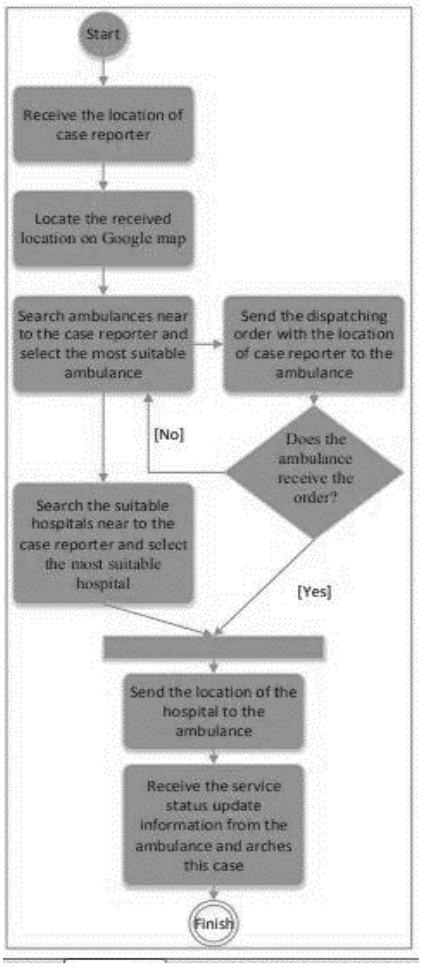

Figure 2: Flow chart for ambulance dispatching for operating procedure at the service center

Architecture of the System

The model that was adopted in developing this system is a server- client model. The server will host a database where data will be saved. When the information is requested by the user, the server will process the request then display the results. This whole process will be implemented by Java.

Interface and backend technologies

HTML JavaScript, CSS and MySQL. JavaScript, CSS and HTML will be playing a role in creating the interface. The role of Java will basically be to validate forms, verify them and support the embedding of MySQL responsible for querying the SQL database. It's also used as a server-side scripting language. Any current browser, including Microsoft Edge, Google Chrome, and Mozilla Firefox, may render (display) the presentation tier. The Java Standard Edition (JSE) and Java Enterprise Edition (JEE) technologies, including Servlet and JDBC, are used in the proposed system's application tier. The data layer is implemented using the

MySQL database management system, and the application tier is likewise designed to be deployed on the Apache Tomcat Server.

Mapping

The mapping system used in the design is powered by LeafletJS – a premier open-source JavaScript library for responsive, interactive maps for triangulation and other mapping operations, and OpenStreetMap – an open data, licensed under the Open Data Commons Open Database License (ODbL) by the OpenStreetMap Foundation (OSMF) that provides the graphical image of relative positions on earth surface. The choice of the library is narrowed to the fact that it gives developer more control over the mapping system and the map data used is because of the type and amount of data and information it provides.

Architecture block Diagram

The following block diagram in Figure 3. shows how dispatcher, driver or admin can have access to the frontend and send request to the database or get response from the database.

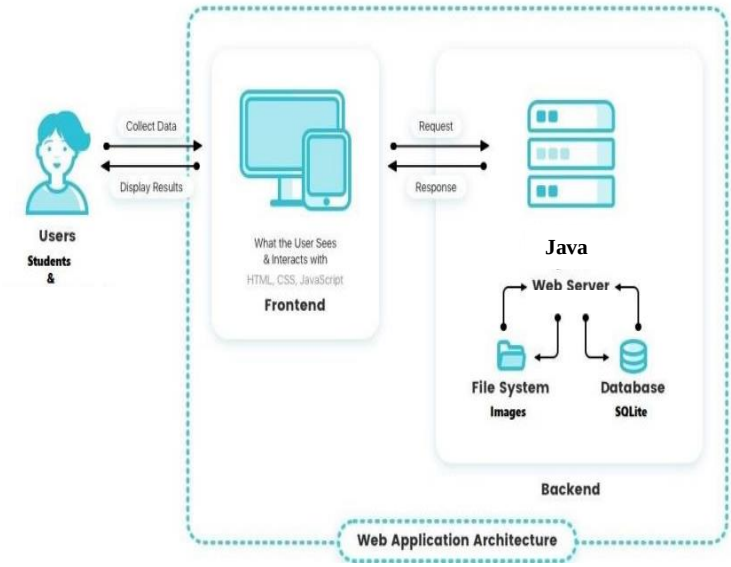

Figure 3: Block Diagram showing the system architecture

Use Case Design of the system

Use case diagrams to describe what a system does from the standpoint of an external observer. The emphasis of use case diagrams is on what a system does rather than how. They are used to show the interactions between users of the system and the system. A use case represents the several users called actors and the different ways in which they interact with the system as shown in Figure 4.

