Design of Nivārana: The power of information in prevention of epidemics

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Abstract

Communicable disease surveillance is an important function that is needed to control the spread of communicable diseases. The Epidemiology Unit (EU) is the principal governmental organization responsible for disease surveillance in Sri Lanka and possesses a wealth of disease related data collected over a period of several decades. Since the early detection and rapid response is the mainstay of controlling a communicable disease outbreak in a community, acquiring the ability for; collection of complete data island-wide in a timely manner, analysis of such data, and timely dissemination of analyzed data as well as guidelines on appropriate interventions will no doubt strengthen the EU's capacity to implement disease prevention and control activities more efficiently and effectively. The software solution "Nivārana" aims to pool the information that is available through data collection and to minimize the response time by the EU and the other preventive health care institutions thereby minimizing the spread of disease. Several existing communicable disease surveillance systems were analysed to identify their capabilities and limitations. Information dissemination was identified as a completely ignored feature in existing systems as a limitation. Use of multiple data sources for better and accurate decision making was seen as an important aspect. Set of design considerations are identified to focus the design to be suitable for Sri Lanka and as well as for other developing countries. Rooted on these design considerations, the system design was carried out using object oriented concepts. The system is designed to fulfil the requirements that are set by the EU and to be configurable in division hierarchy and diseases. With the analysis capabilities and set of comprehensive reporting capabilities combined with swift information dissemination will no doubt make the public health care officers equipped with relevant, up-to-date information that could be used to control the communicable diseases.

Keywords: Communicable Disease Surveillance, ICT

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Introduction

Communicable disease surveillance has evolved as a cornerstone of public health systems[1] and is carried out by every country with the aim of detecting the outbreaks as early as possible[2]. Early detection of communicable disease outbreaks increases the ability to control the spread of the disease[1,2]. Rolfhamre et al. further mention that the data collected by communicable disease surveillance allows the identification of the trends in disease occurrence which is valuable for the health policy makers to be use as a basis for long-term prioritization[1].

The Epidemiology Unit (EU) is the premier institution in the Ministry of Healthcare and Nutrition which carry out surveillance, prevention and control of communicable diseases in Sri Lanka. There are several factors that hinder the capability of EU in disease surveillance activities. Information and Communication Technology (ICT) could be used as the vehicle in breaking these barriers in disease surveillance. Countless benefits could be gained, if the present surveillance system is integrated into an ICT solution.

Nivārana is a joint initiative taken by the University of Colombo School of Computing (UCSC) and the Epidemiology Unit to address the prevailing issues and enhance the disease surveillance capacity of the EU by exploiting the countless opportunities offered by ICT. Nivārana is conceptualized having the saying "prevention is better than cure" in mind and it is expected to facilitate swift public health action to minimize communicable disease burden in Sri Lanka thereby, preventing ill health and suffering in the community and by conserving much needed resources.

This paper is organized as follows. The second section gives an insight into the background of the project with project goals. *Section 3* discusses the literature on existing epidemiological systems worldwide. *Section 4* highlights the design considerations and *section 5* elaborates on the architectural aspects of the system. *Section 6* contains a discussion which is followed by the conclusion in *section 7*.

Background

Communicable disease surveillance

Communicable disease surveillance is an ongoing process consisting of data collection, analysis and interpretation of data and is intended to be used in planning, implementing and evaluating public health policies and practices. Communicable disease surveillance systems serve two key functions; early warning of potential threats to public health and programme monitoring functions which may be disease specific or multi-disease in nature[3]. There are two main objectives when establishing disease surveillance system;

1. To identify disease outbreaks early and thereby take proactive measures to control diseases and
2. To be used as a monitoring tool for disease prevention and control programmes.

Disease Surveillance in Sri Lanka

The prevailing system in EU collects data only from the inpatients of state hospitals. The disease related data are collected from the Bed Head Ticket (BHT) of patients. The data gathered in this way are forwarded to the relevant Medical Officer of Heath (MOH) offices. MOH offices assign Public Health Inspectors (PHIs) to investigate the cases related to their region for confirmation. The investigation results are sent back to the MOH offices. MOH offices prepare "weekly return of communicable diseases" containing the summary of the reported cases during a particular week with the confirmation data. This summary is sent weekly to the Epidemiology Unit (EU) in Colombo and the Regional Director of Health Services.

Upon receiving the "weekly return of communicable diseases" data from the MOH offices, they are fed into the electronic disease surveillance database residing at the EU. The data are compiled and analyzed at the EU. Epidemiologist at the EU make decisions rooted in the analysed information, and device action plans to mitigate any outbreaks detected. The information is published weekly and quarterly, in the form of Weekly Epidemiological Reports (WERs) and quarterly epidemiological bulletins respectively. EU sends these reports to every MOH office, every hospital (state and private) and other medical institutions[4].

