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ORIGINAL RESEARCH

A Framework for Locating Prescribed Medication at Pharmacies

Matiwos Tekalign Wondmagegn[1], Evarist Nabaasa[2], Endashaw Amsalu Melesse[3], Ewunate Assaye Kassaw[1]

[1]Department of Biomedical Engineering, Institute of Technology, University of Gondar, Gondar, Ethiopia; [2]Faculty of Computing and Informatics, Mbarara University of Science and Technology, Mbarara, Uganda; [3]ABH partners PLC, Addis Ababa, Ethiopia

Correspondence: Matiwos Tekalign Wondmagegn, Department of Biomedical Engineering, Institute of Technology, University of Gondar, P.O.Box 196, Gondar, Amhara, Ethiopia, Tel +251923076770, Email matiwostekalign21@gmail.com; matiwos.tekalign@uog.edu.et

Introduction: Accessibility of available medication at pharmacies is one of the core problems in the health sector of developing countries. The mechanism for optimally accessing the available drugs in pharmacies is unclear. Usually, patients in need are compelled to haphazardly switch between pharmacies in search of their prescription medications due to lack of information about the locations of pharmacies with required drug.

Objective: The primary objective of this study is to develop a framework that will simplify the process of identifying and locating nearest pharmacy when searching for prescribed medications.

Methods: Primary constraints (distance, drug cost, travel time, travel cost, opening and closing hours of pharmacies) in accessing required prescribed medications from pharmacies were identified from literature, and the client's and pharmacies' latitude and longitude coordinates were used to find the nearest pharmacies that have the required prescribed medication in stock.

Results: The framework with web application was developed and tested on simulated patients and pharmacies and was successful in optimizing the identified constraints.

Discussions: The framework will potentially reduce patient expenses and prevent delays in obtaining medication. It will also contribute for future pharmacy and e-Health information systems.

Keywords: constraint, nearest pharmacy, drug

Introduction

In the pharmaceutical sector, community pharmacies are one of the basic components and play a crucial role in health care delivery. Mostly they are more easily accessible than other health-care facilities.[1] Especially in developing countries where poverty limits a lot of sick people from accessing hospital service, the majority of the people are users of community pharmacy.[2] Previous studies indicated that patients who visit community pharmacy, in Ghana (55%) and in Ethiopia (57.6%) go to buy prescribed drugs.[2,3] Another study also found out that, more than other age groups, elders use prescription medications as they are more likely to have frequent seasonal illnesses.[4]

In cities as well as in rural sectors, usually, it is difficult to purchase all medicine on a prescription from only one pharmacy especially for critical drugs. A study in Ethiopia has indicated that less than half the prescribed drugs are obtained from the government pharmacy, and one in six patients were forced to purchase drugs in the private sector.[5] A case study on price and availability of locally produced and imported medicines in Ethiopia and Tanzania indicates that, in the private sector, patients paid 17% and 53% (in Ethiopia) and 135% and 65% (in Tanzania) more than the government procurement price for local and imported products, respectively.[6] Another case study on affordability of commonly prescribed antibiotics in a large tertiary teaching hospital in Ethiopia also indicates that costs of a single-day treatment with antibiotics purchased from the public pharmacies and private pharmacies are 29.7 USD and 54.9 USD, respectively, which is almost double.[7] Due to this, commonly, patients are forced to randomly move from one pharmacy to the other in search of prescribed medicine with a better price which is very tedious and uncomfortable especially for sick patients.

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In developing countries, accessibility of available medication in pharmacies is one of the major problems in the health sector.[8] The mechanism for optimally accessing the available drugs in either private or governmental pharmacy stores is rare and weak. Usually, the patient has to search in several pharmacies for the medicine which increases treatment cost and intern negatively forcing the poor to undertreat their conditions and cause medication non-adherence. Some studies have shown that people who do take prescription medications typically take only about half of the prescribed doses and this non-adherence estimated to cause 125,000 deaths and at least 10% of hospitalizations and cost of $ 100 billion a year.[9] Thus, optimizing constraints for timely accessing of required medication is an important facilitator of the overall health of a population.

