10.31341/jios.46.1.12 UDC 004.77:654.165:615.12(669.1)
Open Access Original Scientific Paper

A Mobile Based Pharmacy Store Location-aware System

Bernard Ijesunor Akhigbe *bernard.akhigbe@uct.ac.za*
Department of Computer Science, University of Cape Town, Cape Town, South Africa, & Department of Computer Science & Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria

Oladele Joseph Ososanya *ososanyaoj@oauife.edu.ng*
Department of Computer Science & Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria

Emmanuel Ajayi Olajubu *emmolajubu@oauife.edu.ng*
Department of Computer Science & Engineering, Obafemi Awolowo University, Ile-Ife, Nigeria

Abstract

This paper presents a formulated mobile-based location-awareness model that was implemented into a Location-awareness System (L-aS hereafter) for finding the pharmacy location where prescribed drugs and their prices are available for sale. The scenario that inspired the model formulation was formalized using the unified modeling language. The model was implemented within the android studio integrated development environment with the L-aS database created through SQL lite database. The system was tested using user experience based testing technique. Based on core system performance testing, the system demonstrated a normal response time, resource utilization (i.e. storage and memory usage), and data use potentials of 414.6ms, 4.964mb and 1.9116 kb/secs, and 3.0296mb respectively. Therefore, the system performed well under ordinary conditions as an android application running on small memory devices. The study concluded that the developed mobile based pharmacy store location-aware system was useful to provide information to purchase prescribed drugs especially in perplexed situation(s).

Keywords: Location-aware system, location-based services haversine algorithm, performance evaluation, user experience, ICT

1. Introduction

The contribution of Information and Communication Technology (ICT) to human development in the modern world is unquantifiable. ICT has tremendously improved the ability of man to use environmental elements to influence what happens around them positively. In real-time, it is now possible to use ICT to make informed decisions that can avert danger and improve the quality of human life [1, 2]. As of now, the health sector has benefited immensely from ICT's use to assist in decision-making processes [51, 52]. During emergencies, medical doctors would usually prescribe drugs for quick intervention in patients' health. The de facto standard is to get the drug from the hospital's pharmacy [6, 14]. Patients will need to get the drug from a retail pharmacy store outside the hospital complex when this is not the case. A severe challenge emerges if the prescribed drugs are not readily available nearby. The only option is for patients to transverse several pharmacy stores without guaranteeing the availability of such drugs. This challenge may appear quite simple. However, this could often be cumbersome and energy-sapping for many patients if they have to go far to get the drug right at that moment in time. Cases of this nature are widespread in developing countries, often leading to morbidity [3, 4].

It is often the case to find patients with terminal diseases such as hypertension, diabetes, cancer, etc that for the rest of their life require the regular use of medications being victims of the circumstances thus described. Patients' health condition in this situation often develop complications when the drug(s) they need per time is either not available or when available; they are just hard to get. It could be disastrous - a consequence no one wishes to have - when patients have limited or no access to medication(s). This unavoidable constraint can result in premature death. The Internet - an ICT based solution-oriented technology, has been shown to improve healthcare accessibility and delivery to even remote areas seamlessly. However, in developing countries like Nigeria, it has not been explored to mitigate the challenge of uncertainty in seeking prescribed drugs, particularly in the case of an emergency. The growing and unprecedentedly large number of ICT-Internet savvy individuals (e.g., in Nigeria [22]) makes it overarching to embrace ICT-based solutions to mitigate uncertainty at the point of making a critical life decision, which must be right. It is no gainsaying that the citizens' standard of living of any nation on earth could improve through ICT-Internet-based technologies. These technologies are retrofittable with immense disruptive potentials to improve things [53]. As the world enters the post-COVID-19 Era, it is imperative, and now a matter of urgency, to seek ICT-based solutions to maintain social distancing and reduce physical contact.

This paper, therefore, considering the potentials of using ICT to benefit humans, formulated a model with computational properties that precisely determines the location of a pharmaceutical store. Information about the prices of drugs and the distance from where a patient is to the pharmacy store where prescribed drugs can be found and bought can be known by using the implemented system. This ICT-based solution could help users reduce the number of physical contacts they make before locating the exact pharmacy where drug purchases can be made. The possibility of using ICT based solutions to guide users in an uncertain situation has been reported in the literature [24]. However, the possibility of making less physical contact, which the new normal arising from the post-COVID 19 era demands [51] when using the reported system, was not addressed. This paper is structured as follows with the related literature found in Section 2, and the theoretical framework and conceptual model design presented in Section 3. The paper's methodology, result and analysis, and conclusion are in Sections 4, 5, and 6.

2. Related Literature

2.1. Location Aware System, Wireless Application Protocol, and Services

The literature is replete with studies on location awareness with a particular focus on wireless application protocol enabled mobile devices. As shown in Table 1, research efforts that include the Internet of Things (IoT), search engines, etc are part of these location-based studies. For instance, the pager system [5, 6, 9] is an old application that provides the method to address personnel location problems conventionally. To locate personnel from a central facility, signal(s) is sent out that address a precise receiver unit. The expectation is for a number to be displayed to which a recipient could reach the sender back. The requirement that may be necessary for other systems is the reception of vocal messages transmitted to a number to call back. It was also possible for recipients to call back using the conventional telephone system to confirm a signal and provide a suitable response. In game-based scenarios, some other research interests focused on enabling user interaction. This focus found relevance in the context-aware situation of storytelling and gaming, where contextual content was realised based on the state of an application and the user [7].

Location-awareness is not new in the gaming context [7, 53]. Game-based scenarios with commercial intention have applied multi-player network gaming strategies. These strategies allow players to exchange plays, engage other players as enemies, and simultaneously track each other within the same virtual space [53]. Shimadar et al. in [8] proposed a system that assists medical doctors in selecting the right first-line drugs. The system was specialist-centric and was not helpful for patient-centric prescriptions. In Mathkour [9], a service locator system that uses a GPS-based mobile support system allowed individuals to locate services of interest and their corresponding addresses irrespective of their profession. Worthy of note is that the system could determine the distance proximity between users and the desired locations where services are needed. The system was extendible and flexible in that with ease, additional mobile service providers that are new are easily incorporated. Compared to GPS-enabled devices that are not mobile-based, the service locator system demonstrated the provision of more accurate location computation.

In the research work of Bao and Jang [10], a medicine-based recommender system was designed and implemented. The system used a support vector machine technique that outperformed existing Neural networks and ID3 decision tree techniques. A good trade-off was observed among model accuracy, efficiency, and model scalability. The work also proposed a mistake-check mechanism that ensures accurate diagnosis and service quality. In a very closely related work, a haversine model was developed to discover the location of laundry kiosk(s). These kiosks are domestic service providers [11]. Similarly, Nurizal et al. [12] designed a haversine based model that finds the best route for urban transportation. In [11] and [12], the haversine technique was implemented such that using them to find the distance between a user and the nearest place when the need arises was not possible. However, in this paper, the focus is on determining the nearest distance between users of the L-aS and a pharmaceutical store where prescribed drug(s) can be purchased.

