Smart Decision-Making in Mobile Healthcare Information Systems: An Ontology-Based Approach to Emergency Management

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Abstract Saving patients' lives in peril is a crucial task; therefore, it is the primary concern of physicians and caregivers. While heading to an adequate medical institution that must be determined with precision, late response, information overload, and poor decisions may lead to serious, even catastrophic, health consequences. It is even worse if it is known that some areas do not have good medical coverage such as in rural regions. A good solution is to enhance the functionalities of mobile physicians, an ordinary physician in move with any adequate vehicle. They have the role of visiting the patient when requested, providing initial aid, making an initial diagnosis, and caring for a patient while moving to a medical institution when involved. To facilitate efficient on-road decision-making for mobile physicians, this study suggests a medical decision support system that adopts the ontology-driven approach for efficient emergency management. It permits ascertaining and ranking the appropriate medical institutions as quickly as possible, including healthcare resources institutions per the patient's condition determined initially, thanks to the first diagnosis, and continuously evaluated in real-time.

Keywords: Mobile Health Units, Ontologies, Geographic Information Systems, Health Information Systems, Decision Support Systems.

1 Introduction

Healthcare knowledge management aims to empower providers with current, relevant and efficient healthcare information at their convenience, enabling them to make well-informed

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decisions on patient care. An important problem worldwide is the need for more medical coverage in wide geographic regions, particularly rural ones, due to the low number of physicians and medical personnel [1]. Worldwide, many thousands of individuals are dead due to inaccurate emergency management characterized by confusion inadequate responses, and inappropriate decisions [2].

According to WHO, there is a global shortage of 18 million healthcare workers, with rural areas being most impacted [3]. As a result, tens of thousands of people die yearly because of poor emergency handling involving confusion, suboptimal responses, and even improper decisions. This shortage leads to the poor emergency response which is said to be claiming thousands of lives that could have been prevented yearly [4]. For example, in low income countries, only 37% of delivery is conducted under supervision of skilled health personnel; illustrating the access deficit to emergency health care. Similarly, research published in the American Journal of Emergency Medicine also stressed that longer times to respond to emergencies as being general causes of higher mortality rate, rural areas taking 7-14 minutes longer than urban ones [5]. The more adopted of mHealth solutions is rapidly expanding since the mHealth market is estimated to reach $12.53 billion [6].

The emergence of mobile devices and location technologies in several domains has drawn the interest of scholars and professionals, demonstrating its practicality in the healthcare sector. By providing distant patients with the convenience of being attended to whenever and wherever they want. Such innovative technology has sparked the development of a new set of health ideas, mostly centered on ubiquitous resolutions [7]. Such advanced technologies allow ubiquitous healthcare applications to overcome temporal and geographical challenges, give more accessibility to healthcare practitioners and open up new opportunities and potentials for supporting and ensuring patient treatment [8].

Keeping an eye on patients takes a lot of time, particularly if they are geographically spread or immediately face an emergency. In every situation, doctors have an ethical and fundamental duty to save the lives of their patients. Saving patients in emergencies when they are geographically far from reach is a task that is primarily based on well-organized and efficient emergency management. Mobile physicians, who usually reach their patients at distant places to provide care and make critical decisions, must respond on time and efficiently to assist people in crucial situations, particularly if they are asked to care for patients away from established medical facilities [9]. It can lessen such issues by acting quickly and effectively to reach the patient and the medical facility. This will increase the patient's chances of receiving treatment and survival. Thus, it is crucial to provide mobile physicians with tools that help them handle crises in urgent or important situations [10]. Furthermore, road circumstances are continually changing; therefore, the mobile physician, on his way to the patient's location and when heading to medical institutions, may encounter complications on the road. These difficulties, such as heavy traffic, road maintenance, signals, etc., may prevent them from reaching the destination within a reasonable time, consequently threatening the patient's life.