It is known that applications like Google Maps can help patients to locate different health facilities like hospitals or pharmacies. However, the problem is that the places located on the map do not guarantee the availability of the drug the patient is looking for. Different mobile-based applications were also designed and developed to locate the nearest health care facilities including the nearest pharmacy using GPS, Google Map, and Dijkstra algorithm aiming at mainly optimizing distance.[4,8,10] However, other constraints like drug cost, travel cost, travel time, pharmacy working hours need to be considered in order to effectively optimize the searching process. So, the main goal of this research is developing a framework and a web application that can optimize the constraints and simplify the process of identifying and locating nearest pharmacy with required prescribed medications. The study was conducted in 2020 for one year in Mbarara, Uganda basing mainly on the setting of the indicated developing countries in Africa.

Materials and Methods

In this research, a number of tools, methods, and knowledge were used to achieve the objective of designing and developing a framework and system for optimizing the identified constraints. The methodology for this research is shown in Figure 1.

Literature Review and Constraint Identification

A survey of the available documents on the current scenarios of locating the nearest pharmacy and available frameworks which are used to facilitate in solving similar problem with their gaps and weakness were explored. The basic challenges or constraints in the process of locating the nearest pharmacy were also identified. The literatures were basically obtained from Google Scholar and PubMed search engine databases using search terms: patient challenges, finding prescribed medications, constraint optimization frameworks, nearest pharmacy locating systems and other related terms.

Framework Design

Information from the literature review (identified constraints) was used to develop modules and layers for the framework. A tool lucid chart was used to sketch modules and layers for the framework depending on the communication flow from patient to pharmacies and vice versa.

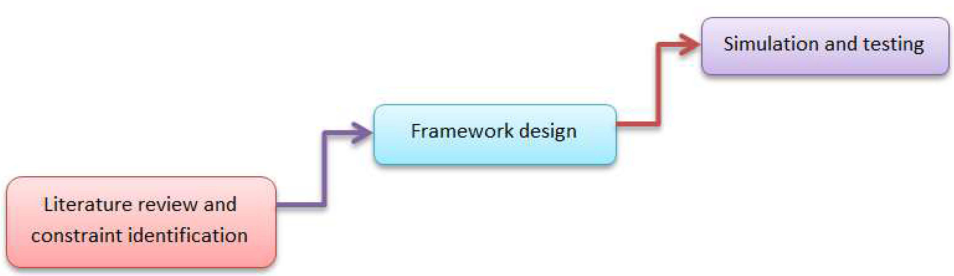


Figure 1 Framework development methodology.

Artifact Development and Simulation

New functionality was developed by designing and developing client geo-mapping, pharmacy constraint mapping, constraint optimization, and pharmacy prioritization algorithms. Because of the suitable working environment and standard design platform they provide, the following software tools and languages were used to build the artifact. MySQL (My Structured Query Language): since it supports a relational database system, it is used to query the database. PhpMyAdmin: to provide an interface as well as ease of use and manipulation of MySQL. XAMMP (Cross-platform for Apache server, MariaDB, PHP and Perl) server: used for testing MySQL and PHP (Hypertext Preprocessor) on the local computer and checking for its functionality. Sublime text editor: to write and edit the source codes.

Languages: HTML (HyperText Markup Language), CSS (Cascading Style Sheet), PHP, and JS (Java Script) have been used to build interfaces and layouts for adding pharmacies, drugs and pharmacy managers to the system database and searching required medications.

Fourteen pharmacies in Mbarara town, Uganda, with their real latitude and longitudinal coordinates were used to calculate the value of respective constraints and test the framework. Then, the system was able to optimize the constraints and sort the nearest cost-effective pharmacies based on the parameters the patient prefers. This implies that the system was able to optimize the identified constraints in the process of searching prescribed medicine which will help to save the wealth and time of patients as well as improves the health outcome of the community.

For computing an accurate representation of the distances and travel times to the pharmacy, three critical elements were considered, which are the patients starting location for the journey (eg, patients home address), endpoint (pharmacy) and method for accounting for the estimated route taken between these two points. Then, the haversine formula is used to compute the straight-line distance between those two points, which intern is used for calculating the travel time and travel cost. Apart from this, an online routing website, Google Maps is also used to indicate the actual road distance and the travel time to the nearest suggested pharmacies. Researches indicate that a travel survey of patients trips to the health care facility found that 87% were made by car.[11] Similarly, in Mbarara car (Boda boda) transportation is the very common means of transportation used by peoples as I see during my study. So, the assumption will not cause so much difference in the result of travel cost calculation. Based on this evidence, in this study, the mode of transportation is assumed as a car to simplify the calculation burden.

