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Benefits of using complex event processing in healthcare

Stand-first: Complex Event Processing (CEP) is a computer-based technique used to track, analyse and process data in real-time (as an event happens). It establishes correlations between streams of information and matches to defined behaviours

Tag: Discipline

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Defining the context

Healthcare is a growth area for event processing applications. By systematic review of existing literature and case studies within the health sector, this article is intended to provide a broad overview of the application of CEP and the data sources that contribute to it.

The rising popularity of the internet and the digital world has given rise to 'big data', a collection of large, complex data, specifically data resulting from the Internet of Things (IoT) such as sensors, cameras, social media, smart phones and other consumer and monitoring devices in use daily. Data scientists break big data into four dimensions: volume (data size), variety (data type), velocity (data speed) and veracity (data trustworthiness).

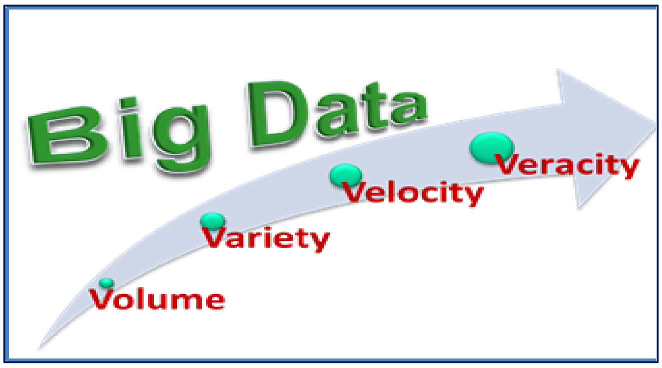

Figure 1: The 4 'V's of Big Data

For healthcare, **volume** refers to the rapidly expanding size of the sets of data that is generated in every area of activity in a healthcare enterprise, from revenue to patient data, to supply and operations. **Variety** includes the diversity of data collected. In a hospital, for instance, data includes patient records containing a variety of information like lab reports, scans, x-rays, prescription details and other medical data. Apart from having access to patient data relating to diagnosis and treatment, other data such as patient scheduling and workflow, data resulting from healthcare administration and hospital hygiene are also available. Exposure to such rich and contrasting elements of data is challenging and requires the use of special techniques to synthesise and process these large sets of data in a reasonable time frame. With the advent of sensor technology, Radio Frequency Identification (RFID), personal health monitors, wireless network of wearable devices and other healthcare monitoring devices, there is significant **velocity** of incoming healthcare data. Finally, **veracity** relates to data assurance and quality issues which are of acute concern in healthcare as important decisions depend on having accurate information.

Data sets yielded from big data are so large that they cannot be processed and managed using traditional methods like Relational Data Base Management Systems (RDBMS). Such data warehouses are not able to handle the processing demands of big data that need to be updated frequently or even continuously (in real-time). So, instead of storing the data in databases for future use, CEP extracts real time data from the IoT devices as soon as it is generated and analysed by applying real time event analytics to find patterns and make better informed decisions about intervention and treatment options.

Research on CEP

This main focus of this article is to derive a holistic view of existing literatures related to the application of CEP techniques in healthcare. The aim is to establish the most common areas within the healthcare sector where the applications of CEP techniques have been widely implemented; and what main data source contributes to the processing of big data in healthcare. The summary below is based on a literature review of twenty-five articles published in English journals and conference papers between 2010 and 2014.

What are the most common areas within the healthcare sector where the application of CEP techniques has been widely implemented?

There are a wide variety of applications within the healthcare domain where the use of CEP is addressed. Some examples include remote monitoring of personal health and fitness to encourage healthier lifestyles; patient flow management system to monitor states in care processes; detection of hygiene care violation for preventing infections in hospital setting; and tele-care/tele-medicine to reduce the amount of personal care devoted to early dementia sufferers by remotely monitoring their condition.

The most widely used examples where CEP is commonly used were for **hygiene compliance** (i.e. prevention of infection**)** and for **remote healthcare.**
Hospital acquired infections have been recognised as one of the major challenges in the healthcare system and serious attempts have been initiated by the World Health Organisation (WHO) to investigate and highlight the problem.

Hygiene compliance includes examples of applications for detecting potential threads of infection, monitoring of hygiene compliance of healthcare workers and the reporting of contaminated medical equipment. This was considered using the scenario of a healthcare hygiene control system equipped with sensors and hygiene control monitored and regulated throughout the hospital facilities by running pattern queries on continuous sensor data. In a real scenario running such a system, every healthcare worker wears an RFID badge and surgical and non-surgical equipment are tagged. Sensors are located in every patient's room, Intensive Care Units (ICUs), emergency rooms, operating theatres and near sanitising equipment. All these sensors continuously sense the environment and send collected events to a centralised system. Not only can the total number of events occurring in a second be very large, but the complexity of the patterns can also be very high, and urgent actions might be necessary in certain cases. Thus running pattern queries over such high input rate systems in real time is a challenge and needs an efficient underlying system to do so.

