Spatial Data Infrastructure using Mobile GIS and web service technologies for public Health Management

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Abstract

The growing need for accurate patient data has propelled the demand for patient level spatial data in the health sector among the developing countries. Unlike developed countries that have embraced developed spatial data infrastructure for public facilities to enable them effectively aggregate disease concentration with accurate locality specificity. Most developing countries still rely on manually collected data from patients whose locality names may mean vast villages with no specific locus. Absence of spatial data infrastructure for public health facilities affects the policy planning as many times medicines are concentrated in localities that are otherwise with minimum patient concentration and areas with massive patient concentration receive less medicines leading to wastage, death, shortages and poor resource planning and allocation. This paper explores avenues for creating a spatial data infrastructure (SDI) in which we develop system mobile GIS prototype system for mobile patient health registry system and using web service technologies, integrate it with spatial data from the water management organisation geo coded information associated with a client meter number. Using the meter number associated with geo coordinates captured, we can extract client/patient spatial information and come up with realistic patient level spatial information. The system is envisioned to greatly improve on efficiency and accuracy in specific patient distribution and locality identification Measures were considered to ensure compliance with the Uganda Health Ethical legislation and the internationally set minimum standards of dealing with patient data.
Key words: SDI, Mobile GIS, Spatially enabled Health Registry System, web services, Uganda

1 Introduction

Effective public health management requires comprehensive records about the patients admitted to the health centres. In addition to patient data, knowledge of patients spatial data especially their residence location is essential in linking environmental exposure to health outcomes (P Elliott et al., 2000). When this spatial data is combined with computing and information technology, it opens up opportunities for healthcare delivery that can be effected without the patient and the healthcare provider being in physical contact (Luo, 2004). This non-physical healthcare provision forms the basis of electronic (e-) health.

Electronic (e-) health is defined as the "use of computers and information and communication technology in support of health and health-related fields, including health services, health surveillance, health literature, and health education, knowledge and research" (Blaya,Fraser and Holt, 2010). Consequently, it promises increased consumer and provider access to relevant information, enhanced quality of healthcare, reduced healthcare errors and increased collaboration (Kreps and Neuhauser, 2010). This, it achieves by enabling public health and primary health care through such activities as patient record management, disease surveillance, primary health data acquisition and analysis, support of community health workers, tele-consultation, tele-education, and research (Kiberu,Mars and Scott, 2017). By enabling management of patients remotely using these ICT channels, e-health is considered a more efficient way of delivering healthcare than transporting the patient from distant places to the medical specialist (Kiberu,Mars and Scott, 2017).

However, for this to happen, the patient's residence location (geo-coordinates) must be explicitly recorded in the electronic health registry system together with other patient details. This location detail would for example be required in instances of either a health emergency where the patient requires immediate physical medical attention or in managing a long-term illness where prescriptions need to be delivered to the patient's residence without them moving to the healthcare units. Additionally, the analysis of electronic health data helps to expand the capacity to generate new knowledge by creating observational evidence to help resolve or supplement the resolution of clinical causality questions (Vayena et al., 2018). Therefore the knowledge of patients' locations would help in spatial epidemiological analyses thereby helping to link environmental exposure to health outcomes within a given population.

Whereas the World Health Organisation (WHO) has published manuals for establishment of Electronic Health Records (EHR) in developing countries (WHO, 2006) and many agencies are funding e-health efforts (Jahangirian and Taylor, 2015), most of the established electronic health-registry systems are not spatially enabled and therefore do not enable explicitly capture of the spatial locations (residences) of the patients. This is partly due to lacking spatial data infrastructures (SDIs) to capture patient-specific spatial data. By not capturing patient residence locations, it makes spatially dependent interventions impossible and well as limiting what can be done with the data collected as spatial epidemiological analyses cannot be attempted.

