Support Dementia

Using wearable assistive technology and analysing real-time data.

Fehmida Mohamedali, Nasser Matoorian
School of Computing & Engineering
University of West London
London, United Kingdom.
{fehmida.mohamedali, nasser.matoorian}@uwl.ac.uk

Abstract:

Support provided to sufferers of Dementia by the National Health Service (NHS) is mainly in the form of personal attendants such as nurses and social workers. The main focus of this paper is to present how the use of assistive technologies can help early sufferers of Dementia patients to overcome barriers in achieving their daily activities and to illustrate how data analytics, such as Complex Event Processing (CEP) in real-time can allow better monitoring of these patients. This activity will contribute to research work which is to provide a suitable framework to accurately analyse real-time data from assistive technology and wearable devices for remote healthcare, particularly monitoring early sufferers of dementia in order to promote good quality independent living.

Keywords—Dementia; Assistive technologies; Internet of Things; wearables; complex event processing; healthcare

I. Introduction

Many issues remain open when designing healthcare systems for bridging health practices in clinical and non-clinical settings. For examples, to design a patient monitoring system for home use, we need to consider how to capture critical information that is meaningful for healthcare professionals to use, and how to visualise the home-monitored data so that physicians can effectively engage and utilise the information during their busy schedules.

Data analytics, such as the application of CEP can analyse events and related data which come from various sources (wearable sensors, environment sensors etc.) in real-time and provide insights for a better healthcare.

Key concepts in CEP are events and event patterns. An event is any action that is happening such as the patients' movement in and outside the home environment, sleeping patterns, eating habits and all other day to day activities. CEP can operate on events from multiple sources and successfully cross-detect patterns as if all sources were one. A major strength of CEP is the automated matching of patterns and triggering of immediate actions.

The use of sensory devices to monitor the activities of daily living of early Dementia sufferers, and then analyse the sensory output to identify deviations from normal behavioural patterns can indicate deterioration in the Dementia condition such as restlessness and wandering, and subsequently seek intervention from the caregivers or the health clinicians.

A. Dementia in context

Dementia is not an illness we can ignore. It has a devastating impact on the people who develop it, and the families who care for them. We all know someone who has been affected, be it a relative, friend or work colleague. It also affects more and more of us each year, as the numbers affected rise with an ageing population. [10]

The word "dementia" describes a set of symptoms that may include memory loss and difficulties with thinking, problem-solving or language. This is caused when the brain is damaged by diseases, such as Alzheimer's disease or a series of strokes.

The structure and chemistry of the brain become increasingly damaged over time and the person's ability to remember, understand, communicate and reason, gradually declines.

How quickly dementia progresses depends on the individual and the way they experience dementia depends on many factors, including physical make-up, emotional resilience and the support available to them. [3]

Dementia is a journey that begins with memory loss and cognitive problems. Without effective support in place, the journey may quickly end with the sufferer being profoundly disabled and requiring care with all activities of their day to day living. [2]

B. Barriers to dementia care

The sharp increase in aging population is exerting enormous pressure on the resources of healthcare and social services systems. Support and care given to dementia sufferers by NHS in the form of personal attendants such as nurses, social workers etc. is one of the major factors responsible for the huge cost associated with dementia care. [1]

While the numbers and the costs are daunting, the impact on those with the illness and on their families is also profound. Dementia results in a progressive decline in multiple areas of function, including memory, reasoning, communication skills and the skills needed to carry out daily activities. Alongside this decline, individuals may develop behavioural and psychological symptoms such as depression, psychosis, aggression and wandering, which complicate care and can occur at any stage of the illness. Family carers of people with dementia are often old and frail themselves, with high levels of depression and physical illness, and a diminished quality of life. Dementia is a terminal condition but people can live with it for 7–12 years after diagnosis. [14]

Recently published article in the Times newspaper mention that about 850,000 people in England are thought to have Dementia but amid fears that most of those affected did not realise they had the condition, ministers gave GPs targets to improve diagnosis rates. While more than 150,000 extra cases were found, it had not led to patients getting help. The chairman of the BMA's community care committee stated that "there is no point in giving someone a label but then not being able to provide support". Although, there is no treatment for dementia, timely diagnosis allows sufferers to access emotional, practical and financial support that is required. [18].