Current issues in communicable disease surveillance

There are several pitfalls in the current manual paper based disease surveillance system which hinders the EU's performance in disease surveillance and control activities. These issues could be briefly described as follows.

Data collection

There is a significant delay in the data collection process. The validity, relevance and quality of the collected data are questionable because of these delays. Furthermore, current system gathers data only from the government hospitals however; there are patients who are admitted to the private sector hospitals and this data is not collected. Therefore, data completeness is suffered and whether the current situation is reflected form these data is questionable.

Data analysis

Manual nature of data analysis causes adverse impact in timely decision making. Incompleteness of the data also impacts on data analysis in an adverse way. It is also important to note that all the data analysis is done centrally at the EU therefore; peripheral level outbreaks are noticeable only when significant number of cases are reported which happens as a result of the low granularity of data analysis.

Quick decision making

The presentation of information is an important factor in decision making. Analyzed information must be represented in a way that is suitable for quick decision making. As an example if the data could be plotted on a map, spatial dimensions could also be incorporated in the information, which leads to more relevant decisions, especially about the spread of diseases.

Currently the presentation is only in the form of graphs and tables. Therefore, extra effort has

to be taken in decision making to incorporate other factors as mentioned above. The capacity for early warning is hindered due to these factors.

Difficulty in identifying emergence of outbreaks
Being proactive is utmost important in preventing communicable diseases. Since there are limitations in data analysis and inefficiencies in data collection, there are obvious limitations in taking proactive measures.

Rapid dissemination of information, decisions and instructions
The information is sent mainly as WERs are posted to MOH offices. This information reaches the destination after significant delay, reducing the value of the information. For proper control of communicable diseases quick dissemination of information is essential.

Goals and Objectives

By witnessing all the issues mentioned above the goal of the new system is to strengthen communicable disease surveillance by addressing the identified issues using ICT. Following aspects will be more focused when achieving the established goal.

Efficient collection of data
Improves the data collection process by incorporating ICT thereby eliminating undue delays in the current system.

Quick decision making
Enhanced analysis, reporting will promote quick decision making. The information presentation is important for time critical decision making[5].

Quick dissemination of information
The generated reports and decisions drawn have to be disseminated properly and promptly in order to transform them into actions. In disease control and prevention activities swift action is very important to battle off the diseases.

Empowering regional and peripheral level officials
Peripheral level and regional level health workers will be able to access the reports and analyze the situation in their respective regions. This will improve the focus on each area as well as the public health care workers will be armed with better information to fight against the communicable diseases.

Literature on existing epidemiological systems

Several communicable disease surveillance initiatives that exist globally were identified and critically reviewed.

The Scalable Bio-Surveillance Architecture is a system proposed to the Department of Defence (DoD) and the Civilian Public Health Authorities in disease surveillance in United States[6]. The main initiation is by the DoD and the intension of this system is to identify bio-terrorist attacks and to identify the suspected disease outbreaks. The Integrated Public Health Information System (iPHIS) is a component of Canadian Integrated Public Health Surveillance. Communicable disease surveillance is a module in iPHIS[7]. SMINET-2's

primary purpose is communicable disease surveillance[8]. Communicable Disease Reporting and Surveillance System (CDRSS) is a system developed to assist disease surveillance in New Jersey, USA[9]. It was developed adhering to the CDC (Centre for Disease Control) standards and guidelines. The intended purpose of this project was to support public health officials in disease surveillance. All of the above mentioned communicable disease surveillance initiatives were able to track cases at patient level.

The communicable disease surveillance initiatives like Real-time Outbreak and Disease Surveillance (RODS)[10-12], National Electronic Disease Surveillance System (NEDSS) initiative[13,14], Scalable Bio-Surveillance Architecture[6], iPHIS[7], SMINET-2[8] and CDRSS [9] uses more than one data source in gathering information. Almost all the above initiatives gather information from hospitals, laboratories and other health care providing institutes. The initiatives like RODS[10] and Scalable Bio-Surveillance Architecture[6] uses other data sources such as absenteeism, pharmacy sales data and web search queries. SAHANA, a web based disaster management system provides a disease surveillance module[15,16]. This module collects only the case based data regarding communicable disease.

EpiSurvery is another tool that uses the mobile technology in data collection[17]. It is widely used in African countries and the data collection process is done via a mobile application running on the user or the health workers mobile device. This tool can be used by any one free of charge and is a highly customizable.