Actors

i. **Patient/Case reporter**: They can caller the operation room and the information of their location will be pin pointed on the map or they can registers an account on the system, after which they are able to login into their account with these credentials where their location will be automatically pin pointed

ii. **Admin**: The Admins account is created by the System administrator and a username and password are generated for the user, driver or other dispatchers. The admin is then able to login into the administrator dashboard with the credentials. The admin is then able to upload information about ambulance dispatching and also overview all of the interactions on the system.

iii. **Driver:** Receive information and request of ambulance dispatching. Account is created by the admin and credentials are used to login to the account.

Use Cases

I. Register
II. Send Request
III. View Message
IV. Generate message.
V. Message Ambulance
VI. Generate report

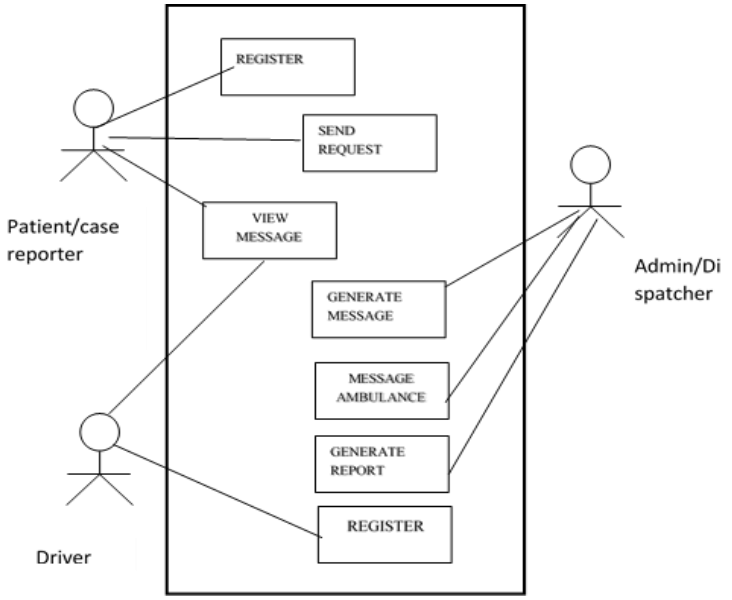

Figure 4: Use case diagram

Results

The resulting web application is broken down into two parts, the front-end, which is the practice of converting data to a graphical interface, through the use of HTML, CSS, and JavaScript, so that users can view and interact with that data, and the back-end which refers to code that connects the web to a database, manages user connections, and powers the web application itself.

Home Page Module

This is the first page that is opened when access has been gained to the website. The page gives the highlight of the website. It answers the anticipation of the user as to what is contained in the website. It further gives the user the opportunity to browse and navigate through the site.

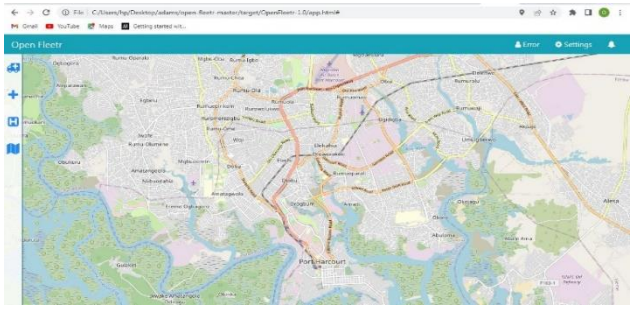

Figure 5: Home page

Login Module

The user's login page is where admin, driver and authenticated users can login to have access to their dashboard. The user is required to enter a username and password and from here if authentication is successful, the home page is loaded.

Figure 6: Login input module

Driver Module

Here is where the driver interact and is interacted with. It consists of the drivers view to pin pointed position on the map and where he check in or check out from.