Results

Identified Constraints

After a survey of the available documents on the current scenarios of locating the nearest pharmacy, the following basic challenges or constraints in the process of locating nearest pharmacy was identified. The current working framework and algorithms that have been developed to solve other similar problem as well as the identified constraints and the techniques used mainly for the past 10 years were also considered in this research.

(i) Distance: A survey showed that distance is a key factor when patients choose healthcare facilities to access the healthcare service they want.[12] But, since the quality of services can convince the people to select a healthcare facility, for preventive health services, they have more flexibility to select service locations and may not seek services from the closest location.[13] The research conducted in Ghana indicates that 75% of pharmacy users prefer to visit a pharmacy close to their home or workplace.[2] Distance is also the determinant factor for travel time and travel costs. One method of lowering the barrier of distance is done by taking or guiding the people to the appropriate service location.[14]

(ii) Drug cost: Another identified challenge is drug cost, especially for developing countries where patients are not able to afford to buy medication. The research conducted in Ghana indicates that from the pharmacy users 27.5% of them choose to visit pharmacy with good and competitive prices of drugs.[2] Another research has also shown that drug cost is one of the barriers to medication access. High drug cost limit patient's access to medications and causes the patient to be less adherent while lower medication costs help patients to become more adherent to their prescribed treatment.[15]

(iii) Travel cost: Another challenge for patients to get their medications from pharmacies is the transportation cost. Studies showed that distance to facilities imposes a considerable cost on individuals, and thus travel cost is a key barrier for accessing healthcare services. The study in Bangladesh indicated that transportation cost is the second most expensive item for patients after medicines.[16] A paper by Owen O'Donnell on access to health care in developing countries also showed that in addition to charges made by the health care providers, travel costs are important costs of consuming health care in the developing world.[14]

(iv) Travel time: In case of emergency, one of the basic parameters that needs to be considered for timely accessing required medication is travel time. A study also showed that 83% of the studies reviewed in the research reported a negative correlation between distance/travel time to healthcare facilities and health outcomes.[17]

(v) Working hour: The last challenge for timely accessing pharmacy service identified in this research is, limited opening hours that do not allow for dealing with emergencies or working times that are not convenient for patients, especially for working people. The study by the Royal College of Emergency Medicine, London, showed that most emergency departments are open 168 hours per week and hospital pharmacies are open only 30–60 hours per week. Outside of these hours, it is the patient's or their carer's responsibility to find an open pharmacy which is inconvenient especially in emergency cases and incur additional travel and time costs.[18] Thus, opening hours is found to be important in determining service use, because, to buy the needed medications, the preferred pharmacy should be open in that specific searching time.

Designed Framework

By taking into consideration the key actors in the searching process which are users, pharmacies and constraints, the optimization framework with five basic modules was developed as follows. Architecture of the designed constraint optimization framework is as shown in Figure 2.

