Using Blood Glucose Data as an Indicator for Epidemic Disease Outbreaks

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Abstract

In the future, transfer of vital sensor data from patients to the public health care system is likely to become commonplace. Systems for automatic transfer of sensor data are now at the prototype stage. As electronic health record (EHR) systems adapt such functionality, widespread use may become an actuality in the foreseeable future.

To prevent spreading of diseases, an early detection of infection is important. At the time an outbreak is diagnosed, many people may already be infected due to the incubation period. This study suggests an approach for detecting an epidemic outbreak at an early stage by monitoring blood glucose data collected from people with diabetes. Continuous analysis of blood glucose data may have the potential to prevent large outbreaks of infectious diseases, such as different strains of Influenza, Cholera, Plague, Ebola, Anthrax and SARS.

When a person gets infected, the blood glucose value increases. If the blood glucose data from a large number of patients with diabetes are collected in a central database, it may be possible to detect an epidemic disease outbreak at an early stage. Advanced data analysis on the data may detect predominant numbers of incidences, indicating a possible outbreak. This gives the health authorities the possibilities to take actions to limit the outbreak and its consequences for all the inhabitants in an affected area.

At the Norwegian Centre for Telemedicine, a mobile system for automatic transfer of blood glucose values has been constructed. By using wireless communication standards such as Bluetooth and GSM, the system transfers blood glucose data to an electronic health record system. Combined with a system accessing and querying data from EHR systems for patient surveillance we are extending our work into an Epidemic Disease Detection using blood Glucose (EDDG) system.

Keywords: Epidemical diseases, diabetes; Blood glucose data; medical informatics; Geographic Information Systems (GIS); Software agent technology; Fuzzy logic.

1. Introduction

The spreading of infectious diseases is generally difficult to predict, and it is of great importance to detect an outbreak as early as possible to reduce further spreading and simplify treatment of people infected. Examples of diseases involving infections are various strains of Influenza, Cholera, Plague, Ebola, Anthrax and SARS.
The International Diabetes Federation estimates that there are currently some 194 million people around the world with diabetes [1]. Monitoring and control of blood glucose levels is critical in the management of Type 1 and Type 2 diabetes. The patients measure their blood glucose levels up to several times a day to minimize long-term complications [2,3].

The basis for this proposed system is the fact that people with diabetes experience an increase in their blood glucose value when they get an infection [4]. If values from all diabetes patients in a region were instantly accessible, it would provide a foundation for extended data analysis. Extreme accumulations of high values in specific areas could be spotted, and the national health care service could monitor and act on such signals. In this way data from patients with diabetes could provide early warnings of an outbreak in the population. This would give the health care services possibilities to take action to limit the outbreak and its consequences for all the inhabitants in the affected area. Typical actions will be advice, vaccination and even isolation in serious cases.

The routines and strategies for storing and maintaining patient information such as blood glucose data vary between different diabetes teams and health services today. The information may be stored on paper-based health records, in electronic health record (EHR) systems or both. Most Norwegian general practitioners (GPs) and hospitals store information electronically in EHR systems, and the expansion of health networks enable communication and collaboration between hospital - hospital and hospital - GPs.

2. Materials and methods

The system described in this paper is based on the methodology and results of previous projects undertaken by the Norwegian Centre for Telemedicine (NST), especially the projects “Automatic transfer of blood glucose data” [5] and “Wireless Health and Care” [6]. One essential element from the former is a system that automatically transfers data from blood glucose sensors to a database. A wireless system that transfers blood glucose data to a relative’s mobile phone as an SMS was developed and tested on a small-scale (n=15) intervention [5] from 2004. The transfer of the blood glucose data into the EHR system “DIPS” (from DIPS ASA Norway) was implemented as a prototype in the “Wireless Health and Care” project. The significance of this prototype for patients and health care personnel is described in proceedings [6] from 2004.

