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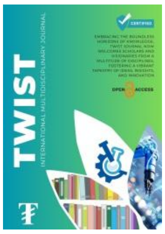

Forecasting the Spread of Air Borne Communicable Diseases:

Bridging the Gap with a Real Time Surveillance System

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Abstract

Air borne communicable disease can be serious and life threatening. Hence, availability of surveillance systems predicting its potential outbreak can be very useful in its controlling and eradication strategies. The study identified the need for the development of a real time surveillance system which will integrate the time series geo analytic model proposed by (Amoo *et al.*, 2021). This will thus aid the real-time collection, distribution and analysis of surveillance data about air-borne disease. This was followed by the identification of the parameters that were relevant for reporting and monitoring communicable diseases from the DSNOs using a structured oral interview after which historical data containing disease surveillance data were collected from disease surveillance data archives.

Following this, the design of the real-time communicable disease surveillance system was specified using the Unified Modeling Language (UML) diagrams. Use case diagram was used to specify the design requirements of the users; data flow diagram was used to design the flow of surveillance data while class diagram was used to design the conceptual data model of air-borne diseases surveillance system. The real-time communicable diseases surveillance system will thus provide a means via which communicable diseases data can be captured, stored, analyzed and accessed easily from a single cloud-based repository by a variety of computing devices ranging from PCs to smartphones there by removing the gap facing accessibility to information by stakeholders. The disease mapping capacity of the system will allow stakeholders to monitor the distribution of communicable diseases across various reporting locations thereby providing accurate report of the public health status of the country. This thus provides a means of adopting evacuation and control measures towards reducing the likely spread of communicable diseases to vulnerable neighbouring locations. Future works is focused on the implementation of the real time surveillance system for air borne communicable diseases based on the proposed conceptual design.

Keywords

Forecasting, Communicable disease, Disease forecasting, Tuberculosis, Real time surveillance system

INTRODUCTION

Many developing countries struggle with communicable diseases as the primary causes of illness, disability, and death. Common examples include Cholera, Ebola Virus, Hepatitis, Influenza, Measles, Severe Acute Respiratory Syndrome (SARS), Malaria, Tuberculosis (TB), Typhoid Fever, Diarrhea, Human Immunodeficiency Virus/Acquired Immuno Deficiency Syndrome (HIV/AIDS), and Acute Respiratory Infection (ARIs). The rapid evolution and spread of microorganisms, particularly their ability to adapt to changing environments, populations, and technologies, present ongoing health risks and challenge efforts to prevent and control these diseases (Bansal et al., 2016). Among these communicable diseases, HIV/AIDS, TB, and malaria are often referred to as the "big three" due to their significant global impact. Tuberculosis (TB) in particular is a severe global public health issue, ranking as the ninth leading cause of death worldwide (kema *et al*., 2019). It is a contagious disease that affects many countries and is transmitted by the bacteria

Mycobacterium tuberculosis (Moosazadeh *et al.*, 2015). Individual with TB can spread the might transfer germs when they cough or sneeze. If a person becomes infected with tuberculosis and is not promptly and appropriately treated, it can have a major impact on their health and even cause them to lose their ability to work, and potentially imfect others (Zhao and Yuan (2017).

The World Health Organization ("WHO"), states that individuals with TB bacteria have a 5-15% lifetime risk of developing the disease (WHO, 2018): However those with weakened immune systems such as people living with HIV, malnutrition, diabetes, or those who use tobacco have much higher risk of becoming ill" (WHO, 2018a). Despite significant advancements in TB prevention and control many low and middle income contries, continue to grapple with a persistent TN crisis, leading to substantial economic losses (WHO, 2018b). TB remains one of the top ten causes of death globally with an estimated 10 million new cases in 2017 resulting in 1.3 million individuals' deaths directly attributable to TB. Over the past few decades, TB has claimed more lives than any other infectious (WHO, 2018a).

Despite extensive efforts to combat TB, it continues to pose a significant health challenge due to its high incidence, associated medical costs, drug resistance, and co-infection (WHO, 2016). Nigeria, in particular faces a high TB burden, being a significant public health issue and one of the leading causes of death worldwide. In 2020, approximately 9.9 million people contracted tuberculosis, with Nigeria accounting for the highest number of TB cases in Africa and 4.6% of the global TB burden (WHO 2021). Early detection is crucial for managing and controlling emerging, re-emerging, and new communicable disease (Institute of Medicine, 2007). Disease Surveillance systems which monitor illnesses, pathogens, and clinical outcomes have long been the cornerstone of communicable disease control. Monitoring and forecasting the spread of these diseases are particularly important for controlling their spread within populations (Guerrisi *et al.*, 2016).

The surveillance of communicable illnesses is a fundamental aspect of public health policy and practice, traditionally involving the continuous collection, analysis, interpretation, and dissemination of health data for planning, implementing, and evaluating public health interventions (Woolhouse *et al.*, 2015). Routine disease surveillance is essential for authorities to detect and respond to disease outbreaks (WHO, 2003). Without an effective surveillance system, it is impossible to determine the true disease burden, identify the infection sources or understand infection trends and patterns. However despite efforts to improve communicable disease reporting, many developing nations still struggle with underreporting and inadequate surveillance. Additionally, regions that have implemented computer-based systems for disease reporting face challenges due to intermittent power and Internet connections, poor infrastructure, and a lack of facilities and trained personnel. Monitoring the state of communicable illnesses is one of the most difficult problems confronting the public health sector; nonetheless, alternative technologies are needed to boost communicable disease surveillance systems in resource-constrained situations.

