Towards Near Real Time Public Health Surveillance (A Decision Support System for Public Health Surveillance)

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ABSTRACT

In recent years with increasing population and changing climatic conditions over the globe gave room to outbreak of different diseases, proper and timely handling of disease cases can result in saving many important human lives. Public health surveillance is the ongoing, systematic collection, analysis, interpretation and dissemination of data regarding a health-related event for use in public health action to reduce morbidity and mortality and to improve public health. Data disseminated by a PHS system can be used for immediate public health action, program planning and evaluation, and formulating research hypotheses. Timely access to disease related data and geographical location is very necessary for public health officials and decision makers in order to avoid mortality and morbidity rate in a particular area of interest (AOI). In this paper we propose and developed a web-GIS based system for public health surveillance about data collection and dissemination through internet. A database of disease cases has been created with six years of historical data from Chiang Mai province Thailand. This system efficiently provides the maps and charts in real time through internet-GIS concept for decision makers and public health officials for analysis and taking preventive actions.

General Terms

A decision support system for Public Health Surveillance.

Keywords

Public Health Surveillance, Internet GIS, Decision Support System

1. INTRODUCTION

In recent years with increasing population and changing climatic conditions over the globe gave room to outbreak of different diseases like a recent outbreak of dengue fever in Lahore Pakistan. As of November 2011, this dengue outbreak has killed over 300 people in the last several months and over 14,000 are infected by this vector born disease (Wikipedia, 2012). A disease outbreak is the occurrence of cases of the disease beyond what would normally be expected in a community defined geographical area or season. An outbreak can occur in a limited geographic area, or can span several countries. It may take several days or weeks, or for several years (WHO, 2010). Similarly diarrhea has been a major public health problem for many years in Thailand (Chaikaew et al., 2009). According to (Epidemiology, 2001-2006) it has been estimated that nearly 1 million cases every year (in the period 2001–2005: 1,020,377, 1,055,393, 966,760, 1,161,877 and 1,142,581 respectively, with corresponding deaths: 176, 160, 124, 93 and 77). The total number of diarrhea incidences were estimated 1,245,022 and 9 deaths in 2006 only, highest rate of incidences were recorded in Chiang Rai, and Roi Et provinces. These are all located in northern and north-eastern region of Thailand (Epidemiology, 2001-2006).

Disease outbreak detection is very important. Unlike explosions, epidemics are silent. Outbreaks kill or sick them before they are detected (M.Wagner et al., 2006). Disease outbreaks can inflict such damage quickly, and they can also spread quickly. The window of opportunity to limit this damage can be as short as a few days in the worst case (Wagner et al., 2001). The U.S. spends billions of dollars a year on various forms of health surveillance. The main costs are for the control of hospital infections, Public Health Surveillance (PHS), monitoring air and water, training, improved information technology infrastructure for public health and research (M.Wagner et al., 2006). Proper and timely handling of disease cases can result in saving many important human lives.

PHS is the ongoing, systematic collection, analysis, interpretation and dissemination of data on events related to health for use in public health action to reduce morbidity and mortality and to improve public health (Teutsch SM, 2006). PHS systems should the ability to collect and analyze data, data dissemination to public health programs, and regularly evaluate the effectiveness of the disseminated data. In 1993, The World Health Organization (WHO) launched a public health mapping GIS programme (http://www.who.int/health_mapping/en/). In addition, the revised WHO International Health Regulations set out basic capabilities, such as the use of early warning systems and information technology more effective, to be implemented by Member States to improve detection and surveillance of health threats, including meningococcal disease. The national GIS system for disease surveillance can be accessed through internet, such as the Swedish and SmiNet, which provides epidemiologic infection in various formats including GIS (Reinhardt et al., 2008). GIS has also been established to monitor the spread of infectious diseases and intervention strategies to target more sophisticated units such as hospitals military installations (Kho et al., 2006) or cities (Zenilman et al., 1999).

