Semantic Sensor Networks for Personalized Health Systems for Risk Prevention

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Abstract. Current monitoring systems for chronic disease management and assisted living are advancing with giant strides, providing more complete and personalized solutions. So far, standardization and physiological tracing strategies have mostly overcome difficulties dealing with integration and interoperability. However, with the deployment of massive sensing infrastructures, another big problem appears on the scene: an enormous amount of data, coming from the different and heterogeneous sources, and trying to describe one single scenario or situation. This problem becomes more and more evident in we focus in the needs of risk prevention scenarios, where the level of complexity of the targeted indicators relays in informal and less reliable sources. This paper proposes a new architecture for data indexing and correlation that provides a semantic middleware to search and select relevant information from a complex and flexible monitoring scenario in a work environment. Risk prevention must look back for trends and patterns, and furthermore, with a personalized approach. Indexing of semantic concepts would optimize algorithms to trigger emergency situations, provide dynamic and adaptive decision support and improving lifestyle and care of both employees and patients.

1 Introduction

Monitoring of health related parameters, behaviors, signs and symptoms in patients with diagnosed conditions is still a challenging issue [1]. This is evident, if not because the need of more advanced sensing technologies, also due to the intrusiveness and the excessive technological component of the more trivial solutions proposed. However, the need for enhanced control and support of said patients and the corresponding professionals makes, in many cases, the usage of less comfortable solutions bearable for the sake of a greater good. However, this situation is brought to the extreme when the desired scenario deals more with primary prevention, populations at risk or promotion of healthy habits. Is in these cases where we need to demonstrate that the role of advanced ICT technologies can and will cause a dramatic impact in the possibilities of supporting and adapting to the evolving needs of

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individuals and groups, overcoming the problems of feeling inside a continuous 'big brother'[2] .

Thus, technologists and professionals of health promotion and disease prevention need to work together to create imaginative solutions that could enable that each person is able to create his own personalized sensing environment, that provides the right level of support, with the adequate capability for adaptability and within a comfortable level of intrusiveness. This situation is not a utopia as it may seem, as individuals and groups do very often reduce their level of desired privacy if they feel within a comfortable environment or they receive positive outcomes that match their expectations more than they feel as being controlled. In this framework, new solutions that enable truly personalized sensor systems in not formally controlled environments need to be proposed and validated in order to foster a new generation of personalized health solutions. In primary prevention, this Personal Health Systems (PHS) will be used in what in the medical world is called "uncontrolled environments". This means that the usual clinical golden standards (that have been set for controlled environments) cannot be applied as such.

Nevertheless, advances need to be done in different technologies and different layers of the architecture: in relation to the type and characteristics of the sensors themselves, in relation to the capacity of the information processing, in the standardization of the protocols and in the middleware. However, the aim of this paper is to focus in the challenges and opportunities that arise from the design and development of a middleware for advanced personalized health sensor networks for non medicalized environments.

2 Material and Method

In between the Factory of Future (FoF) and the Internet of the Future (IoF) paradigms, healthcare and risk prevention have arisen as key points for contribution to development and competitiveness in Europe [2] [3]. Within this scenario, Ambient Intelligence (AmI) can play an important role when applying multimodal monitoring by using different types of sensors and sensing procedures for both, human and machine activity. Thus, the acquisition of information through different sources can contribute to setting up sub-networks that provide redundancy and enable to create more solid measurements and conclusions from "uncontrolled environments".

Future interfaces will be able to detect behavioral patterns and changes that may occur during the performance of daily activities, and then react as a global platform according to these changes. Biometrical sensors are the basement of these interfaces. Apart from a continuous monitoring, where emergency situations can be triggered out just analyzing whether the parameters are or not into a normal range, they allow to complement other information coming from other sensor sub-networks, trimming down the number of freedom degrees to apply algorithms and workflows, and improving results sturdiness.

As a matter of fact, integrated platforms or systems are not realistic in these environments, as the level of agreement, standardization and homogenization required, both at the business/political level as well as in the technical, are extremely difficult to obtain, if not impossible. Furthermore, the more closer we get to primary prevention the less willingly the person will renounce to his freedom to have the ‘opportunity’ to be completely spied by the system. FoF model must engage the concept of an open solution where the different modules that build it up can be added, discarded, replaced or updated without modifying the core, interoperating and contributing to depict the picture of the person and his behavior. This approach can be only affordable with a semantic based system.