To accomplish the goals mentioned earlier and overcome the limitations, an ontology-driven method incorporating road guiding has introduced in a medical decision support system. This system aims to improve the effectiveness of mobile physicians in emergency scenarios by efficiently locating the nearest healthcare facilities to the emergency site and identifying those equipped with suitable medical resources for patient transfer. This system strives to ensure the quick arrival of mobile physicians to their designated destinations through a search engine utilizing an incremental routing algorithm. Approach of this study uses the Delaunay triangulation algorithm to swiftly pinpoint the closest healthcare facility while departing from the emergency scene.

This method [11] takes into account dynamic transformations of the search locations based on the algorithm for a route calculation. It gives correct responses for continuous k-nearest Neighbors (CkNNs) searches pertinent to the road. This is chosen deliberately as it helps in achieving the intended outcomes and accommodates the dynamism in mobility demand by the involved physicians. Regarding this process, the creation of an Ontology with a high expressivity and reasoning ability has been developed. It provides means for description of structured data and relations, which allows the system to define what resources are needed in the medical sphere and whether the required resources are available in the nearest hospitals. Here, each medical resource is annotated to indicate what it shall be used for in order to include another resource in the event that the former is required.

When an emergency call happens, a mobile physician should reach the patient as quickly as possible. They must be prepared to be skilled to evaluate and analyze the clinical data and be able to take speedy and competent decisions to assist their usual or random patients. After reaching the patient, the mobile physician evaluates the patient's medical status and decides whether to treat the patient on-site or to the closest healthcare institution. Though several current systems can locate the nearest hospital, they must determine which facility has the effective medical resources required to meet the patient's demands.

To help the mobile physician make decisions, this study suggests a road guidance ontology-based medical support system that can swiftly retrieve the best medical facility for the situation. The retrieved institution must meet the patient's condition while ensuring the rapid reach of the patient by providing an impediments-free road. Such a system aims to support mobile physician decisions and empower them to form another way of approaching medical emergencies that could benefit many cases in distant regions such as rural areas.

Specifically, this work aims to fulfil the following main objectives:

1. Discover the healthcare institutions neighboring the emergency situations while providing the shorter paths leading to them.

2. Identify necessary medical resources for the patient's condition before visiting a healthcare facility.

3. Identify healthcare facilities with the appropriate medical resources to meet the demands of patients.

The following paper is organized as follows: Section 2 reviews related works; Section 3 presents the proposed system; Section 4 describes the implementation and experiments; Section 5 presents a case study of a mobile physician decision system; and Section 6 concludes the paper.

2 Related Works

The development of ubiquitous technology allowed people to take care of themselves and complete chores at any time or place. The primary goal of ubiquitous computing is to enable any user using mobile devices to access any data or service from any location. By overcoming time and location limits, the ubiquitous infrastructure will allow us to improve and develop new services that are helpful in the healthcare sector. This is made possible by the rapidly advancing technologies of mobile devices and accompanying mobile applications, which have increased and are altering how people use healthcare facilities. Researchers, patients, application developers, and healthcare professionals have all been paying close attention to mobile healthcare. In this field, mobile devices are used to access healthcare services, wireless networks and sensors are used to monitor various conditions, healthcare personnel make decisions about whether to offer emergency care, etc. Mobile healthcare has played a significant role in expanding healthcare coverage, improving healthcare decision-making, and, most importantly, providing appropriate care in an emergency.

Peri-prosthetic healthcare systems can enhance healthcare services by facilitating ways to get beyond geographical and technology constraints when tackling specific healthcare issues. There are new opportunities to guarantee better patient care and overcome time and space barriers between patients and caregivers with applications for ubiquitous healthcare. In addition to providing access to essential clinical data and services, they guarantee the management of encountered medical problems and enable physicians and patients to move without restriction. Healthcare personnel must respond to ever-increasing emergency needs, and ubiquitous medical systems can assist them. Services which are based on the location are the main components of ubiquitous medical systems, which provide quick and dependable medical services using ad hoc connections [12] to supply information and services to medical actors. In this scenario, mobile doctors are among the users who initiate location searches; therefore, this is assured by replying to their requests. It takes efficient planning, management, and coordination with location-based services for a decision support system to play a major part in successfully handling emergencies.