It should be noted that this lack of spatially-indexed patient data is more exclusive to the developing world especially countries in Africa. For developed countries for example the USA, the patient's ZIPCODE is used as an approximation of their residence while the UK uses POSTCODES in the same way (Paul Elliott and Wartenberg, 2004). For Scandinavian countries, the Personal Identification Numbers (PINs) are linked to each person's residence (Ludvigsson et al., 2009). These are thus recorded along with other personal details, upon hospital consultation or admission. Due to the importance of spatial data in electronic (e-) services delivery as well as their cardinal contribution in spatial epidemiological analyses, developing countries have been encouraged to make considerable investments in the establishment of SDIs.

As such, countries like Uganda for example are undergoing steps to secure a base-map for the whole country, upon which such SDIs can be based. However, these initiatives span over very long periods to get completed. To solve the immediate need to capture patient-specific spatial data at hospitals and healthcare centres, we propose an alternative in this project. This alternative involves the use of already collected utility geo-coded data as a basis for unique location of patient residences.

2 Related work

Public health in developing countries continues to be detrimental both in relative and absolute terms (Tanser and Le Sueur, 2002). The GIS web system should be in position to solve some of the challenges related to poor planning and poor resource allocation.

Successful research in the use of Spatial Data Infrastructure frame work has been cited in literature (Mansourian,Rajabifard and Zoej, 2005). In this work, the authors developed a web based GIS system for disaster management.

Web service technologies have also been applied before in the mapping of landslide susceptibility (Farnaghi and Mansourian, 2013). In this research the services are derived using artificial intelligence and registered as new geo spatial web services (Mansourian,Farnaghi and Taleai, 2008).

However, the lack of suitable GIS data sets which are of great importance for patient level spatial analysis in many developing countries in the public health sector continues to be difficult and expensive to access (Briggs and Elliott, 1995). Yet, there are known similarities in the field requirements for using GIS between sectors like forestry, ecology, archaeology and epidemiology, e-utility service providers that could provide substantial benefits by the sharing of experiences and the pooling of resources(data) (Clarke,McLafferty and Tempalski, 1996). This is because most GIS require both longitudes and latitudes. However, much of the spatial data collection efforts within Africa have been conducted in a decentralised and uncoordinated manner.

To come up with realistic public health interventions therefore, developing countries in Africa could build usefully projects such as the Global Spatial Data Infrastructure (Holland et al., 1999) which aim to support ready access to geographic information to support decision making at all scales for multiple purposes. Geographic datasets are being developed for some countries in Africa through these initiatives, but a systematic programme is required to make geographic data readily available from one sector to another for the continent as a whole.

3 Methodological concept and system design

3.1 Concept

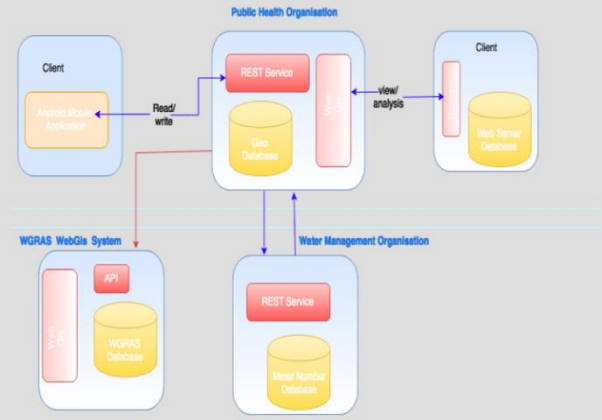
For improved decision making, public health organization need to reliably access patient level spatial data and functionality via mobile GIS, a proper tool for patient data collection to update organisations data servers.

Public health management staff need a system to support easy capturing of real time patient indexed location. The basic question therefore to answer is; if most electronic health-registry systems are not spatially enabled, how can patient indexed location be captured effectively?

Thus the aim of this prototype system is to implement a mobile patient registry system for capturing patient level spatiality. Using web services capabilities, the system design in Figure 1 creates a platform for Spatial Data Infrastructure through the use of webservice RESTful API that renders location data from water management organization databases to the public health server.

