Volume 1 | No. 2 | July – December 2017

Survey of Applications of Complex Event Processing (CEP) in Health Domain

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Abstract:

It is always difficult to manipulate the production of huge amount of data which comes from multiple sources and to extract meaningful information to make appropriate decisions. When data comes from various input resources, to get required streams of events form this complex input network, the one of the strong functionality of Business Intelligence (BI) the Complex Event Processing (CEP) is the appropriate solution for the abovementioned problems. Real time processing, pattern matching, stream processing, big data management, sensor data processing and many more are the application areas of CEP. Health domain itself is a multi-dimension domain such as hospital supply chain, OPD management, disease diagnostic, In-patient, out-patient management, and emergency care etc. In this paper, the main focus is to discuss the application areas of Complex Event Processing (CEP) in health domain by using sensor device, such that how CEP manipulate health data set events coming from sensor devices such as blood pressure, heartbeat, fall detection, sugar level, temperature or any other vital signs and how these systems respond to these events as quickly as possible. Different existing models and application using CEP are discussed and summarized according to different characteristics.

Keywords: *Business Intelligence (BI); Complex Event Processing (CEP)*

1. Introduction

Various examples of domains exist in the world such that product manufacturing system, fraud detection, anomaly management, cloud computing and many more. But in our perspective health issue is the major concern for all age groups of male and female at every stage of life from birth to death.

Health is the major concern for all age groups and for all genders as Health Information System [19] are on the demanding research field. Majority of patients who lie between the ages of 40 to 70 years having critical diseases which may be caused due to age factor, inherited family disease, and improper routine checkup. Most of the severe-ill, aged patients cannot travel at regularly basis due to critical health situation, they need proper monitoring and immediate treatment. To avoid the travelling time for checkups, for proper monitoring and self-assessment, and to get exactly the correct and trustworthy result, to facilitate both doctor and patients, different wearable body sensors are available which can sense different vital signs such as blood pressure, body temperature, ECG respiration rate etc. These body sensors can facilitate both patients and doctors as the results are accurate and true and also helpful for prevention and prediction of disease at the right time.

Business Intelligence (BI) [15], [16] and [17] describes business analysis of any field in which how extraction of required information is possible from different sources of raw data. To design new tactics and strategies for business having long-term solidity is the aim of BI. Many technologies of BI included data mining, text mining, predictive analysis, Complex Event Processing (CEP) and etc.

Change of state of any actor, system, machine or object when any method or function has triggered is an event. There are

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two types of events: Event Stream Processing (ESP) and Complex Event Processing (CEP). Generally, CEP is a subpart and a technique of ESP. The CEP is appropriate for complex system in which the composition and correlation of atomic events constructs complex event or complex patterns which are very essential and beneficial for the system. CEP contracts with multiple events from different sources and produces significant events. The CEP is suitable for large real-time domains where production and growth of event occur at each level or layer of these domains.

Complex Event Processing (CEP) is a technique of BI, which creates actionable events or patterns from data of multiple sources. These events are helpful at any layers of organization for current development and future prediction. CEP can be used in many areas: weather prediction, traffic controlling, social media posts, health domain, finance, RFID management, Supply chain management etc. The CEP can be classified into two categories: Aggregation-oriented CEP executing on-line algorithms while, Detection-oriented CEP detecting events patterns.

2. Literature Review

A detail framework of BI&A (Business Intelligence and Analytics) which provides history, various applications and recent trends of BI&A [1]. The history of BI&A included BI&A 1.0, BI&A 2.0 and BI&A 3.0 have also been discussed in detail. Applications included E-Commerce and Marketing Intelligence, E-Government and Politics 2.0 and more. Also multiple recent and future trends of BI&A were discussed which included big data analysis.

"Designing and Developing Complex Event Processing Application" [2] is a white paper given a detail guideline of CEP, its techniques and developer consideration. Furthermore, how pattern matching technique with correlation and aggregation is used for CEP. Also how CEP deals with big data has been discussed in depth. A very detailed assessment of all aspects of CEP [3] and [4] which included CEP specification, methods, experiments and a very helpful guideline for tools selection at both commercial and academic levels.