The literature has several proposals for healthcare solutions that use location-based services. A diabetes monitoring system that allows users to use smartphones to see and manage their psychosocial data and settings at any time and location is provided [13]. By conducting many examinations and transmitting the collected data to an expert system, this kind of technology lessens the likelihood that their health issues will worsen. The technology offers patients in remote places a quick diagnosis based on the analysis of the data that was received. The authors offered an integrated healthcare delivery platform to reduce the risk of injury to participating patients. They can search for a nearby doctor who can contribute to the healthcare process by giving patients various features, finding hospitals and medical centres where patients can be treated, and accessing many medical services at any time and from any position [14].

A system for immediate emergency detection and reaction to serious cardiac situations is shown in [15]. Its primary objective is the timely and appropriate provision of therapy for old and unable individuals suffering from chronic cardiac problems. Three categories exist in this prototype for notifications. The initial one gives the position of the monitored patient; the second is related to an alarm that sounds when the heartbeat of the patient rate goes beyond a certain threshold; and the third is in charge of calling for an ambulance that is equipped to rescue the patient in a serious condition.

The authors of [16] provided a health monitoring system designed for patients with cardiac conditions such as hypertension and arrhythmia. To detect the position of patient in situation of urgency and locate the closest medical facility, activate the emergency healthcare service and this mobile cardiac emergency structure is location-based. The authors of [17] presented an easily portable telemedicine system that is primarily used to treat patients in remote rural regions, focusing on diabetics, heart patients, and accident survivors. The authors of [18] suggested a paradigm for remote patient monitoring. Modelling this environment will allow crucial signals between patients and caregivers in a remote patient monitoring area facilitated by mobile agents. Healthcare professionals may identify and describe severity levels using measured vital sign data, and they can respond accordingly.

Pre-hospital emergency services are managed using a multi-agent decision-making support system [19]. They combine fleet vehicle management with demand, special events, personnel scheduling, and replacements. The suggested approach aims to improve a system for supporting decision-making that helps caregivers intervene in resolving medical cases and displays the outcomes for analytical reasons. In [20], authors used a multi-agent-based approach to address rescue allocation issues in mass casualty disasters while considering the environment's dynamic changes. Hospital, transit, and patient agents are the three primary agents employed to distribute scarce resources. The work of these agents ensures that patients are safely carried to relevant hospitals according to their diagnosis and the seriousness of their illness. The multi-agent decision support system is a complex emergency and disaster management technique that involves a great deal of uncertainty and has strict time constraints [21]. This study has identified the stages of crisis and catastrophe management preparedness, response, and recovery.

In [22], The authors primarily focused on large-scale events that include crowds, such as sporting events, musical performances, festivals, New Year's festivities, etc. If safety precautions are not taken, such situations can lead to total unrest and many victims. In this case, the decision support system uses the ontology area developed for managing healthcare urgency in huge crowds to assist it in deciding what is the best way to assemble people. In [23], a method for handling emergencies centred on controlling emergency vehicles is proposed. Its objective is to reduce the time that elapses between the moment an emergency call is placed and the rescue team's arrival. The rescue team is responsible for transporting patients in urgent or critical situations to medical institutions so they may receive the treatment they need. The solution that is being suggested takes into account the factors associated with route advice that reduce waiting times. The authors in [24] offered a clinical decision support system with various tools to improve clinical decision-making by reducing medical errors and raising the standard and effectiveness of healthcare. According to [11], a ubiquitous help system for travelling physicians is suggested. It is built on a route-guiding technique. Using a Delaunay triangulation (DT), this approach guarantees that mobile inquiries on a road network will discover the closest hospitals. This technique establishes CkNNs on road networks while considering dynamic location changes.

3 The proposed system

This section presents the architecture of solution based on a mobile cloud computing framework and describe two ontologies necessary for emergency management decision-making.