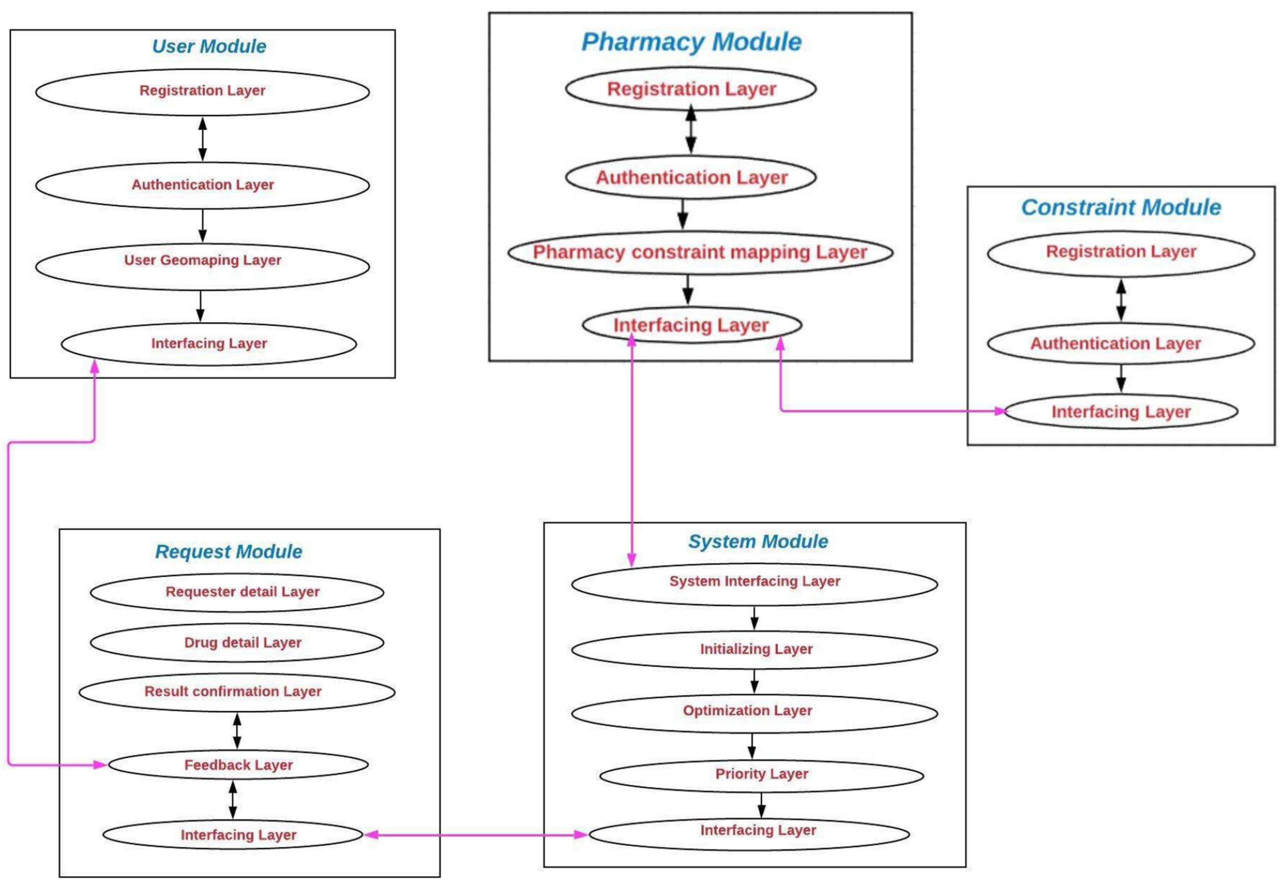


Figure 2 Architecture of the constraint optimization framework.

Framework Modules

User module: this module contains four layers. Registration layer: for capturing basic user details like name, contact, email, username, and password. Authentication layer: for verifying the user whether registered or not by checking username and password. User geomapping layer: for capturing the user's GIS details (latitude and longitude) and Interfacing layer: for connecting the user module to the request module.

Request module: this module contains five layers and communicates requests between the user and system modules. Requester detail layer: used to capture basic patient details like name, address, weight, and age required for performing drug search requests. Drug detail layer: to capture basic drug details like drug name, amount, or strength and ingredient as it appears on the prescription paper. Result confirmation layer: for receiving a list of nearest pharmacies from the system module based on the request made by the requester. Feedback layer: to capture feedback from the user module and communicate it to the system module via the interfacing layer and finally interfacing layer: for connecting this module to the system module.

System module: this module communicates between the request and pharmacy modules and contains five layers. System interfacing layer: for connecting this module to the pharmacy module. Initializing layer: for initializing the parameters on which the optimization calculation is done which are distance, travel time, travel cost, drug cost, opening and closing hours. Optimization layer: for performing the optimization calculation on the identified parameters based on the request from the request module. Priority layer: for comparing, sorting, and assigning priorities for pharmacies according to the calculated result and Interfacing layer: for connecting this module to the request module.