This study is prompted by the necessity to create a real-time surveillance system that incorporates the time series geo analytic model and framework proposed by (Amoo *et al.*, 2021). The real-time surveillance system will leverage use of cloud services to store, analyze, and forecast the spread of communicable diseases. It will enable the interoperability between desktop and mobile devices for data storage and analysis, leading to improved data reporting, more comprehensive data, and timely reporting of disease spread. The system aims to address issues such as delayed data collection and diversified device compatibility particularly in developing countries in sub-saharan Africa, by facilitating a seamless reporting process.

The real-time communicable diseases surveillance system will allow for the capture, storage analysis, and easy access of disease data from from a single cloud-based repository via various computing devices from PCs to smartphones. This will thereby bridge the information access gap for stakeholders enabling them to track the distribution of communicable diseases across different areas, resulting in accurate report of the country's public health condition.

Related Work

Cui *et al.* (2022) introduced a microscopic exposure-risk-based model for predicting the transmission trends of respiratory infectious diseases. The model comprises of four modules: individual movement, virion-laden droplet movement, individual exposure risk estimation, and transmission trend prediction. The first two modules simulate the motions of persons and infector droplets during their expiratory activities, respectively, while the outputs are input into the third module to estimate the personal exposure risk, and finally, the number of new cases is projected in the fourth module. To assess the model's performance, new COVID-19 cases in the United States were forecasted. The model's performance was compared to that of four other existing macro- or micro-models. The suggested model's mean absolute error, root mean square error, and mean absolute percentage error are 2454.70, 3170.51, and 3.38% less than the minimum results of comparison models, respectively. The quantitative results show that the model was able to effectively anticipate transmission trends from a microscopic perspective, which can help with future research into several microscopic disease transmission mechanisms.

Farida *et al.,* 2020 developed community-based pulmonary tuberculosis monitoring information system that provides comprehensive, accurate, easily accessible, and timely data. The authors used a qualitative approach to investigate problems and user expectations. The System Development Life Cycle (SDLC) was used to create information systems, which is divided into four stages: planning, system analysis, system design, and system implementation. The System testing was done using Black Box Testing, and information system approval was measured using the Technology Acceptance Model (TAM) technique with 34 cadres and managers from the Public Health Center for the Pulmonary

Tuberculosis Program and the Public Health Office. Black Box Testing verifies that the system's actions and responses were completed successfully and in accordance with the system's objectives. The results showed that the majority of respondents gave high ratings and information system acceptance was evaluated using the Technology Acceptance Model (TAM) technique, with 34 respondents from cadres and managers from the Public Health Center for the Pulmonary Tuberculosis Program and the Public Health Office. Black Box Testing demonstrates that the system's actions and responses were carried out successfully in accordance with the system's objectives. The findings revealed that the majority of respondents provided high ratings to the existence of advantages (31.48), ease of use (32.13), readiness to use (31.52), and interest in using (31.92).

Jiyang *et al*., (2018) analyzed TB prevalence rate across four World Bank income groups. Kruskal-Wallis analysis of variance and multiple comparison tests are used to determine whether or not the differences in tuberculosis prevalence rates between income groups are statistically significant. A novel combined forecasting model with weights optimized by a recently developed artificial intelligence algorithm cuckoo search is proposed to forecast the hierarchical tuberculosis prevalence rates from 2013 to 2016. Numerical findings reveal that the established combination model is not only simple, but also capable of approximating the actual tuberculosis prevalence rate, making it a useful tool for mining and analyzing huge data in the medical industry.

Mandla *et al*., 2017 evaluated TB surveillance system in Eden District's Western Cape Province, South Africa. Secondary data from 40,033 TB cases entered into Eden District's ETR.Net from 2007 to 2013 were used to examine data quality, sensitivity, and positive predictive value, as well as 79 purposefully selected TB Blue Cards (TBCs), a medical patient file and data source document for ETR.Net. The ETR.Net's simplicity, adaptability, acceptance, stability, and utility were assessed qualitatively through interviews with TB nurses, information health officials, and sub-district and district coordinators involved in TB monitoring. The results show that data were less complete in the ETR.Net (66-100%) than in the TBCs (76-100%), but were consistent for most parameters except pre-treatment smear results, antiretroviral therapy (ART), and treatment. outcome. ETR.Net recorded variables had a sensitivity of 98% for gender, 97% for patient category, 93% for ART, 92% for treatment success, and 90% for pre-treatment smear grade. Their findings indicate that the method provides useful information for guiding TB control program actions in Eden District. However, there is an urgent need to rectify gaps in clinical recording on the TBC and data capture into the ETR.Net system.

Jiang et al. (2021) discussed the benefits and obstacles in deploying the new TB system, as well as the implications for the NHIS roll-out. The new TB monitoring system, which was piloted in each prefecture of the project provinces, was created using the local information system with the uniform premise of organizing patient information under a unique ID and implementing data sharing functionality. The new system's major advantages included automatic data extraction rather than manual entry, assistance with clinical service providing, and expanded statistical functions. The license issue and the variety of infrastructures that impede the marketing of the new system at a reasonable cost were the key hurdles in its installation and scaling up.

RESEARCH METHOD

In this study, the main focus was to design a real-time surveillance system and integrate the geo analytic model that will be required for monitoring the spread of communicable diseases.