According to the Alzheimer's society, there will be 1 million people with dementia in the UK by 2025. [2]

II. ASSISTIVE TECHNOLOGY

The IoT provides connectivity and intelligence to convert small devices into smart objects which allow integration and transfer of enriched data from embedded sensors and wearables to facilitate disabled people with assistance and support that they need to achieve a good quality of life and independent living.

Wearable wireless body area sensor networks (WBANs) and mobile phones have been recognised for their potential in rehabilitation of elderly and for obtaining information about elements such as patient's movement and posture. [11]

Use of assistive technology for supporting dementia patients not only eases their everyday life, but can also increase their personal safety by triggering automatic alarms in case of a deteriorating health status. For those living alone, particularly the elderly, there is often a fear of having an accident and being unable to call for help. This includes falls, accidents in the kitchen, but also general safety e.g. when leaving the home. [10]

It is therefore important to provide the elderly with tools, which support them regarding these issues and which, in case they cannot call for help on their own, will automatically trigger an alarm and call for assistance.

The application of CEP techniques via the proposed wearable middleware framework will help to identify patterns and causes that may lead to an imminent fall or injury, and in turn assist carers to better monitor such at-risk patients.

Therefore, home monitoring and effective use of assistive technologies will help to identify changes in health and behaviour in home settings, and to facilitate successful adaptation to those changes.

III. CEP FOR DEMENTIA SUPPORT

CEP encompasses methods, techniques, and tools for processing events from a variety of sources in real time; while they occur in a continuous and timely manner. It derives valuable higher-level knowledge from lower-level events. This is referred as complex events; combination of several events.

Figure 1 illustrates the CEP architecture which receives continuous real-time chain of events that are processed by the CEP engine to trigger an alarm and allow for decisions and reactions to take place. The use of ontologies assists to formally model knowledge about a domain and allow reasoning over this knowledge. The most common use of ontologies is to standardise the terminology in a domain and to facilitate knowledge sharing.

A. Event processing

Event patterns which are any particular configuration or arrangement of events can be specified using an event query language. Unlike database queries, event queries are evaluated continuously as the events happen. These events are everywhere but need to be collected and combined in real-time in such a way so that they can be used for detection of interesting situation(s), which if relevant, can be modelled into patterns that represent topics of interest or certain situations of interest which need to be detected in real-time.

Patterns are dependent upon several factors such as user's needs, changes in the event sources, environment etc. and therefore, must be dynamically verified. This in turn entails that the description of a complex situation must be maintained over time, i.e., changed/adapted to new conditions etc.

To improve the quality of event processing and to derive intelligent higher-level knowledge from lower-lever events, knowledge about events and their relationship to other non-event concepts is used. Complex events can be inferred from raw primitive events based on their incoming sequence, their syntax and semantics.

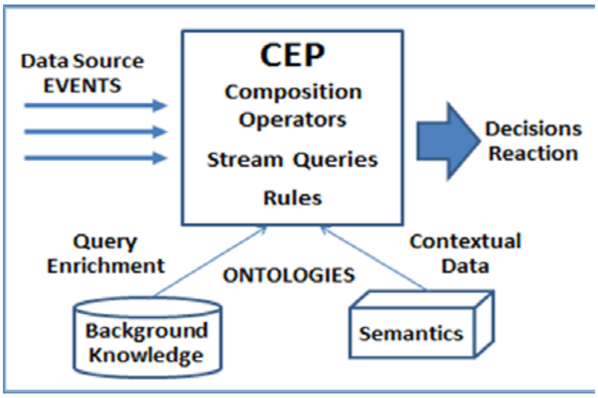

Fig. 1. Complex Event Processing architecture

B. *Knowledge based domain*

Knowledge based domain refers to the gathering of knowledge in terms of what concepts exist in a particular domain.