3.1 Architecture of the proposed solution

The proposed system architecture is based on a mobile computing platform which offers high accessibility to healthcare givers, allowing them to get or administrate information.

It integrates mobile devices, such as mobile physician smartphones, with cloud computing technologies. It provides online access to unrestrained hardware, software, and medical information cloud resources to mobile physicians and other participating caregivers. Thus, in this work

This study proposes a context-aware system that exploits location, patients, and caregivers' medical information to select the adequate medical institution suitable for the context of a patient's urgent case. Cloud computing-based services save costs in acquiring, delivering, and maintaining computing power for caregivers. They also permit mobile access and storage of medical information using various mobile devices anywhere and anytime. Such technologies permit medical services to scale up and down according to caregivers' increasing requirements. Moreover, the different hosted applications can be accessed through any network-based device thanks to broad network access achieved using built-in web browsers. Using the resource pooling concept, multiple medical institutions can share the basic physical and software cloud infrastructure; multi-tenancy allows the colocation of medical services owned by numerous caregivers' providers in a single data center. All the benefits described above contribute to enhancing collaboration and maintenance services and providing vital information that actively contributes to saving lives when well used by caregivers.

When considering the emergency case of its patient, the mobile physician questions the cloud platform using an appropriate mobile device such as their smartphone where the application interface is downloaded and well installed. As a result, the patient's and the mobile doctor's positions are automatically determined and utilized to search for a list of surrounding healthcare facilities that appear on a map-based interface. The system concurrently links the results of the main diagnostic to the list of required medical resources, including medical personnel and equipment.

Next, using a matching algorithm between the recognized emergency case demands and the hospital features contained in particular databases, the system verifies the existence of every medical resource in the list of localized healthcare facilities. Then, the algorithm ranks the candidates based on the aspirant hospitals' desired medical resource availability and convenience, hospital distances from one another, and the mobile physician's dynamic position while travelling. Ultimately, the doctor deciding which healthcare facility to visit receives the sorted list back. The following enumerates the primary SaaS components. The mobile physician's major diagnostic is fed into the Ontology reasoner, which uses it as input to locate the necessary medical resources for the emergency patient situation. It makes use of a knowledge base for this purpose that is mostly made up of two Ontologies:

1. The first includes illnesses. An ontology that lists the medicinal supplies needed for every illness connected to the initial diagnosis.

2. The second includes a hospital ontology that lists the medical resources available in hospitals and clinics relevant to emergency treatment requests.

The CkNN localization tool looks for the k closest medical facilities in the vicinity using the mobile physician's dynamic position as input. However, identifying them does not guarantee that they will be appropriate for the urgent issue at hand. It should be mentioned that the system declines the CkNN Engine to expand the search area if it cannot provide a result deemed inappropriate [11]. The latter uses a technique that guarantees a legitimate outcome for tracking the k closest neighbors and the necessary fast updates for the underlying data and the phone query results. It allows for the triangulation-based modelling of a road network and the restoration of a legitimate answer for an ongoing search for the kids. The outcome of these inquiries is a collection of localized places of interest on a region's road network map. To analyze queries effectively, the method primarily divides the network to identify the first neighbor in a triangle that includes the query point. The algorithm for finding the 1-nearest neighbor (1NN) is applied for the first time. A second algorithm limits the zone of influence to locate the second nearest neighbor by adjacency. Then, to provide the k – 2 neighbors who follow the closest neighbors from q with the proper result, the algorithm for expansion will shift the region of expansion to another zone.

3.2 Ontology for decision support in emergency management

Ontology is a cognitive artefact that permits knowledge to be jointly designed and operated [25]. It consists of concepts connected to relationships from a topic of interest, such as medical emergency management. The idea of ontology was given several meanings as a new paradigm. Though the notion of ontology has been expanded upon and changed, it was first described as a formal definition of a conceptualization in the context of artificial intelligence and knowledge engineering [26]. Adding the concept of share to the previous definition obtained an explicit and formal description of a shared notion, leading to a precise and unambiguous meaning [27]. Formal, multilingual, consensual, and referenceable domain conceptualizations are expressed in terms of classes and characteristics. A systematic understanding of a domain using ideas and connections was described as a domain ontology [28]. Ontologies are useful for sharing shared understanding and analyzing domain knowledge, among other key applications. To top it off, ontologies allow for the reuse of domain knowledge and significantly contribute to software systems [29].