Some Research Effort in L-aS	Type of L-aS provided	Technique(s) Employed	Other Contributions	Comment	Cite
IoT-Aware System for the Monitoring of the elderly	Support geriatricians for the early detection of Mild Cognitive Impairment & Frailty conditions	**RDA** and other ensemble of statistical, knowledge engineering and **MLA**	System Architecture; Personal Data Capturing System; performance analysis	**L-aSs** is useful for emergency situation by providing location information regarding Distance & other Con-textual In-formation	[16]
Sensing Architecture that use IoT-Aware Technologies	Analyze the Elderly's Behaviour unobtrusively & prevent mild cognitive impair-ment and frailty problems	Inertial sensors; **PDA**; wearable device/ user's smartphone; **BLE** devices	**SPM**; Sensing Architecture		[17]
Location-aware Outpatient Support using Mobile App	Examined factors that influence the willingness of counsellors to use location -aware services for outpatient support	Survey Methodology	Examined location-based reminders; identified factors of influence	Gave knowledge about factors that influence Acceptance	[18]
Circle Distance Model for Locations on non-Flat Surfaces	Determine the distance b/w two locations on a non-flat surface for determining **c**losest location	Researched with Haversine Algorithm	Graphical visua lization of Calculated Distances	Gave insight on the use of longitude and latitude for determining locations	[19]
A Search Engine Location-Aware System	Location-Aware Information Detection & Extraction from web pages	Rule-based Algorithm that Uses web page Structures	Framework with **L-A** ability; **T-MA**; Identified components for building **L-ASE** to **D&ELI**	Inspires implementation of framework	[20]

NOTE: L-aS (Location-aware System); **WAP** (Wireless Application Protocol); **IoT** (Internet of Things); **RDA** (Risk Detection Algorithms); **MLA** (Machine Learning Algorithms); **PDA** (Position Detection Algorithm); **BLE** (Bluetooth Low Energy); **SPM** (Stability Period Mechanism); **L-A** (Location-Aware); **T-MA** (Text-Matching Algorithm); **L-ASE** (Location-Aware Search Engine); **D&ELI** (Detect and Extract Location Information); **L-ASs** (Location-Aware Systems)

Table 1. Summary of other research efforts in L-aS aside from the use of WAP

Generally, mobile computing comes with the challenge of maintaining the awareness of locations [53]. Location awareness is thus an irrefutable attribute. Among many studies in the literature regarding location awareness, no known study has combined location findings with the availability of drugs in the database to help patients become aware of where drugs are available. This study fills this gap using the haversine technique to assist patients (i.e. users) to know whether a particular drug is available in a pharmaceutical store. Information about the cost of the drug(s) a user needs and the distance between the user's location and the pharmacy where the drug(s) are available for purchase is provided by the proposed LaS before the user ventures out. In case of emergency, patients or their relation(s) will not need to figure out by themselves the pharmacy store within their locality that has the drugs they need. With the use of the LaS, users will not need to rigmarole from one pharmacy store to another in search of drugs. The distance provided by LaS to users will help them know exactly where to go and make their drug purchases, and they are also able to make decisions in terms of drug prices. In emergencies, the chances are that the farthest pharmaceutical store in terms of distance sells in prices that fit people's budgets. In this case, an informed decision can be made to buy in the closest pharmacy store as a trade-off for saving a life. This study provides an easy and convenient method to drug accessibility by patients, which is very germane in healthcare delivery [13].

2.2. Shortest Path Computation and Functional and non-Functional Requirements

The haversine algorithm has shown promise in finding the shortest path among several routes for location-aware guidance. In Mahmoud & Akkari [21], user location served as a yardstick to suggest the nearest location based on this algorithm. Other similar research (e.g., [23], [24], and [25]) show that the provision of accurate location information, judging by a significant reduction in navigation time, is hinged on two essential parameters - latitude and longitude coordinates - in the algorithm. Based on a Desk-based Literature Search (DLS), existing L-aS are implemented based on either functional or non-functional requirements. There are also instances where a mix of both requirements are known to guide the implementation of L-aS (e.g. [26, 27, 28]. Available in Table 2 is a summary of the DLS findings concerning the functional and non-functional requirements that guided the development of L-aS in the literature. The DLS findings conclude that the goal of an L-aS (is what) determines the functional and non-functional requirements that guide its development. Some of the literature search findings also show that the primary goal-oriented purposes of L-aS include using location-based data within a time frame to locate nearby facilities where services are available. The other found design goals were the conduction of route search, the provision of trail experiences, sharing location-based information within a social network, enabling shoppers to re-discover their proximities to what they want, etc [19, 24].

In order to satisfy L-aS goal-oriented purpose, the concept of valence has been relevant. This concept is a novel way of abstracting and fusing functional and non-functional requirements to enhance the service delivery and performance of L-aS [28, 29]. In Philips et al. [30], this practice was used to enhance the performance of an outpatient L-aS. Similarly, in Yew et al. [24], the functionalities to help search and record experience were critical components of the proposed L-aS. Users' experiences going by their report showed heritage and tourism trail experiences and serendipity were supported. Route search by calculating distances to suggest the shortest path between two locations has been of high priority, along with the provision of visualisation experiences in L-aS. These functional considerations provided the support users needed to figure out distances on non-flat surfaces, as shown in the research work of Prasetya et al. [19]. Recent debates in the literature are about the knowledge and understanding that valence of requirements is necessary to implement important system features in L-aS [28, 29]. Therefore, to enhance the performance and service delivery of l-aS that met the user experience needs of users, non-functional requirements such as engagement, usability, privacy, positive appeal, user experiences and satisfaction, and trustworthiness assessment have been considered in the literature [24, 28, 29, 30].

Identified Require - ments	Delineations	FR	n-FR	Citation					
				[43]	[40]	[44, 45, 20]	[46]	[47, 48, 49, 50]	[30]
Location and Time-Awareness	Signify the Possibility of Collecting Location Data, which is Time Bound	✓	✕	✕	✓	✕	✕	✕	✕
Modular System Design	Systematic approach to develop modules that are application-independent with tasks functionality that provides easy solution-pattern that are adaptable	✓	✕	✕	✕	✕	✕	✓	✕
Relevant Location Informati on	L-aS use this Information to adapt itself to Learn/be Aware of other Information	✕	✓	✓	✓	✕	✕	✕	✕
Scalability	It is about adding more data and improving database easily	✕	✓	✕	✓	✕	✕	✕	✕
Location PLan	This is information about nearby facilities or services	✕	✓	✓	✕	✕	✕	✕	✕
Contextua l Informati on	From this information; (i) entities associated to locations are easily identified; (ii) lead to new/additional facts and knowledge; and (iii) present more information to users' vis-à-vis their current position and location	✓	✓	✕	✕	✓	✕	✕	✕
Service Accessibili ty	Reveals if **L-aS** is easily available with **QoS** with profit provisioning service metrics	✕	✓	✕	✕	✕	✓	✕	✕
Usability	**L-aS** is Fit to use when personalization, search, location-&-orientation-aware services, location accuracy, portability, response time are present	✕	✓	✕	✕	✕	✕	✓	✕
Valence	(i) Is about the use of performance metrics - engagement, usability, privacy, cost to find positive intrinsic appeal to L-aS and (ii) it is also about ease of use, system usefulness, ease of understanding, trustworthy assessment	✕	✓	✕	✕	✕	✕	✕	✓

FR (Functional Requirement); **n-FR** (non-Functional Requirement); **L-aS** (Location-aware System); **QoS** (Quality of Service)

Table 2: Summary of identified functional and non-functional requirements that has informed L-aS development

The justification for using a mix of functional and non-functional requirements stems from the finding that performance in terms of how systems meet their users' information needs depends on the technical part of the system and how users value or perceive the system. A balance of these aspects of performance is needed. As enshrined in the literature, in this paper, a combination (i.e., a mix or a valence) of requirements - functional and non-functional - were considered during system implementation [24, 28, 29, 30]. Consistent with the valence concept, the first functional requirement to adopt was location specificity using distance as a determinant to make it functional to use users' mobile phone functionalities. For the second functional requirement - system interaction, the non-compromising of mobility was considered necessary, among other conceptions. This characterisation frame the context of implementation that aimed to promote the easy adoption of the prototype system.

