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Research

The use of a spatial information system in the management of HIV/AIDS in South Africa

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Abstract

Background: South Africa is experiencing an HIV/AIDS pandemic of shattering dimensions. The availability and provision of antiretroviral (ARV) drugs could bring relief to the situation, but the treatment is unfortunately complex with each patient being assigned a different antiretroviral therapy varying in diet-medication regiment. The context of South Africa, its variety of urban and rural settings adds to the challenge of administering and monitoring the HIV+ person throughout the treatment, which will last for the rest of their lives. The lack of physical infrastructure, reliable statistics and adequate resources hinder the efficient management of HIV/AIDS.

Results: The collection of reliable data will be a first step to assess the status of HIV/AIDS in communities. A number of hospitals have started this process using the conventional approach to collect information about their patients using a paper-based system. Since time is of essence in the fight against the pandemic, data exchange between various hospitals, municipalities and decision-making bodies is becoming more and more important. The logical response to such a need is a computerised system, which will collect and administer HIV/AIDS related information within the local context and allow a monitored access to the data from a number of stakeholders.

Conclusions: The purpose of this study was to design and develop an HIV/AIDS database, which is embedded in a Spatial Information Management System. The pilot study area is the Gugulethu township in Cape Town where more than 27% of the 325 000 residents are HIV+. It is shown that the implementation of the HIV/AIDS database and the Spatial Information Management System can play a critical role in determining where and when to intervene, improving the quality of care for HIV+ patients, increasing accessibility of service and delivering a cost-effective mode of information.

Background

It is estimated that today 4.74 million people are HIV+ in South Africa and the South African Medical Research Council (MRC) projected that without appropriate treatment to prevent the development of AIDS, the number of AIDS deaths within the next decade would be more than double the number of deaths due to all other causes, resulting in 6 to 7 million cumulative AIDS deaths in South Africa in 2010 [1]. The pandemic entails both a medical and a logistical challenge. Leaving the medical challenge to the medical profession to overcome, engineers can contribute to the logistical challenge, which is based on managing health care using technology. The main challenges for the efficient and effective

management of HIV/AIDS in South Africa are the inadequate physical infrastructure and the lack of reliable statistics on the disease. The data available are either estimates or projections and therefore range between educated guesses and wild speculation. The South African Government believes that the provision and supply of antiretroviral drugs to HIV/AIDS patients might be ineffective given the scale of the pandemic and its intersection with poverty and other epidemics such as Tuberculosis and Malaria. The lack of health centres, infrastructure and amenities (e.g. electricity and water) as well as low levels of treatment literacy are additional concerns for the required medication adherence rate of 95% (Orrell 2002 – Personal Communication). Due to the limited resources of the country and in attempting to address the 'hot spots' first, there is a need to establish areas with the highest HIV/AIDS prevalence. Some of the data that is required to address the pandemic relates to:

- Location of high HIV/AIDS prevalence
- Level of infrastructure available to communities
- Infection rates of HIV/AIDS
- Status quo of medical care within communities.

Most of this data is available in a number of systems. Municipalities will have data relating to the levels of infrastructure and the status quo of medical care. Doctors in the hospitals know how many patients with HIV/AIDS enter the clinic on a daily base and when and how these patients were infected. The design of a system that combines this information needs to address the following two issues: firstly combining data that is being managed by various authorities in a number of systems and secondly combining data that is spatial and non-spatial in nature. The system should function as an information system containing accurate HIV/AIDS and infrastructure data and support decision-making and management. The easy integration of the system into existing GIS environments that are established within the governmental structures such as the Electricity Department, the Surveyor General's office, the Deeds Office and others is essential. The information obtained will then be turned into knowledge for use in efficient planning, evaluation and policy-making. The belief is that any system based on geographic or spatial information system technology will provide a tremendous opportunity in HIV/AIDS patients' health informatics in South Africa. Whilst Spatial Information System (SIS) cannot solve the HIV/AIDS pandemic, it should be seen as an information-gathering tool that can be employed in the mobilization and response to the disease. The project aimed to establish parameters and benchmarks relating to the use of SIS to administer and manage patient data.