Outbreak detection was highlighted more in Scalable Bio-Surveillance Architecture[6], CDRSS[9] and RODS[10]. The Scalable Bio-Surveillance Architecture[6] uses highly sophisticated Bayesian Belief networks. The RODS system described by RODS[10-12] uses algorithms like algorithms PANDA[18] and What's Strange About Recent Events" (WSARE)[19].Number of other useful outbreak detection algorithms and approaches like Serfling method[20], Recursive-least-square (RLS)[18], Autoregressive Moving Average (ARIMA)[21], Wavelet-based Anomaly Detector (WAD)[22], Hidden Markov Model (HMM)[21] ,CuSUM[21] and use of detection filters[23] were also studied.

Various kinds of communicable disease surveillance systems studied uses different approaches and verity of data sources to collect information relating to communicable diseases. Their outbreak detection strategies vary from very sophisticated approaches such as Bayesian networks to very simple approaches CuSUM and detection filters. The most important finding of the literature survey was that none of the existing communicable disease surveillance systems have looked in to the aspect of information dissemination, which we saw as the key to initiate actions that lead to controlling communicable diseases. Thus by identifying all the strengths and limitations in existing communicable disease surveillance systems, proposed system, Nivarāna was designed.

Design

The system was designed following object oriented concepts and using a prototyping approach. The use of prototyping approach enabled user participation in design and development, resulting in better user requirement identification.

It is important to identify design considerations in order to have a clear focus in the designing process and it enables unambiguous justification of design decisions. The system architecture

of the project is based on five design considerations namely 1) low cost, 2) sustainability, 3) ease of use, 4) configurability and 5) extendibility.

Low cost could be viewed in two perspectives namely, recurrent cost and initial implementation cost. When developing countries like Sri Lanka are considered, these costs will be a burden and may render the system unusable upon failure to pay the licensing fees. Therefore, the disease surveillance system that is developed for Sri Lanka should be a low cost product.

Sustainability is a crucial factor for the long run of a system. Several considerations are there when sustainability is concerned. Maruster et al[24] discuss the sustainability of an information system and illustrates three requirements for information system sustainability, namely 1) adapts to its environment, 2) involves relevant stakeholders and 3) supports the knowledge lifecycle. When developing countries are considered however, financial aspects also have to be considered.

Maintainability, product licensing, upgrading and user training could be seen as the most important aspects of a system. Maintainability is a measurement of the ease and speed with which a system can be restored to operational status after a failure occurs. These failures may occur due to the changes of a business process or due to an unfixed bug in the system. Maintainability is needed to adapt to the changing environment. If the system could be easily maintained, the cost involved with maintenance is less and if the source code is openly available the cost of maintenance will be further reduced. Thus the use of open-source products will be beneficial. Most of the open-source projects have communities who contribute to the project. These development communities are also an added advantage for the maintainability when open-source products are used. For the system to be effective in the long run it should be updated to suit and use the underlying system features. Updating can be seen as an adaptation mechanism for the changing environment. These updates should be cost effective and stable. The system serves the users' needs. The users have to know how to get these services. If users find it difficult to learn the system, then the system will be unusable and it will not be a sustainable system. Thus the entire system will become a failure where the ultimate goal is not met. Therefore, user training is of paramount importance.

There are many systems with various features, but less user-friendly and hence less usable for the ordinary user. As an example EpiInfo[25] is such a system and it is less usable for ordinary users without proper training though it has many useful features. Extensive training for a complex system will be costly. Therefore, the system should be highly user friendly, and the requirement for training users should be kept to a minimum. Most of the users are familiar with web browsers and web mail. Therefore, web based interfaces could be used to improve the ease of use and thus reduce the cost and time incurred for training[26].

Adaptability could be defined as the systems' ability to change according to the changes in the environment. Most of the systems developed are only suitable for specific requirements of the prospective clients. If the system is adaptable, system could be easily used in various scenarios and in different environments. The difference in the organizational hierarchy and the diseases that are under surveillance are major concern when it comes to adaptability. The system to be used by various parties these two aspects should be easily configurable.

The information needs changing day-by-day. Information technology is a rapidly growing domain. Extendibility makes the system more agile and makes it usable in different

applications and easily integrated with other information systems. Modularity, high decoupling and use of standard interfaces is important when extendibility is concerned.

Architectural aspects of Nivārana

Based on the design considerations stated above, the system architecture of Nivārana was designed in order to fulfil identified user requirements. Modularity, extendibility and loose coupling were achieved through the use of object oriented design concepts.

Nivārana system architecture is illustrated in the *Figure 1*. There are 7 modules namely 1) data collection module, 2) analysis module, 3) reporting module, 4) information dissemination module, 5) user authentication module, 6) activity logging module, and 7) system management module. Among these modules data collection module, analysis module, reporting module and information dissemination module implements the business logic. The other three modules are system management modules.

