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A self-learning nurse call system

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ABSTRACT

The complexity of continuous care settings has increased due to an ageing population, a dwindling number of caregivers and increasing costs. Electronic healthcare (eHealth) solutions are often introduced to deal with these issues. This technological equipment further increases the complexity of healthcare as the caregivers are responsible for integrating and configuring these solutions to their needs. Small differences in user requirements often occur between various environments where the services are deployed. It is difficult to capture these nuances at development time. Consequently, the services are not tuned towards the users' needs.

This paper describes our experiences with extending an eHealth application with self-learning components such that it can automatically adjust its parameters at run-time to the users' needs and preferences. These components gather information about the usage of the application. This collected information is processed by data mining techniques to learn the parameter values for the application. Each discovered parameter is associated with a probability, which expresses its reliability. Unreliable values are filtered. The remaining parameters and their reliability are integrated into the application.

The eHealth application is the ontology-based Nurse Call System (oNCS), which assesses the priority of a call based on the current context and assigns the most appropriate caregiver to a call. Decision trees and Bayesian networks are used to learn and adjust the parameters of the oNCS. For a realistic dataset of 1050 instances, correct parameter values are discovered very efficiently as the components require at most 100 ms execution time and 20 MB memory.

1. Introduction

Due to a longer life expectancy and dwindling fertility rates, the percentage of people over 60 is growing more rapidly than any other age group [1]. Because of health problems, a lot of the elderly are no longer able to live independently and require some form of institutionalized long-term care, e.g., residential care or long stays in the hospital [2]. These developments are accompanied by emerging staff shortages in the formal care sector. In 2006, the World Health Organization (WHO) reported an estimated shortage of almost 4.3 million doctors, midwives, nurses and support workers worldwide [3]. Moreover, people are increasingly living longer with one or more chronic diseases, which increases the complexity of diagnosis and treatment and requires more personalized healthcare and specialized staff. Consequently, the healthcare costs have also been on the rise. Spending on healthcare almost consistently grows faster than the Gross Domestic Product (GDP) [4].

To achieve a more optimized use of resources and rostering of staff and to reduce the healthcare costs, Information Technology (IT) and technological equipment, e.g., monitoring equipment and Electronic Patient Records (EPRs), are often introduced in institutionalized healthcare settings [5]. Electronic Healthcare (eHealth) software and services can then be built that take advantage of all the collected information to ideally support caregivers in their daily work practices. The benefits of eHealth, such as improved operational efficiency, higher quality of care, and positive return on investments, have been well documented in the literature [6]. However, the increased introduction of eHealth also increases the complexity of healthcare as the caregivers are responsible for tweaking and configuring the eHealth solutions to suit their needs. The various healthcare environments where the services are deployed, e.g., different nursing units or hospital departments, have slightly different requirements pertaining to how the collected information about the patients, caregivers and environment is taken into account. It is difficult to capture these small nuances at development time as domain experts often find it difficult to

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assess these parameters. Consequently, the resulting services are not really personalized towards the needs and preferences of the caregivers and they have to significantly alter their workflow patterns to accommodate the technology instead of the other way around [7]. This hinders the adoption of these services [8].

An important way to coordinate work, communicate and provide continuous care is by making use of a nurse call system. In previous research, we have developed an ontology-based Nurse Call System (oNCS) [9], which finds the most appropriate caregiver to handle a call based on profile and environment information captured in an ontology, e.g., the risk factors of the patient, the locations of the staff and patient, the priority of the call and the current tasks of the staff. Simulations showed that the workload distribution amongst nurses and the arrival times of caregivers at calls are positively influenced by using the oNCS [9]. However, user tests performed with the prototype also showed that small nuances were often required in how the profile information was taken into account within a specific healthcare setting. Domain experts also found it difficult to specify the parameters of the oNCS, i.e., which context should be taken into account and how, at development time. However, little previous research has been done on how discovered trends and patterns can be used to automatically optimize the nurse call assignment. To resolve this issue, this paper presents an extension of the oNCS that allows automatically adjusting its parameters at run-time. More technical details about the self-learning, probabilistic, ontology-based framework, which was developed to realize this extension, can be found in Ongenae et al. [10].

The remainder of this paper is structured as follows. Section 2 gives an overview of the oNCS and the associated priority assessment and nurse call algorithm. Section 3 details the extension of the oNCS with components, which enable the autonomous adjustment of its parameters. The implementation of these components is discussed in Section 4, while Section 5 highlights how the correctness and performance of the extension was evaluated. Finally, Section 6 discusses the results and Section 7 summarizes the conclusions.