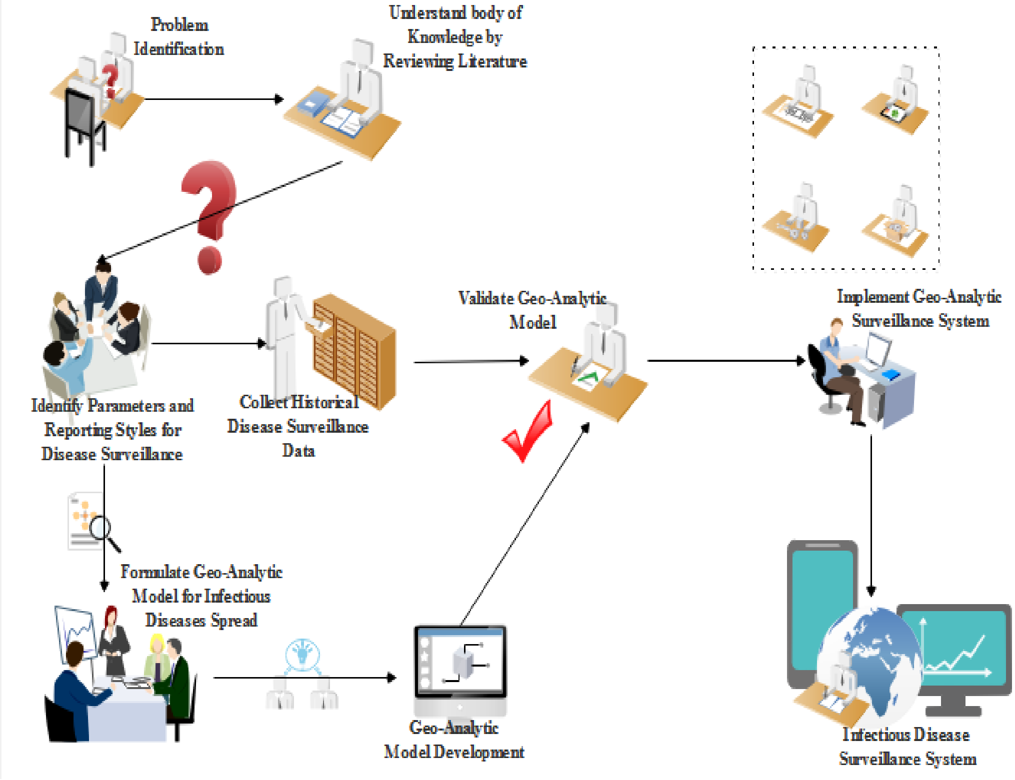

Fig. 1 A Conceptual View of the Research Design

Figure 1 shows a description of the research design which presents the different methods that were adopted in the methodology employed for the development of the surveillance system. The study identified the need for the development of a system which will aid the real-time collection, distribution and analysis of surveillance data about air-borne disease in Nigeria. This was followed by the identification of the parameters that were relevant for reporting and monitoring communicable diseases from the DSNOs using a structured oral interview after which historical data containing disease surveillance data were collected from disease surveillance data archives.

Following the formulation of the proposed geo-analytic model for monitoring the spread of communicable disease, the design of the real-time communicable disease surveillance system was specified using the Unified Modeling Language (UML) diagrams. Use case diagram was used to specify the design requirements of the users; data flow diagram was used to design the flow of surveillance data while class diagram was used to design the conceptual data model of air-borne diseases surveillance system.

The Unified Modeling Language (UML) tools were used to specify the design of the air-borne disease surveillance system based on a framework for the real-time monitoring of air-borne diseases which will integrate the geo-analytic model formulated.

Data Identification and Collection

For the purpose of monitoring the spread of air-borne disease, it was pertinent to determine the parameters that provided a complete understanding of the system. It was therefore necessary to interview epidemiologists and DSNOs in Osun State Ministry of Health in order to identify the relevant parameters. The data collation officers located at health facilities within wards of the local government areas of Osun State were considered as the source of data identification and collection due to their involvement in the reporting of air-borne disease to various stakeholders of the nation.

The information that was required to be collected from the DSNOs was provided via a structured interview. The air-borne diseases surveillance system was expected to store information about air-borne disease data from a specific known location (called the health facility such as public and private hospitals, clinic or laboratory) for different instances of time on which air-borne disease data was reported. The location of the health facility was used as a means of mapping the reported data to a known location. Information provided at the point of disease occurrence includes the following:

i. Demographic profile data such as gender, age group, education and occupation of patients about whom reported data was provided;
ii. Location data such as location of health facility reporting and the location of the address of the patients reported;
iii. Reported data such as the number of cases and /or deaths that were reported in a periodic manner (e.g. daily, weekly, monthly etc.).

In addition to the identification of the reported data provided and location of reports, it was gathered that the reporting facilities are primarily located in wards. As a results of this, the location of all health facilities within a ward were given the location of the ward to which they belonged so that reported data can be reported at ward level from each associated reporting centers. Furthermore, according to the political structure of the Federal Republic of Nigeria, two or more wards made up a local government area (LGA), two or more LGAs make up a state and 36 states including the FCT makes up Nigeria. Therefore, a reporting center belongs to a ward located in a LGA which is located in a State in Nigeria.

Data about air-borne diseases required for this study were collected from a standard data bank provided by the State of Osun, Federal Ministry of Health which contained information about Tuberculosis data reported in a quarterly manner by the DSNOs of each LGA to Osun State Public Health stakeholder. The data reported from health facilities were required to be used by various stakeholders either operating through non-governmental organizations (NGOs like the UN or WHO), private institutions, public institutions etc. The data were required to be presented using tables, charts including maps which can facilitate the effective monitoring of the spread of air-borne disease by public health experts across Nigeria.

Conceptual view of the distribution of reported data

Based on the interview conducted with intending users of the system, a number of observations were made regarding the flow of reported data across the system between users. The proposed system is expected to be used by the reporting officer and other stakeholders located within a ward for making and viewing/analyzing the reported cases.

Figure 2 shows the conceptual view of the distribution of reported data across the system. Since mobile devices (such as smartphones) can be used from any remote location as long as there is Internet, information can be reported from the focal person located at each health facility directly to the central system which is accessible by the DSNO located at the local government area (LGA) to which the ward belongs to. Therefore, public health officers of wards within a LGA can share information with other wards within their LGA however, they cannot share information with other wards of LGAs belonging to other States.