In some high-income countries, the PHS includes systems that use computer technology and monitor health data in near real time, facilitating the detection of outbreaks and timely situational awareness. In September 2007, a meeting held in Bangkok, Thailand to consider the adaptation of near-real time surveillance methods to developing settings. Thirty-five participants represented Ministries of Health, universities and the military in thirteen countries and the WHO (Chretien and Lewis, 2008). The keynote presentation by a WHO official stressed the importance of national capacity for improved surveillance and response under the International Health Regulations, which came into force in June 2007. Other speakers presented innovative electronic surveillance systems for outbreak detection and reporting of diseases in developing countries, and methodologies used in near-real-time monitoring systems in the United States. When discussing small and easy group, participants identified key considerations in four areas for adapting surveillance in near real-time and identified the parameters of development: software, professional networking, training and data acquisition and treatment. This meeting was a first step in extending the benefits of near real-time monitoring of the development countries (Teutsch SM, 2006).

2. CURRENT DISEASE REPORTING SYSTEM IN THAILAND

Controlling disease spread and epidemic outbreak have been a major problem around the globe. In 1970 a surveillance system focusing on 14 diseases was established to monitor trends, detecting outbreaks and recommending effective prevention and control measures (Thaewnongiew et al., 2009). It was a passive system from which the flow of information is shown in the figure1.

In the current flow for disease reporting the Local health centers (LHC) regularly record the disease report cases on a prescribed form called Form 506 and store it locally. This data is transmitted to a higher level i.e. District Health Offices (DHO), Provisional Health Offices (PHO) and the Bureau of Epidemiology (BOE) on weekly basis through email or diskettes. The spatio-temporal analysis is done on health centers for further investigation and actions (Thaewnongiew et al., 2009). It is a kind of slow data movement and can cause delay in identifying the possible disease outbreaks. Literature reviews suggested that the surveillance system needs improvement (Djibuti et al., 2007; Tan et al., 2007; Wuthikun, 2001).

3. METHODS

This section describes about the implementation details of the prototype system. The system have been developed using the concept of three tier web application by using Open Source Software's (OSS). Due to technical complexity and high cost, communities in developing countries lacking the expertise and resources cannot benefit from commercial software's. OSS offers the potential to solve these problems (Tan et al., 2007). The prototype system is built by using Hypertext Preprocessor (PHP), Apache, MySQL and Asynchronous JavaScript and XML (AJAX).

3.1 THREE-TIER INTERNET GIS BASED APPLICATION

Three-tier architecture refers to the separation of application process in three different layers, namely presentation layer, application layer and data layer. Users interact with the system through presentation layer. The middle layer or tier i.e. application layer or logic tier performs the internal processing that occurs, for example when a user submits a request for a map with specific parameters through a query, the user query is processed at this layer and send the result back to user (http://weblogs.asp.net/nannettethacker/archive/2008/03/05/3-tier-web-application-development.aspx). When used correctly, using a multi-tier architecture improves performance and scalability. If a Web page needs an update or redesign, all that can be manipulated by changing the CSS and HTML, without affecting the business logic or data. All three levels can be replaced or updated individually without affecting any other part. For example, if designer change the database on the back end, it would not affect the presentation or business logic levels, other than changing the database connections (http://weblogs.asp.net/nannettethacker/archive/2008/03/05/3-tier-web-application-development.aspx). A schematic diagram of three tier web application is shown in figure 2.

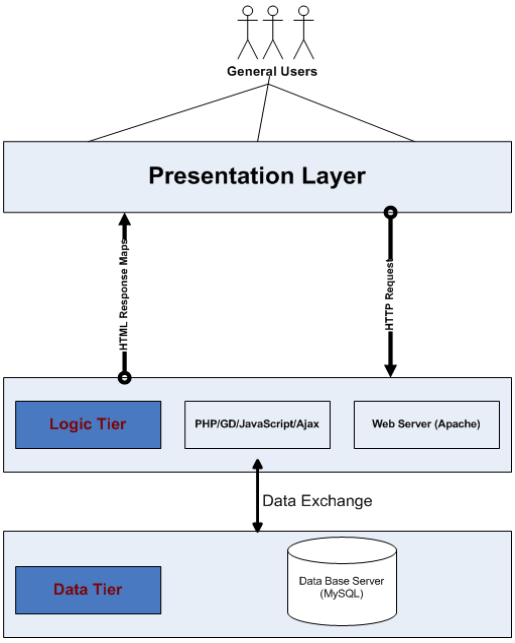

Figure 2: Three Tier web application architecture

Figure3 below shows the architectural diagram for the proposed system. The system consists of mainly three servers including database server, map server (also web mapping service) and web server. It is based on service oriented architecture (SOA). Health data confidentiality is an important issue and we have tackled this problem through decentralized authentication mechanism using the concept of OpenID (Asif and Tripathi, 2012).