By compiling and analyzing copious amounts of data from several sources, the emergency management domain of ontology [30] enhances decision-making by choosing and executing the best possible action. This is finished to have a clear, uniform framework of relationships and ideas for emergency management that are all semantically related [31]. One of the main benefits of using ontology-based representations in urgent care management is reducing delays in healthcare responses caused by difficulties verifying the availability of different emergency medical facilities. Additionally, using ontologies in emergency management is beneficial as individual emergency cases may include several healthcare institutions and dynamic activities that could obstruct the decision process.

3.3 Modelling Ontologies

Researchers in medical informatics interested in formal knowledge representation and reasoning in healthcare have been interested in Ontologies due to their rise in various domains. It is necessary to organize knowledge about emergency systems to utilize it for multiple purposes, including location-based health services, quick diagnosis, descriptions of medical supplies, etc. The suggestion proposed in [32] involves a location-based service that utilizes ontology-based semantic searches to organize and inquire about data in a semantic manner effectively. This service focuses on indoor events within an academic environment. It gathers and provides location-specific details about a destination based on user-provided keyword reasoning guidelines formulated for semantic searches. By connecting an indoor topological network model with a road network model, a network-centered topological data model is created [33]. This model chooses, from a list of choices, the most economical path between an indoor or outdoor site and the user-selected inside destination.

The literature proposes three major strategies for developing ontologies: top-down, bottom-up, and hybrid approaches [34]. Strategy in this study uses a top-down approach to create the necessary ontologies, obtained by researching the emergency management domain at a higher degree of abstraction, developing ideas from the top levels, and expanding the lowest levels by adding more specificity. For this study, initially information is gathered on different healthcare facilities to represent their specific medical asset and to approach the first Ontology. To reach the second Ontology, first the various kinds of potential urgent scenarios or illnesses are recognized and then determine the essential healthcare resources for each emergency circumstances. In emergency management, quick and effective decisions must be made on based on vast amounts of clinical data to save lives. For this reason, ontology to monitor is employed for this volume of information efficiently. First ontology outlines the necessary medical resources for every urgent situation, such as specialist personnel and equipment. The personnel of each service and the various medical devices in the participating healthcare facilities are described in the second ontology. The primary classes that are a part of this system are defined as follows:

As part of proposed system, the Hospital class contains a list of various healthcare facilities. Any healthcare facility is defined by a combination of static and dynamic characteristics. Static characteristics characterize long-term consistency, whereas dynamic attributes represent information that is subject to frequent change and might influence the mobile physician's decision.

1. The Service class compiles the list of services offered by each healthcare facility and generally correlates it with the potential urgent cases that need to be taken into consideration. Static and dynamic properties are also characteristics of each service.

2. The Equipment class provides each healthcare institution's list of available medical equipment. Static and dynamic features characterize each piece of medical equipment. A Boolean property indicates if any equipment is available.

3. The Staff class represents those in the medical field who handle urgent problems. A unique characteristic designating each member of the medical staff's availability is used to make that determination.

4. To determine the medical resources, such as specialist personnel and equipment suitable for certain circumstances, the Illness class offers a list of potential ailments to be treated.

4 Experimentation

This section describes the several engines that comprise mobile physician assistance system, how they were developed, and the implementation tools. The four primary stages of the application are as follows:

1. The first stage involves searching the Disease Ontology for the relevant medical resources that may be used to manage the patient's condition.

2. The second stage involves utilizing the same list to verify that the required medical resources are available at every healthcare facility.

3. The third stage is organizing the list of the closest medical facilities based on the accessibility of medical resources and the distance from the doctor.

4. The last stage is to direct the travelling physician by providing him with the best route to his destination as soon as possible.