Information collected from the wards at the LGA can also be viewed at the state level as an aggregation of the reports from the wards in each LGA within the state. Public health officers of LGAs within a State can share information among other LGAs within their State – they cannot share with LGAs belonging to other States. Information collected from the LGAs at the State can also be viewed at the National level as an aggregation of the results of the LGAs in each State within the Nation. The information stored at wards, LGAs and State level can also be viewed as a spatial distribution of the occurrence of disease from their individual reporting locations. The occurrence of the diseases per unit time (daily, weekly, monthly or yearly) can be used to observe the distribution of diseases across Nigeria.

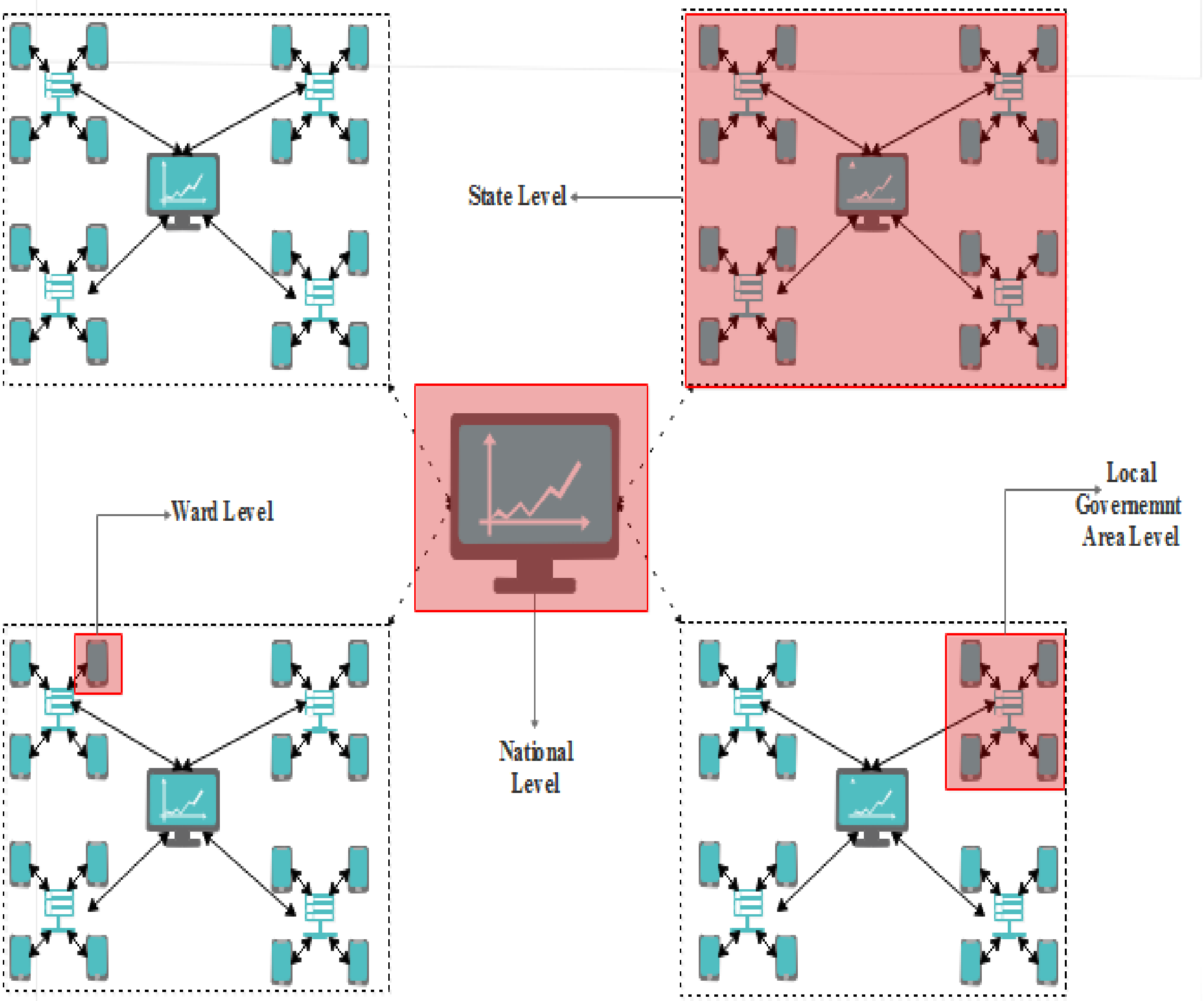

Fig. 2 Flow of the Communication of Surveillance Disease Reports

SYTEM DESIGN

Different design approaches were involved in the course of this research. These are discussed below.

Use case modeling of the user requirements

Use-case diagrams are requirements discovery techniques that was used in modeling the interactions between the system and the actors (users). In its simplest form, the use-case identified the actors (users) involved in an interaction, the names and the types of the interactions involved. These use case scenarios were used to present the system requirements of the disease surveillance system that made use of the data collected from different sources.

Using the scenarios afforded the opportunity to obtain the realistic description of the workflow of the system, which was to explicitly describe the intentions and actions of the users. For this study, there are a number of users of the system, they are presented as:

- **a.** **System administrator** is responsible for creating profiles for the registered health facilities such as laboratories, clinics, public and private hospitals alongside the users assigned to the respective health facilities registered.
- **b.** **Data collation Officer** is responsible for providing reports about disease data from their respective health facilities. They can also view information stored by them and the total information stored at their health facilities.
- **c.** **Investigator** belongs to either a reporting health facility or laboratories and they can view the data that is stored by data collators in their health facilities. The data stored can be viewed using frequency distribution tables, pie charts, bar charts and the distribution of reported data over time.
- **d.** **Stakeholder** is an individual who is stationed at a particular level either from the LGA, state or Federal level and can view reported data alongside perform forecast and estimate the spread of reported data. The data stored can be viewed using frequency distribution tables, pie charts, bar charts and the distribution of reported data over time. In addition, an investigator can also view the data stored based on location using a digital map.

