Building a Decision Support System for Developing Nations

Introduction

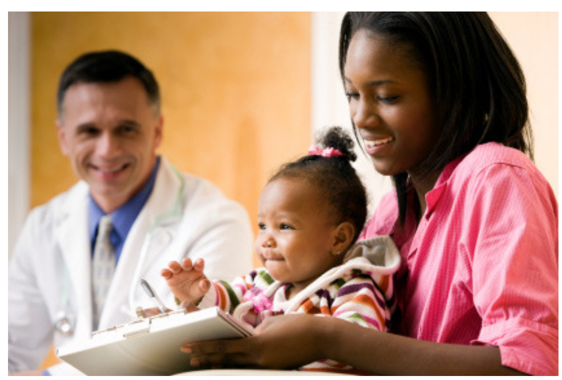
Developing countries are increasing their reliance on technology to modernize their industries, and the healthcare industry is no exception. Their governments, healthcare ministries, and public health officials are utilizing IT solutions to improve health outcomes. International Health and Human Services (HHS) organizations such as the World Health Organization, the International Red Cross, and U.S. agencies such as USAID are assisting them by:

- Providing resources that help them improve care by strengthening their healthcare-related infrastructures.
- Providing them with expertise in the fields of medicine and disease management.
- Utilizing technologies to drive important healthcare-related decisions for improving healthcare outcomes.

Some of the HHS organizations are utilizing technology to improve program effectiveness and to audit their own work in the field. One such organization is utilizing a cutting-edge semantic technology Decision Support System (DSS) to determine potential healthcare issues in a developing country and to also measure and monitor the impact of their disease control initiatives.

This paper describes the challenges and opportunities in building a Decision Support System for developing nations. It also outlines how such nations are fusing their healthcare needs and high technology products with their infrastructures (or lack thereof in various places) to accomplish desired outcomes.

Product Purpose



To meet the requirements of a large international HHS, our company developed a DSS that is a semantic technologies-based platform with an integrated Geographic Information System (GIS) designed to be used for disease management-related decision making in developing nations. Its initial release was developed for a prevalent disease (malaria) in an African country. However, it is currently being expanded to address numerous diseases in multiple countries.

The system is used to determine the disease footprint in a region so that remedial initiatives can be undertaken by the local public health officials, both proactively and reactively. The HHS also utilizes the product as an audit tool to determine an initiative's effectiveness and to refine the subsequent iterations of the program based on prior results. The disease control initiatives include a wide range of measures such as the use of various types of insecticide sprays.

Product Description

The DSS uses ontological principles (semantic technology) to model geographic, entomological, and insecticidal nomenclature. Standardization of insect related terminology allows data from multiple organizations to be effectively combined and queried. Additionally, since terms have hierarchical relationships, the technology allows for automatic categorization and grouping of related data.

As new terms are added, dynamic queries automatically include them. This provides the DSS with a high degree of flexibility, as terms and relationships between terms can change and adapt dynamically in the field to accommodate new requirements.

Furthermore, the geographic ontology standardizes terms for geographic features. This ensures data interoperability and allows for the GIS system to work, even in cases where the exact longitude and latitude of a data point is not known.

The DSS uses GIS to capture, store, and analyze data associated with geographic locations in order to generate maps as a visual tool. A map consists of one or more layers, with each layer defined by a query created in the DSS. The layers can be overlaid and color-coded into meaningful representations of relationships and correlations between the data and geographic locations. These custom-generated maps greatly assist public health officials in making informed decisions regarding disease control.

The developed product is capable of providing reports and query results using local data alone or data aggregated across geographic and governmental hierarchies. For example, an end user can query the system and utilize data from healthcare facilities at a village, city, district, state, or regional level—as well as a countrywide level.

The HHS expects geo-tagged data collection to occur throughout the African country and intends to use it for reports at all levels. This will be accomplished by deploying self-contained, fully functional copies of the DSS at all the locations and levels of interest. Data collected at each level will be forwarded to the next higher aggregation point in order to achieve a wider coverage report at subsequent levels.