This study chooses the program "Protégé" to develop ontology for the following reasons:

1. By utilizing a robust community of developers, academic support, government endorsements, and corporate users in various sectors, this framework enjoys significant advantages.

2. Employing an open-source Java, this adaptable knowledge-based framework facilitates the creation of personalized applications focused on knowledge solutions [35].

In recent years, several ontological formalisms have been established, from which it may identified ontology models that aid in constructing newly specified ideas of conceptual non-canonic ontologies. By applying specific operators, the ontology allows the derivation of new concepts from more basic ones. As an illustration, it may infer a new notion called Begin where (Begin= Point > Instant) from the ideas of Point and Instant. The start is a clear term. However, Point and Instant are imprecise ideas. Conceptual non-canonical ontologies give tools for describing domain knowledge in various conceptualizations [36].

The semantic web gives rise to ontological languages that make it possible to define conceptual non-canonical ontologies like OWL (Ontology Web Language). Regarding the definition of ontologies, it is among the most popular languages. Its original purpose on the semantic web was to produce and distribute ontologies. To describe intricate ontologies, it provides a rich vocabulary. A rigorous syntax defines the formal semantics that constitute the foundation of OWL. It enables the construction of intricate links between resources and offers capabilities that make other ontologies easier to create. It incorporates a variety of constructors for attributes and classes, such as identity, equivalence, class complement, cardinality, symmetry, transitivity, disjunction, and so on [37].

The methodology of this study uses OWL as its ontology language. OWL's widespread usage as the most generally accepted standard is the primary driving force behind this decision. The W3C highly recommends OWL, which has strong expressive capabilities for constructing conceptual non-canonic ontology. OWL consists of three sub-languages: OWL Lite, OWL DL and OWL. In OWL Ontology, individuals represent objects within the relevant domain, while classes are viewed as groupings of these individuals. Relationships between two entities are established through properties. Three main categories of properties are identified in Protégé's OWL: object properties pair individuals with other entities, data type properties link with data value, and annotation properties provide additional details regarding classes, properties and individuals. The Ontology in Protégé can be converted into semantic web formats such as XML and RDF, facilitating sharing across multiple networks and devices [38].

For the following reasons, we utilized Eclipse for Java Developers to construct mobile physician support system:

1. Eclipse is an integrated development environment available as open source. Its primary goal is to create an extensible platform for software development that includes tools, runtimes, and frameworks for developing, deploying, and managing software throughout its life cycle.

2. Various plugins, including an Android plugin, may be used to create applications with Eclipse.

In approach to implementing Ontologies, this study utilized the open-source Android platform. This platform is a key element of the stack for creating and integrating mobile devices, which consists of an operating system, middleware and essential applications. Within the Android platform, libraries and tools are available for developers to create applications that can operate on smartphones powered by Android. Ontology offers a language that denotes concepts and expressions used in that field, explaining a particular field of study and demonstrating their interrelation. The application of ontologies in emergency management is highly advantageous since it involves several healthcare facilities and a range of activities that make decision-making more difficult and, therefore, affect the prompt and efficient delivery of medical emergency care.

If mobile doctors can quickly get their patients to the right hospitals, they can save urgent or critical situations. Consequently, the key inquiries are:

How can the doctor determine the necessary medical resources, such as specialist personnel and equipment, to meet the patient's needs?

Does the closest medical facility have these essential supplies?

In partnership with specialists in medical emergencies, data to determine Ontology's major concepts (i.e., classes) and their subclasses for better knowledge capture.

first ontology, "Hospital Ontology," which describes healthcare facilities, was created in response to the first query. It includes hospitals and its many services, personnel, and medical supplies.

To demonstrate the connections between the various Ontology categories at this level, we employed three "object properties":

1. Each hospital offers many services. An object attribute called "Has" associates the concepts of "hospital" and "service."

2. Every service is outfitted with personal medical devices, and by the object feature "HasEq," the concepts "service" and "equipment" are connected.