The CEP models can be analyzed by using different logics such as first order logic (FOL) and fuzzy logic. The authors of [18] have given a detailed review of all logics.

2.1. Complex Event Processing (CEP) In Health Domain

In [5] those patients who need full-time continuous monitoring and alone at home, the web enabling body sensor are very helpful for proper monitoring of the patients. The wireless body sensor used to record patient's vital sign and by using web enabling sensors, doctor can access data anytime through web for accurate diagnosis.

Distributed and centralized are two different approaches to process continuous stream of data generated from multiple sources. This system used the centralized approach. The SOA used to create a gateway to combine multiple sensors network, web services sent integrated data to doctor via web and last complex event processing (CEP) generated multiple meaningful events from the cloud of events. The CEP, analyzing raw sensor data and identify abnormal health conditions.

The proposed system focused on two perspectives: healthcare monitoring of alone patients and fall detection of old patients for these two perspective environmental, body, physiological and motion sensor have been used. For rules generation Strawman EPL has been used. See table 1.

The [6] Emergency Medical Assistance (EMA) is the biggest example of Complex Event Processing (CEP) in healthcare, which quickly facilitates the sudden diseases. The reason to build EMA is to reduce the wait time to call an ambulance. For this assistance full real-time information about the current location of ambulance crew is needed.

To achieve this information built-in tablet sensors have used e.g. tablet GPS identify the ambulance location, the further

built-in sensors emitted different data, to filter out the required data and to improve ambulance availability (response time) CEP is used with EMA-DSS.

The event processing rules are generated by Event Processing Language (EPL) having two parts condition and action. The EMA-DSS is a 2-layer distributed architecture model. Layer1: *EMA Coordination Centre* located into "central control center" to locate the actual location of each ambulance to patients by using GPS. The GPS used to locate the nearest available ambulance's location. While, the layer 2: *Ambulance Vehicle (CEP)* is located into "ambulance vehicle". Every vehicle has tablets with built-in sensors. Built-in GPS used to locate ambulance position. This location received at "central control center".

In [7] the RFID plays verity of role in healthcare domain such as patient monitoring and healthcare unit, drug and medicine compliance etc. The RFID generates large volume of data, to extract medical information from this data stream, the CEP framework used with the RFID-mounted hospital.

The RFID have capability that it can detect and sense data sets from other mounted sensors in hospitals such as physiological and environmental sensors. This generates large volume of data. The CEP is the most suitable solution to get required data sets form raw data sets in real-time, do continuous processing and detect critical situation.

In this paper, the main focus is "Surgical Procedure" in the RFID-enabled hospital. Many issues of surgical procedure have been mentioned and handled in real-time by using CEP. The CEP rules generation has been defined through Event-Condition-Action (ECA) like expression of rule. While, CEP architecture designed by using an open source software Drools 5.0 including expert and Drools fusion.

The wearable sensors are efficient to senses human activities such as walking, running, cycling, eating and chewing etc. In [8] a detailed survey to recognize human activities by using wearable sensors.

Table 1: Result Table

Ref. No	***DOMIAN***	***TECHNIQUE***	***SOFTWARE SPECIFICATION***	***SENSOR***
[5]	Healthcare	Design "Patient Health Monitoring System" by using **CEP**	The rule generation by Strawman EPL.	Physiological, motion, environmental sensors
[6]	Healthcare	Develop an Emergency Medical Assistance Decision Support System (EMA-DSS) by using **CEP**	Event Processing Language (EPL) based on event processing rule (cond. Part, action. Part) Platform: Esper on an Android device	Built-in tablet's sensor and GPS
[7]	Healthcare	Develop surgical procedure system in RFID enabled hospital by using **CEP**	CEP rules generation by Event-condition-action (ECA) and CEP engine implemented by using Drools 5.0 including Drools expert and Drools Fusion.	RFID