Product Walkthrough

An example of the type of Decision Support System under discussion may be helpful in understanding the challenges and opportunities in using such systems in developing nations. Depicted below is a hypothetical example of DSS visuals resulting from queries performed by public health officials (or anyone with access to the system).

Integrated DSS- Product Visual Display

Map from - http://go.hrw.com/atlas/norm_map/zimbabwe.gif

Scenario

To start, a government healthcare official decides to view results of multiple queries aggregated across the entire country. The purpose is to determine patterns of disease-related activities across select areas in the nation and utilize the results to assess the effectiveness of the initiatives already undertaken in the Chiredzi region (circled on the map). By so doing, the official expects to be able to determine the next steps to be taken in disease management initiatives.

Data from the lowest designated level (a city healthcare facility, in this case) have been collected and diligently aggregated through the next higher governmental levels, thus providing a comprehensive countrywide view. The official is aware that not all of the data from all of the areas have been aggregated and is willing to consider the missing data to be within the margin of error for such a report.

The healthcare official conducts a series of queries, and the results of each query are overlaid on the GIS visual display as shown in the depiction above. The resulting display shows:

- Map of the entire country, as well as the localized area of interest.
- Results of all the reported disease cases at collection points of interest. These appear as blue and pink boxes. Blue boxes represent reported cases below a particular threshold chosen by the health official, and pink show those exceeding the threshold, thus indicating problem or high risk areas.
- Results of all the geo-tagged insect collection samples in particular areas. These are represented by gray and red-colored egg shapes. Gray represents insect collection of disease carrying insects below a set threshold, indicating normal levels of insect concentration among the collected samples. Red represents a high level of disease carrying insects from the collected population, thus signifying high

chances of reported cases in nearby areas.

- Results of post-initiative measurement applied at the Chiredzi location show a reduction in reported cases to below the set threshold levels, despite a heavier concentration of disease carrying insects in the region.

Analysis

In this hypothetical example, the health ministry official was able to view the results of multiple queries aggregated at a national level and determine that the disease control measures undertaken at the selected location produced favorable results. By measuring the success or failure of the program at Chiredze and utilizing the feedback to refine subsequent iterations of the program, the official could then move with confidence to undertake similar initiatives elsewhere.

Disease control initiatives may include:

- Spraying insecticides at locations with higher concentrations of disease carrying insects.
- Altering insecticide concentrations if post-spray measurements do not indicate the expected reductions in the targeted insect population.
- Initiating public awareness programs in preventative care, with the goal of reducing the number of reported disease cases.
- Utilizing other combinations of techniques that have proven successful with disease control and containment.

Challenges and Solutions

The challenges of creating a flexible software system that will prove adaptable to various conditions within developing nations are numerous. In these countries, the population is fundamentally engaged in meeting the basic necessities of life; therefore, high speed data communications infrastructure, climate controlled computer centers, and technology are typically not available.

Internet coverage in developing countries is limited. Where the Internet is available, it may not always work, or the connection may break frequently, or transmission speeds may degrade rapidly. Therefore, file transfers between different locations must be optimized to meet those conditions.

Basic infrastructure, such as roads can be non-existent in places so that transportation is often unreliable, and telephone lines may or may not work.

Public health facilities in some places may consist of nothing more than a shed or a hut. Medical diagnostics, equipment, or even a doctor's availability can be unpredictable. A public health official may or may not always be available for a wide variety of reasons, and heavy patient workloads may make the forwarding of collected data quite difficult at times.

In addition, the climate itself is often a compounding factor. For example, monsoons can wreak havoc on the already stressed infrastructure of a country, as washed out roads and underwater railway lines become a problem due to flooding. The monsoon season is also the prime season for mosquito-borne diseases such as malaria and dengue fever.

On a deeper technology level, there are more challenges, and covering them all is beyond the scope of this paper. However, here are a few of the issues typically encountered by developing nations when adapting technology solutions to improving healthcare outcomes.