3. A list of specialist personnel is available for each service: He uses the object attribute "WorkIn" to relate the idea "staff" to his "service."

Each medical resource in the Hospital Ontology now has a Boolean property called "Availability" that indicates whether or not the resource is accessible right now. Additionally, this study defined each concept's role in the Ontology using semantic annotation to see whether any missing medical resources might be substituted. For instance, based on a comparison of the semantic annotation of each medical equipment, an alternative ultrasound machine may be used if the cardiac ultrasound machine is unavailable for the urgent situation. To define examples of urgent and critical care circumstances, the second ontology—disease ontology—was created. Stated differently, this Ontology reveals the gear and skilled personnel required for each medical problem. At this stage, this study identified the medical supplies and trained personnel required for a particular illness using the object attribute "needs." To enhance the care given to patients in critical or urgent situations connected to their condition, for instance, if the patient has cancer, we may ascertain the necessary medical resources that should be present at the healthcare facility using the object property "Needs."

4.1 Matching patient cases with physician's needs

Instead of figuring out which healthcare facility is closest to get around the present emergency management restrictions, the doctor must ascertain whether these locations have the required medical resources and if they are available. he integration of a matching tool into the mobile support system for physicians resulted in the ability to identify patient needs and physician preferences. This tool was driven by the route calculator algorithm, which effectively handled the localization process. Using the SPARQL Protocol and RDF Query Language, the mobile physician could explore the Ontologies related to the patient's health status and the essential medical resources required, such as services, equipment, and qualified personnel that must be accessible. The Semantic web domain heavily depends on the SPARQL Web query language [39].

It enables data exploration by retrieving values from data, querying unknown relationships, and converting RDF data from one language to another. After creating the CkNNs healthcare institutions list, SPARQL retrieved essential medical resources from the Disease Ontology and determined their availability in each healthcare facility [40]. This was done based on changing attributes that described the accessibility of resources and semantic marks that indicated the chance of resource substitution.

This study suggests a matching algorithm that carries out two primary tasks after obtaining the list of medical equipment and trained personnel needed to handle the patient's condition and the list of medical resources accessible in the closest healthcare facilities. The initial part of the algorithm's process involves comparing the two lists to ascertain which medical resources are accessible for the urgent situation. To improve the availability of all the resources. The algorithm examines the semantic annotations of unavailable resources and suggests potential replacements based on predefined equivalence or similarity relations defined within the ontology. One of the primary criteria used to rank the compiled list of the closest medical facilities is the total quantity of medical resources accessible.

4.2 The process of ranking healthcare institutions

Evaluating strategic options is one of the most challenging tasks. Over the past few decades, some software products that use Multiple Criteria Decision Aid (MCDA) techniques have emerged to address this issue. They take into account several competing factors that must be assessed and, consequently, prioritized [41]. An MCDM assesses m options for one or more decision-makers based on n criteria. Its goal is to specify the preferred choice among the pre-specified alternatives as well as the comparison and ranking of these options. The most basic and commonly used MCDM technique is the Weighted Sum Model (WSM). To rank a list of healthcare facilities, the Weighted Product Model (WPM), considered an enhanced WSM method, computes the product of the individual ratios assigned to each criterion when evaluating one option against the rest. Each ratio is then raised to the power of the relevant criterion's weight [42].

In general, to compare two alternatives, AK and AL, the following formula has been computed. The weight of the jth criteria, represented by wj, the number of criteria denoted by n, and the actual value of the ith choice concerning the jth criterion are all essential factors. Comparing option ak to optional can be determined by assessing the ratio $R\ (ak/al)$, where a value greater than or equal to one indicates a preference for option ak over option al. The selected option is considered superior to all others or at least equivalent to them.

$$R\left(\frac{ak}{al}\right) = \prod_{j=1}^{n} \frac{akj}{alj} wj \tag{1}$$

A finite set of options A, including the nearest healthcare facilities discovered through the CkNN search {H1, H2}, and a set of criteria C, establish the basis for decision-making in this scenario. The primary ranking parameter is the distance between the closest hospitals and the current location of the traveling physician. The quantity of medical resources that each healthcare facility on the candidate list has accessible is second criterion of this study. Based on the patient's condition, each criterion has a different weight. For example, if the patient is in critical condition, the distance criterion has a larger weight than the other criteria. In this ranking, greater weight is placed on the available requirements criterion in cases where the patient's condition is urgent:

1. The weight of C2, which expresses distance, is equivalent to 0.6 in the case of a critically ill patient, while C1, which describes requirements that are now met, is equal to 0.4.