2. Ontology-based nurse call system

The main functionality of the oNCS is to provide efficient support for wireless nurse call buttons and to employ a sophisticated nurse call algorithm that takes the profiles of the staff members and patients into account. A detailed description can be found in Ongenae et al. [9]. To realize the latter, a continuous care ontology [11] is used of which the most important classes pertaining to the dynamic algorithm are visualized in Fig. 1. An ontology [12] formally models all the concepts and their relationships and properties within a domain. The ontology models people and associates them with their roles, location, profile, the hospital department they work or lie on, risk factors, and current tasks. Additionally, the ontology models the various types of nurse calls. Patients can launch three types of calls, i.e., service calls for "caring" requests, sanitary calls originating from sanitary spaces and normal calls for mostly medical requests. All the other calls,

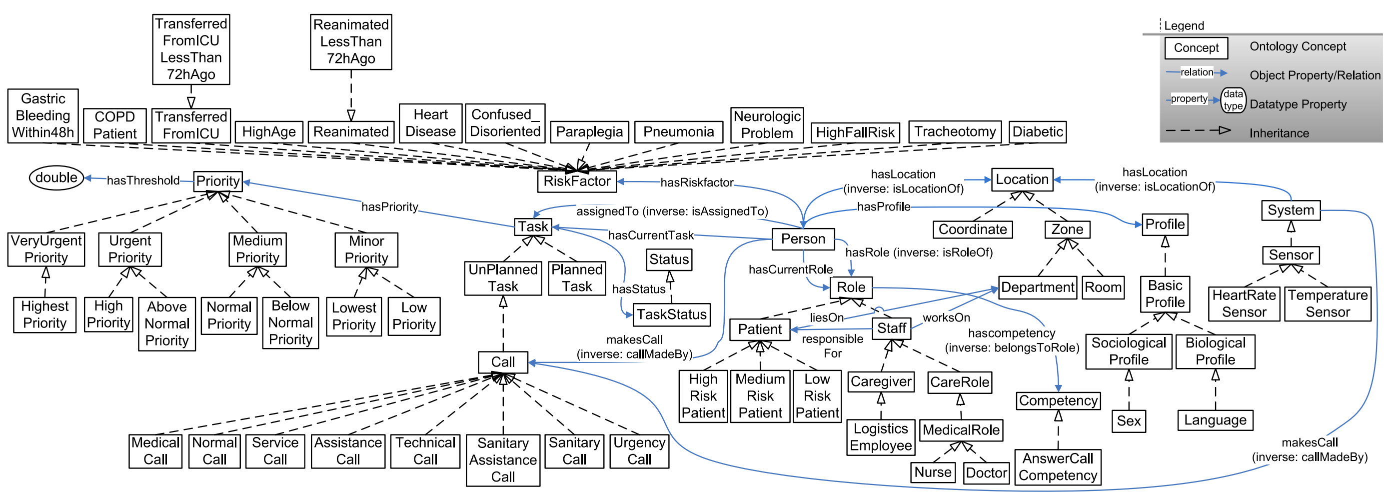

Fig. 1. Prevalent concepts of the continuous care ontology.

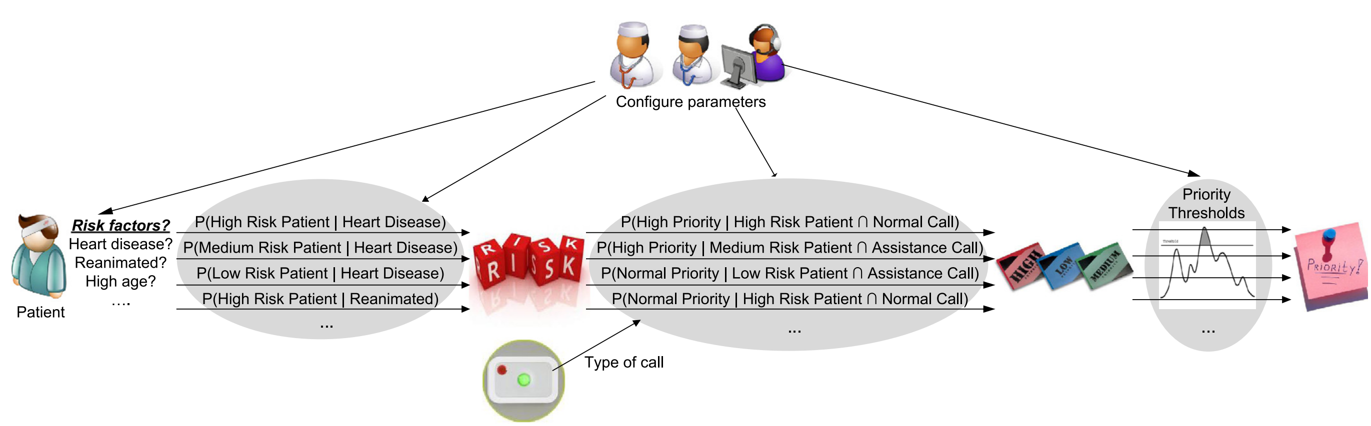

Fig. 2. Probabilistic priority algorithm.