Imperfect Data Collection Methods

Reported infections, deaths, male-female/adult-child statistics, and other relevant disease management data may get reported in a wide variety of forms. These may include information on a piece of paper, manual data entry into the system on a case-by-case basis, or through Microsoft Access database or an Excel spreadsheet.

TerraFrame's DSS solution had to recognize and accommodate all of these methods of data entry. Clearly, with unpredictable data upload/forward and data integrity, quality of reporting is a problem to be overcome. Proprietary algorithms were developed to determine whether data were reported to a peer system (*e.g*. another healthcare facility nearby) or to a system higher up in the healthcare hierarchy. The algorithms also had to deal with data consolidation and had to detect the following:

- Data report dates, which may be out of synch with peer reporting of incidents.
- Duplicate data reporting.
- Missing data from a facility.

The same algorithms ensured that proper checks and balances at each level were performed in order to keep the data as clean and reliable as possible. Each aggregation point ensured similar data integrity so that accurate reporting at the next higher level could be achieved.

Unreliable Internet Connectivity

Data at various collection points are expected to be collected using the Internet. Many problems are possible, however. A typical healthcare official may or may not be able to transmit the data within the scheduled time range. In addition, a file may become corrupted during transmission. The system may stop working, or power may be interrupted, thus rendering the transmission incomplete.

Such challenges were dealt with through data-transmit-commit algorithms, as well as checksums, which serve to ensure that data were correct and not corrupted. In the case of file corruption, the aggregating point's policies are to request a re-transmission from the initiating facility.

As the Internet is not ubiquitously available, some facilities must forward the data using a computer disk and regular mail. Others may end up simply forwarding copies of all their records to the aggregation point. Therefore, duplicate data entries may easily occur. The checks and balances built into the system, however, ensure that duplicates are identified and rejected.

De-centralized/Unconnected Networks

The final data aggregation point, typically located in the capital city of a country, is also considered the "master system" where all policies, changes, and adjustments to the system are determined. These changes and policy decisions are then forwarded to all the satellite locations in the system. The infrastructure issues cited previously prohibit a mass synchronization to all these systems simultaneously, which is an issue that faces many software deployments in developing nations.

Our solution ensures that each system is capable of stand-alone operation, regardless of where it is deployed—from a local facility level through to the uppermost aggregation point. This means that the local versions of the system are self-contained, fully operational entities that are at least current with the previous version. The synchronization of all the machines to the same version and policies must occur over a period of time as changes reach the facilities in various ways—Internet, mail, and by hand, in many cases.

Data Entry Errors

Issues related to data collection and quality of data has already been discussed, but data mapping is another potential problem area subject to mistakes. A data entry person, for instance, may enter a city's name correctly once, but enter it incorrectly at another time. Alternatively, an Excel sheet may consistently have a city name miss-spelled.

Such human errors are common everywhere and are certainly not unique to developing countries. A typical approach to this issue is to request that the source clean up the data. However, such approaches are not always feasible in places where there are other, higher priority issues that must be dealt with—often by very thinly stretched staff.

A solution was created by developing a self-correcting system using GIS, semantic technologies (or ontological principles), and data analysis. Just as a search engine provides related terms to a typed (or mistyped) term or offers suggestions like "did you mean...", the ontology-based algorithm provides meaningful suggestions—and once the end user identifies the correct term, from that point on, the system is capable of recognizing the mistyped word as the correct one. Over a period of time, the system builds a robust vocabulary, thus effectively addressing data mapping/mismatch issues.

Out-of-date/Non-standard Technologies

Developing nations are often hampered by limited computing capabilities. A typical situation involves a mix of modern laptops and computers of all types, as well as older computers that are no longer supported in developed nations. The majority of computers at various healthcare facilities may be 3-5 years old—or even older, in some instances.