Use of background knowledge about events and their relations to other concepts in the application domain can improve the expressiveness and flexibility of complex event processing systems. Huge amounts of domain background knowledge stored in external knowledge bases such as patient's medical history, ethnicity and demographics can be used in combination with event processing in order to achieve more knowledgeable complex event processing. The value of decision support is largely dependent on the amount and quality of knowledge about that domain. This is a critical factor when complex event processing is used in environments that are rich in domain and background knowledge, e.g. in a care home or hospital setting.

C. *Context aware semantic modelling*

The use of semantic technologies is widely used to manage background knowledge and mix different data streams to execute reasoning processes. Therefore, the combination of event processing for dealing with volume of data and semantics to manage several streams and background ontologies can improve the recognition of important situations in a timely manner [13]

The key properties of ontologies can be summarised as:

- Structured: facilitate interoperability between events published by different sources by providing a shared understanding of the domain in question.
- Formal: the explicit representation of the semantics of complex event patterns through ontologies will enable CEP systems to provide a qualitatively new level of services such as verification, justification, and gap analysis
- Allow inference: add expressiveness and reasoning capabilities.

Therefore, ontology rules provide a way to define behaviour in relation to a system model and allow for shared conceptualisation and agreed upon understanding of a domain.

Semantic ontology is used where CEP techniques have used conceptualisation of the application domain to allow reasoning on events in combination with other non-event concepts using formalised vocabularies/syntax and declarative rules. In the example of dementia sufferer, semantics repository is responsible for maintaining the contextual knowledge model that capture relevant information about the environment into which the application is deployed. In this example, the physical layout of the patient's home and environment are referred to as static semantics whereas the patient's movement and engagement in activities is dynamically updated based on their behaviours over time is dynamic semantics. [15]

For developing a suitable framework to accurately analyse data from assistive technologies, our approach to modelling is based on the assumption that dynamic changes in the patients situational conditions such as room occupancy and movement within the living environment has to be analysed against the semantic knowledge about the condition' symptoms and the patient's related profile (medical history, age, etc.). Therefore, we can define our proposed framework as context-aware and knowledge-based. e.g. context-awareness can detect short room occupancy and wandering behaviour, which is analysed against the knowledge of the patient history of restlessness and inferred as deterioration in the patient's dementia condition. [16]

IV. Wearable-Middleware

The infrastructure of a real time data processing system will incorporate a two-way data binding for live data transportation. The existing device and sensor data processors require a real time middleware system for wearable and embedded devices.

The research project proposes the use of extended middleware for the health care and dementia with real-time data processing unit using Complex Event Processors, with connectivity to wearable and mobile devices as clients.

The current standards for middleware require real time processing of data from wearable devices with built-in real time pattern recognition and analysis. The Wearable-Middleware equipped with the two-way data binding will bring the power of the middleware into the devices.

An outline of the middleware as illustrated in Figure 2:

- Information from patients, using wearable sensors in terms of a wearable device, will be collected in terms of location and behaviour. Patterns and the variation in the speed of the changes in these patterns will be analysed in real-time.

- Data streams will be processed in real-time to detect variations in the behaviour of patients using sensor data from wearables.
- Data buffering will be achieved by storing the data as message queues in the form of message-oriented-middleware feeding to the CEP engine.
- The Data Processor Unit will provide the implementation for the algorithms in the context of dementia patients and take into account the background knowledge base and context-aware semantics.

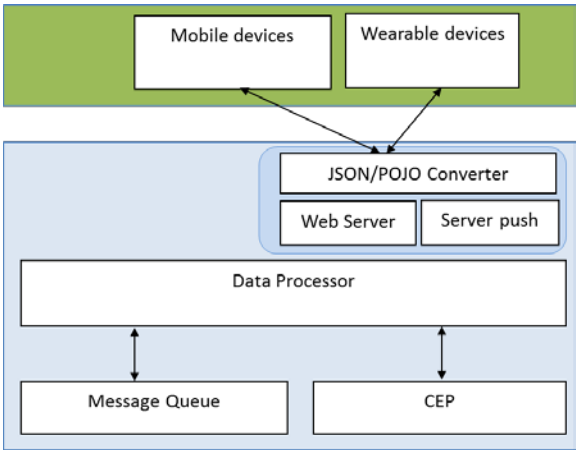

Fig. 2. Wearable middleware

V. CONCLUSION AND FUTURE WORK

Though the dramatic growth of IoT, wearable devices, cloud computing, sensor networks, etc., have made various kinds of products available for assistive living, there is a lack of integration of these services to fully utilise the power of assistive living for healthcare. Integration of separate devices and services in larger systems benefits from collecting and processing large volumes of data, evaluating more complex situations and scenarios, collaborative tasking, precise identification of potentially dangerous situations and finding solutions. The need for interoperability, dynamic configuration, communication, context awareness, security and privacy are of major concern.