[8]	A survey paper to recognize human activities by using wearable sensors.	**Machine Learning** (ML) application used for feature extraction.	Supervised and semi supervised algorithm such as decision tree, Bayesian methods etc.	Wearable body sensors
[9]	Healthcare	Proposed Remote Health Monitoring System by using **CEP** (CRHMS)	The CEP engine was implemented through Drools Fusion 5.4 and CRHMS system development by Java7. For IDE software development Netbeans7.0 and for backend database MySQL 5.5 is used.	Zephyr Bio-Harness 3 sensor and GPS
[10]	Healthcare	Develop a proactive Remote Patient Monitoring (RPM) with **CEP**	The implementation of this system is shown by using MyCardioAdvisor (MCA) is a mobile app	Zephyr HxM BT

[11]	Product Manufacturing	Design a Product Manufacturing System using **CEP**	Complex Event Processing Language (CEPL) used as EPL. Siddhi CEP engine by using WSO2 used Complex Event Processor.	RFID
[12]	Traffic condition monitoring	Traffic condition monitoring by using **CEP**	CoReMo simulation platform has been used. PetriNets used to model complex agents behavior. Open source "EsperTech" used as CEP engine.	GPS

This survey focuses on machine learning applications for features extraction such as supervised and semi-supervised learning algorithms. Recognition of human behavior and activity by using wearable sensors is the on-demand topic of research as it is applicable in many areas, for example medical, tactical scenarios, etc.

There are two different ways to recognition of humans' activities and behaviors. The first one is by using external sensor and the second by using wearable sensors. External sensors installed at any predefined points (camera) and wearable sensor attached to human's body.

ML application can be categorized into supervised or semi-supervised and unsupervised. Many supervised techniques have been in [8] such as decision tree, Bayesian methods, Instance based learning and neural networks, etc.

The traditional batch processing approach is slow to detect abnormalities form Remote Health Monitoring System (RHMS), while event driven approach of Complex Event Processing (CEP) using sensor is more appropriate solution for RHMS. Because CEP

correlates sensor data to generate complex events which are helpful for proper monitoring and abnormalities detection. The abnormalities detection is possible when vital signs are out of range from their normal range and that can be captured by body sensor. The proposed CEP based Remote Health Monitoring System (CRHMS) [9] is useful home alone old patients.

Several patients wear sensor, the sensor's data stream collects form patients smartphone, which also specifies patient's location. Now, the collected streams of raw data are send to CEP, the CEP system detects abnormalities in vital sign of patients and generates alert, These alerts notification are now sent to caretaker and doctor for immediate solution.

In this scenario, Zephyr Bio-Harness 3 sensor is used that can sense heart rate, ECG and respiration rate, etc. The patient's location is sensed by GPS activation in cell phone. While, CEP engine was implemented through Drools Fusion 5.4 and CRHMS system development by Java7. For IDE software development Netbeans7.0 and for backend database MySQL 5.5 is used.

In [10] Mobile-based monitoring through sensors is a very common approach in the field of medical and healthcare. In this, the person who requires remote monitoring wears a wearable sensor. The data collected form sensor are sent to smartphone for storage, where mobile CEP engine was implemented that generated complex event form raw data stream. Now, these events send to server CEP through Wi-Fi. The server CEP provides real-time feedback.

2.2. Further Application of Complex Event Processing (CEP)

Another real-time application of CEP in product manufacturing domain has been proposed in [11] by using RFID. By using RFID manufacturing system can easily detect any complexity. For real-time product's monitoring, RFID tags have been attached with products while, RFID reader mounted at different locations in the factory. Complex Event Processing Language (CEPL) is a query based language like SQL which is used to process event stream. CEPL having capability to process RFID data stream, data filtering and real-time analysis. The main part of this system is probabilistic CEP, used to detect complex event. Siddhi CEP engine by using WSO2 used Complex Event Processor.

[12] To monitor the traffic condition is another application of CEP. In this article the huge amount of traffic related data produces complex events in many scenarios and it can be handled through CEP. To implement traffic management system using CEP, CoReMo simulation platform has been used. PetriNets used to model complex agents behavior. Open source "EsperTech" used as CEP engine.