Personal Health Systems (PHS) normally share a common architecture based in a closed-loop approach, combining monitoring and feedback to different levels of care. This model can be easily exported as the base for more open scenarios such as the ones targeted by this paper. The main characteristics that the architecture needs to cover are:

- The object of the monitoring are not sick patients but citizens at risk, so they need a greater degree of freedom in relation to the number, type and characteristic of the monitoring sensors in their personalized system.
- Not only pure health parameters need to be assessed but also behavior and emotional characteristics of the person need to be taken into account.
- People do not normally live alone; they normally interact with other persons and groups and many times share with them a same physical scenario for long periods of time (at home, at work, at school).
- To be successful, business and usage models associated to these types of systems need to be extremely efficient and low in cost, taking profit of existing infrastructure and aligning with the personal preferences of the actors involved.

With these requirements in mind, the proposed architecture will aim at providing a flexible setting where different types of sensors could be dynamically combined to create an environment of knowledge where specialized algorithms could generate a personalized response for the user. Furthermore, this same architecture, with personalized instances and potentially different configuration of sensors, should be useful for different members of the social unit, and for different purposes. That it’s to say, it does not make sense that every member of the family has his own sensor for their own risk, but that they share a common basic infrastructure and the system adapts to the needs and preferences of each individual at the moment of interaction. Besides, different users in the same scenario could also prefer to use a different interface or a different sensor for a similar purpose, such as using a wireless pedometer or an iPhone with an integrated accelerometer.

Taking into account that the sensors sub-networks are the basement of these kinds of systems and also pretending to have as much information as possible from many different sources, the conception and definition of an interoperable layer is essential. When a wide range of devices and sensors, each one working with their own communication protocols, provide heterogeneous amount of data, two problems must be faced: data meaning and link layer.

Healthcare industry is progressively focusing on putting standards for a new era of m-health and e-health systems. But till nowadays it is still missing the real implementation of a full-standardized system. Nonetheless there are many companies working together, in Continua Health Alliance (CHA) [4] to overcome this hurdle for the development; but so far only a few companies offer certified devices compliant with 11073 standard [5].

3 Architecture

The architecture model will require a semantic based middleware, which allows easy configuration of different sensors in a dynamic way, identifies similarities and differences and learns from the interaction with the users how to more efficiently configure the semantic sensor network in order to match the concrete requirements of each situation. Furthermore, each time more, these sensors will incorporate a certain level of processing, allowing not only extracting raw data but also high level parameters that could be directly combined in the middleware for the first automatic level of response [7], [8]. These components, that allow to know more about small parts of the individual's status are identified in the proposed model as 'software sensors', extending the capabilities of data acquisition to more than just physics. These components need to be identified and connected through the middleware, creating bigger pieces of more complex information and providing feedback ones to the others in order to enhance their individual performance and better adapt to the evolution of the person. The final objective will be to have a dynamic evolving and adapting picture of the person's status and behavior that is as close as possible to the reality and that can be used for configuring and providing authomatized personalized care and creating the foundations of decision support systems for the person itself and his related health professionals.

Sensor sub-networks are braked out into six different types of sub-networks, facing the current state of art in monitoring technologies and the purpose of a holistic system. Each sub-network is made up by an Application Hosting Device (AHD), which acts as a manager of the sub-network, and the sensor network itself, that may be constituted by a complex inter-dependant sensor mesh or just by an isolated sensor.

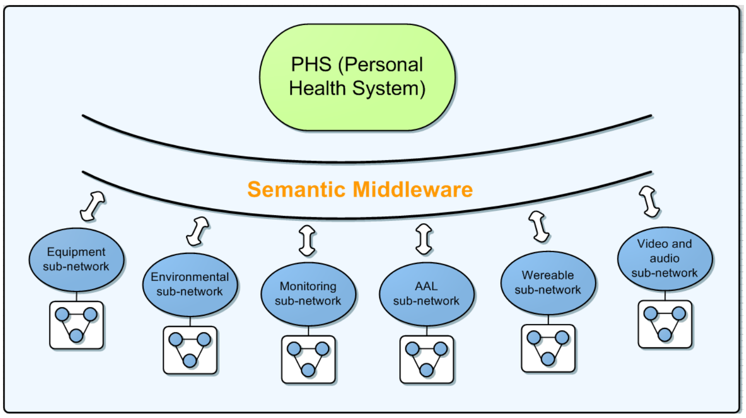

Fig. 1. Proposed Architecture for a Personal health System. Sensors are grouped into sub-networks, where an Application Hosting Device (AHD) acts as a data concentrator and intelligent gateway towards the Semantic Middleware.