The Gugulethu township

Gugulethu is situated about 20 km from Cape Town and is arguably one of the oldest and fastest developing black townships in South Africa. Gugulethu is home to approximately 325,000 people (Bekker 2003 – Personal Communication), generally poor as indicated by the averaged monthly income of R1126 [2]. The current HIV prevalence rate in the Gugulethu community is 27% (Bekker 2003 – Personal Communication). This translates into ±88,000 HIV/AIDS people and predominantly claims the lives of adults aged 19 to 40 leaving behind children and aging parents. The scale of the pandemic in the township is continuing to expand and as a result, the number of patients visiting the clinic is increasing (Matoti 2003 – Personal Communication).

Challenges currently being faced at the Gugulethu community clinic

One of the main challenges in most of the township-based clinics is the paper-based management system of HIV/AIDS patients. Each patient visiting the clinic has a folder comprising of personal information including name, address, next of kin. Clinical information for example height, weight, blood group, type of disease are also recorded. At each visit, respective folders for the patients are retrieved and entries are made in the patients' file by either the administrative clerk or the nurse. Since the registration, consultation and dispensing processes are carried out manually, human errors such as misplacing or losing the folders are bound to occur.

In addition, it is common that patients, who feel they are not benefiting from the health care and service that is being provided, will opt to go to another health centre. Several cases of patients transferring to other health centres or even patients from elsewhere coming for treatment at the Gugulethu community clinic have been registered. The main drawback in such cases is that the patients' health history is unknown and this is particularly dangerous in the case of antiretroviral treatment, since the history of the patients plays a major role in deciding on the treatment.

Another concern expressed by the staff is that as Gugulethu is a township, it is regarded as being a neglected and underprivileged area. Health officials and managers rarely access the township and are therefore unaware of the situation on the ground. Matoti (2003 – Personal Communication) reasoned that for the Gugulethu community clinic to undergo any upgrading to the infrastructure, it must first and foremost be visible on the South Africa health centres map. He further stated that health officials and