The system proposed in this paper involves immediate transfer of patient-initiated blood glucose samples into one or more national or international databases. Using geographic information systems, software agent technology and fuzzy logic, this will enable an analysis for detecting infectious disease outbreaks at an early stage.

One example of a “Real-time Outbreak and Disease Surveillance system” (RODS) is in use in Western Pennsylvania [7]. This system and others like it capture clinical data from health systems, not from the patient in her daily environment as we suggest.

3. Results

The main components of the Epidemic Disease Detection by blood Glucose (EDDG) system and how they in a future implementation will interact with each other are described below.
Data sampling

Our starting point is an application implemented using a programmable mobile phone, communicating wirelessly with a blood glucose meter using the short-range communication standard Bluetooth. The glucose meter is attached to a Bluetooth adapter through the serial port, and the mobile phone is equipped with a built-in Bluetooth chip. The mobile phone (Nokia 7650) is programmed to send the measurement result automatically, by means of an SMS to a distant mobile phone or a database server using GSM, see figure 1.

The process is seamless and invisible to the user, and the elements are being refined in concurrent projects at NST. Implementing the proposed system requires capturing of the user ID, blood glucose value and geographical location. Even though the blood sampling process is manual and invasive for persons with diabetes today, in future this process will become fully automatic using implantable and non-invasive sensors. The Institute of Nanotechnology in the UK characterises “Body friendly implants” and “Sensors (bio and chemical)” as areas where nanotechnology will have an impact in the short term [8].

Figure 1 - Wireless blood glucose transfer system.

Data repository

After the data have been sampled and stamped with user ID, time and location, data is sent to a data repository. Depending on the size of the area in which the system is to be implemented, it must be considered whether data is to be transferred to one or more repositories. The system will potentially operate in both narrow and wide geographical areas. When the system covers a large area, software agents will be used for transferring and processing tasks across repositories.

Our research team has developed a prototype where blood glucose data is sent to the electronic health record system “DIPS”. This process is automated to the extent that the blood glucose value, sample time and user ID are automatically sent and stored in the repository after the user has taken a blood sample. People with Type 1 diabetes take blood samples several times a day, while those with Type 2 often take daily or weekly samples.

Considering where the competences of specific local epidemic disease characteristics are located, it seems introductorily natural to store data at the nearest regional county hospital’s EHR system.

Geographic location

There is a need both to record the geographic location of where each blood sample is taken, and to process the data with respect to its geographic location after the data acquisition. Using Geographic Positioning Systems (GPS) integrated into the sensor system is not an alternative due to factors such as battery consumption, reduced service inside buildings and costs. Since the proposed EDDG system is based on an implementation including a mobile phone as the data transport unit, we propose to use the information transmitted from GSM/3G network nodes for adequate positioning. For the purpose of discovering
congestions of high blood glucose values in a town or village, this precision is assumed to be adequate, but needs further investigation and is not yet implemented.

Once all blood glucose sample data are stamped with their geographic position, a tool for analysing the trend in the spatial dispersion of the data is required. Geographical Information Systems (GIS) are one kind of tools which would support this task (traditionally cartographically tasks), and are also used for health and epidemiology issues in a growing number of cases. An example of this is the RODS in Western Pennsylvania mentioned earlier, which uses GIS as one of the tools in analysing the data for suspicious trends [7]. The role of GIS as an important component in epidemiology is documented in a review by Clarke, McLafferty and Tempalski [9].

**Software agent technology**

The role of software agents in an implemented system will be to collect both dynamical and static background data such as geographic information, climate, air pollution, human-related activities and infrastructures, and specific patient data, to be entered into the epidemic disease detection system. Depending on the size of the area, the EDDG system will benefit from offering two or more levels of analysis. Briefly, the analysis will be based on the blood glucose values and other relevant data, ending with a computation of geographic dispersion and a conclusion on whether there are indications of outbreak of infectious diseases or not. An increase in relevant data used in the computations can give a more holistic picture of the result from the detection system.

