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An intelligent system for prognosis of noncommunicable diseases' risk factors

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ABSTRACT

Noncommunicable diseases are the main reason to the rise of diseases incidence in the developed world. The management and prevention of these diseases can be done by controlling the behavioral and biological risk factors which are related to them. ChronicPrediction is an intelligent system for noncommunicable diseases care which determines in real time the impact on risk factors due to actions taken by users. Based on impact information, the system presents on users' smartphones strategic messages to help in their treatment. ChronicPrediction applies Bayesian Networks (BNs) which use risk factors for mapping the causes of noncommunicable diseases worsening. The support to multiple chronic diseases and the integrated use of multiple BNs based on risk factors are the main contributions of this work and differentiate the proposed system from related work. We have built a functional prototype that allowed us to conduct two experiments. The first one successfully tested the main functionalities provided by ChronicPrediction to support BNs based on risk factors and the sending of messages to users' smartphones. The evaluation involved the building of a BN for predicting coronary artery disease made with real world data obtained in a prospective cohort study. The study involved 302 patients from a hospital localized in southern Brazil. The second experiment assessed the ChronicPrediction support to multiple BNs at same time. The test involved the previous BN and another from a thirty part research work to map risk factors of diabetes. The results were encouraging and show potential for implementing ChronicPrediction in real-life situations.

1. Introduction

Noncommunicable diseases (NCDs) are the main reason to the rise of diseases incidence in the developed world. The NCDs incidence has raised with high rates due the population aging and the increased longevity of people with many chronic conditions. These diseases create economic impacts in individuals, families, health systems and general society, once they affect people in their productive years, reducing the productivity and the ability of gain at domestic level (Puoane et al., 2008).

The main NCDs include cardiovascular diseases, cancers, chronic respiratory diseases and diabetes. Visual impairment and blindness, hearing impairment and deafness, oral diseases and genetic disorders are other chronic conditions also classified as NCDs.

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The causes of most NCDs are well established and known, which are mainly related to behavioral and biological risk factors. Among the most present risk factors are unhealthy diets, including the excessive ingestion of calories, lack of physical activity and smoking habits (WHO, 2005).

Despite the clinical differences between each chronic condition, these diseases put patients and families to face the same needs, for example, change their behavior to tackle with the social impact of symptoms and interact with medical care all the time. In turn, the medical assistance should ensure that patients will receive the required treatment, information and support needed to control their diseases, minimize symptoms and manage their health (Wagner and Groves, 2002).

Most people with NCDs struggle with physical, psychological and social needs of their diseases without much aid from health professionals. Frequently, the received help cannot give the right support nor comply with the people needs for an effective health management. This is further aggravated if the NCD needs a continuous treatment (Wagner et al., 2001; Bodenheimer et al., 2002).

Hence, it is strategic that NCD patients have quick and straight access about their situation regardless of the time or location. In that sense, the rise of mobile devices with Internet access such as smartphones, offers great potential for easing the control and continuous tracking of diseases by the patients, since most people carry their smartphones everywhere. Furthermore, with ubiquitous Internet access they can get specialized aid whenever is needed (Google, 2012).

Weiser (1991) called *ubiquitous computing (UbiComp)* the massive and integrated use of computers and sensors that interact seamlessly to create an always present computational platform. This high density of distributed computational devices generates a massive quantity of data that can be used to anticipate situations faced by NCD patients (Pejovic and Musolesi, 2015). For instance, the physical activity practice is related to acute myocardial infarction (Ôunpuu et al., 2015). Data collected by sensors embedded in smartphones may be used to monitor physical activity of chronic patients helping to anticipate an infarct.

In this sense, we propose *ChronicPrediction*, a system for ubiquitous prognosis of NCD risk factors. ChronicPrediction uses Bayesian Networks (BNs) created from the mapping of causal relationship of risk factors. The BNs consider the behavioral data generated by the patients, while they use their smartphones. In this way, ChronicPrediction ubiquitously helps patients to be aware of their treatment, assessing whether the actions taken are helping to improve their health conditions or not. The main strength of ChronicPrediction resides in its capacity to deal with multiple types of NCDs, and its architecture that allows a near real time prediction of NCDs risks factors based on patients' behaviors. On the other hand, the support of multiple NCDs by ChronicPrediction is not entirely automated. It needs the collaboration of health specialists that are responsible for designing BNs for each NCD.

This article is organized in six sections. Section 2 presents an introduction to UbiComp and NCDs care. Section 3 addresses works that apply, in some manner, prediction in NCDs care. Section 4 describes the ChronicPrediction. Implementation aspects, assessment and results are covered in Section 5. Section 6 presents final remarks and directions for future works.

2. Background: ubiquitous computing, u-Health and NCDs

Circulatory and respiratory diseases, cancers and diabetes, are considered the NCDs with most prevalence in a global level (WHO, 2005; WHO, 2008; Brazilian Health Ministry, 2008). These diseases belong to the group of chronic conditions that involves a large spectrum of health problems, such as long term mental disorders, permanent transmissible infections and continuous physical impairment (WHO, 2002). In general terms, these conditions have the same characteristics as they require "life style changes" and "long term health management". Moreover, they are caused by lifestyles and risk behaviors, such as unhealthy diets, smoking habits, sedentary lifestyle, alcoholism, high-risk sexual behaviors and social stress. In addition to those behaviors factors, age and biological factors can influence the incidence of chronic conditions.

The management, prevention and control of NCDs can be done through the care of behavioral and biological risk factors related to those diseases. According to World Health Organization (WHO, 2005), *"if these risk factors were eliminated, at least 80% of all heart disease, stroke and type 2 diabetes would be prevented; over 40% of cancer would be prevented"*.

Moreover, about 25 years ago, Weiser (1991) introduced the concept of Ubiquitous Computing, or UbiComp, predicting a world where computing devices would be present in objects, environments and human beings themselves. These devices would interact naturally with the users without being noticed. Ten years after, Mahadev Satyanarayanan reinforced the concept through an article that would become a classic (Satyanarayanan, 2001).

Context-Aware Computing has been considered a strategic research topic to support the UbiComp (Hoareau and Satoh, 2009). Context is any information that can be used to identify the situation of an entity (i.e. a person, a place or an object) and that has importance in the interaction between user and application (Dey et al., 2001).

Among the goals of context-aware computing are the acquisition and usage of information of the physical world to then, select, configure and offer a variety of services in a meaningful way. Context-aware systems are fundamentally interested in acquiring context information (for example, by sensors) and understand this context (for example, by merging sensed perception for a particular context). This kind of system is able to fit its operations for the actual context without an explicit user intervention, and by that, raise its usability and effectiveness by taking into account the environment context (Baldauf et al., 2007).

Context history, or trail (Barbosa et al., 2016), has been recognized as the collection of users' past contexts. According to Ciaramella et al. (2010), context history is an important piece of information to recognize the user's status. When recorded for a long time, such histories can offer the opportunity to infer users' actions, and by doing so, reinforce the services offered by computational systems. In addition, prediction based on recorded contexts is an actual challenge for the context history subject (Barbosa et al., 2013; König et al., 2013; da Rosa et al., 2016).

UbiComp has found application in a diverse range of knowledge areas, such as, health (Vianna and Barbosa, 2014), commerce (Barbosa et al., 2016), competence management (Rosa et al., 2015), learning (Barbosa et al., 2013; Barbosa et al., 2014; Abech et al.,