Further research into wearable assistive technology and development of our wearable-middleware framework will aim to achieve the following outcomes:

- The use of sensors should provide robust, high-precision perception of context and components related to assistive living.
- Identify mobile and wearable devices that are comfortable to wear and less obtrusive. Assistive devices can be designed to enhance not only physical but also cognitive skills of human users through mobility experiences.
- Allow carers to better monitor and adapt to the patient's gradual physical and cognitive decline, as well as to any sudden changes such as a hip fracture.
- Allow researchers and developers to pay attention to the combination of biological, physiological and medical aspects in order to develop intelligent cognitive devices for assistive services.
- A framework to allow for system coordination, components integration, service allocation, and knowledge sharing in order to support the use of assistive technology.

The motivation for the research documented in this paper is that assistive technologies can play a useful role in building dementia support systems by intelligently inter-relating the abnormalities in patient behaviour captured by wearable and other sensor devices to dementia symptoms defined by clinical guidelines in order to assist medical aid and support.

Figure 3 gives an overview of the proposed framework. Future work will focus on the development of the proposed framework to allow integration of real-time information about related sensory events together with context-aware semantics and knowledge base that will use rule-based CEP techniques to infer knowledge about the Dementia patient's medical state. In addition, every effort will be made to ensure that the deployment of the proposed framework in a sensitive environment such as healthcare addresses all possible ethical and privacy issues.

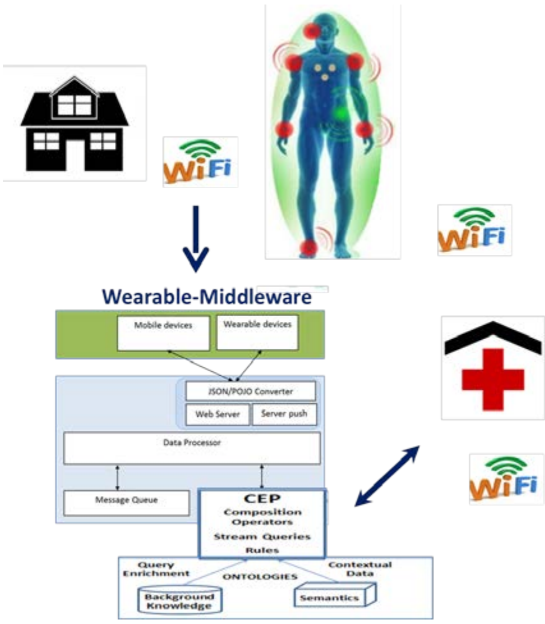

Fig. 3. Overview of proposed framework

Big Data Analytics, Complex Event Processing and IoT together have extreme potential in solving existing and future problem of healthcare industry. 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 [12].

REFERENCES

[1] S. Bhardwa, "Barriers to dementia care," 2015. [Online]. Available: http://www.independentnurse.co.uk/news/barriers-to-dementia-care/72505/. Accessed: Jun. 26, 2016.

[2] A. Society, "Alzheimer's society - dementia support and research charity," Alzheimer's Society, 2016. [Online]. Available: https://www.alzheimers.org.uk/. Accessed: Jun. 26, 2016.

[3] . [Online]. Available: http://TheAlzheimer's Association, 2013 Alzheimer's Disease Facts and Figures. URL ⟨http://www.alz.org/downloads/facts_figures_2013.pdf ⟩2013. Accessed: Jun. 26, 2016.