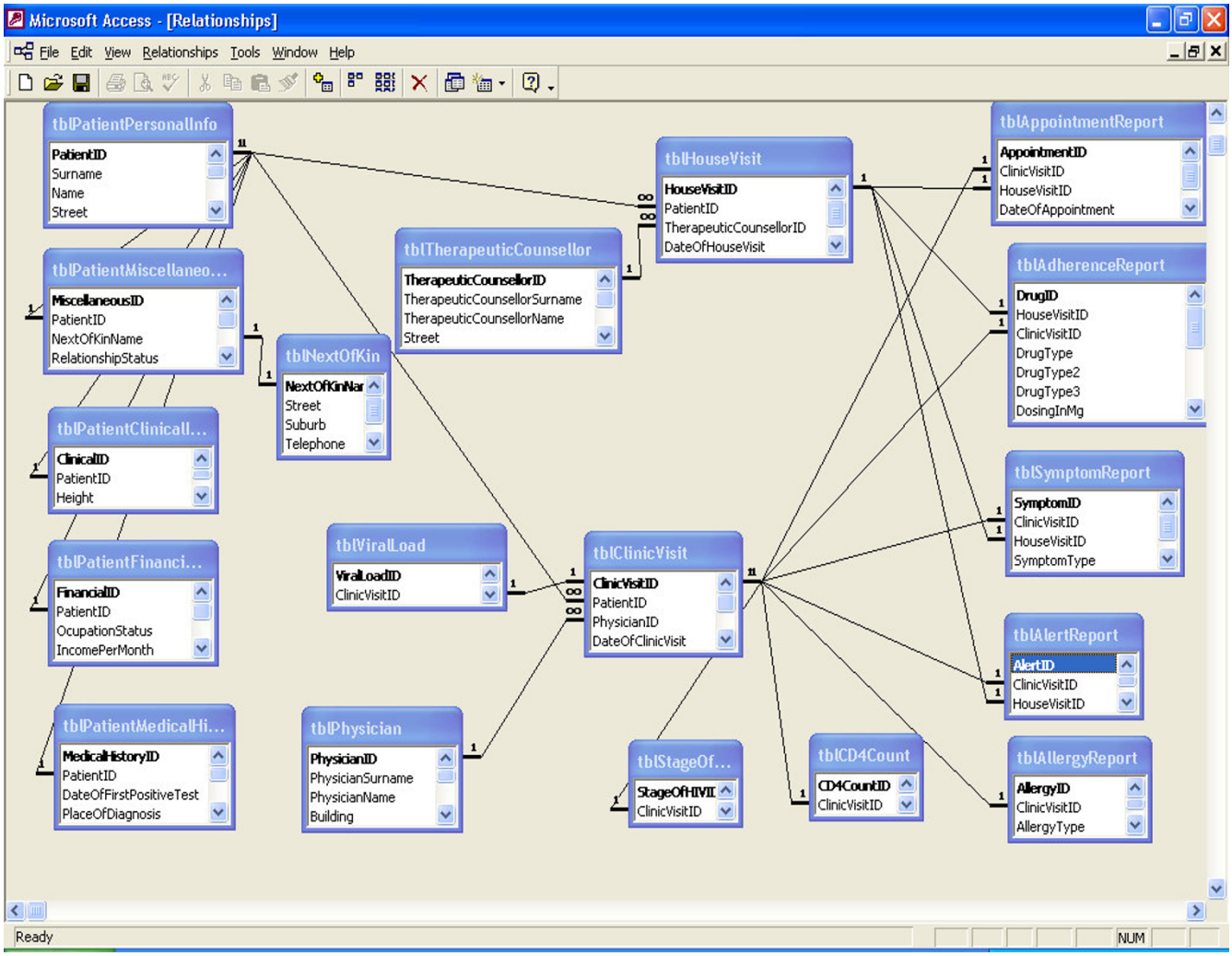

Figure 1
Design of the HIV/AIDS database

managers must be made aware that over 27% of the inhabitants in Gugulethu are HIV+, that the people are struggling with the pandemic in the context of extreme poverty and that the poor existing infrastructure at the clinic hinder the delivery of efficient health care and service.

Methods

The proposed HIV/AIDS database

The HIV/AIDS database was established to facilitate the management of HIV/AIDS patient data at the Gugulethu community clinic. The various menus in the HIV/AIDS database record information concerning the patient's health, the medication, the adherence patterns as well as possible need for appointments, what allergies and symptoms they are experiencing and how severe these are. Microsoft Access was chosen to design the database, since it allowed drawing conclusions with regard to the success and functionality of the design in the small-scale pilot project. However, for a nationwide integrated database, other database platform might be more appropriate. The information within the database can be viewed, sorted, manipulated, retrieved and printed in various ways and gives users the flexibility to obtain data in multiple formats. Figure 1 is an output of the design of the HIV/AIDS database showing the relationships between the different entities and their attributes.

As stated by Longley et al. [3], not all users see the world through the same eyes and for the system to be effective,

Figure 2
User Display of the HIV/AIDS database

it must have the confidence of all users. Since most of the users will not be concerned with how the database works, the system should be designed such that it meets the interests, skills and needs of the individual user. In view of increasing the potential benefits of the system, well-designed and user-friendly interfaces are developed to reduce the need to memorise commands and to provide visual feedback. Figure 2 shows the user display of the HIV/AIDS database. The design of the data input screens as shown in Figure 3 standardises data collection and ensures accurate data entry.

Other functions within the HIV/AIDS database allow users to find and update the records. Microsoft Access also allows automated query and report procedures. The results of queries and reports help the users to focus, examine and abstract the resources without the need to understand the intricacies of the individual tables. The aim is to make it easy for the users to find out the types of data, which exist and provide the tools for appropriate information editing and retrieval that will help them with the maintenance of the patient-medication related documentation.

The proposed spatial information management system

The Spatial Information Management System (SIMS) is conceptualised as a series of layers of information including:

◆ The health districts

◆ The erven

◆ The location of health centres: clinics, government hospitals and private hospitals

◆ The location of roads and streets

◆ The location of main transport routes: taxi and bus

◆ The basic amenities: water, telephone, sanitation and fuel for lighting.