If the area object for an EDDG system is large, i.e. an international extension of the system, data may have to be processed at several sites and coordinated. It may therefore be expedient to divide inhomogeneous geographic areas into segments, depending on the characteristics of the access to health registers, population, climate and/or infrastructure, before performing the final analysis. Then, for this second-level analysis, multi-agent technology may be needed for coordinating data from all sites in the EDDG system into a central international risk analysis. Multi-agent technology is characterised by cooperation between individual agents for achieving a common goal [10], which may be necessary in epidemic disease detection for a large area.

**The Epidemic Disease Detection using blood Glucose (EDDG) system**

The EDDG system and its decision algorithms do need to handle a kind of fuzziness. Fuzzy logic handles the concept of partial truth – truth values between "completely true" and "completely false", e.g. Horstkotte [11]. Fuzzy logic has proved to be particularly useful in expert systems, systems having a collection of membership functions and rules [12], considering parameters such as those mentioned above. The proposed EDDG system will use the concept of fuzzy logic in its analysis process when considering the impact the background data, together with the main data source: blood glucose measurements from people with diabetes. The result of the analysis will end up as outputs that indicate whether there are any tendencies towards infectious diseases. This output only needs to be sent to health care surveillance authorities if the result needs to be investigated further.

The main elements of an implemented EDDG system will be the blood glucose sensor, sensor adapter for wireless communication of data, personal communication unit (e.g. smartphone), EHR import routines, geographic positioning solution, geographic information system element, software agent technology, fuzzy logic algorithms and routines for detecting and handling potential alerts. Half of the elements are implemented while the second half are part of ongoing projects and research thesis.
4. Discussion

An agent-based distributed information system called NZDIS in New Zealand [10] uses asthma incidence as the disease case. Software agents are used for processing the asthma incidence with geographic location and climatological information in queries. Our plan for the EDDG system is to provide indicators of infectious disease incidences (clusters of high values of blood glucose) in real time to intelligent agents. The agents must always be ready to consider new values that enter the system. This requires high demands for coordination, processing and stability in the elements that form such a system.

In Norway, the yearly influenza spreads the most in winter. Five to ten percent of the population are then infected, i.e. between 200,000 and 450,000 persons [13]. This highlights the fact that background data such as seasonal variations and average spreading numbers must form part of the detection system. This also implies a need for input from, and communication with, updated sources for the background information, something that implies coordination with health registers and other registers. Our work is now continued in a project where also use of “sensors” in the form of software systems distributed to places where patients show up, i.e. deploying the results and principles from Bellika et al.’s SNOW Agent system [14].

In Norway alone, the National Insurance Administration records that in the year 2003 reimbursement was given for 36 million blood glucose measurement strips, with a total value of EUR 36 million [15]. This large sum of money for a country as small as Norway with a population of 4.6 million, results today only in the patient’s one-time use of the blood glucose measurements. No data is transferred to the health care services, even though there ought to be very good health- and economically reasons for this in the long-term. We are aware that we are proposing a futuristic use of the sensor data for an epidemic disease detection system, and our aim is to increase awareness of the possibilities: technically, health-related and economically.

5. Conclusion

Most of the prerequisite of the EDDG system are prepared and an implementation is started as a cooperative project between the Norwegian Centre for Telemedicine and the University of Tromsø, Norway. Through the work with the previous mentioned projects and studies, the system specifications are considered to be acceptable. In this paper, we have outlined the architecture of a system and indicated the effects of using blood glucose data for this epidemical disease detection purpose.

The work that has already been done on this approach, confirms that it is possible to achieve a fully automated system for the transfer of blood glucose data from the patient into an EHR system.

The remaining technical issues to solve are mainly at the receiving side of the system. This involves merging all elements together in a functioning system, which includes an analysis of the aggregated data, executed in decision support management modules to provide the national or international health care surveillance authorities with justified information related to epidemic disease outbreaks.

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7. References


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