Figure 3 shows the use case diagram that was used in specifying the requirements of the users intended for this study. The figure shows the different users of the system depicted using *stick-men* such that the arrow pointing relating users shows the level of generalization of the users.

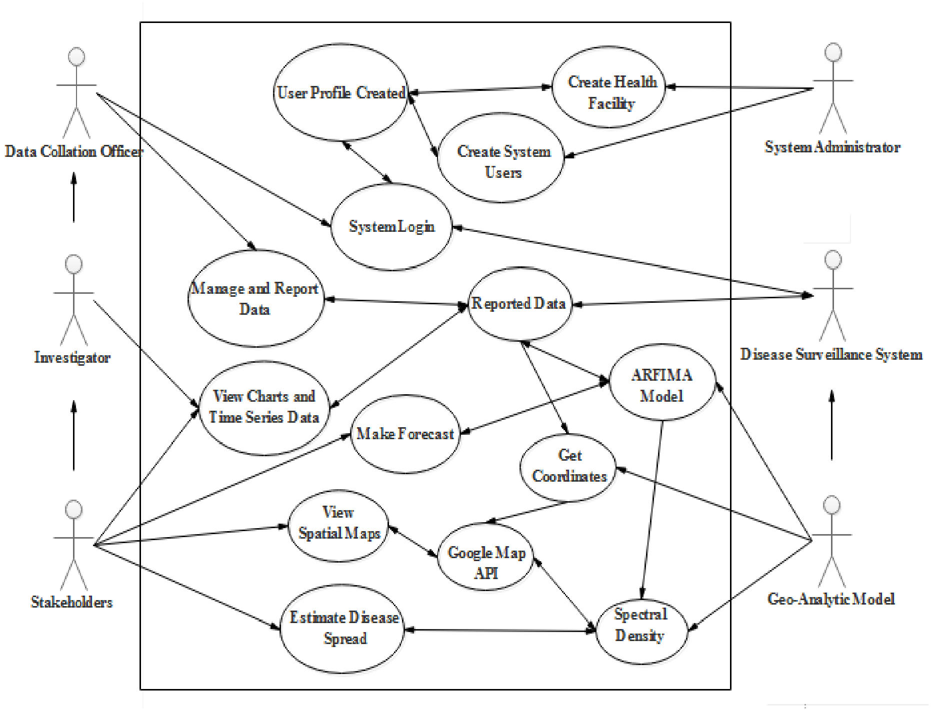

Fig. 3 Use Case Diagram of System User Requirements

As a result, stakeholders are generalization of the investigators who are also in turn a generalization of the data collation officers. This is because the investigators can do all what the stakeholders can perform except making forecasts and viewing the digital map while the data collators can only view data within their facilities and have no privilege to the distributions that the investigators have access to.

The oval structures in the diagram show the different activities that the users can carry out using the proposed disease surveillance system. The system administrator manages information about health facilities and their respective users (such as creating new data, updating existing data and removing non-existing data) following which login details were provided for giving registered users access to the system. The system users such as the data collation officers, investigators and the stakeholders are required to provide login details before access is granted to the system following which their respective activities can be performed. The system verifies the authenticity of the collation officer and the user's session is created for his/her profile.

The system required that information about reported diseases be provided by the data collation officers following which the system updates the disease surveillance system with the reported information from all collation officers located in all the wards.

After updating disease data, the spatial database will be used to store and link the reported data to their respective location determined by the coordinates of the location such as wards, LGAs and State via support from the Google Map API.

The distribution of the reported data will be presented using bar charts, pie charts, frequency distribution tables based on the location to which the requesting user is registered to and based on the privilege of the user considered. The geo analytic model will be used to create forecast of disease alongside the spectral density function which will be used to estimate the spread of disease based on the data presented and the time of forecast provided.

Data flow diagram (DFD) of disease surveillance system

Data flow diagram (DFD) was used to specify a graphical representation of the flow of data through the proposed disease surveillance system by identifying the flow of data from objects via process which translate into a storage location. It was a way of specifying the structural requirements of the system in terms of the system users by showing the kind of information presented as input and processed into output and where the data is coming from and going to, and to where the data will be stored.

Figure 4 shows a description of the flow of reported data within the proposed system which will start from the creation of users by the system administrator followed by the collection of data by the collation officer located on-site such as the data collation officer, investigators and the stakeholder. The data collation officer collates and submits information regarding the number of cases of diseases based on the observations that were made at the site of data collation. The data will be stored in the database for future analysis by the investigators or stakeholders for facilitating decision making. The surveillance data about diseases which was stored by the data collation officer also contained location-based information about the data reported from specific locations. This contained details about the physical location of disease incidence alongside information that describes the individual affected such as gender, age group, education and alongside personal and clinical information about the individual affected. The disease surveillance data will be stored for analysis using the geo-analytic model to determine the future forecast of diseases and to estimate the extent of the spread of disease to various surrounding locations from the point of outbreak.