In order to complete the valence criteria, two non-functional requirements - portability and response time- were also considered. It was observed that the locals in the study area use mobile phones. This usage context implied that mobility was a primary concern to the locals. This understanding invariably shows that portability was a non-functional requirement to consider. Secondly, information about the location(s) where drugs are available for purchase was essential in light of the goal of the L-aS. As such, the location information must be displayed as promptly as possible with a very short (or fast) display rate. This attribute was considered critical because users do not have to spend hours finding the nearest distance (or the shortest part) to where drug purchases can be made when using the prototype L-aS. This consideration made this research work consistent with the general philosophy of L-aS that highlights response time in terms of fast display rate. This metric is thus essential to characterise the performance of L-aS systems and determine their value.

3. Theoretical Framework and Conceptual Model Design

This section presents the frameworks, both theoretical and conceptual that guided the model design, as shown in subsections 3.1 and 3.2 respectively.

3.1. The Theoretical Framework

The model uses Haversine (H_θ) formula to compute the shortest path between point A and point B on a sphere using latitude and longitude along the surface [11. 19]. The H_θ is expressed as trigonometric function:

$$H_\theta = \mathrm{Sin}^2\left(\frac{\theta}{2}\right) \tag{1}$$

The H_θ of the central angle dr is calculated by

$$dr = H_\theta\ ((\beta_2 - \beta_1) + \mathrm{Cos}(\theta_1)(\mathrm{Cos}\theta_2)H_\theta(\varphi_2 - \varphi_1) \tag{2}$$

Where H_θ is the haversine, r is the radius of the earth approximately 6371 Km, d is the distance between two pointsβ_1 and β_2 and latitude of the two points φ_1 and φ_2. Applying the inverse of sine function, then

$$d = rhav^{-1}(h) = 2r\sin^{-1}(\sqrt{h}) \tag{3}$$

The haversine computation may not give accurate distance due to the fact that the earth is not a perfect sphere. But, the estimate it gives is very useful for this application. The difference between the real value and the estimate is very negligible, therefore it was ignored in the computation of the distance. It was also observed that the ratio of the variation is not constant. This depends on the distance and some other factors, which is not part of this work. In this paper, the angle used by haversine algorithms comes from the position on latitude and longitude which is θandφ respectively. This latitude are lines that run from west to the east and are parallel to the equator while longitudes are parallel to the prime meridians and converged at the pole. It was important to clarify this, since latitude increases from 0^0 to 90^0 as movement goes to the north or south, and then since they are also the instruments that help to determine the precise location of any point on the earth's surface, which this paper leverages.

3.2. The Conceptual Model Design

The conceptual design of the system assumes that all the Pharmaceutical stores that are available are currently connected into the Internet and that their products are digitized and stored in the database, which is connected to the Internet. This design is presented as shown in Figure 1 as follows.

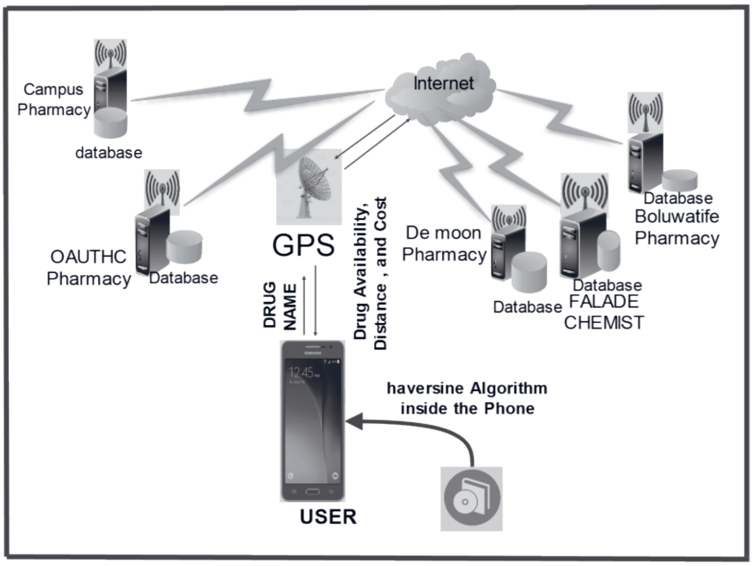


Figure 1. System Architecture

The system design used five pharmaceutical stores that are located within the study area - Ile-Ife and their position on the Latitude and Longitude as presented in Table 3. Each of the stores is expected to be connected to the Internet. All the pharmaceutical products in each store are expected to be digitized and stored in a database connected to the Internet. The haversine algorithm was developed using the haversine theoretic.

This theoretic has earlier been presented as a theoretical framework (see equations 1 – 3 above). It is this formalisation that was transformed into the android-based prototype application - L-aS. The application in a smart phone will get connected to the Internet through the Global Positioning System (GPS). Search will be possible to the database of the connected stores as shown in Figure 1 to provide information to the end users. If the medicine required by the end user is available in any of the store, the application will list the stores chronologically using the distance to the end user. The price of the product in each of the store and the distance to the user are provided for the user to make informed decision. This application solves the problem of running here and there when patients are in dare need of medicine for survival.

Name	**Latitude**	**Longitude**
Campus Pharmacy	7.50669	4.56974
OAUTH Pharmacy	7.51854	4.52089
De moon Pharmacy	7.50078	4.5716
Falade Chemist	7.49249	4.55778
Boluwatife Pharamacy	7.5009	4.54998

Table 3. Latitude and Longitude of the Pharmacy Stores

4. Methodology

4.1. Haversine Model Formulation and Use

Whenever a user wants to check pharmacy locations, the haversine algorithm is called as a function to calculate the current (or new) position of the user and compares it with the location of the pharmacies where prescribed drugs are available. The algorithm, which performs the haversine function is as shown in Algorithm 1. It computes the shortest distance using the latitude and longitude parameters in Table 3.

Algorithm 1: Outline of procedure to use CDD

```
function:
      haversineGreatCircleDistance ($latitudeFrom,
      $longitudeFrom, $latitudeTo,
      $longitudeTo, $earthRadius = 6371000)
        {
          convert from degrees to radians
            $latFrom = deg2rad(floatval($latitudeFrom));
            $lonFrom = deg2rad(floatval($longitudeFrom));
            $latTo = deg2rad(floatval($latitudeTo));
            $lonTo = deg2rad(floatval($longitudeTo));
            $latDelta = $latTo - $latFrom;
            $lonDelta = $lonTo - $lonFrom;
          apply Haversine formula
```

```
        $angle = 2 * asin(sqrt(pow(sin($latDelta / 2), 2) +
        cos($latFrom) * cos($latTo) * pow(sin($lonDelta /2),
        2)));
    convert result to kilometre
        $result = (($angle * $earthRadius) / 1000);
    return the result of the haversine algorithm
        return round($result, 2);
}
```

* **CDD** (Coordinates to Determine Distance)

For better result, every time the system receives a GPS update from a user location the technique outlined in Algorithm 2 is called. As a result, distance, pharmacy latitude, and pharmacy longitude variables are called persistently by this method. With this arrived at, it was necessary to implement location awareness and the technique in Algorithm (procedure) 3 made this possible.