Remote healthcare includes examples on improving support for the elderly/disabled in their home and care for early dementia sufferers. Remote monitoring is an expanding application area, dealing with the possibility to remotely track relevant status of a person in real-time and to monitor his or her status over a longer period. This is a common approach in healthcare domain (remote patient monitoring) where some vital parameters of the patient is tracked and thereafter analysed for finding some types of anomalies. For example, the ECG (Electrocardiogram) signal of a patient can be analysed on different types of arrhythmia (an irregularity in a rhythmic action such as a heartbeat or breathing), allowing useful detection of cardio problems. Patients' use of wearable devices and remote patient monitoring devices has proven that they can capture valuable data for certain patients, including those with chronic diseases. Some hospitals also have reported positive results after remotely monitoring patients who were discharged from their facility. Remote patient monitoring technology allows clinicians to observe patients without seeing them in person and quickly react to any worrisome changes in their health.

What has been the main data source types contributing to the processing of big data in healthcare?

Big data in healthcare offers a wide variety of data types. Use cases that were explored indicated a range of data sources related to patient healthcare and well-being; clinical decision support systems (medical imaging, laboratory and pharmaceutical data and other administrative data); sensor data from medical devices that monitor vital signs; social media; web pages; GPS (Global Positioning System); and RTLS (Real Time Location System) data resulting from tracking devices/patients/staff at precise locations.

For example, for the patient flow monitoring system to reduce waiting times in hospitals, RTLS tags are assigned to patients and key care providers. These tags use Wi-Fi and infra-red signals to reach location accuracy of about 10 cm. This location data, along with data from existing hospital systems is triangulated using CEP to infer the current patient state and wait time (Badreddin and Payton, 2013). However, the most popular types of data sources discussed in the papers contributing to the processing of big data in healthcare was the **use of sensor technology, which included personal and environmental sensors, RFID and wearable sensors.** The hygiene compliance and remote healthcare monitoring examples considered earlier are typical examples of the popularity of such data sources.

Why does it matter?

Findings from this literature search indicate that CEP is effective and efficient in mining and correlating streams of data for detecting trends and anomalies in non-clinical applications but has limited capability of reacting in real-time to opportunities and risks detected that are related to clinical applications which require on-demand diagnosing and treating of patients. Popular use cases around 'remote healthcare' indicate a growing interest in studying and designing health technologies to meet the mounting healthcare needs of the aging population, and the management of chronic diseases and personal health. Technologies are thus designed to help shift the burden of care from the clinical setting to home or other non-clinical settings. Monitoring data from patients wherever they are can be a direct benefit to healthcare such as reduced hospital re-admissions, shortened hospital stays and improved health outcomes.

Issues with CEP technologies

There is a need to overcome a number currently highlighted deficiencies in the sector; including rushed practitioners not following established practice guidelines; lack of care co-ordination; lack of active follow-up to ensure the best outcomes; and patients inadequately trained to manage their illnesses. For example, the management of care for diseases such as depression, obesity, asthma, diabetes and heart diseases requires a health care system that is essentially pro-active and focused on keeping a person as healthy as possible rather than reactive and responding only when a person is sick (Wagner, 2010). It is evident from this research that sensor technologies have given rise to a rapid growth in healthcare data and this can make a significant impact to healthcare delivery. It should be noted that it also introduces a data overload problem, for both systems and stakeholders that need to utilise this data.

Some of the ways to reduce data overload and optimise data usage in analytical work is to ensure that the various data input methods are standardised across healthcare institutions to allow for better integration and extraction of real value from the deluge of data that is produced every day. The use of decision support systems that integrate and filter meaningful patient data and present it to the clinician as required will also aid in alleviating some of the issues. Thus, the integration of real-time physiological data with patient history, electronic medical records and other administrative health data such as lab data will require careful implementation of a number of initiatives to make patient care more data-driven.

This confirms the need to apply efficient and effective event processing techniques to transform the large volumes of data into meaningful intelligence. From some of the case studies reviewed, it is clear that big data analytics can assist hospitals in efficient resource management by reducing emergency waiting times, tracking patient movements and preventing hospital-acquired infections. Operational data sources together with big data sources create an on-demand analytical view across key areas in the health sector which give powerful insights into patients' medical details, treatments, clinical processes, and services. Thus, the fusion of diverse data sources - both big data and traditional data sources - will provide in future a full holistic view to most aspects of healthcare related data.

Conclusion

Although CEP and the IoT together have extreme potential in solving existing and future problems within the healthcare industry, challenges regarding privacy, security, determining standards and the need to continually improve tools and technologies will need to be carefully addressed. Application of these technologies is still in infancy in the healthcare domain. With renewed focus on better healthcare, growth in population and increasing costs, healthcare industry has to embrace such technologies for effective and efficient functioning (Nagishbandi, Sheriff and Qazi, 2015). This will provide decision-makers (i.e. patients, carers, clinicians and administrators) with access to the data they need at the time they are making decisions. Therefore, the use of data analytics layered over other data sources will help to transform the data mountain into actionable information for better healthcare.

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Key terms and definitions

Terms	Definitions
CEP	Complex Event Processing
EMA	Emergency Medical Assistance
EMR	Electronic Medical Records
GPS	Global Positioning System
IOT	Internet of Things
RDMS	Relational Database Management System
RFID	Radio Frequency Identification
RTLS	Real Time Location system