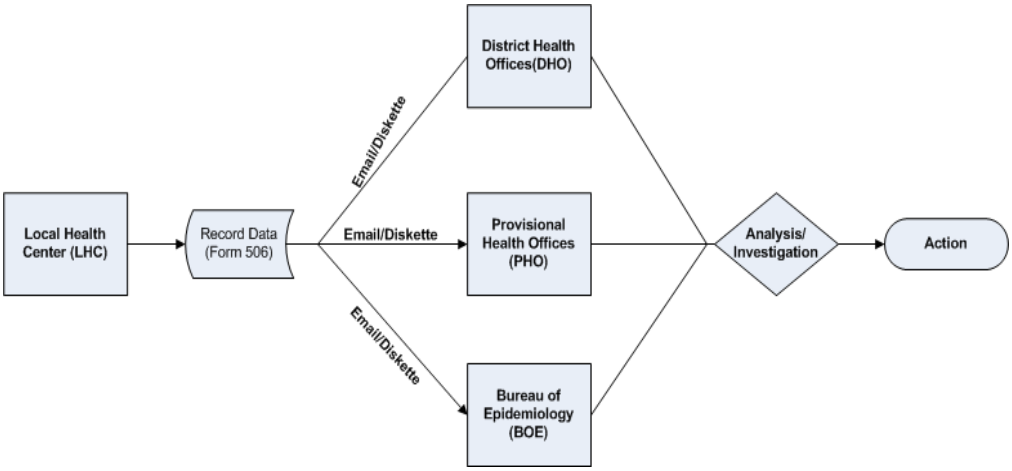

Figure 1: Data flow diagram for current disease reporting system in Thailand

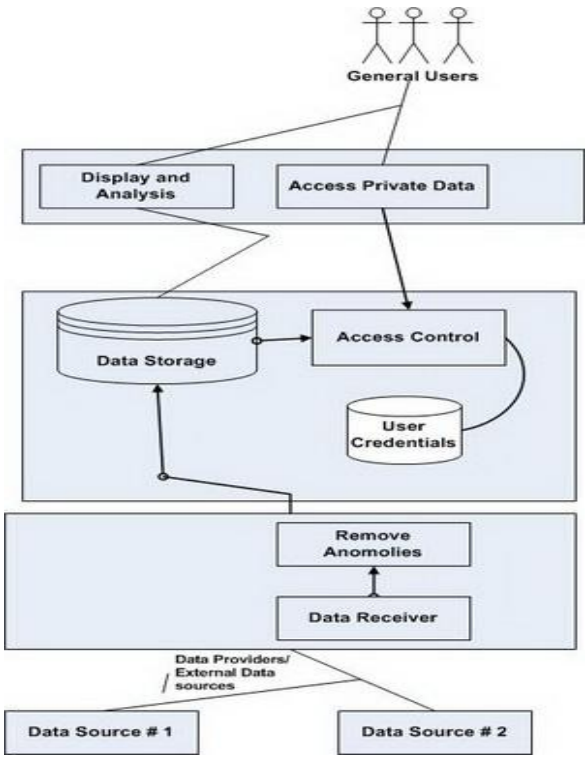

Figure 3: Architectural diagram of the proposed system.