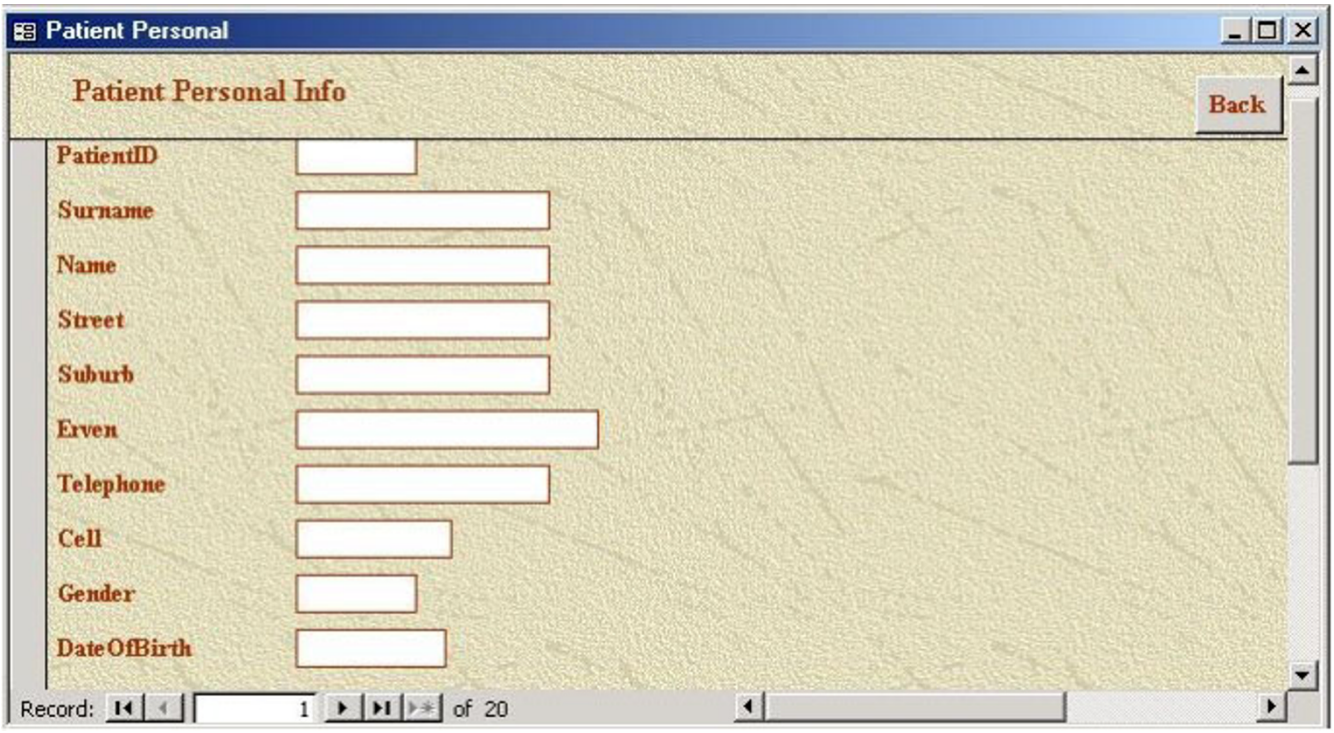

Figure 3
Data input screen of the HIV/AIDS database

The data in shapefile format was obtained from the Cape Metropolitan Council (CMC) of Cape Town and the software chosen for the design of the SIMS was ArcGIS 8.2.

The conceptual design of the SIMS

Figure 4 shows the conceptual design of the SIMS whereby the spatial data and the non-spatial data (HIV/AIDS database) are integrated in the SIMS geodatabase in ArcGIS. The software allows for inputting, updating and analysing the data while maintaining the spatial integrity of each data collection. The technology also supports the spatial display of data, map layouts and handles queries and reports. The geocoding functionality within ArcGIS is used to support and facilitate the integration of data records by location. This functionality means that patient-related data can be geographically located. The creation of a new geocoding service was done via the ArcCatalog interface. The geocoding wizard within ArcMap supported the geographical location of the HIV patients and the therapeutic counsellors. The overlay of the quantitative graphics provides the ability to realize the spatial distribution of the HIV patients in the Gugulethu region in a clear manner. The display depicts ground reality: the red triangles represent the location of the HIV patients while the purple pentagons locate the therapeutic counsellors. The strong point of the system is the ability to identify and access information about any particular patient on the map as shown in Figure 5.