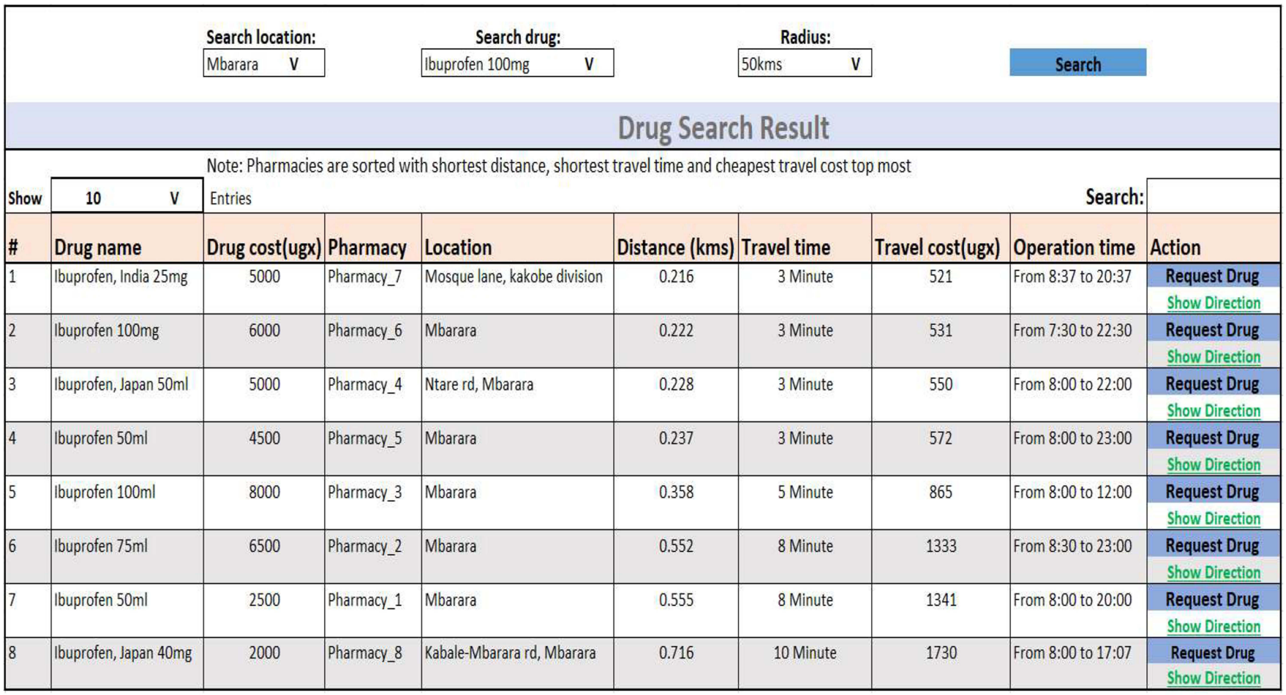
Pharmacy module: this module communicates between the system and constraint modules and contains four layers. Registration layer: captures basic pharmacies detail like name, contact, location or place, latitude and longitude. This layer also captures information on the type or category of pharmacies like public, private, military, and religious affiliation of pharmacies. Authentication layer: for verifying the pharmacy whether it is registered or not. Pharmacy constraint mapping layer: for mapping pharmacy constraints and capturing drug details like drug name, quantity, dosage, cost, ingredient, stock date and expire date, and Interfacing layer: for connecting this module to the system and constraint modules.

Constraint module: this module communicates with the pharmacy module and designed to have three basic layers. Registration layer: captures the identified constraints to be optimized, by which the initializing layer in the system module used them as input parameter which are distances, travel time, travel cost, drug cost, opening and closing hours. Authentication layer: for verifying the constraints by checking whether they are registered or not and Interfacing layer: for connecting this module to the pharmacy modules.

Internet: serves as a communication medium between different modules in the framework. It provides GIS information about the constraints (travel distance and time) from each pharmacy to the patient's current location using Google Map API. In the context of this research GPS tracking is not utilized for the purpose of controlling the lives of others rather it is for making the process of finding prescribed medication easier for those who need it which is beneficial to the person being tracked and thus not detrimental.[19] So, the purpose of tracking is among the way of using GPS which can potentially save lives. Moreover, in further application of the system, the tracking of people will be done in a just and ethical fashion and in a way which is beneficial to the person involved and the wider community. The framework potentially optimizes five constraints which are identified as basic according to the literature review. The modules as well as the layers of the framework are designed and developed based on agile method of software development in the way that can easily be modifiable and functional for system implementation.

Simulation

The application was tested every time functionality was implemented to ensure that the final end product had a few errors. There was no potential participant involved. The developer (myself) with four of my friends was acting as patient and pharmacist in the simulation and testing process. Other similar applications were also developed and tested in a similar fashion. A similar application for locating nearest pharmacy in Ghana was tested on students and was able to search for desired drug using the machine where the application was locally hosted.[20] Also, in Iraq, a framework for developing an online hotel booking system for tourists was also developed and tested in a similar way. Customers were able to do the payment process through their cell phones using payment service providers and were able to sort hotels