Algorithm 2: Outline of update procedure to use raw GPS data

```
UpdateDistance (lat, lon):
    if current_lat != null &&current_lon != null:
            distance += haversine (pharmacy_lat,
            pharmacy_lon, current_lat, current_lon)
        current_lat = lat
      current _lon = lon
```

Algorithm 3: LA procedure to determine the location of a user and PS

```
'/Location awareness
    function watchLocation (successCallback, errorCallback)
        {
            successCallback = successCallback || function(){};
            errorCallback = errorCallback || function(){};
    Get geolocation.
            var geolocation = navigator.geolocation;
                if (geolocation) {
    Check for a real geolocation service.
            try {
                function handleSuccess(position) {
                successCallback(position.coords);      }
                geolocation.watchPosition(handleSuccess, errorCallback, {
                enableHighAccuracy: true,
                maximumAge: 0, // 5 sec.
                timeout: 10000
                });
     Report error in getting location
                } catch (err) {
                    errorCallback();    }
                } else {
                    errorCallback(); }
    Co-ordinates detected (latitude and longitude)
```

```
                function init() {
                    watchLocation(function(coords) {
            document.getElementById('latitude').value = coords.latitude;
        document.getElementById('longitude').value = coords.longitude;
                }}, function() {
        init();}
```

***LA** (Location Awareness); ****PS** (Pharmacy Store)

The mobile-based pharmacy store L-aS is named "Pharmfinder". It was developed to reduce the stress of users/customers going to several pharmacy stores before getting to know a particular pharmacy store where the prescribed/required drug is available. The system is meant to tell the user if a particular drug is available, which pharmacy has such drug and the closest pharmacy to the current location of the user. The steps to follow for a customer using the proposed system are as follows:

(i) The user must ensure location icon is turned on before launching the application
(ii) Type or Key-in the drug name into the textbox and click on search
(iii) A list of related drugs, prices and pharmacy stores are shown and the user checks which one is preferable
(iv) The user now gets direction to the selected pharmacy.

The system administrator follows the following steps to register/add a pharmaceutical store:

(i) Open the Pharmfinder application
(ii) Select switch app to Administrator
(iii) Username and password based on the registration from the superadmin is entered
(iv) The drugs, prices and description can then be added to the application by the administrator.

The opening user interface developed for the registration of a pharmaceutical store is shown in Figure 2 as follows:

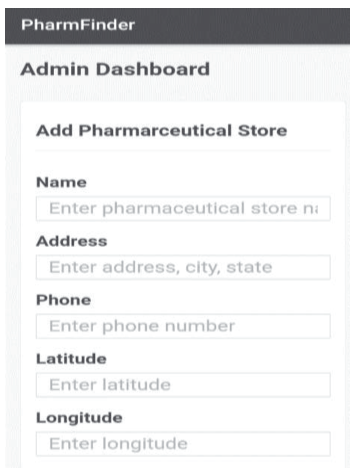


Figure 2. Opening page for super-admin to register interested pharmacies

4.2. System Implementation

The Knowledge of the type of phones those in the study area (i.e. locals) uses was important. This informed the choice of android base smart phone technology for the system implementation. Both functional and non-functional software requirements provided the foundation for the prototype development of the L-aS. The non-functional requirements provided support in the area of ensuring that quality assurance as a service-based system requirement was met. These non-functional software requirements served as constraint (or quality) attributes following the operations of the system to gauge its success as perceived by its users. This decision is consistent with the provisions in the literature [31, 32, 33] that the use of functional and non-functional requirements guarantees the success of the L-aS. In Table 2 functional and non-functional requirements were identified with the caveat that the non-functional requirements that is adopted depends on the functional requirement or the goal of the system in question. To this end non-functional requirements that portends location, usability and users valence towards the use of the L-aS (hereafter used interchangeably with PharmFinder) were enforced.

Based on the requirements proposed earlier, a resultant user friendly mobile application (app) with versatile functionality was developed in Java with a sample user interface of the system shown in Figure 3. The backend was set up following the practice in [34] and [35] that support the use of real-time Database (Db). Therefore, the My Sequential Query Language (MySQL), which is a real-time Db and suitable for location-based technologies were used to setup the backend of the prototype L-aS. This made it practicable to cloud-host the backend database for remote location and synchronised real-time connection to client - user interaction.

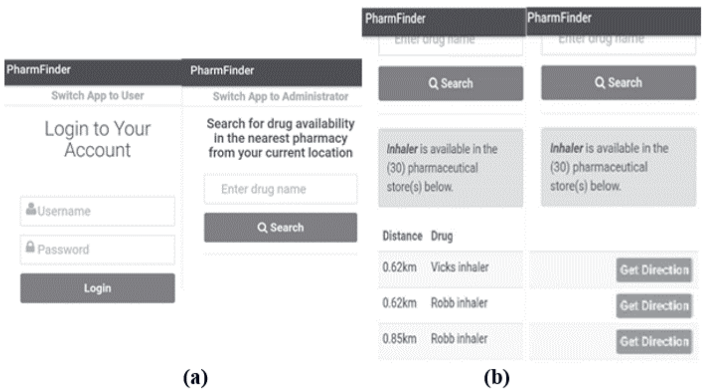
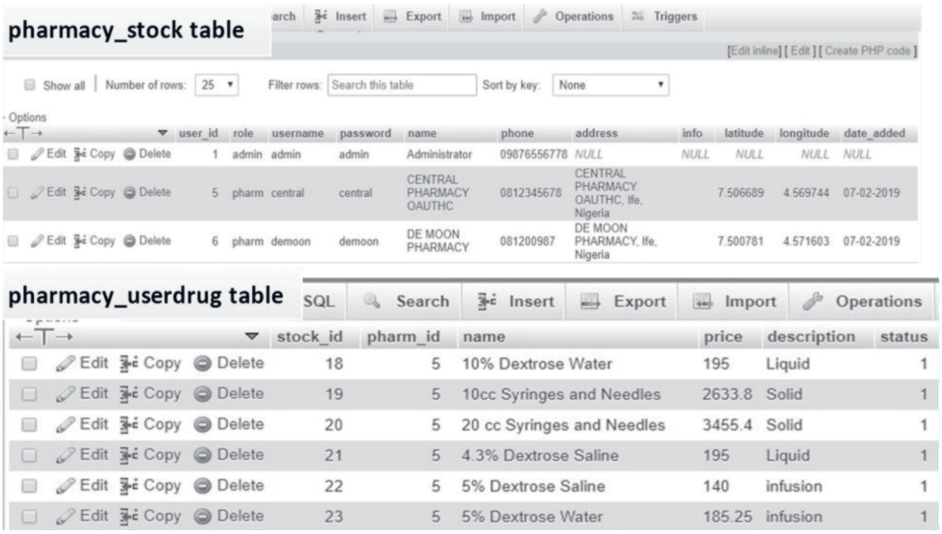


Figure 3. Developed interface to interact with the mobile app (i.e. PharmFinder)