Results and discussion

The SIMS delivers the complete requirements for a data-driven information system, which features the following functionalities:

◆ The visualisation of the HIV/AIDS distribution. The spatial distribution provides a clear representation of HIV/AIDS people.

◆ The identification of areas, which are more prone to the pandemic. The 'hot spots' are earmarked and health professionals can initiate strategies as to how to curb the further spread of the disease.

◆ The display of the existing infrastructure provides an insight into the lifestyles of the HIV infected patients in terms of availability of basic amenities and means of transport.

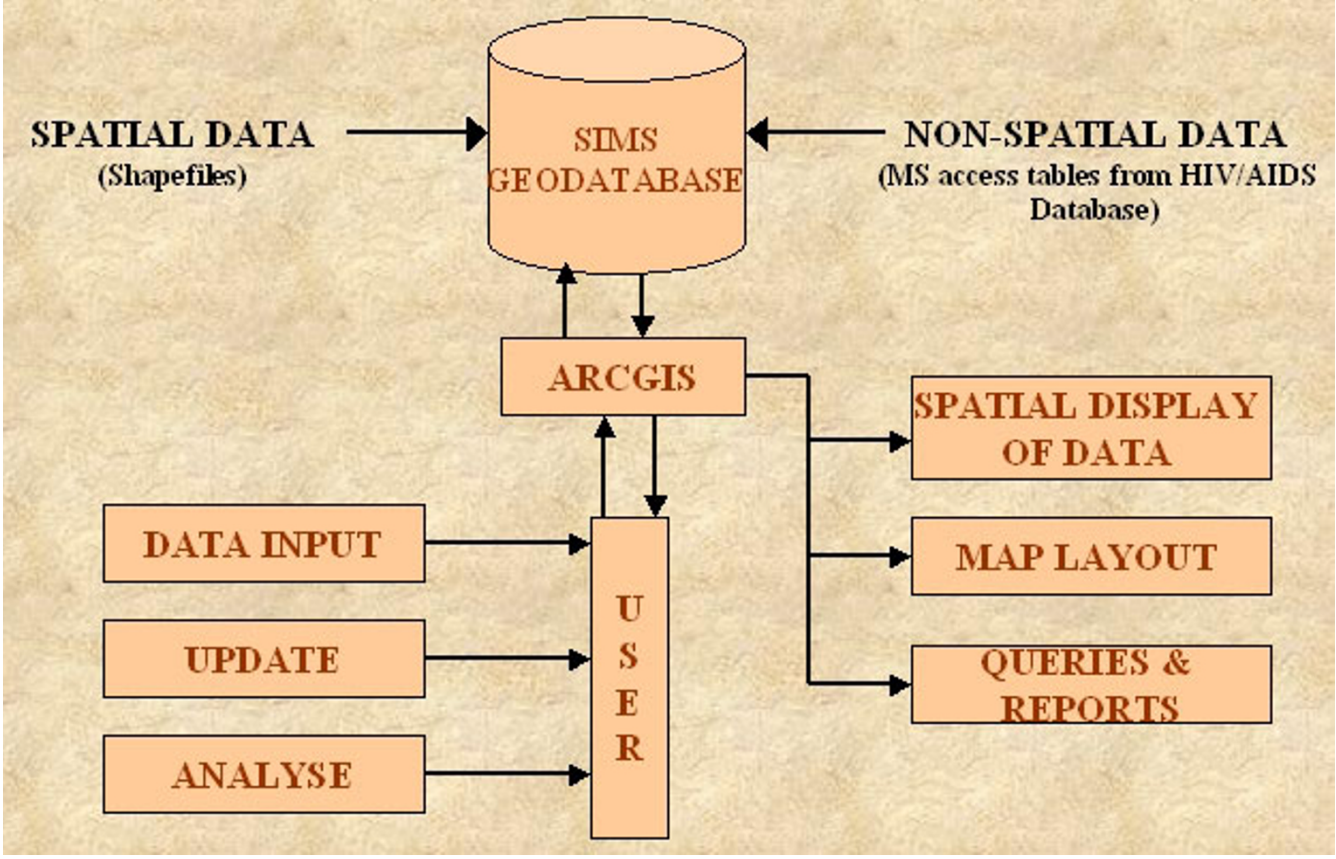

Figure 4
Conceptual design of the SIMS (Adapted from [4])

◆ Comparisons and relationships relating to the spatial distribution of HIV/AIDS patients can be drawn between areas with infrastructure and other areas with non-adequate infrastructure. In addition, decisions can be made concerning the allocation of resources in underprivileged regions.