#	Drug name	Drug cost(ugx)	Pharmacy	Location	Distance (kms)	Travel time	Travel cost(ugx)	Operation time	Action
1	Ibuprofen, India 25mg	5000	Pharmacy_7	Mosque lane, kakobe division	0.216	3 Minute	521	From 8:37 to 20:37	Request Drug Show Direction
2	Ibuprofen 100mg	6000	Pharmacy_6	Mbarara	0.222	3 Minute	531	From 7:30 to 22:30	Request Drug Show Direction
3	Ibuprofen, Japan 50ml	5000	Pharmacy_4	Ntare rd, Mbarara	0.228	3 Minute	550	From 8:00 to 22:00	Request Drug Show Direction
4	Ibuprofen 50ml	4500	Pharmacy_5	Mbarara	0.237	3 Minute	572	From 8:00 to 23:00	Request Drug Show Direction
5	Ibuprofen 100ml	8000	Pharmacy_3	Mbarara	0.358	5 Minute	865	From 8:00 to 12:00	Request Drug Show Direction
6	Ibuprofen 75ml	6500	Pharmacy_2	Mbarara	0.552	8 Minute	1333	From 8:30 to 23:00	Request Drug Show Direction
7	Ibuprofen 50ml	2500	Pharmacy_1	Mbarara	0.555	8 Minute	1341	From 8:00 to 20:00	Request Drug Show Direction
8	Ibuprofen, Japan 40mg	2000	Pharmacy_8	Kabale-Mbarara rd, Mbarara	0.716	10 Minute	1730	From 8:00 to 17:07	Request Drug Show Direction

Figure 3 Search result and sorted list pharmacies with the drug Ibuprofen based on distance as well as travel cost and travel time.

according to their price or quality.[21] However, it would have been ideal to test this application with people with less experience in technology which will be done for the future in Ethiopia and when the application is hosted on remote server.

After the required interfaces are developed, the framework and its web application were tested on simulated pharmacies with constraints. Pharmacies have been allocated to pharmacists so that each of the pharmacists can only control (add or update drugs and other details) of their own pharmacy. Then, sample drugs and values of other required parameters were added to the system database, and the test was conducted.

On successful login, the patient is redirected to the drug searching dashboard as shown in the Figure 3 and can search the medication by selecting the drug with required details (drug name, type, quantity) as indicated on the prescription paper from the alphabetically ordered list of drugs in the searching menu which are retrieved from the drug database automatically. Once all this is done, the search button can be clicked and the nearest pharmacies with the required drug appear on the result table sorted based on distance as well as travel time and travel cost as shown in Figure 3. Then, the patient can also further prioritize those pharmacies based on drug cost value using clickable constraint names at the top of the table as indicated in Figure 4.

Once the patient chooses and decides the pharmacy from the list, they can reserve a medicine using the "request drug" button by filling the details required for reserving the medicine and send it to the pharmacy as shown on Figure 5. Then, the request will appear on the pharmacist's dashboard of that specific pharmacy and can either accept or reject the request. Upon a successful request, the patient will receive a confirmation message and can get a Google map guide to go and buy the drug using the "show direction" menu below the "request drug" menu of that specific pharmacy.

Discussion

This research optimizes the identified constraints by developing a framework and a web application that can simplify the process of identifying and locating nearest pharmacy with required prescribed medications. Different mobile-based applications were designed and developed to locate the nearest health care facilities including nearest pharmacy using GPS, Google Map and Dijkstra algorithm aiming at mainly optimizing only distance. However, this study tries to optimize the possible identified constraints as indicated on the result section.

Search location: Mbarara V

Search drug: Ibuprofen 100mg V

Radius: 50kms V

Search

Drug Search Result

Note: Pharmacies are sorted with shortest distance, shortest travel time and cheapest travel cost top most

Show 10 V Entries

Search:

#	Drug name	Drug cost(ugx)	Pharmacy	Location	Distance (kms)	Travel time	Travel cost(ugx)	Operation time	Action
8	Ibuprofen, Japan 40mg	2000	Pharmacy_8	Kabale-Mbarara rd, Mbarara	0.716	10 Minute	1720	From 8:00 to 17:07	Request Drug Show Direction
7	Ibuprofen 50ml	2500	Pharmacy_7	Mbarara	0.555	8 Minute	1341	From 8:00 to 20:00	Request Drug Show Direction
9	Ibuprofen, India 25mg	4000	Pharmacy_9	Amazon Building, Masaka road	0.935	14 Minute	2250	From 8:00 to 00:00	Request Drug Show Direction
4	Ibuprofen 50ml	4500	Pharmacy_4	Mbarara	0.237	3 Minute	572	From 8:00 to 23:00	Request Drug Show Direction
1	Ibuprofen, Japan 50ml	5000	Pharmacy_1	Mosque lane, kakobe division	0.216	3 Minute	521	From 8:37 to 20:37	Request Drug Show Direction
3	Ibuprofen, India 25mg	5000	Pharmacy_3	Ntare rd, Mbarara	0.228	3 Minute	550	From 8:00 to 22:00	Request Drug Show Direction
2	Ibuprofen 100mg	5000	Pharmacy_2	Mbarara	0.22	3 Minute	531	From 7:30 to 22:30	Request Drug Show Direction
6	Ibuprofen 75ml	5500	Pharmacy_6	Mbarara	0.552	8 Minute	1333	From 8:30 to 23:00	Request Drug Show Direction

Figure 4 Sorted list of pharmacies with drug Ibuprofen based on their drug cost value.

Brenda A. from Ashesi University College of Ghana developed a "Dawa Papa" web application for locating the nearest pharmacy with the desired medicine using Google Maps API for the query of place information and Haversine formula to get the nearest pharmacy based on the patient's location.[20] The application was able to suggest the nearest pharmacy with the desired drug, patients can make medicine reservation and access directions to the pharmacy via Google Maps. However, this application fails to indicate detailed information about variables like distance, the time it takes to reach the pharmacy, the cost of the drug at each of the suggested nearest pharmacies, transportation cost and pharmacy working hours that need to be optimized in the process which are primarily addressed in this study.

Location-Based Application for Accessing Emergency Pharmacy Services over the Mobile was also developed in India by B.G. Premasudha using GPS for computing position and Dijkstra's algorithm for finding the shortest path from the user's current location to the nearest pharmacy.[22] The application was able to search for required drug/s with all the nearest pharmacy in a given locality where the required drug/s of desired quantity, not exceeding the expiry date is available and also the working hours, traveling direction, address, and traveling time. However, the system was developed mostly for emergency cases and fails to consider non-emergency scenarios like transportation cost and drug cost in pharmacies which are included in this research.

Judith S. and Thomas D. have also developed an application called CamPharma, a mobile tool which operates on the client-server model for interaction between pharmacies and patients in Cameroon.[10] It was able to determine five better pharmacies among N pharmacies with their detailed information. But the application was not designed for locating the nearest pharmacy. Moreover, it only suggests the five better pharmacies in the locality which may not necessarily have the drug by which the patient is looking for.

Literatures also indicate that optimization frameworks and algorithms for locating the nearest pharmacy are very few. A framework was developed to locate the nearest hotel for tourists in Iraq using the Dijkstra algorithm to search and locate different hotels in the city and sort them according to their price, the number of stars, and location distance.[21] Since the framework was not developed for locating the nearest pharmacy, it did not take into consideration constraints like prescribed drug cost, pharmacy working hours, and other constraints which are basically considered in this study.

In this study, the developed framework and web application system were hosted and tested on local server, and able to accurately locate the nearest pharmacies with required drugs using the necessary parameters from the database. It first