The core of the Personal Health System (PHS) is the Semantic Middleware (SM). It will work as an Ontology does [6] but with a human reasoning approach. The engine within will be capable to correlate measurements arriving from different sub-networks and perform data differential analysis to refine rules and algorithms. Data analysis will not be more based in just working with values or conditions. New data analysis is focused to compare a value in a context, and then analyze these contexts in order to obtain behavior patterns and trends. In this way a fundamental topic when talking about health prevention is covered. As a dynamic engine, new data and context correlations can be identified, and just by an easy inquiry to the system is able to draw a comprehensive state of the person in its concrete context.

Standards from HL7 [7] as v2.6, v3 Reference Information Model and ISO IEEE 11073 are helpful when describing health related contents and so on, for semantic management. So far, these standards and their correspondent information models are defined for an application special domain (i.e.: v2.6 for sending messages between clinical entities), so there is a need to sort huge collections of data in an easy-understandable way based in:

- Keyword (not comparable to key or ID)
- Context meaning (who, what, why, when, where)
- The value itself

Logic and rules into the semantic repository will be able to relate measurements with contexts and also identify correlated measurements, contexts and patterns.

Therefore an environment is provided for searching and picking up information by just describing low level aspects (for instance: employees with systolic BP greater than 130 when they arrive at work) and above of this large libraries of indexed metadata can be automatically fulfilled

The suitable way to stimulate interoperability and self-custom systems regarding meta-data is the use of XML codification. CDA specifications for HL7 and CHA Guidelines v1.5 can be taken as a reference to this kind of data storage. A useful tool is one developed by National Institute of Standards and Technology "NIST", the ICSGenerator [7].

Rules and indicators which are present in the SM can be extrapolated and optimized for specific sub-networks, and so, speeding up the process of triggering an emergency situation.

The headmaster of the sub-network is the AHD. It defines an integrated unit split up by three main layers: Physical layer, Logic Layer and Gateway Layer.

3.1 Physical Layer

The Physical Layer gathers all the physical interfaces the sensors offer. Following the approach of interoperability and standards implementation, three main interfaces defined in continua and 11073 guidelines are present: USB, Bluetooth and ZigBee.

The system may be opened also for other kind of physical interfaces such serial RS-232 or IrDA, or even for special interfaces that manufacturers have such serial-jack.

As a hardware layer, the restrictions for connecting sensors may depend on the localization of the Application Hosting Device.

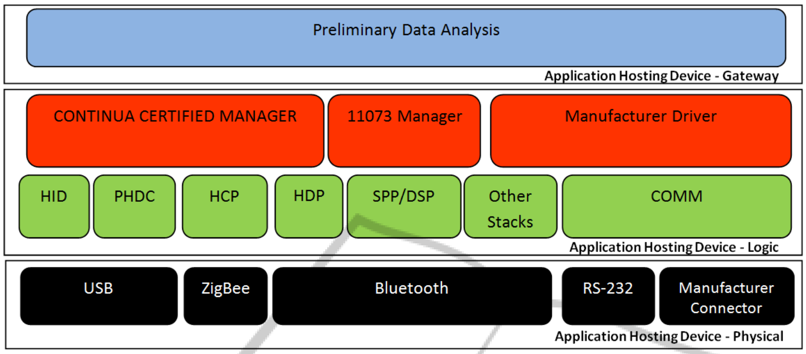

Fig. 2. Application Hosting Device Stack.

3.2 Logic Layer

This Layer is conceived as a pipe. The sensor is connected to one side of the pipe and in the other side of the pipe is expected to receive the value measured.

The main purpose of this layer is to put together the necessary classes which deal with each physical interface and obtain the measurements. As it has been said, market standardization is continuously facing obstacles because hardware and health sensors companies still work with their own protocols and connection procedures. Thus, in order to provide a transparent solution for the transport layer, independently of the device connected, the Logic Layer will be build up by four modules:

- *USB module:* It will contain a Human Interface Device (HID) and Personal Health Device Class (PHDC) libraries that will provide the basic functionalities to initialize, maintain and close the communication with USB wired sensors.
- *ZigBee module:* It will contain the Health Care Profile (HCP) libraries to connect to ZigBee [8] nodes.
- *Bluetooth module:* Using Bluetooth hardware access libraries, such Microsoft, Toshiba and Bluesoleil stack, and other open source solutions as 32feet, a channel to communicate with Bluetooth sensors will be provided. Also the basic Serial Port Profile (SSP) and Service Discovery Protocol (SDP) functionalities of the Bluetooth 2.0 specification and the Health Device Protocol (HDP) as defined by Continua Health Alliance are implemented within this layer.
- *COMM module:* For peer-to-peer communications against RS232 and IrDA interfaces.