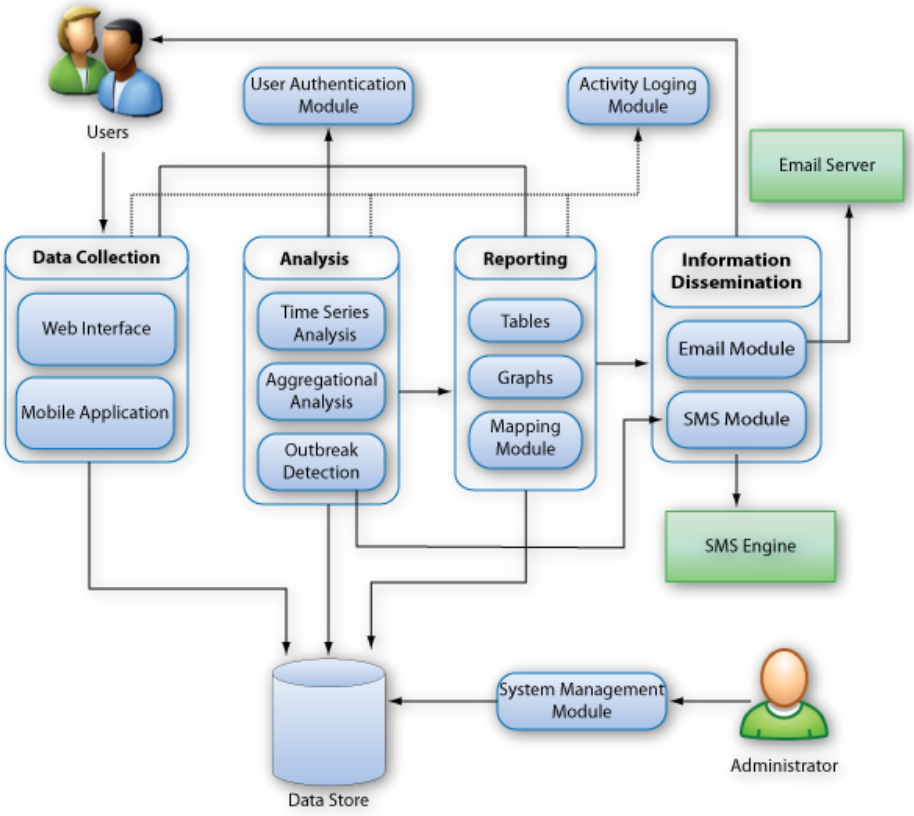

Figure 1. Nivārana system architecture

The data collection module could be seen as the fundamental module in Nivārana. At the initial stage this module will facilitate the gathering of weekly returns of communicable diseases through the use of web interface and in subsequent phases of development case based data collection and the mobile interface will be provided.

The analysis module provides various data analysis services ranging from basic statistical analysis, time series analysis and outbreak detection. Time series analysis is important to identify the trends and patterns of disease occurrences. The outbreak detection sub-module

will warn the system users regarding outbreak situations by analyzing the collected data regularly and will enable the user to take proactive measures to prevent the spread of disease.

The reporting module is responsible for generating reports and its capability ranges from tables, graphs to heat maps. The tabular reports are important when information about several attributes is interested. The graphs will enable the information to be compared easily. The heat maps will display the spatio-temporal information and is useful to identify how the interested disease is spreading.

There are two types of information to be disseminated:- 1). detailed information such as reports and 2). alerts which are small amount of information requiring quick response from the recipients. Detailed information will be sent using e-mail and for sending alerts Short Messaging Service (SMS) will be used.

Discussion

All the aspects of the identified issues have been addressed in the resulted design of the Nivārana architecture. Information dissemination module could be seen as the most important and unique feature in Nivārana. While almost all the other related communicable disease initiatives focus on the data collection and data analysis, Nivārana extends the focus to information dissemination dimension, believing that the information dissemination is the bridge to filling the gap between information and action.

Regional and peripheral level public health care officers will be equipped with information in two aspects. Easily accessible reporting and analysis modules will enable them to keep an eye on what is happening in there region. On the other hand the information dissemination module will deliver detailed information and alerts efficiently without reducing the value of the information.

Conclusion

The software solution Nivārana will be a customizable, easy to use, cost effective and sustainable disease surveillance system. Since the system could be easily customizable, the system will be useable with many other disease surveillance programs having different structures. As the name "Nivārana" suggests, no doubt, it will be a life saver for many innocent people suffering from communicable diseases by preventing spread of diseases in Sri Lanka.

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