One of the common applications of CEP is Anomaly Management [13], which can be applicable in many systems such as in fraud detection to provide safety to user in case on stolen credit card or mobile, in health care to monitor different vital signs such as heartbeat, blood pressure, sugar level. of the severe ill patients, Just-in-line (JIT)-logistics, Stock market Analysis and many more areas. In [13] the anomaly management using CEP have been developed for the novel security monitoring tool for computer system.

The authors of [14] have proposed another application of CEP with Graphical Processing Unit (GPU). In this several CEP operators (event window, event filter and stream join) has been redesigned and implemented on GPUs by using NIVIDIA CUDA to increase the performance of parallel processing or parallel computing.

2.3 How Complex Event Processing (CEP) Systems respond to incoming events

The CEP is a "sense and respond" system. First CEP system 'SENSE' meaningful events from input event streams and secondly quickly 'RESPOND' them. (See figure: 1).

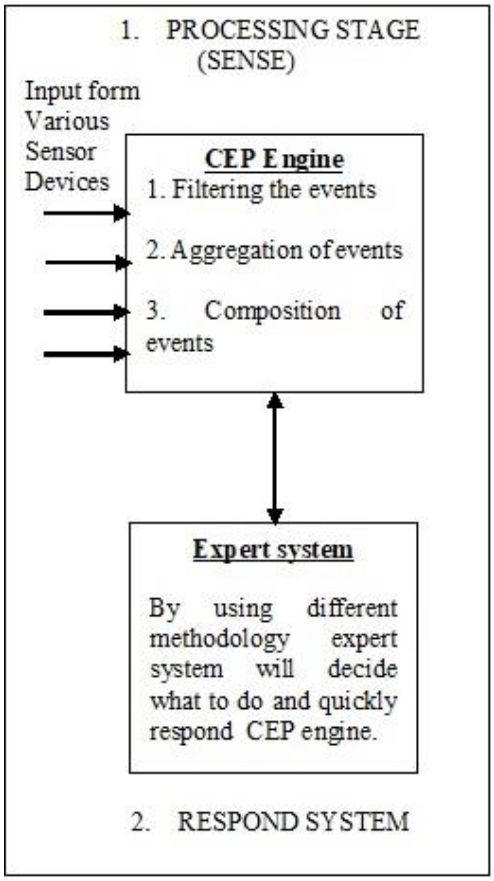

Figure 1: The CEP "Sense and Respond" Model

In this figure, a CEP sense and respond model are shown in which sense system based on CEP engine which takes input from multiple sensors. The CEP engine having following responsibilities filtering, aggregation and composition of events to generate meaningful events. While the respond system is an Expert system that quickly responds to these events by using different methodology such as machine learning algorithm, logic-based driven approach.

3. Result

The results/comparative study of the above mentioned survey is shown in table 1 which clearly indicates the techniques used and the use of wearable body sensor devices. Two of the approaches [11] and [12] are not from health domain but it can be applied to health domain.

4. Conclusion

The importance of the application of CEP in health domain is evident from the literature review. Health related data is very essential for short and long term decisions making and diagnosis of unusual and unexpected events in human body which may result in a human loss if not identified and cured.

In the light of given survey we conclude that Complex Event Processing (CEP) is the appropriate solution for many critical situation in health domains where speedy responses from expert system is the major concern. To manipulate sensor data and generate event stream form sensor data CEP is a very helpful tool.

The CEP approach will facilitate the individuals, patients and doctors to analyze and respond to unexpected events for early prediction, but also very helpful for specific patients to reduce their routine activities and traveling time. It is very beneficial for people for self-assessment and monitoring and to take precautionary measures in case of unwanted event or to immediately consult a physician.

5. Future Work

In this survey, we have shown the usefulness of Complex Event Processing (CEP) in health domain and also in other areas. In future, we will model Complex Event Processing (CEP) in health care for managing/monitoring patient health using body area sensor network.

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