4. RESULTS

The specification of system is quite generic but in order to test the usability and functionality currently the system is in testing phase for the Chiang Mai province of Thailand. Chiang Mai is the largest province in northern Thailand, with a location 18 ° 47'N and 98 ° 59'E, covering an area of 22,061.17 km ². It is mostly covered by mountains and forests, with an approximate altitude of 310 meters above mean sea level. Chiang Mai province is divided administratively into 24 districts (Chaikaew et al., 2009). Currently the system is under testing for the six kind of disease namely Dengue fever, diarrhea, fever unknown origin, food poisoning, influenza and malaria. Data has been acquired from Chiang Mai Provincial Public Health Office (CMPHO), Thailand for the years 2001-2006. These records included the disease cases referred from other hospitals and the population figures from the Ministry of the Interior, Thailand. The system entertains two types of users a) general users and b) users with special access permissions, first type of users can submit queries in order to view current trends of a particular disease for a specified time. Users with special access permissions are authenticated through the modern authentication scheme (Asif and Tripathi, 2012). Authorized staff at the participating hospitals and institutes fall under the category of second type of users. System accepts data from authorized users in order to generate accurate results. Due to SOA based architecture the system can also utilize the data through external sources e.g. (Nigel and Son, 2012) developed a public health database (GENI-DB) for infectious diseases around the globe. Despite of its own data base, this system can use this database in order to produce the visual results in near real time.

4.1 Disease Trend Analysis

Monitoring the disease patterns in a particular calendar year is very important in order to take preventive measures. Public health officials and decision makers can visualize the disease pattern trends through this component. The proposed system provides functionality for monitoring the disease trends in particular year for one or more diseases collectively. For example figure4 illustrates dengue trends in year 2006. This kind of information is very useful for decision makers for better planning and control.

Our system can also generate automatic bar charts of disease trends from simple and user friendly queries for simply analysis of trends. Figure 5 shows cumulative trends of all the diseases in year 2006 for Chiang Mai Province.

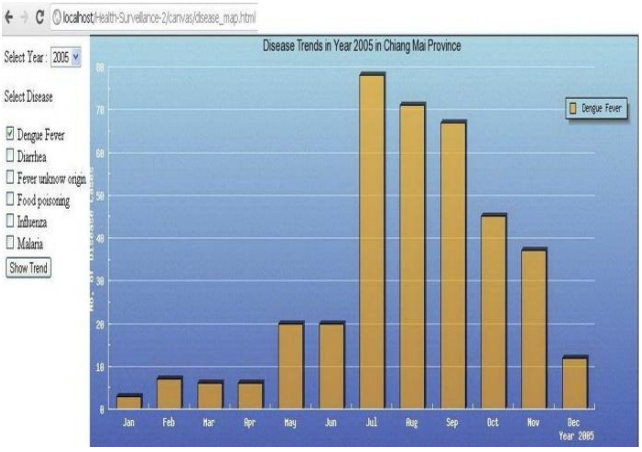

Figure 4: Dengue trends in year 2005 in Chiang Mai Province

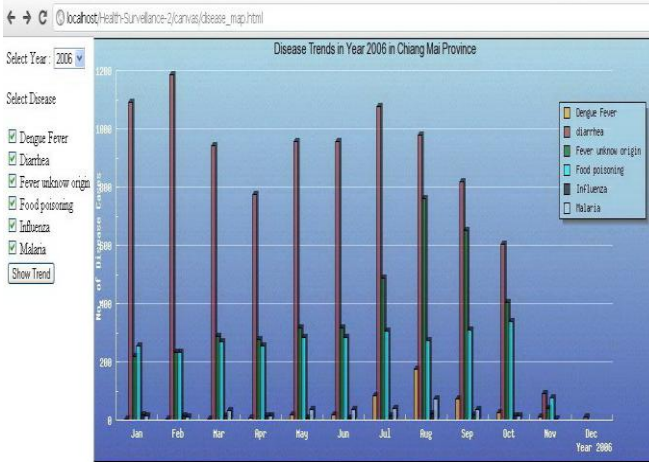

Figure 5: All diseases trends in year 2006 in Chiang Mai Province

4.2 Multivariate Surveillance

Multivariate surveillance of disease incidences is of utmost importance in order to visualize the disease patterns geographically. The purposed health surveillance system is capable of generating real time dynamic maps for spatial patterns of one and more than one diseases in the area of interest of different time intervals. The system generated risk maps can help the policy makers and people in order to take preventive measures. Some results are shown in figure6 for the disease name fever of unknown origin in eighth week of 2005. Similarly system can generate maps of this kind on weekly and monthly basis.