2. The weights of C2 and C1, representing the patient's available requirements and distance, equal 0.4 and 0.6 if the patient's condition is urgent.

Physicians have well-established criteria for selecting the various weights of the criteria. A higher value for a criterion indicates its greater importance over the others.

5 Case study of a mobile physician decision system

In the following, this study presents a case study to show the performance of the developed decision-support system. Assume that a patient, somewhere in Tunis city, has a cardiovascular illness. The system will first look up the patient's and mobile physician's locations to find the closest medical facilities. The following is the output that the CkNN engine produced:

1. The Habib Thameur Hospital can be reached in 6 minutes.

2. The Materi Hospital can be reached in 24 minutes.

3. The Mongi Slim Hospital can be reached in 32 minutes.

4. The Charles Nicolle Hospital can be reached in 1 hour and 20 minutes.

Using a SPARQL query on the first Ontology, the system will concurrently link the necessary medical resources, such as specialist personnel and the right equipment, to the disease—in this example, cardiovascular disease—that the mobile physician recognized.

After that, the system uses the matching between the CkNN search results and the Ontology engine to determine which healthcare institutions in each candidate have the most available medical resources. This allows the system to rank the medical resources in each healthcare institution identified in the list of results from the CkNN search. The end product is an index of potential healthcare facilities rated according to the WPM.

When this outcome is shown, the mobile physician may decide which healthcare facility is best for him. He turns on the road, guiding the engine and looking for the route to take him there. Decision-support system, specifically designed for mobile physicians, offers greater benefits than the traditional approach to emergency care. To locate the best healthcare facility, it provides methods of sorting through the essential medical resources such as staff members and equipment pertinent to the emergency. In times of emergency, it helps mobile doctors manage cases, save time, and reduce the possibility of fatalities. Furthermore, this method enables the doctor to select the appropriate action. That way, the travelling physician doesn't have to waste time going along a route full of potential hazards. But because this system searches for the right hospital rather than just the closest one, it takes a little longer to execute than the conventional emergency management system.

6 Conclusion

Mobile doctors are uniquely equipped to make fast, effective judgments in a tight window of time in an emergency. The volume of urgent, critical information may overwhelm even skilled physicians, potentially jeopardizing patient safety. Physicians may benefit greatly from having information readily available regarding healthcare facilities' resources related to conditions seen in emergencies. With the use of this study, the healthcare institutions that are closest to the emergency scene can be identified while also providing shorter routes to get there and precisely identify the medical resources that are required to treat the patient's condition while the patient is being transported to the medical facility; and precisely determine the healthcare facility that has the necessary medical resources to meet the needs of both the patient and the mobile physician. In this way, the proposed cloud platform allows us to determine the right destination or the most appropriate medical institution; nevertheless, minimizing the road constraints leading to the destination still threatens to minimize the time needed to reach the hospital. Indeed, the medical convey, including the physician and the patient, may be deleted or blocked by obstacles on the taken roads. Therefore, the localization tool must be enhanced to provide indications about zones of roads presenting obstacles; thus, the medical convey can avoid once the physician selects the healthcare institution heading to, the enhanced localization tool has to take the chosen destination as input. It triggers the search for the most appropriate route, leading to it while avoiding dynamic obstacles.

Future research will focus on improving a semi-automated diagnostic process, considering the context of road traffic when localizing, and improving ontologies, enabling effective matching and ranking of healthcare facilities. These improvements will further optimize the four suggested engines.

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