[4] O. Badreddin and L. Peyton, "Real time patient flow management using business process management, location tags, and complex events processing," pp. 357–359, Nov. 2013. [Online]. Available: https://www.researchgate.net/publication/262172837_Real_time_patient_flow_management_using_business_process_management_location_tags_and_complex_events_processing. Accessed: Jun. 26, 2016.

[5] S. A. Baffoe, A. Baarah, and L. Peyton, "Inferring state for real-time monitoring of care processes," IEEE Press, 2013, pp. 57–63. [Online]. Available: http://dl.acm.org/citation.cfm?id=2663575.2663590&coll=DL&dl=ACM&CFID=674387497&CFTOKEN=19858697. Accessed: Jun. 26, 2016.

[6] "Informatics Engineering and Information Science,". Springer Science + Business Media, 2011, pp. 228–242. [Online]. Available: http://www98.griffith.edu.au/dspace/bitstream/handle/10072/43576/76486_1.pdf?sequence=1. Accessed: Jun. 26, 2016.

[7] G. Young, "The implications of an ageing population on the UK economy,". [Online]. Available: https://www.bankofengland.co.uk/publications/workingpapers/wp159.pdf. Accessed: Jun. 26, 2016.

[8] S. Palmer and Daughter, "Helping people to stay at home," Just Checking, 2007. [Online]. Available: http://www.justchecking.co.uk/. Accessed: Jun. 26, 2016.

[9] Carl A Thompson, Karen Spilsbury, Jill Hall, Yvonne Birks, Colin Barnes, Joy Adamson, "Systematic review of information and support interventions for caregivers of people with dementia," BMC Geriatrics, vol. 7, no. 1, p. 1, Jul. 2007. [Online]. Available: http://www.biomedcentral.com/1471-2318/7/18. Accessed: Jun. 26, 2016.

[10] M. W. J. Strachan, J. F. Price, and B. M. Frier, "Diabetes, cognitive impairment, and dementia," vol. 336, no. 7634, Jan. 2008. [Online]. Available: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2174783/. Accessed: Jun. 26, 2016.

[11] H. Aloulou et al., "Deployment of assistive living technology in a nursing home environment: Methods and lessons learned," BMC Medical Informatics and Decision Making, vol. 13, no. 1, p. 42, 2013.

[12] Naqishbandi, T., Sheriff. C, I., & Qazi, S., "Big Data, CEP and IoT: redefining holistic healthcare information systems and analytics," in International journal of engineering research and technology, 2016. [Online]. Available: http://www.ijert.org. Accessed: Jun. 26, 2016.

[13] Aggarwal, C., Managing and mining sensor data. Springer Science + Business Media, 2013. [Online]. Available: http://charuaggarwal.net/sensortoc.pdf. Accessed: Jun. 26, 2016.

[14] Department of Health, "National dementia strategy living well with dementia: A national dementia strategy putting people First," 2009. [Online]. Available: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/168220/dh_094051.pdf. Accessed: Jun. 26, 2016.

[15] T. Osman, A. Lotfi, C. Langensiepen, S. Chernbumroong, and M. Saeed, "Semantic-based decision support for remote care of dementia patients," pp. 89–96, Dec. 2012. [Online]. Available: http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=7009463&url=http%3A%2F%2Fieeexplore.ieee.org%2Fxpls%2Fabs_all.jsp%3Farnumber%3D7009463. Accessed: Jun. 26, 2016.

[16] N. K. Vuong, S. Chan, C. T. Lau, and K. M. Lau, "Feasibility study of a real-time wandering detection algorithm for dementia patients," p. 11, May 2011. [Online]. Available: http://dl.acm.org/citation.cfm?id=2007050. Accessed: Jun. 26, 2016.

[17] R. Li, B. Lu, and K. D. McDonald-Maier, "Cognitive assisted living ambient system: A survey," Digital Communications and Networks, vol. 1, no. 4, pp. 229–252, Nov. 2015. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S2352864815000589. Accessed: Jun. 26, 2016.

[18] T. N. L. 2016, "Rush to diagnose dementia is dismissed as pointless," 2016. [Online]. Available: http://www.thetimes.co.uk/article/dementia-7k9pkq5rn. Accessed: Jun. 26, 2016.