Above these communications functional modules, the managers will be placed, being able to talk the same language of the sensors. Continua, 11073 and the owner protocol for each device will be capable to send commands through each of the four modules mentioned before.

3.3 Gateway Layer

The Gateway Layer is used to connect sensors sub-networks with the Semantic Middleware above. It will be able to interconnect different networks each one deploying its own architecture and protocols. The purpose of this layer is to turn the measurements from the sensors (data) into values that a semantic engine can understand (metadata)[11].

This component will be the intelligent module in the AHD, it will be capable to detect errors in the incoming data burst, perform high level data processing to discard irrelevant information and endow a context for the metadata routed to the Middleware.

4 Conclusions

More extensively developed semantic sensor networks need to be developed to face the challenges and requirements of more open scenarios for health related monitoring in personalized systems. These semantics will enable different combinations of sensors, which could vary in time and in instantiation, incorporating more sources of information and allowing a more efficient traceability of the person in a more comfortable way. This scalability and flexibility needs to be supported both in the technical level but also at the level of data fusion and data processing. The semantics are basic to represent the complexity of the acquired parameters, reflex the relation between concepts and measurements and provide the mechanisms for time coupling the information in a broad sense.

In addition to this, questionnaires and the same user interaction could also be considered as one type of sensor, allowing assessing qualitative data that is also required to provide the most appropriate response. The incorporation and mixing of this qualitative data with more quantitative parameters and its usage through automatic or semi-automatic decision support systems need a strong semantic support and an adequately defined knowledge base. This will prevent the emergency of erroneous conclusions but it will also allow to maximize the usage of all kinds of small pieces of information that, all together and interpreted with the correct approach, could become the difference between a successful and efficient personalized primary prevention strategy and a superficial one. Furthermore, this approach seems to be much more cost effective and provides the person with a much higher degree of freedom to choose, increasing the possibilities of sucess.

Prevention in healthcare and in the FoF model must look to the future with the focus in evidence based medicine and co-creation of health between multiple stakeholders outside medicalized environments. To accomplish that, a powerful and adaptive semantic middleware on top of a scalable and flexible monitoring infrastructure is necessary and can make a dramatic change towards a new way of building health and preventing risks.

References

1. Institute of Medicine. Crossing the Quality Chasm: A New Health System for the 21st Century. Washington : National Academy Press, 2001.
2. European Project PREVE – Co-funded under the 7th Framework Programme of Research of the European Commission, Information and Communication Technologies Priority, ehealth unit (www.preve-eu.org)
3. K.L. Belkic, P.A. Landsbergis, P.L. Schnall, D. Baker. *Is job strain a major source of cardiovascular disease risk?* Scandinavian Journal of Work, Environment and Health 2004; 30 (2) 85-128.
4. F Kauffmann, D Drouet, J Lellouch, D Brille. *Occupational exposure and 12-year spirometric changes among Paris area workers.* British journal of Industrial Medicine 1982; 39: 221-232.
5. Continua Health Alliance. http://www.continuaalliance.org/about-the-alliance.html
6. ISO/IEEE 11073, Personal Health Data. http://en.wikipedia.org/wiki/ISO/IEEE_11073_Personal_Health_Data_(PHD)_Standards
7. Paolo Baronti Prashant Pillai Vince Chook Stefano Chessa Alberto Gotta Y. Fun Hu, Wireless Sensor Networks: a Survey on the State of the Art and the 802.15.4 and ZigBee Standards, Computer Communications, 2006, pp. 1-30.
8. Akyildiz, I. F.; Weilian Su; Sankarasubramaniam, Y.; Cayirci, E.;, A survey on Sensor Network, IEEE Communication Magazine, August 2002, Volume 40, Issue 8, Aug. 2002 Page(s):102 - 114.
9. O. Bodenreider, J. A. Mitchell, and A. T. McCray. *Biomedical Ontologies: Session Introduction.* Pacific Symposium on Biocomputing 10:76-78(2005).
10. HL7. Health Level Seven Standards. http://www.hl7.org (Last Access July 2010)
11. National Institute of Standards and Technology Web Page. http://xw2k.nist.gov/ medical-devices/index.html (Last Access July 2010)
12. ZigBee Alliance. ZigBee Health Care web page. http://www.zigbee.org/Markets/ ZigBee-HealthCare/Overview.aspx (Last Access July 2010)
13. Magedanz T. Evolution of SOA Concepts in Telecommunications. IEEE Computer, vol. 40, no. 11, 2007, pp. 46-50.