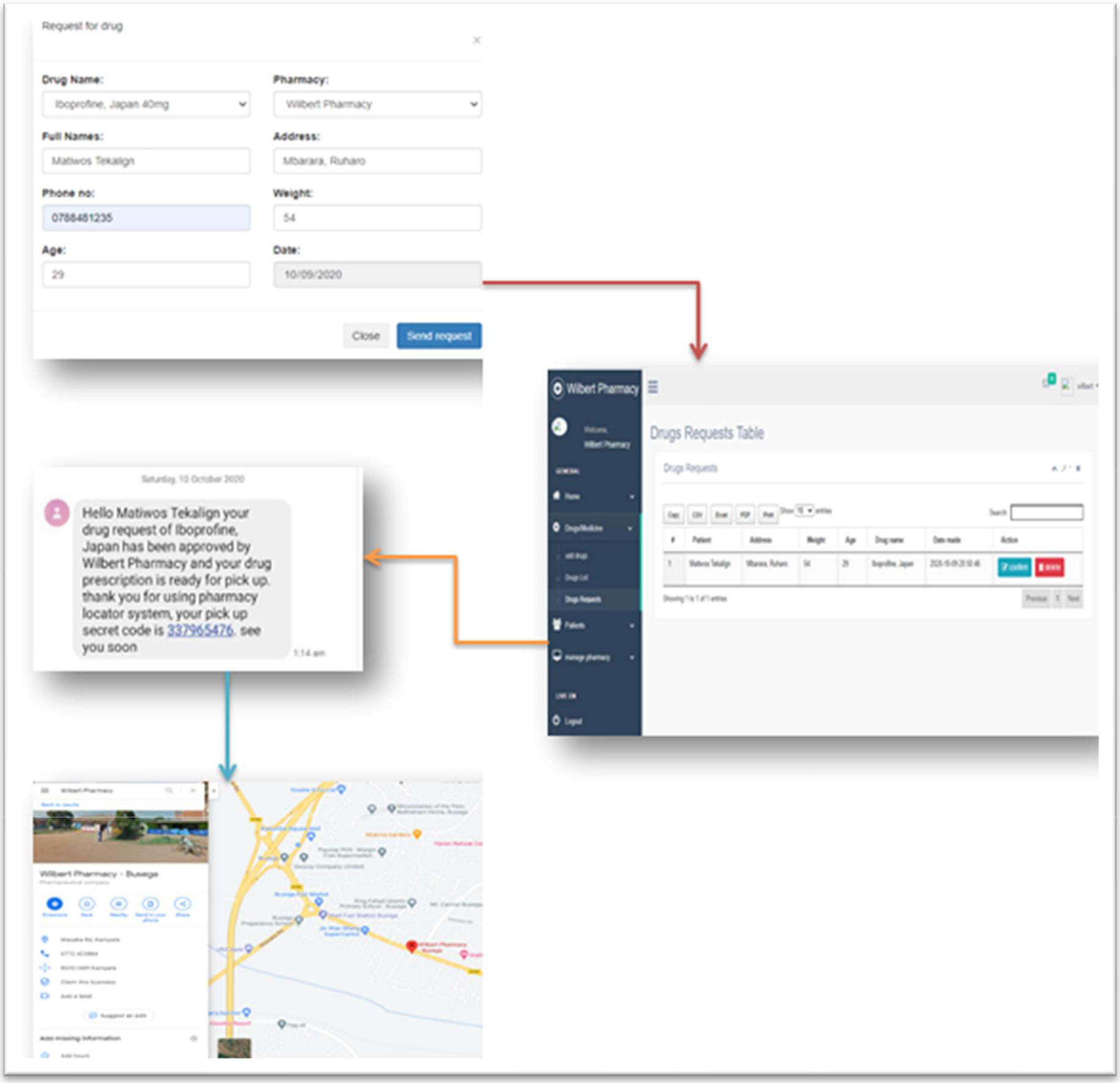


Figure 5 Drug reservation request, confirmation message and Google map guide to Pharmacy_8, the nearest pharmacy in the list.

captures the latitude and longitudinal address of the client and pharmacies, checks the opening and closing time of the pharmacies, searches the requested drug, and returns the list of sorted pharmacies. The value of each identified constraints was calculated and mapped to each of the pharmacies with the requested drug. Lastly, by comparing their constraint values, pharmacies were prioritized starting from the nearest and least drug cost. The system allows the user to reserve a medicine on the preferred pharmacy and get a Google map guide as shown on Figure 5 which will help patients to save money and time by decreasing out-of-pocket costs. There were no errors occurred during the simulation process. However, the application needs to be tested on more people and pharmacies while hosted on actual remote server which is the limitation of this project that needs to be addressed in the future.

Generally, this finding will simplify the process of searching prescribed drugs at pharmacies by saving the time and cost of patients and will also minimize emergency death due to on-time unavailability of medication especially critical drugs. It will also contribute more to the pharmacy information system which assists the pharmacist to view patient orders, thereby providing the ability to view the complete picture of a patient's therapy throughout multiple episodes. Moreover, it will help pharmacies in medication management processes for managing their stocks and optimal decision-making. Since the framework is new, it will add knowledge to the already existing wealth of knowledge and research in the field.

Conclusions

This framework and its web application are recommended for use as a guide for searching critical drugs and locating the nearest pharmacies, especially for emergency cases. And it implies that, with further research, the study can assist patients in even a more effective way to search for their medication by optimizing other constraints which are not considered in this research.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

Endashaw Amsalu Melesse is affiliated with ABH partners PLC. The authors report no other conflicts of interest in this work.

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