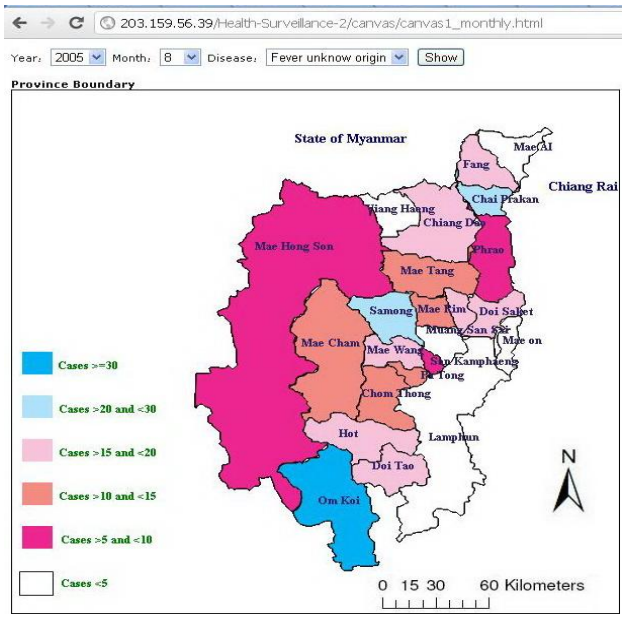

Figure 6: spatial surveillance of fever unknown origin in August 2005

4.3 Cumulative Disease Trend Analysis

Monitoring multiple diseases at a time can result to give useful information in order to analyze the relationships among different disease and the cause of inter dependencies among them. It might be of interest of authorities to monitor the cumulative trend of one or more disease in a particular period of time e.g. 2001-2006 in order to check the effects of one disease to another. The system comes up with an interface through which the users can achieve the objective of visualizing the spreading trends of one disease or multiple diseases in the area of interest in near real time.

Historical trends of dengue fever from year 2001 to 2006 are shown in figure7.

Similarly, a sample output of the cumulative trend situation from 2001-2006 of all diseases under study is shown in figure 8.