Purposefully, when users of the L-aS sign-up, they receive unique user ID. This made it easy to store and retrieve the data that belongs to specific users. Every pharmacy's latitude and longitude along with their names, and address were collected, and the database of the prototype system was designed to be updated regularly with what is available in a particular pharmacy. The backend view of the proposed system is that of a database created using MySQL. The database contains two tables which are the pharmacy_stock table and the pharmacy_user_drug table (see Snippet in Figure 4). In the pharmacy_stock table, what is found is the stock_id, pharm_id, drug_name, drug_price, drug description – the status and the date added. Additionally, the pharmacy_users table contains user_id, role, username, password, pharmacy_name, phone_no, address, longitude, latitude and date_added. While the pharmacy_stock table shows the details for each pharmacy such as pharmacy names and location through addresses, the pharmacy_userdrug table shows all kind of drugs in a pharmacy. The database was hosted in the cloud for the purpose of the experiment and for future use and support for all access from remote location. The prototype system used the Internet for testing and to show its workability.



pharmacy_stock table

user_id	role	username	password	name	phone	address	info	latitude	longitude	date_added
1	admin	admin	admin	Administrator	09876556778	NULL	NULL	NULL	NULL	NULL
5	pharm	central	central	CENTRAL PHARMACY OAUTHC	0812345678	CENTRAL PHARMACY OAUTHC, Ife, Nigeria		7.506689	4.569744	07-02-2019
6	pharm	demoon	demoon	DE MOON PHARMACY	081200987	DE MOON PHARMACY, Ife, Nigeria		7.500781	4.571603	07-02-2019

pharmacy_userdrug table

stock_id	pharm_id	name	price	description	status
18	5	10% Dextrose Water	195	Liquid	1
19	5	10cc Syringes and Needles	2633.8	Solid	1
20	5	20 cc Syringes and Needles	3455.4	Solid	1
21	5	4.3% Dextrose Saline	195	Liquid	1
22	5	5% Dextrose Saline	140	infusion	1
23	5	5% Dextrose Water	185.25	infusion	1

Figure 4: Snippet of pharmacy stock and user_drug tables

4.3. Experimentation

Going by the literature [39], when systems behavior is observed in practical sense (i.e. scenario) that is when the reliability of a system in terms of expected service delivery can truly be justified. To comply with this the experimental setup for the system operation in subsection 4.3.1, the user experience testing in subsection 4.3.2, and performance evaluation in subsection 4.3.3 are presented as follows.

4.3.1. System's Operation

To set up the experiment a smart phone with android version 2.3.4 as the minimum requirement though was provided and used. The android operating system was chosen for the experiment since the majority of the locals use android-based phones. This was why Android Studio integrated development environment was set up and used for the experiment. A public server within the university hosted the database that the android phone with GPS enabled functions interacted with. This experiment was performed on an android phone, which version was stated earlier with the experimental app written in Java (i.e. the mobile app. stated earlier) and developed for the android mobile phone operating system, which version is sate above. In this process, the haversine implemented in the app (i.e. PharmFinder) was applied to perform its function of distance calculation using parameters from the Db. This process successfully simulated the processes captured in the system architecture shown in Figure 1. The second part of the experiment was the testing to ensure that more than one user can use the technology. This is explained in the next subsection under user experience testing.

4.3.2. User Experience Testing

The User Experience Testing (UET) was carried out on the prototype system - PharmFinder. The UET involved randomly selected users who have used at least a mobile app before. They were drawn from among locals in Ile-Ife - a town in Nigeria that was adopted as the pilot study location. Armed with the questionnaire as a fact-finding technique, users' views of the system after use were elicitated. This questionnaire was vetted by experts in the Department where the research was conducted and then hosted using Google form (G-form) for easy accessibility. The question in the hosted questionnaire was drawn from non-functional requirements to ascertain the quality of the system. System quality was delineated for the purpose of this evaluation as a system that assists users to find the location of drug availability. This was done to ensure that the user experience of users; that is their perceptions and responses, which resulted from their use of the system deliver the required services as prescribed in [36]. A total of eighty four (84) end users partook in the UET exercise. The 84 end-users installed the Pharm-Finder prototype system on their mobile phones from the local but public server facility stated earlier in subsection 4.3.1. A-five point Likert scale of Strongly Agree (SA), Agree (A), Indifferent (I), Disagree (D) and Strongly Disagree (SD) with Likert points of 5, 4, 3, 2 and 1 respectively was engaged to present the question for rating. After using the prototype system (i.e. mobile app), the users were ask to fill the G-form, from which data was collected for the UET.

4.3.3. System Performance

To test the system performance two performance metrics: Response Time (ResTm) and System Resources Usage (SRU) were used as the performance indicators. These were system-based metrics. They were meant to show that the prototype system gave standard users' experience in terms of the amount of data that the system can process within a unit of time and show the extent to which the system will use available system resources. This approach is consistent with what is obtained in the literature [37, 38]. This is because as performance metrics, accurate description of end user's experience during system use can be proven [37, 38] through ResTm and SRU. This was possible using JMeter since its use minimised some inevitable effects. Many factors such as system reliability, user requirement and available capacity could have affected

ResTm. Therefore, ResTm was tested with SRU with available capacity and system resources (i.e. memory, data and storage usage) in mind. PharmFinder was installed on five different Android phones and ResTm and SRU of the system were observed based on the usage of system resources.

5. Result and Analysis

The existing drug purchase scenario described at the inception of this paper is fraught with uncertainty as captured in the formalism presented using the sequence diagram of the unified modeling language shown in Figure 5. This formalism highlights both the challenge of uncertainty that locals face regularly and the proposed solution and contribution of this research work. The solution is shown within the broken lines highlighted in red, which is the development of a prototype system - called PharmFinder – that helps users in uncertain situation. With the prototype system on their mobile phone it was possible to know the number of pharmacies in their locality with the drugs that are available for sale.

As shown in Figure 3b earlier, the prototype system was able to show the list of distances in terms of Kilometers (Km) and the drug(s) that are available after login in and using the system. By this the location in terms of distance between the pharmacies and users' location are known. The other location-awareness information that is available is the direction to the pharmacy where the drugs are available using the Get Direction button. This implementation was guided by the philosophy that uncertainty as a non-deterministic phenomenon will fizzle out in the face of knowledge (or information).

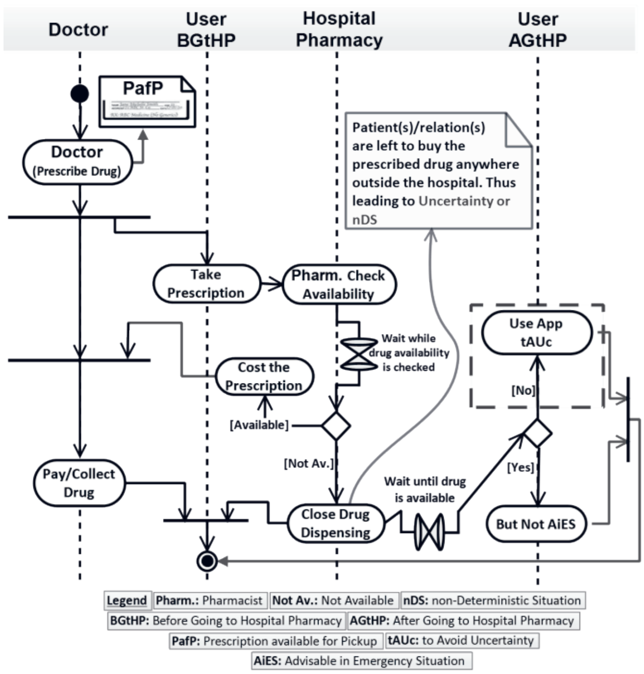


Figure 5. Reworked procedure of existing drug purchase

Hence, with these relevant information users' uncertainty particularly in emergency situation were mitigated based on results from user experience testing. In non-emergency situations the prototype system was also found to be useful. Users' time and money were saved. The usual wear and tear locals pointlessly experience when left guessing about where to find prescribed drug to buy was also mitigated, which is consistent with findings from the research effort in Phillips et al. [18]. Of particular interest is the technical capabilities offered by the proposed L-aS and the operational context provided by locals' mobile phones as was the case also in [18]. This synergy leveraged the context of users' location(s) to provide the support needed for an L-aS to serve interested local users.