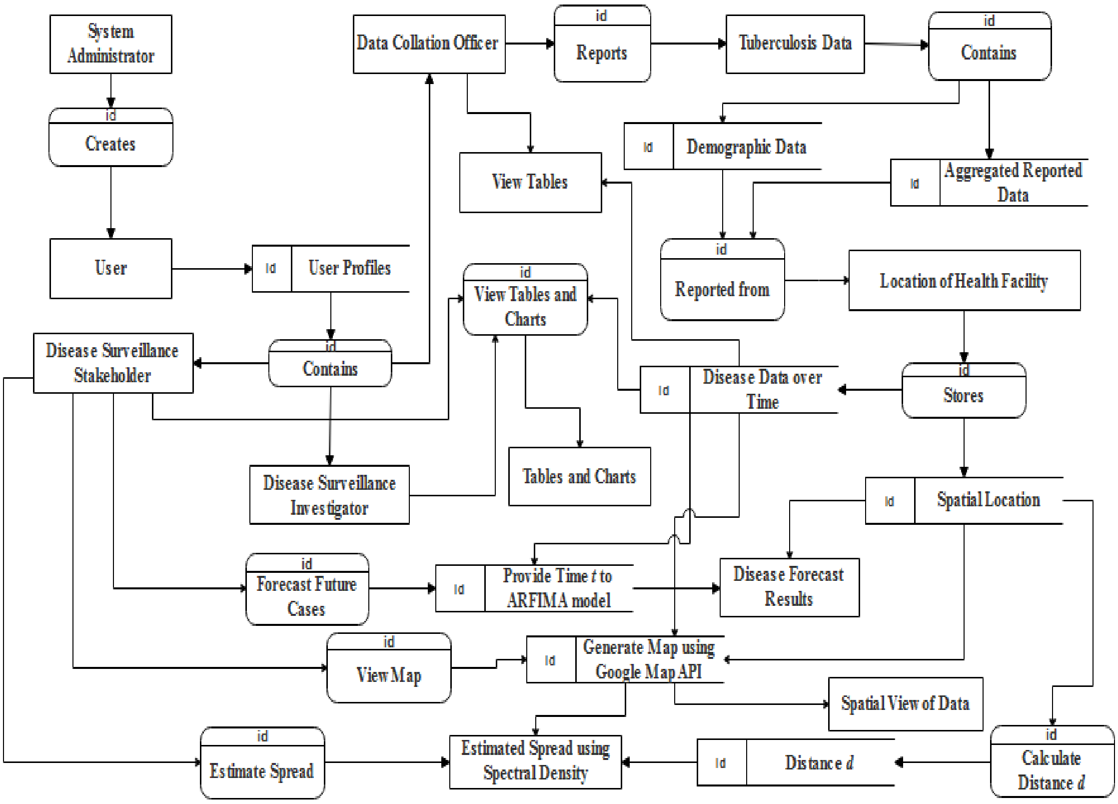

Fig. 4 Data Flow Diagram of Information through Disease Surveillance System

The geo Analytic model will be used to estimate the future forecast of disease reports for the next *n* periods in the future which was collected by the spectral density function for the estimation of the spread of disease to neighboring locations based on the value of distance recorded. The information stored about reported cases of the disease alongside their demographic variables will be viewed as tables, charts and graphs while the forecast will be presented as a time series plot and the estimated spread displayed on the digital map.

System Architecture

The design of the system architecture of the prototype disease surveillance system is presented in Figure 5. It was done in order to create a clear picture of the structure of the prototype system. The system architecture consists of three main components, namely: two (2) client side consisting of disease surveillance data collation alongside stakeholder components and a disease surveillance server-side.