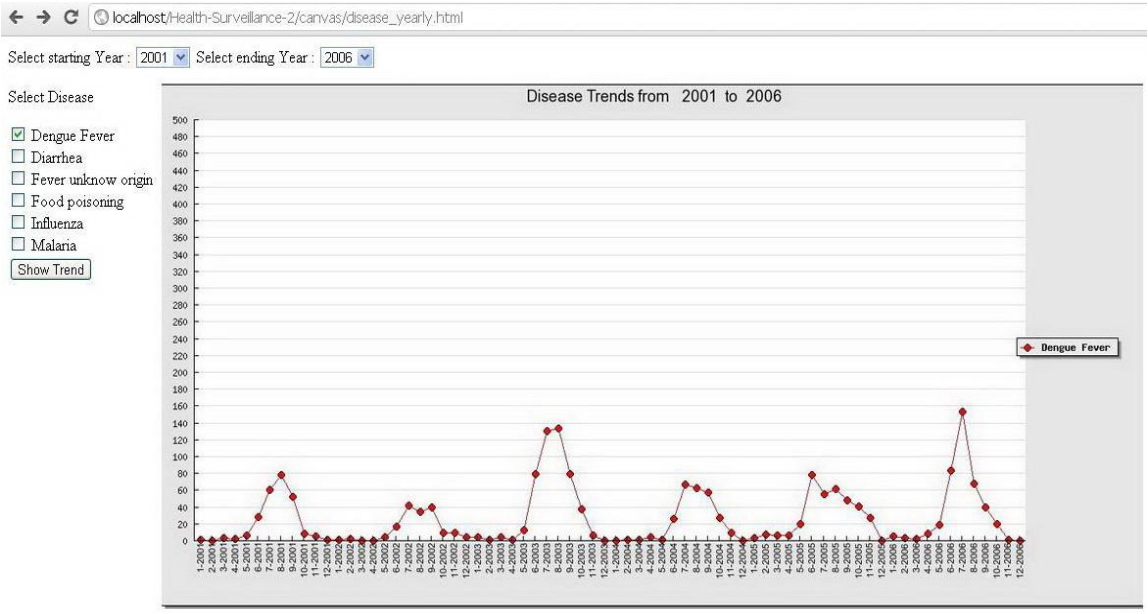

Figure 7: Historical trends of dengue fever

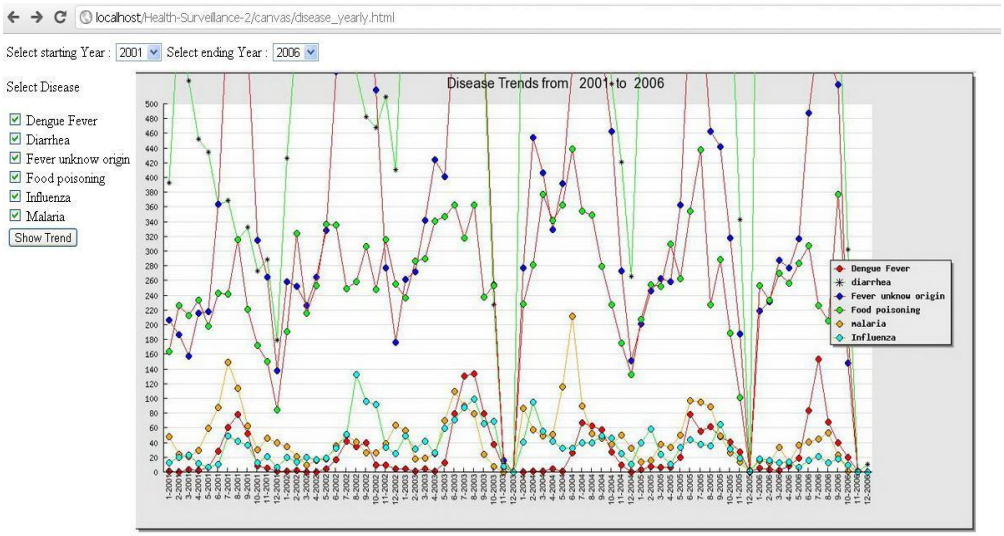

Figure 8: Historical trends of all diseases

5. CONCLUSION

In recent years with increasing population and changing climatic conditions over the globe gave room to outbreak of different diseases like a recent outbreak in 2011 of dengue fever in Lahore Pakistan. An outbreak can occur in a limited geographic area, or can span several countries. It may take several days or weeks, or for several years. Inefficient monitoring of diseases can lead to loss a number of human lives. This study explores the existing disease surveillance systems in Thailand as well as in other countries. There exists some offline disease surveillance system which might not be useful for near real time monitoring of disease situation in the area of interest, also the Ministry of Public Health (MOPH) have their paper based reporting system which is not efficient to monitor the disease spread in real time.

It is very necessary to establish a near real time health surveillance for online surveillance. This paper presented an online web-GIS based disease reporting and surveillance system through different parameters. The interaction between different servers e.g. map server, web server and data base server has been handled by the concept of Single Sign On through improved version of OpenID protocol in order to authenticate the users for data input and monitoring results. Data is the most valuable component in these kinds of systems and the system is not useful without data. This research provides the two kind of data collection system, one is a desktop based client interface for disease data collection and the second is a mobile based application for data collection from remote locations/ healthcare centers lacking of internet facilities. The mobile based application is a customization of open source software Epicollect and is based on open source operating system for mobile applications i.e. Android operating system by Google.

The system is implemented with the help of open source software and is quite efficient for near real time surveillance of health data. This system takes the challenges of handling six type of disease namely Dengue fever, Fever of unknown origin, Food poisoning, Influenza, Diarrhea and malaria. The system is based on three tier application and is quite generic in nature, it can be easily converted to any number of disease and maps generation classes can be increased/decreased with little modification in source code. The results include but not limited to dynamic generation of color coded maps of disease patterns, monitoring of geospatial spreading of these diseases geographically. Statistical analysis of disease spread has been implemented and cumulative disease trends for more than one year are implemented and are very useful in order to understand the disease spread patterns and can help the decision makers in order to take preventive actions for disease spread.

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