Users' willingness to utilise the technical capabilities, which the system offered was significant. The lack of a priori information, as was the case with the participants (i.e. locals) in the context of this study highlighted this significance in that the tendency to blindly attempt to locate the right pharmacy, which was always the norm was solved by using the developed system. This meant that in the case of emergency, when a particular drug is needed to save a life; if the drug is not available in the hospitals pharmacy, the first idea is no longer to go round existing pharmacies outside the hospital based on guesses. This feeling of speculation based on wild guesses was often frustrating and like other L-aS [24], the developed system was found to mitigate (if not remove) the feeling as shown in the test run case report. It was found also that users were able to engage the developed prototype system after installing it on their android mobile phone through the user interface in Figure 3a. Based on usages experiences the test case result in Figure 6 shows the responses of users who participated in the UET of PharmFinder.

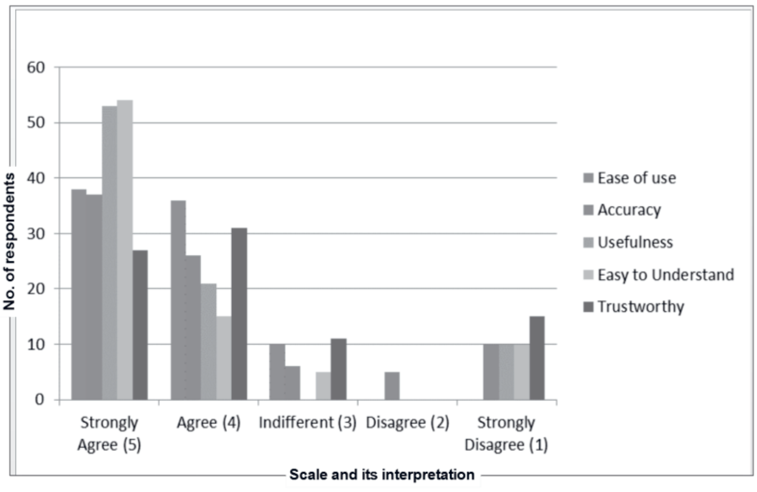


Figure 6. Test case result based on locals usage experiences

In comparison to what obtains in the literature, the level of accuracy the prototype displayed affirms the findings in [19] and [24] that L-aS can provide accurate information about location(s) and the direction to such locations(s). The result in

Figure 6 clarifies this by the number of users of the prototype system who strongly agree and agreed that the prototype system's location accuracy was okay. This number is unarguably more than those who were indifferent as well as strongly disagreed. This implied that the haversine technique used was rightly applied as demonstrated in [24].

The accuracy of recommendation based on distance calculation was a keen interest. This criterion showed that distance recommendation is necessary, when the real location of points must be determined. For the L-aS prototype (i.e. PharmFinder) users of the prototype app were able to locate the exact pharmacy to make drug purchase. As an important functional requirement, this was met in the proposed prototype system going by users' validation, which is consistent with the assertion in [20] and [21] that L-aS accuracy criterion must be met. There are other Subjective non-functional Criteria (SnC) that showed the prototype system as a valid tool to help users transcend the experience of serendipity in their quest to locate the exact pharmacy where to find drugs. These SnC are ease of use, usefulness, ease of understanding, and trustworthiness. From the result in Figure 6, more users agreed and strongly agreed that L-aS is easy to use. Accordingly, system usefulness was also rated by more users who strongly agreed and agree that L-aS is useful in detecting pharmacy proximity. Similarly, the number of users of the prototype system who strongly agreed as well as agreed that the system is easy to understand were more too. This implied that the L-aS was not too complex for users to understand and engage.

The number of users who "Strongly Agreed" and "Agreed" that the system is trustworthy going by the result in Figure 6 is in agreement with the findings in [41, 42] that the criterion of trustworthiness is important in determining the usefulness of L-aS to users. This validated the question of the fact that L-aSs are trustworthy. Intentionally, the trustworthiness criterion was meant to find out if the prototype system would help locals overcome the fear of uncertainty. Before launching the prototype system locals would go to pharmacies only hoping to find the drug they want by chance. But, with the prototype system this changed according to users' assessment. Based on the result in Figure 6, PharmFinder assisted users in finding the drug they want at the nearest pharmacy location displayed to them by the app. It was interesting to know that this made users to earn the trust of PharmFinder since it helped users to transcend from serendipity into certainty when the need arose to patronize the pharmacy.

Aside from users' attesting to the usefulness of the prototype system based on the summarized results in Figure 6, the results in Tables 4 and 5 also corroborated it by showing the technical usefulness of the system. Two performance metrics - ResTm and SRU were employed to show that the developed prototype system would perform well with guaranteed user experience (i.e. user satisfaction). By implication the average amount of memory usage by the system over a period of time going by the result in Table 5 was 1.9116 kb /sec. Based on the interpretation provided in Table 4, this implies that user satisfaction from using the system was guaranteed.

6. Conclusion

This paper presented a location awareness system that provided pharmacy location based services. The system is a prototype Mobile-based Pharmacy Store.

Response Time (in seconds)	Interpretation	Comment
0.1	-Most preferred response time	-Signifies that a System is working as Expected
1.0	-The maximum limit of a response time	-Any response time > 1.0secs but < 5.0secs shows user experience is guaranteed
Between 0.1 & 1.0	- Maximum user satisfaction	- User satisfaction guaranteed
10	- Maximum limit after which response time goes beyond acceptable limit	- Users are likely going to abandon the system when response time > 5secs

Table 4. Response time and interpretation

S/N	Android Specification	Android Version	Average Response Time (*in milliseconds*)	**Storage** (*in Megabyte*), **Data** (*in Megabyte*) & **Memory usage** (*in Kilobytes/seconds*)	
1.	Infinix Hot5	7.0	421	Storage: Data usage: Memory:	4.87 4.92 1.544
2.	Techno Wx3p	7.0	382	Storage: Data usage: Memory:	4.14 0.568 0.778
3.	Motorola X8	4.44	352	Storage: Data usage: Memory:	3.75 3.55 0.244
4.	Infinix X510	5.1	449	Storage: Data usage: Memory:	6.11 0.380 0.1122
5.	ZTEE 7L Tablet	5.1	469	Storage: Data usage: Memory:	5.95 5.73 6.88
Average Total			414.6	Average Storage Used: Average Data: Average Memory Usage:	4.964 3.0296 1.9116