Today’s cutting-edge technology applications may not perform effectively on such old machines. These are machines that are typically received through donations or are often handed down from other organizations or government offices that received newer computers. The software on these computers may be comprised of a mix of brands and operating systems and their various versions. Therefore, when an application is deployed, standardization cannot be expected; in fact, quite the opposite must be taken into account.

To address these computing issues, it was necessary to design lightweight applications that could be supported by whatever computing power might exist in the field. There needed to be an accommodation for the minimal computing power of the older machines and an accounting of the percentage of facilities that may have these machines. For example, a survey of existing computers may indicate that the majority of healthcare facilities have 3 year-old and newer machines and can support a certain group of operating systems and versions, while the remaining facilities may be operating with 5 year-old equipment. This information delineated the boundary conditions within which the lightweight application was designed to function.

Opportunities

While existing infrastructure, human resources, and technical challenges appear daunting for any company doing business in developing nations, there are also great opportunities, as well. African nations are poised for growth, and from a technology standpoint, Africa has several advantages that are worth noting:

Mobile Computing

Many developing nations have bypassed the traditional landline infrastructure by leapfrogging directly to cell phones. These phones are being adopted at a rapid rate throughout Africa.* Applications developed using mobile computing will reap significant benefits due to a robust existing infrastructure in wireless networks. However, the developed applications will have to remain lightweight as the most common denominator in cell phones in these countries is not the *smart* phone, but the *basic* phone with limited computing capabilities.

Few Legacy Technology Burdens

While developing nations may be behind in technology adoption, they are poised to benefit from newer technologies that developed nations are slow to adopt because of existing infrastructure and investments in legacy systems. Just as technology has allowed the move directly into mobile phones, bypassing the traditional landline infrastructure, the lack of legacy infrastructure has minimized concerns about compatibility with new deployments.

An example of this is the speed of the IPV6 (Internet Protocol Version 6) adoption in Africa vs. other nations. IPV6 is an advanced version of IPV4. Developed nations are still utilizing IPV4, and due to the unprecedented growth of the Internet, all the IP addresses available to IPV4 will run out by 2011. One of the advantages of IPV6 is the new numbering scheme that allows for many more machines to be provided with IP addresses.

Because Africa is adopting IPV6 very rapidly,** new infrastructure capable of future expansion provides a host of opportunities in utilizing the Internet for information management. Companies that understand the technology leap that is occurring in Africa are poised to utilize newer technologies for rapid deployment and management of their initiatives.

Technical Workforce Development

With the next generation technology adoption, the demand for technically qualified professionals in developing countries has increased. The bulk of technology management services are currently provided by non-African staff from companies deploying their own technical personnel or non-profit organizations utilizing external agencies to deploy their products. One of the objectives of many of these organizations, however, is to develop competent local staff, which is increasing the demand for a more technically oriented workforce.

Companies with existing products can benefit by providing training and exposure to their product lines at local technical schools and institutes. The presence or awareness of these applications will assist the emerging technical workforce to be adept at, and familiar with, existing applications, thus consolidating the position of the company in the region. This also ensures that their applications can be supported in-country by local workers who offer companies the advantage of a less expensive labor force.

Conclusion

Developing countries must use technology to advance their economies and to better the lives of their citizens. Developing a product for use in these countries, however, requires a thorough understanding of the country's technical landscape and associated challenges and opportunities.

Incorrect assumptions about these nations may lead to a product or an application that may work well in a development setting but may fail miserably once deployed in those countries. While developing a product, the lowest common denominator (*e.g.* the computing power of existing machines in-country) may become the driver of how robust the developed application can be.

While clearly there are challenges associated with developing technology products for these countries, there are also opportunities for those who understand how to take advantage of them.

* Africa-The fastest growing mobile phone market in the world - http://www.innovationafrica.org/2008/05/africa-the-fastest-growing-mobile-phone-market-in-the-world/

* *Africa hopes to leapfrog other regions in IPV6 adoption
http://www.techworld.com.au/article/310298/africa_hopes_leapfrog_other_regions_ipv6_adoption