◆ The spatial distribution of the population in relation to health centre positions assesses the accessibility to appropriate health services. Health officials can utilise this information to site additional health centres with the aim of minimising the distances that patients need to travel to obtain care and services.

◆ The distance that the therapeutic counsellors need to travel for their regular house visits can also be calculated. This information is useful in coordinating the roles and responsibilities of the therapeutic counsellors so that they counsel patients living in the same vicinity rather than miles away.

◆ It is a powerful management and decision-making support system that enables decision-makers to identify and prioritise population health needs, configure health care delivery systems, and evaluate service utilization and health outcomes.

◆ Last but not least, SIMS can be regarded as a virtual information bank that allow focused, long-term and cost effective HIV/AIDS management thus contributing to health development.

Evaluation of the SIMS

The evaluation involved a presentation to the prospective users of the SIMS namely: the physicians, the health managers and the data manager. The main concerns of the users were:

◆ The transition from paper-based management system to a computerised management system would be difficult.

◆ The issue of confidentiality must be addressed.

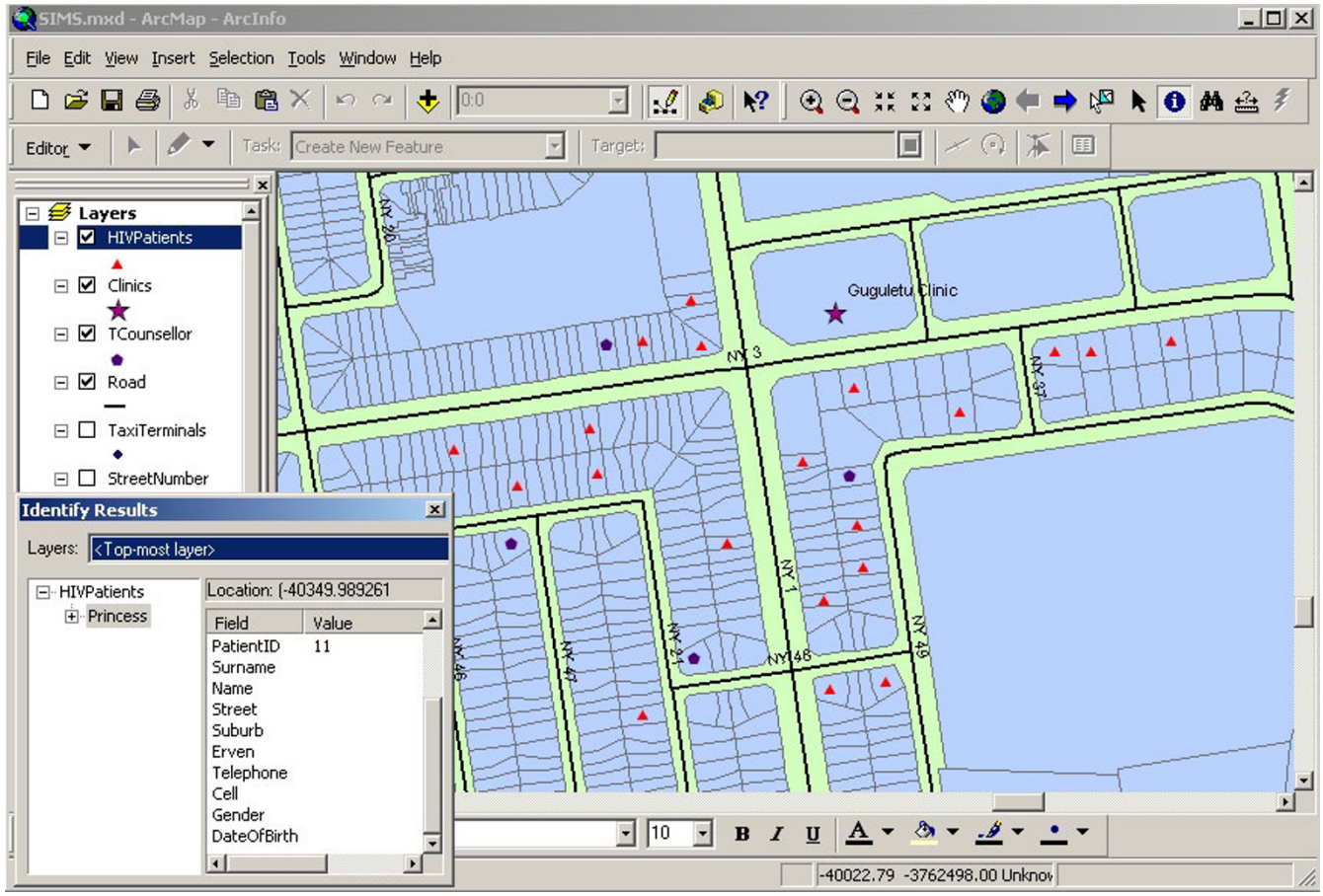

Figure 5
Identifying patients on the map

The users believed that if the system were to be implemented throughout South Africa, the most difficult phase would be the transition from the paper-based system to the computerised one. By designing a system that is intuitively and easy to use and adds real value to the work of the health professionals, it can be expected that the response will be positive. Since the system can be maintained by nurses or administrators, medical doctors might want to use it, but will not be forced to maintain it.

The users felt that access to the system has to be restricted in order for privacy of patients to be protected. The system must ensure that information is used appropriately and confidentially otherwise people will avoid using it. The confidential information should be shared only among authorized people and some balance must be struck between an individual's right to keep information confidential and the benefits that can be accrued if the information is made public. In addition, the records must have adequate security in terms of encryption measures such that personal information about patients is not divulged broadly.

Conclusions