3.2 System design

Figure 1: System design for web based patient spatial system



3.3 System overview

When a patient visits a health facility, the hospital administrative staff is authenticated at the client side of the android mobile application. He is able to capture clinical and location information about the patient. The patient's personal information such as First Name, last name, gender, date of birth, phone number, National Water and Sewerage Corporation (NWSC) meter number, sex, date of birth, telephone number and clinical information such as disease, method of diagnosis and results from diagnosis are also captured into the local database. Location data using meter number is also captured.

Once this information is submitted to the web server database, the GIS analyst can then query the Water Management Organisation database through a RESTful web service for the geo-coded spatial API that matches the meter numbers with the corresponding geo coordinates stored in the geo database. Web services as known in literature provide loosely coupled and platform independent ways for organisations to link their applications (Yin et al., 2006). The analyst through a client browser can then use this geo coded data and patient information to generate realistic spatial disease risk maps.

3.4 Mobile GIS for patient data collection

Patient health registry system is used by the health personnel to capture patient data on an android smartphone as shown in

Figure 2. Once the meter number of the patient is captured, a customized geo coded matching algorithm is designed to match meter number with a corresponding geo coordinates that form spatial information for spatial analysis.

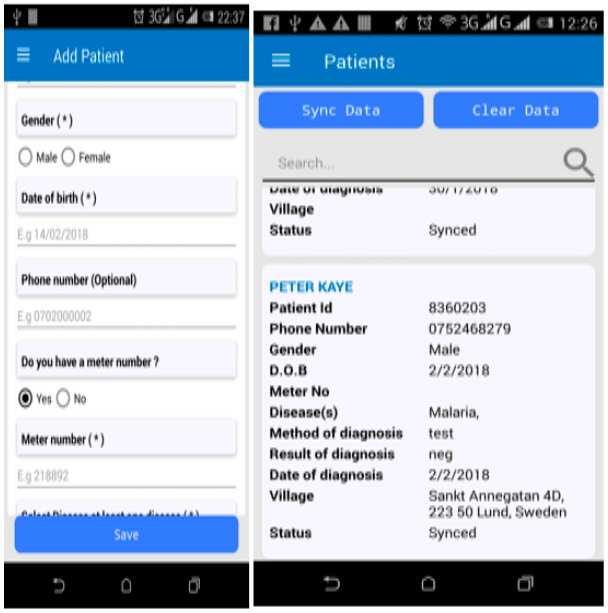
On patient location (android), the mechanism for capturing the geo coordinates was derived out of the following procedure;

Do you have a meterNo?

- If (meter number is available)
  - Enter meter number. The system tries retrieve the position from the server.
- Else
  - If (internet connection is available)
    - Show an interactive Google map where one can click and select the patient position.
  - Else
    - Ask for city/village name. The system tries to retrieve the position from the city/village name afterward. It would be good if we could see a list of village and city names in a dropdown control.
    - Ask for a description of the address. Here user may enter something like NEAR a certain school, Hospital, Junction, etc. to enable one to approximate the locations more precisely.

This structure was designed to be exclusive, meaning that if one asked for meter number the user wouldn't be asked to enter village/city name and vice versa.

Figure 2: Mobile Patient data capture and corresponding report after a successful data sync



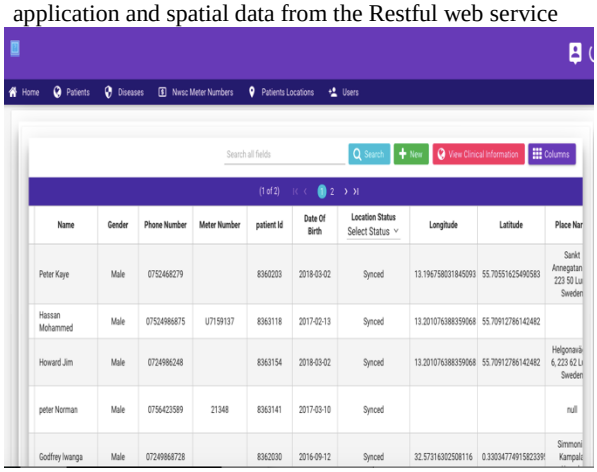
3.5 Mobile GIS for patient data collection

On successful synching of patient details, the system generates reports on the following information: List of detailed information regarding the patient who has been admitted in the hospital is generated as shown in figure 2.