Table 5. Performance evaluation result of prototype system

Location-aware System. An architecture-based approach guided its implementation such that as an ICT – based system users were able to use it on their smart phone devices. The techniques - algorithms applied and the results from user-based evaluation and performance assessment showed that the system was capable of giving standard user experience to users when they use the system. This is consistent with the belief that Mobile applications should seek to facilitate the resolution of paradoxical experiences. For example, users should not lose it or themselves, particularly when they are unable to find their way in a situation where prior knowledge could have been of utmost assistance. Based on Yew's et al. [24] postulation this type of experience is paradoxical. The solution is to deploy a system that has the potential to provide up-to-date information on the go as demonstrated in [18, 24, 40]. The developed system presented in this paper was able to provide appropriate location information, and thus performed the role of a guide assistance. It can be concluded that the system satisfied the requirement of stepping in to intervene when users' needed direction and certain level of information about the nearest pharmacy where prescribed drug(s) is available and as such helped users to rise from serendipity into certainty. The performance testing carried out as a critical task to determine if a software system can provide users with optimal experience when used showed that the prototype system gave commendable user experience when deployed. For future work, effort will be made to (i) work on the system to become an app that is downloadable from Google play store to assist users find exact pharmacies where prescribed drugs are available in a locality, (ii) upgrade the user and pharmacies geographical positioning system automatically when both move to new location, to help continue to map and do purposeful tracking, (iii) make sure that more pharmacies are involved in the project to help prevent a situation where prescribed drugs are not available when the system is in use, (iv) consider drug inventory that was not possible now because of trust and other related issues from the owners of the pharmacy stores.

Acknowledgements

The authors of this paper acknowledge the following institution for their support in seeing this paper through. Firstly, the Africa Centre of Excellence in Software Engineering and Obafemi Awolowo University, Ile-Ife, Nigeria, is acknowledged for providing the space to start the research work that resulted in this publication. Secondly, I acknowledge that Hasso Plattner Institute's (HPI) financial support for Digital Engineering through the HPI Research School at UCT, Cape Town, South Africa, made a considerable difference. The completion and submission of the work took place after arriving for a Postdoctoral fellowship at the University of Cape Town, Cape Town, South Africa.

References

[1] Lipovina-Božović, M., Kašćelan, L., & Kašćelan, V. (2019). A Support Vector Machine approach for predicting progress toward environmental sustainability from information and communication technology and human development. Environmental and Ecological Statistics, 26(3), 259-286.

[2] Senthilkumar, M., Gnanasundar, D., Mohapatra, B., Jain, A. K., Nagar, A., & Parchure, P. K. (2020). Earthquake prediction from high frequency groundwater level data: A case study from Gujarat, India. HydroResearch, 3, 118-123.

[3] Ozawa, S., Shankar, R., Leopold, C., & Orubu, S. (2019). Access to medicines through health systems in low-and middle-income countries. Health Policy and Planning, 34(3), iii1–iii3. https://doi.org/10.1093/heapol/czz119

[4] Stevens, H., & Huys, I. (2017). Innovative approaches to increase access to medicines in developing countries. Frontiers in medicine, 4, 218.

[5] Kaasinen, E. (2003): User needs for location-aware mobile services. Springer-Verlag London Limited 7(1), 70–79.

[6] Kokane, V., J. and Avhad P., S. (2016): The Role of the Pharmacist in the Health Care System. The journal of community health management, 3(1) : 37-40.

[7] Romero, L., Santiago, J. and Correia, N. (2004): Contextual information access and Storytelling in mixed reality using hypermedia. ACM Computers in Entertainment 2(3), 12-12.

[8] Shimadaa, K., Takadaa, H., Mitsuyamaa, S., Bana, H., Matsuoa, H., Otakeb, H., Kunishima, H. and Kanemitsu, K. (2005): Drug-Recommendation System for Patients with Infectious Diseases. AMIA 2005 Symposium Proceedings, 1, 11-12.

[9] Mathkour, H., I. (2011). A GPS-based Mobile Dynamic Service Locator System. Applied computing and informatics, 9(2), 95-106.

[10] Bao, Y., and Jiang, X. (2016): An intelligent medicine recommender system framework. In preceding of 2016 IEEE 11th Conference on Industrial Electronics and Applications (ICIEA) pp. 1383-1388.

[11] Hartanto, A. D., Susanto, M. R., Ilham, H. D., Retnaningsih, R., & Nurdiyanto, H. (2018, April). Mobile Technologies of Formulation Haversine Application and Location Based Service. In Proceedings of the Joint Workshop KO2PI and the 1st International Conference on Advance & Scientific Innovation, Medan, Indonesia (pp. 23-24).

[12] Priandani, N. D., Tolle, H., & Yunianto, D. R. (2016). Design and implementation of mobile-based application for Malang city public transportation route search. Int. J. Advance Soft Compu. Appl, 8(3).

[13] Prashanti, G., Sravani, S., Noorie, S., (2017). A Review on Online Pharmacy. IOSR Journal of Pharmacy and Biological Sciences, 12(3), 32-34.

[14] Albanese, N., P. and Rouse, M., J. (2010). Scope of Contemporary Pharmacy Practice: Roles, Responsibilities, and Functions of Pharmacists and Pharmacy Technicians. Journal of the American Pharmacists Association, 50, 35-69.

[15] Pu, P., Chen, L., & Hu, R. (2012). Evaluating recommender systems from the user's perspective: survey of the state of the art. User Modeling and User-Adapted Interaction, 22(4-5), 317-355.

[16] Almeida, A., Mulero, R., Rametta, P., Urošević, V., Andrić, M., & Patrono, L. (2019). A critical analysis of an IoT-aware AAL system for elderly monitoring. Future Gen. Comp. Systems, 97, 598-619.

[17] Mainetti, L., Mighali, V., Patrono, L., Rametta, P., & Stefanizzi, M.L. (2017). An IoT-aware system for elderly monitoring. In 2017 IEEE 3rd International Forum on Research and Technologies for Society and Industry (RTSI) (pp. 1-5). IEEE.

[18] Phillips, J.G., Currie, J., Ogeil, R.P., & Vaeau, F. (2020). Drug and alcohol counsellors' opinions of therapist negotiated location aware outpatient support using a mobile app. British Journal of Guidance & Counselling, 48(2), 240-250.

[19] Prasetya, D.A., Nguyen, P.T., Faizullin, R., Iswanto, I., Armay, E.F. (2020). Resolving the shortest path problem using the haversine algorithm. Journal of Critical Reviews, 7(1), 62-64.

[20] Tabarcea, A., Gali, N., and Fränti, P. (2017). Framework for location-aware search engine. Journal of Location Based Services, 11(1), 50-74.

[21] Mahmoud, H., and Akkari, N. (2016). Shortest Path Calculation: A Comparative Study for Location-Based Recommender System. In Proceedings of the IEEE 2016 World Symposium on Computer Applications & Research (pp. 1-5). DOI 10.1109/WSCAR.2016.16

[22] Akhigbe, B.I., Akhigbe, O.O., Gambo, I.P., & Afolabi, B.S. (2017). ICT: An Emerging Paradigm for Success in Nigeria. IEEE IT Professional, 19(6), 13-17.

[23] Das, R. C., Purohit, P. P., Alam, T., & Chowdhury, M. (2014). Location based ATM locator system using OpenStreetMap. In The 8th International Conference on Software, Knowledge, Information Management and Applications (SKIMA 2014) (pp. 1-6). IEEE.