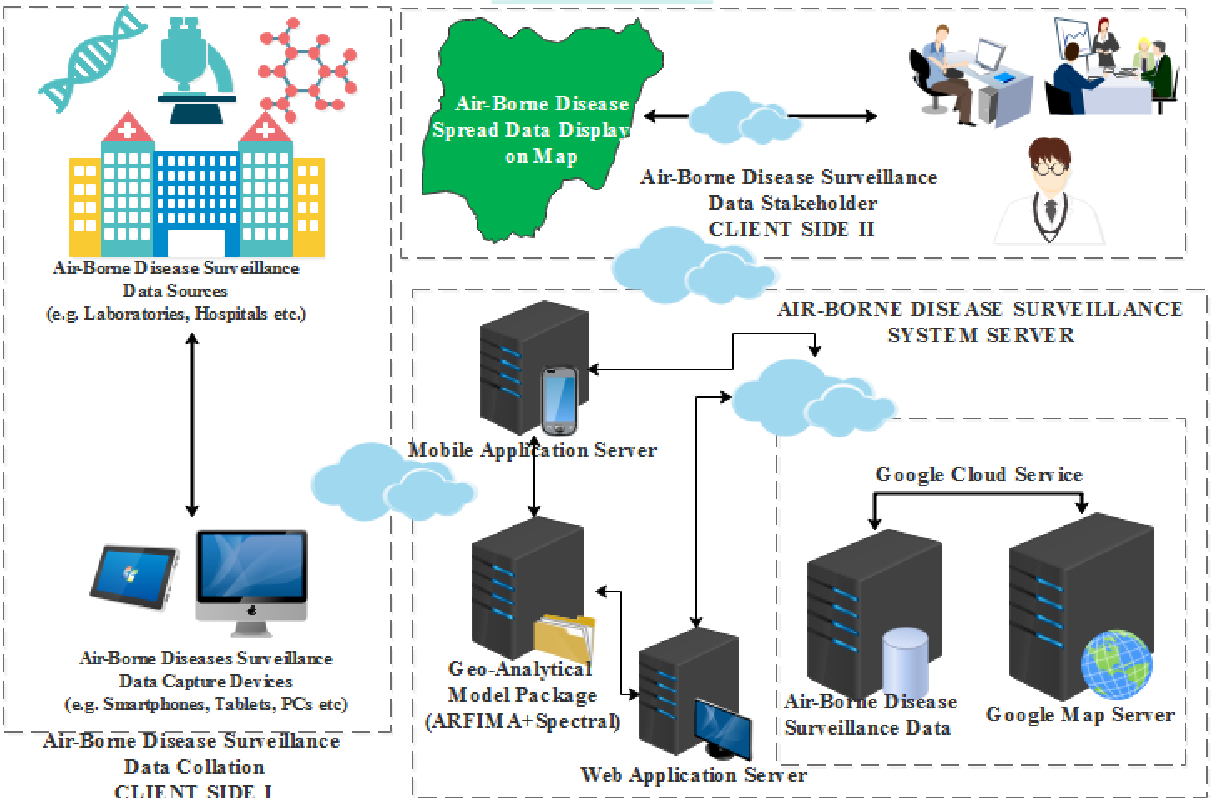

Fig. 5 System Architecture for the Air-Borne Disease Surveillance System

Within the data collation client side, the laboratories, public and private hospitals will be able to report disease outbreaks from their establishments using their mobile devices, PCs and laptops as long as there is Internet access irrespective of the type of device been used to communicate with the surveillance system. Information is transferred into the disease surveillance system through the disease surveillance data collation component. Information from the disease surveillance data collation component will be transmitted to the disease surveillance system server which consists of a Google Cloud Service portal which provided the cloud-based Google Map API for rendering digital mapping functions alongside a Google Firebase Platform for storing disease data from the mobile or web application server based on the type of device used be it mobile or PC.

The geo-analytical model package will be called whenever there was a need to make a forecast of the disease data stored in the Google cloud service which will be displayed as a spectral density of the spread of the diseases from point of outbreak using the Google Map API. Information stored and processed by the disease surveillance system server will then communicated to the disease surveillance data stakeholders (client side II) who were then able to access the information either stored or processed by the system server. On the Client side II of the architecture, the map of the country will be displayed on the interface of the user's device showing the respective view requested by the user, namely: tables, graphs, charts, maps etc.

REAL-TIME REPORTING AND FEEDBACK

This study will adopt the Google Firebase Cloud Service for the delivery of information in a real-time manner so as to facilitate prompt notification of newly reported cases of diseases. Following the process of reporting data from registered health facilities, the data stored will be collected by the server and will be sent to the cloud-based repository provided by Google Firebase. The data-as-a-service structure facilitates the storage of data from a local computer onto a cloud-based storage which can be accessed by any other system with privilege of information access. Once the device is offline, the last known data reported from the cloud server is made available pending update following the next access to the Internet. This process aids the prompt delivery of information from data sources thereby facilitating a real-time mechanism which updates the data stored on every device for the purpose of retrieval. Using the Google Cloud Service to store the disease surveillance data on the Firebase cloud infrastructure allowed the users to communicate with the system using either iOS, Android or Web devices for the easy retrieval and storage of data in a single repository thus facilitating real-time reporting and analysis.

Data modeling of disease surveillance systems

The data modeling process was an important aspect of the database design of the proposed disease surveillance system. It is the first step in database design and useful for many other purposes ranging from high level conceptual data models to physical data models. It allowed for the database design of the system to be easily visualized and showed how each data item are related alongside their presentation and processing of data using the UML class diagrams. These are static structure of the proposed disease surveillance system which described the abstract representation of the system by showing the classes, their attributes, operations (or methods), and the respective relationships existing between classes as shown in Figure 6. In the figure the different types of classes and the relationships that exist between the classes were presented in the conceptual data model for the proposed prototype disease surveillance system.

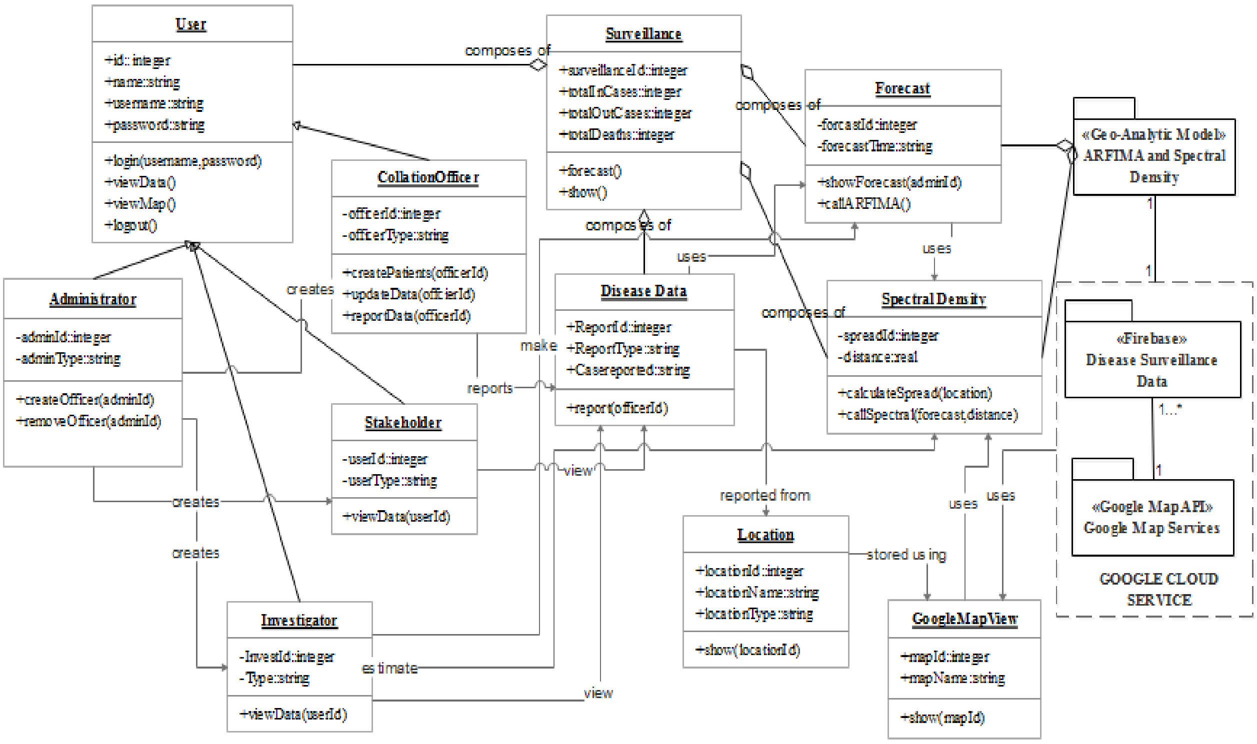

Fig. 6 The Conceptual Data Model of the Disease Surveillance System

There are classes that represent the users of the system e.g. system administrator who creates profiles for other users alongside other classes that store information of disease reported such as: location of outbreak, number of cases (or deaths) recorded per unit time, and other for making forecast of disease and for estimating the spread of diseases. Some classes were generalization of others such as the user class is a generalization of the system administrator, investigator, data collation officer and the stakeholder while the geo-analytic model was a generalization of the ARFIMA model for making future forecast and the spectral density function for estimating disease spread.