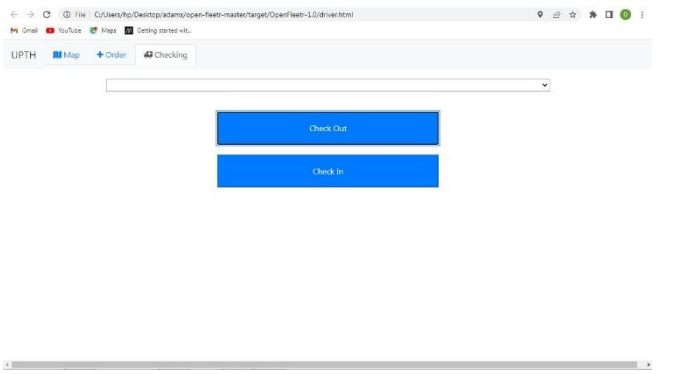

Figure 7: Driver Input Module

Admin module

This is a page linked to the admin dashboard where the admin can add or create a driver and user account by inputting the required text field.

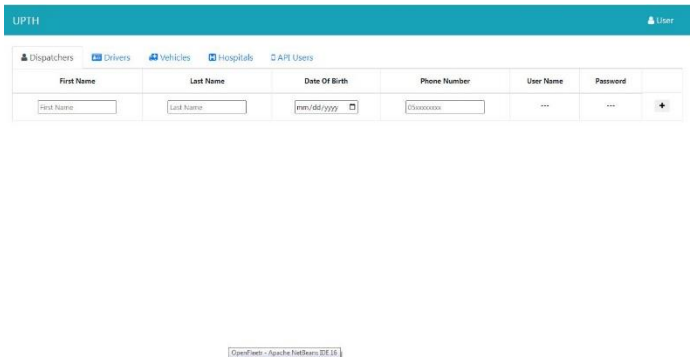

Figure 8: Admin Dashboard

Conclusion

An interactive mapping application has been created for the ambulance dispatch system of the University of Port Harcourt Teaching Hospital. With the new system, there will be proper tracking of the operational ambulances of the hospital. The staffs of the emergency medical service of the institution should be enlightened with seminars in other to train them on how to fully understand the implementation of the new proposed system which will address the problem of the waiting time between dispatching and ambulance tracking.

References

[1]. Adebowale-Tambe N. 2021 Nigeria to introduce emergency medical, ambulance services, Premiumtimesng.
[2]. Adewole I, Kayode F, Giwa S, Shoga M, Adejumo A, Ademiluyi S. Ambulance services of Lagos State, Nigeria: a six-year (2001–2006) audit. West Afr J Med. 2012;31(1):8–13.
[3]. Awoyemi 2019 EMS Around the World: Bare Bones—EMS in Nigeria
[4]. Bork et al. 2006 Surveillance of ambulance dispatch data as a tool for early warning. Pubmub
[5]. Church, R. and ReVelle, C. (1974) Maximal Covering Location Problem. Papers of the Regional Science Association, 32, 101-118.
[6]. Federgreun,1997 Heuristics for multimachine minmax scheduling problems with general earliness and tardiness costs https://ideas.repec.org/a/wly/navres/v44y1997i3p287-299.html
[7]. Khandekar and Pandey 2009 Evaluating the effectiveness of telephone triage for priority emergency ambulance dispatch. Journal of Clinical and Diagnostic Research 3(5):1726-1730.
[8]. Khalique et al. 2017 automatic ambulance dispatch system via one-click smartphone application. Indian Journal of Science and Technology 10(36) DOI:10.17485/ijst/2017/v10i36/119178.
[9]. Leonard and Valacich 2008 Information Systems Today - Google Books.
[10]. Lowthian 2011 Increasing utilisation of emergency ambulances, Google scholar.
[11]. Maloney, Robert J. 2003 "The Evolution of Patient Transport." FireEMS: 52-60.
[12]. Mould-Millman N-K, Dixon JM, Sefa N, Yancey A, Hollong BG, Hagahmed M, et al. The state of emergency medical services (EMS) systems in Africa. Prehospital Disaster Med. 2017;32(3):273–83.
[13]. Toregas, C. (1971) The Location of Emergency Service Facilities. Guidelines for the Practice of Operations Research. Operations Research, 19, 1259-1551.
[14]. Vítor.and Mylopoulos 2013 designing an adaptive computer-aided ambulance dispatch system with Zanshin. DOI:10.1002/spe.2245.
[15]. Värbrand and Granberg 2016 decision support tools for ambulance dispatch and relocation. Operational Research for Emergency Planning in Healthcare: Volume 1 (pp.36-51).