This study focused on the design and development of an HIV/AIDS database and SIMS, which could be used as an information gathering and management tool in South Africa for the management of HIV/AIDS. As the necessary physical infrastructure is not yet in place for effective management of HIV/AIDS in South Africa, the research was motivated by the need to provide a "virtual" infrastructure of support. In essence, the SIMS was designed to administer and retrieve the patient-medication related data, locate the HIV/AIDS patients and the existing infrastructure, contribute to decision-making and policy development in view of providing a spur to improve health care service and delivery.

Based on the findings of this study, it can be noted that implementing the SIMS to manage HIV/AIDS across South Africa is a long-term undertaking. SIMS cannot solve the HIV/AIDS pandemic but is seen as an information-gathering tool that can be employed in the mobilization and response to the disease. The SIMS can perform several functions, fulfill many roles and may provide tremendous opportunities in HIV/AIDS patients' health care service and delivery. The technology is regarded as a vehicle for facilitating public health planning and contributing to community-based decision-making and policy development.

This study has addressed a SIMS for the management of HIV/AIDS in South Africa but there are certain areas that could be investigated and developed further. Firstly, complete medical records of patients are very valuable information and can open new dimensions of research. Instead of the HIV/AIDS database standing alone, other databases such as Tuberculosis, Malaria etc can be integrated into the SIMS. In this regard, the HIV/AIDS, Tuberculosis and Malaria patients can all be mapped spatially, enabling physicians and health officials to visualise the three different patterns and to draw comparisons among the three most important diseases in South Africa. The overlay of the HIV/AIDS, Tuberculosis and Malaria distribution can also identify critical "hot spots" where additional support is needed. The different databases residing in the SIMS can provide a powerful management and decision-making support system that enables decision-makers to identify population health needs and prioritise these needs, configure health care delivery systems, and evaluate service utilization and health outcomes. In addition, collaborative projects and data access, distribution and sharing among the country's health centres can ensure a continuous and current understanding of disease profiles in South Africa.

List of abbreviations

AIDS Acquired Immune Deficiency Syndrome

ARV Antiretroviral

GIS Geographic Information Systems

HIV Human Immuno-deficiency Virus

HIV+ HIV Positive

SIMS Spatial Information Management System

SIS Spatial Information Systems

Authors' contributions

This paper was completed by KB as part of the requirements for her Master of Science (Msc) of Engineering in Geomatics. UR supervised the MSc. Both authors read and approved the final manuscript.

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