The relationships between classes was a way of specifying the logical connections between the classes described within the system. For some classes in the proposed system, dependency relationships were used to model the relationship since such classes depend on themselves to function such as the forecast which depended on the data stored about air-borne diseases, the view of the digital map which depended on the Google Map API, the spectral density function also depended on the results of the forecast made by the system. Also, it was observed that the surveillance system was composed on the surveillance class for storing disease reports, the user class for storing information about users, the forecast and the spectral classes for analyzing the data stored about diseases reported.

In addition, data model also presented the cardinality of the classes identified in the UML class diagram of the data model proposed for disease surveillance. As shown in the diagram, some classes have a one-to-one relationship such as: the geo-analytic model which can only have a single process for every session requested by a user (no user can handle more than a session at once), a disease occurrence can only be reported by a collation officer from only a particular location while some relationships are one-to-many such as: the surveillance data of disease been reported (analyzed) across various locations, each Google map view is the distribution of various report or a single Google Map session used to render multiple data stored on Firebase.

Disease Surveillance System Development Tools

For the purpose of the development of the disease surveillance system, a number of software development tools will be adopted for the development process. Some of the development tools proposed will be used for implementing the front-end while some will be used for implementing the back-end. Following is a description of the different development tools that will be used to implement the proposed surveillance system.

The Google Firebase API is a mobile and web storage environment which provides an environment for database storage and syncing data between android, iOS and web application in a seamless manner thus facilitating real-time capabilities. Data will be stored in the Google Firebase Platform using the JavaScript Object Notation (JSON) format derived from the initial SQL tables created for storing and managing disease data. JSON is an open standard format that uses human readable text to transmit data objects consisting of attribute–value pairs and array data types (or any other serializable value). Storing data using JSON within Firebase also facilitated prompt query of data compared the use of SQL tables.

The Google APIs is a set of application programming interfaces (APIs) developed by Google which allow communication with Google Services and their integration to other services. Using the Google Map API, it will be possible to embed Google Map into the surveillance system by using the data stored in Google's Firebase based on the reported data and the location stored. The Google Map API will be used used to capture information about the distribution of diseases across various locations based on their coordinates captured using the longitude and latitude values.

C# is a multi-paradigm programming language encompassing imperative declarative, functional, generic and object-oriented programming developed by Microsoft within its .NET initiative which will be used to implement the front-end of windows based devices. The Hypertext Markup Language (HTML) will be used alongside the Cascading Styling Sheets (CSS) to implement the front-end of the web-based devices interfaces which were ported into a Structured Query Language (SQL) database using PHP. The data stored in the SQL database will later transported to Google Firebase. The mobile application will be implemented using Java and extensible Markup Language (XML) via the Android Studio for providing functionality and layout required by the interface of the mobile application.

The mobile and web applications that will be developed will be hosted using a Cloud-based hosting service such that the application server was resident on the cloud. As a result of this, seamless access to the services of the disease surveillance system will be provided to the system users irrespective of the type of device the user was making use of. The R program will be used to develop the simulation required for developing and validating the ARFIMA models which will be required for forecasting the future spread of reported data and that of the spectral density function required for estimating the spread of disease from one location to another. This will be adopted as the business logic of the system which will connect to the mobile and web application server via the R online server whenever the need arises for making forecasts or estimating disease spread.

CONCLUSION

This paper has identified that a great number of human lives are been lost to communicable diseases across the globe and the availability of timely reports of outbreaks and epidemics of such diseases in developing nations like those in sub-Saharan is still a serious challenge. Tuberculosis was also discovered to be the new world's most communicable diseases that claim about 4500 lives per day. This has led to the need of developing a real time surveillance system which employs the use of cloud services for the storage, analysis and forecast of the spread of communicable diseases. Which alongside will integrate the geo analytic model proposed by (Amoo et al, 2021) thus providing a means by which the spread of communicable diseases can be analyzed from a point of outbreak to a neighboring locations. The study will assist in providing a means of using location-based information in combination with time to estimate the spread of communicable diseases to an exposed location from a point of reference. The real-time communicable diseases surveillance system which uses a geoanalytic model will provide a means via which communicable diseases data can be captured, stored, analyzed and accessed easily from a single cloud-based repository by a variety of computing devices ranging from PCs to smartphones thereby removing the gap facing accessibility to information by stakeholders.

Future Works

Future works in line with this study are focused at the implementation of the conceptual design of the real time surveillance system. The system will be implemented by integrating the geo-analytic model as the business logic of the web interface using Hypertext Markup Language (HTML), Pre-Hyper Processor (PHP), JavaScript and that of the mobile interface using Java, extensible Markup Language (XML) via Android Studio with both hosted on two separate cloud application servers. The Google Map® API for providing the digital map interface and Google's Firebase® Cloud Services for storing and accessing surveillance data in real-time. This study will contribute to knowledge by developing a real time system which employs the use of cloud services for the storage, analysis and forecast of the spread of communicable diseases.

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