3.6 Creating SDI between patient data and water management geo spatial data

Once data about the patient and the meter number is captured from the mobile smart phone and synced to the web server (see figure 3), one can check for location data based on meter number and the corresponding geo coordinates. However, if location information is lacking, a query to the web service API to avail the required data to external systems like the Public health organization database for further disease analysis. A platform for a Spatial Data Infrastructure (SDI) between applications is thus generated.

Figure 3: Patient information synced from the mobile application and spatial data from the Restful web service



4 Discussions

In this study we have developed a prototype mobile GIS and web service application has been implemented to provide public health practitioners with the ability to collect patient data and patient spatial information from other organisations like using already existing geo spatial data from Water management organization which is in correspondence with a customer meter number. Once the meter number is captured by the mobile GIS system at the health facility, patient spatiality can be obtained.

Web service technologies provide smart mobile devices the capability to run on servers overcoming the limited computational resources of the mobile phones. This thus enables mobile GIS systems to have the same functionality on a remote server.

To evaluate the importance of a Spatial Data Infrastructure using web service technologies and mobile GIS systems for public health management, a prototype system was developed. Using the developed system, medical practitioners from the public health management organization can access location data through a web service API from the water management organization (see Figure 4).

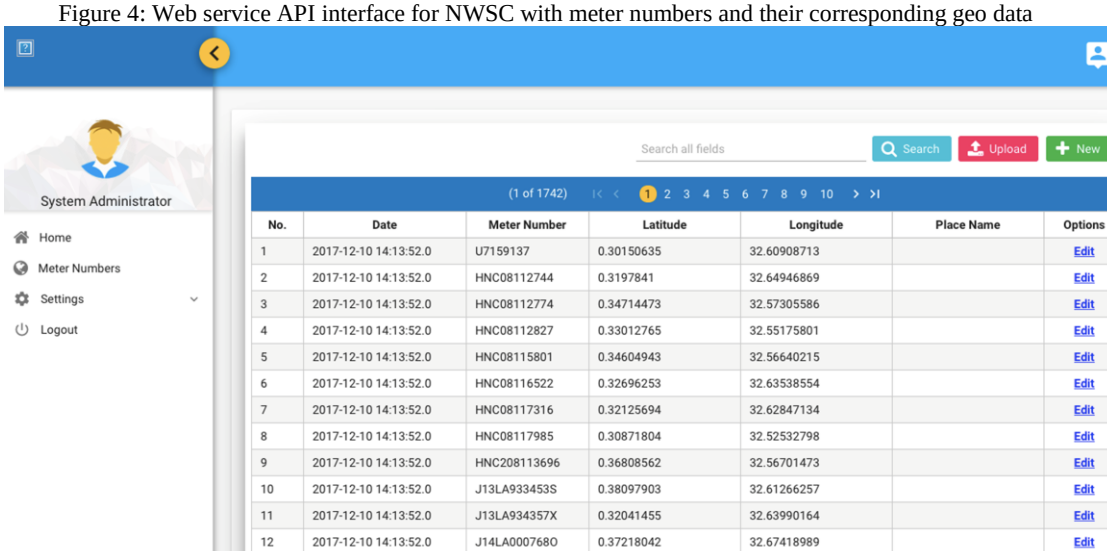
5 Conclusions and future work

This research has illustrated the possibility for creating an SDI platform in public health management organisations where there is a problem of unavailability of reliable patient level spatial data.

Web service technologies and mobile GIS systems were utilized for enabling development of applications at the server side and to facilitate geospatial data acquisition from water management remote servers.

Future work is towards utilizing of web service technology to achieve access to functionality from an already existing Web GIS Risk Assessment System (WGRAS). The advantage with this is that one does not need to build GIS functionality from scratch but use the opportunity provided by web services to share analysis functionality.

Figure 4: Web service API interface for NWSC with meter numbers and their corresponding geo data



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