Software Engineering-Inspired Approach to Prevention Healthcare

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Abstract. The paper extracts proven principles from software engineering to be applied in the field of prevention and wellness preserving. For instance, the concern-oriented partitioning principle could support the analysis and design of healthcare information systems. Results of such an approach are multifaceted systems that integrate all stakeholders' concerns. For such a system, the paper proposes a multi-agent system, where a patient avatar negotiates with expert systems assisting the user to monitor his health state and supply proven prevention alternatives. The aggregated patient-centered virtual organization also aims at stimulating the patient empowerment through personalized information based on their conditions.

Keywords: patient empowerment, prevention, virtual health assistant, patient-centric virtual organization, multi-agent systems.

1 Introduction

In the past two decades, much of the growth in health expenditures has been attributable to chronic conditions in the context of global population ageing. Future health reform should rely on stimulating patient empowerment [1], i.e., people to take responsibility of their health status and act proactively upon maintaining it [2]. One of the most promising applications of patient empowerment is in the field of prevention, aiming to avoid even the debut of chronic conditions, with an alarming increasing prevalence in young people [3]. However, the existing healthcare information systems are not suitable for this purpose because they focus on acute disease care and favor diagnosis and treatment based mainly on the current symptoms [4]. The paper approaches the healthcare area from the original and seminal perspective of software analysis and design, applying proven methods for tackling partial knowledge problems in the prevention field. Using a concern-oriented approach to health monitoring and prevention, a multi-agent system is designed around the Personal Health Record (PHR) to provide continuous assistance throughout the whole lifespan of the user.

Section 2 presents a brief state of the art in the fields this paper relies upon. To address some of the identified problems, the conceptual design of a multi-agent system is presented in Section 4, building upon a theoretical basis described in Section 3. Conclusions and future work are presented in section 5.

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2 State of the Art

The use of agents in healthcare has a wide range of applications, including decision support, medical data management, resource planning and pervasive care [5]. Numerous prototype agent systems were proposed which demonstrate clear strengths compared to classic programming, such as support for expert systems or personalization.

Significant improvements in clinical practice have been demonstrated through the use of decision support sytems [6]. Such systems also present new opportunities for patient empowerment through feedback and recommendations.

3 Theoretical Background

The goal of our research is to compare the software development process with the management of the patient's health state in the attempt to apply proven methods from the former to innovate in the prevention field. Although apparently very different in nature, the two domains have many similarities: both produce unique, unrepeatable work, both make critical decisions relying on some abstract model built through iterative analysis and both emphasize the continuous nature of their work, i.e. treatment and maintenance, respectively. Furthermore, both medical assistance and software development requests are triggered by a change in an unpredictable universe, health status and business environment, respectively.

The IEEE defines the concerns for a system as "those interests which pertain to the system's development, its operation or any other aspects that are critical or otherwise important to one or more stakeholders" [7]. Concern-Oriented Software Development [8][9] is an approach to partitioning a software system in a concern-driven way, with the aim of supporting the specification of stakeholders' concerns and their composition into a working system. The concerns about a system are represented as *facets*, usually interrelated and overlapping. A key supposition is that the sum of all the facets identified is the system to be developed, because the composite representation subsumes all the knowledge about the system available at that moment [8]. Thus, the system analyst has to consider all the stakeholders' concerns and design the software system to harmonize all the different facets. Similarly, the medical specialties have different, sometimes overlapping or even conflicting views and concerns about the health state of a patient that should be harmonized in the final medical advice.

In software development several requirements often recur in similar forms, e.g., the requirement for security, but to implement it correctly, worldwide-agreed standards and proven solutions are reused. In medical practice, the proven knowledge is built on clinical trials [10] that quantify the benefic or detrimental effect of habits and lifestyle on the health state in the form of a Relative Risk (RR%), and embedded in clinical guidelines and protocols that indicate the best therapeutic attitude.

After delivery, a software system enters the maintenance phase throughout which its various problems and limitations emerge in the ever-changing business environment. Similarly, in healthcare, while treating a patient multiple adverse effects together with unexpected medical conditions may begin to manifest. However, regular monitoring could predict acute and possibly dangerous manifestations.