[24] Yew, J., Deshpande, S., Precians, N., Cheng, K., and Do, E.Y.-L. (2020). A location-aware app to support the heritage trail experience in Singapore. Journal of Heritage Tourism. DOI: 10.1080/1743873X.2020.1741594.

[25] Hendawi, A., Stankovic, J. A., Taha, A., El-Sappagh, S., Ahmadain, A. A., & Ali, M. (2020). Road network simplification for location-based services. GeoInformatica, 24(4), 801-826.

[26] Capra, M.R.M., Benford, S., Oppermann, L., Drozd, A. and Flintham, M. (2005). The multimedia challenges raised by pervasive games. In: Proceedings of the 13th Annual ACM International Conference on Multimedia. New York, NY: ACM (pp. 89–95).

[27] Raper, J., Gartner, G., Karimi, H., & Rizos, C. (2007). Applications of location–based services: a selected review. Journal of Location Based Services, 1(2), 89-111.

[28] Renjith, S., Sreekumar, A., & Jathavedan, M. (2020). An extensive study on the evolution of context-aware personalized travel recommender systems. Information Processing & Management, 57(1), 102078.

[29] Reddy, R. R., Vaishnavi, C., Mamatha, C., & Ananthakumaran, S. (2021). Location-Aware Keyword Query Suggestion Techniques With Artificial Intelligence Perspective. Computational Analysis and Deep Learning for Medical Care: Principles, Methods, and Applications, 35-51.

[30] Philips, J.G., Currie, J., Ogeil, R.P., & Vaeau, F. (2020). Drug and alcohol counsellors' opinions of therapist negotiated location aware outpatient support using a mobile app. British Journal of Guidance & Counselling, 48(2), 240-250.

[31] Syaripudin, U., Fauzi, N. A., & Uriawan, W. (2021). Haversine Formula Implementation to Determine Bandung City School Zoning Using Android Based Location Based Service [online]. Available: https://web.archive.org /web/20210105220258id_/https://eudl.eu/pdf/10.4108/eai.11-7-2019.230 3558. [Accessed: Aug. 21, 2021].

[32] Daneva, M., Buglione, L., and Herrmann A., (2013). Software Architects' Experiences of Quality Requirements: What We Know and What We Do Not Know? In Proceedings of the 19th International Working Conference on Requirements Engineering: Foundation for Software Quality. Springer Berlin Heidelberg, 2013 (pp. 1–17).

[33] Ameller, D., Franch, X., Gómez, C., Martínez-Fernández, S., Araújo, J., Biffl, S., ... & Muccini, H. (2019). Dealing with non-functional require - ments in model-driven development: A survey. IEEE Transactions on Software Engineering, 2019 (pp.1-17). DOI: 10.1109/TSE.2019.2904476.

[34] Li, W.J., Yen, C., Lin, Y.S., Tung, S.C., & Huang, S. (2018). JustIoT Internet of Things based on the Firebase real-time database. In 2018 IEEE International Conference on Smart Manufacturing, Industrial & Logistics Engineering (SMILE) (pp. 43-47). IEEE.

[35] Cardoso, B., Ribeiro, M., Prandi, C., & Nunes, N. (2020). Gamification and Engagement of Tourists and Residents in Public Transportation. arXiv preprint arXiv:2006.16077.

[36] Zollinger, M. L., Distler, V., Roenne, P. B., Ryan, P. Y., Lallemand, C., & Koenig, V. (2021). User Experience Design for E-Voting: How mental models align with security mechanisms. arXiv preprint arXiv:2105.14901.

[37] Kyllonen, P.C., & Zu, J. (2016). Use of response time for measuring cognitive ability. Journal of Intelligence, 4(4), 14.

[38] Sayantini (2020). JMeter vs LoadRunner – Battle of the Best Performance Testing Tool. Retrieved from https://www.edureka.co/blog/jmeter-vs-loadrunner/ on 27-08-2020 @ 1:10 am.

[39] Ahsan, A., Lslam, M. Z., Siddiqua, R., & Rhaman, M. K. (2020, June). An IoT Based Interactive LPG Cylinder Monitoring System with Sensor Node Based Safety Protocol for Developing Countries. In 2020 IEEE Region 10 Symposium (TENSYMP) (pp. 398-401). IEEE.

[40] Calderoni, L., Maio, D., & Palmieri, P. (2012). Location-aware mobile services for a smart city: design, implementation and deployment. Journal of theoretical & applied e-commerce research, 7(3), 74-87.

[41] Choi, K., Wang, Y., & Sparks, B. (2019). Travel app users' continued use intentions: It's a matter of value and trust. Journal of Travel & Tourism Marketing, 36(1), 131–143.

[42] Wang, E.S.-T., & Lin, R.-L. (2017). Perceived quality factors of location-based apps on trust, perceived privacy risk, and continuous usage intention. Behaviour & Information Technology, 36(1), 2–10.

[43] Nnebe, S. E., & Chiemeke, S. C. (2011). Location-aware information services platform for mobile users in Nigeria. Journal of Engineering and Technology Research, 3(3), 54-61.

[44] Domnitcheva, S. (2001). Location modeling: State of the art and challenges. In Proceedings of the Workshop on Location Modeling for Ubiquitous Computing, September 30, Atlanta, Georgia, 2001, (Vol. 9) (pp. 13 - 19).

[45] Hong, J.-Y., Suh, E. H., & Kim, S. J. (2009). Context-aware systems: A literature review and classification. Expert Systems with applications, 36(4), 8509-8522.

[46] Ramshe, N., & Ahamdi-Javid, A. (2018). Socially optimal design of a service network with location-aware multi-services under different delivery policies. Computers & Industrial Engineering, 125, 490-499.

[47] Baldzer, J., Boll, S., Klante, P., Krösche, J., Meyer, J., Rump, N., ... & Appelrath, H. J. (2004). Location-aware mobile multimedia applications on the Niccimon platform. In The 2nd Symposium on Informationssysteme fur Mobile Anwendungen IMA (Vol. 4, pp. 318-334).

[48] Karagiozidis, M., Zacharopoulos, I., Xenakis, D., Demiris, A. M., & Ioannidis, N. (2002). Location aware visually enhanced ubiquitous services. IST Mobile & Wireless Telecommunications Summit 2002, 16-19.

[49] Engelsberger, M., & Greiner, T. (2016). Application-independent approach for the dynamic management of IT-resources in cyber-physical systems. In

2016 IEEE International Conference on Industrial Technology (ICIT) (pp. 830-835). IEEE.

[50] Keikhosrokiani, P., Mustaffa, N., Zakaria, N., & Sarwar, M. I. (2012). A proposal to design a location-based mobile cardiac emergency system. Stud. Health Tech. Inform., 182, 83-92.

[51] Adekannbi, J.O., Akhigbe, B.I., and Adisa, R.O. (2021). Social Informatics and Use of ICT-based Applications in the COVID-19 Era. African Journal of Sustain -able Development, 11(1), 1-22.

[52] Pratap A. et al. (2022) A Study on IoT-Based Health Monitoring Systems for Nurse Assistance. In: Tuba M., Akashe S., Joshi A. (eds) ICT Systems and Sustainability. Lecture Notes in Networks and Systems, vol 321. Springer, Singapore. https://doi.org/10.1007/978-981-16-5987-4_47

[53] Pinelle, D., Wong, N., Stach, T., & Gutwin, C. (2009). Usability heuristics for networked multiplayer games. In Proceedings of the ACM 2009 international conference on Supporting group work (pp. 169-178).