4 The Patient-Centric Virtual Organization

The system represents a Patient-Centric Virtual Organization (PCVO) and consists of three parts: the PHR, the *Virtual Health Assistants* (VHA) and the patient *avatar*.

Conceptually, the **PHR** provides views on the patient's current health state and clinical history, including both self-gathered data and authoritative information retrieved from the Electronic Health Record (EHR). **VHA**s are collaborating expert systems whose role in the organization is to predict and prevent health deterioration based on the PHR data. The system is designed using a concern-oriented approach, with each VHA dedicated to a medical specialty. This organization enables distributed development and responsibility of the prevention Knowledge Bases (KB) containing proven advices. In the PCVO, **the avatar** is the leading agent that coordinates the activity and the only entity that directly communicates with the user. One of its main tasks is to capture the user profile and to adapt to it in order to increase its influence on her/his life style. On the other hand, in terms of virtual/real distinction, it is a boundary agent that maps the real into the virtual [4] and provides the required information to the VHAs. It is a design objective for our system to be low-intrusive, essentially remaining a reactive system and using proactive communication channels only for critical health conditions. A typical usage scenario is presented below (Fig. 1):

- The user contacts the avatar which in turn asks the VHAs for information requests.
- Each VHA responds taking into consideration the known state of the respective anatomic system, predispositions and interactions with other VHAs.
- The avatar aggregates and provides the user a personalized view on these requests.
- The user responds based on current symptomatology and/or by executing several quick self-tests (e.g. glucose level) and her/his responses are stored in the PHR.
- To build a clearer image, a VHA can request further pacient information.

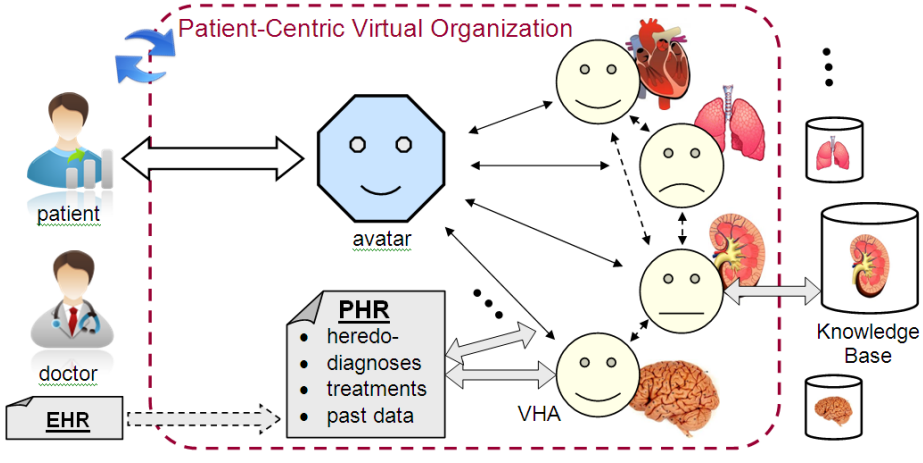

Fig. 1. Patient-Centric Virtual Organization

- The different recommendations are negotiated between VHAs, e.g., potassium salt is good for patients with high blood pressure, but questionable in case of arrythmia.
- The final recommendations are presented to the user and integrated in the PHR.

5 Conclusions

Software development was compared to healthcare provisioning and proven methods were applied in the field of medical prevention. The paper presents the conceptual design of a concern-oriented multi-agent system for monitoring the health state and stimulating the patient empowerment. Unlike most existing agent systems [5], the control loop does not include any medical staff, thus allowing for a quicker adoption. What differentiates our approach from other medical expert systems [6] is the emphasis on prevention targeted at persons with no previous symptomatology. Incipient stages of an otherwise unsuspected illness are detected and help is provided to prevent its debut. Future work will address the behavior of the avatar and the negotiation among the VHAs that determines the questions and recommendations for the patient.

The user of the system benefits from a continuous and unobtrusive monitoring achieved through simple and personalized questions. From the user's perspective, the system is in continuous evolution following his current health state and providing proper advices. On a social dimension, an important expected impact is on stimulating the patient empowerment and disseminating basic medical information, through pertinent advices and continuous care provided by the system. However, the greatest potential of the system relies in the opportunity to avoid the very development of a chronic condition, one of the today's major health concerns.

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