Expert Systems with Applications 36 (2009) 5844–5858

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Integrating case-based planning and RPTW neural networks to construct an intelligent environment for health care

Javier Bajo [a,*], Juan F. de Paz [b], Yanira de Paz [b], Juan M. Corchado [b]

[a] Escuela Universitaria de Informática, Universidad Pontificia de Salamanca, Compañía 5, 37002 Salamanca, Spain
[b] Departamento Informática y Automática, Universidad de Salamanca, Plaza de la Merced s/n, 37008 Salamanca, Spain

ARTICLE INFO

Keywords:
Case-based planning
Case-based reasoning
RFID
Health care
RPTW neural network

ABSTRACT

This paper presents an intelligent environment developed for monitoring patients' health care in execution time in hospital environments. The CBPMP (case-based planner for monitoring patients) is an autonomous deliberative case-based planner designed to plan the nurses' working time dynamically, to maintain the standard working reports about the nurses' activities, and to guarantee that the patients assigned to the nurses are given the right care. The planner operates in wireless devices and is integrated with complementary software into an intelligent environment, named AmI-P (Ambient Intelligence for patients). CBPMP description, its relationship with the complementary technology, and preliminary results of system prototype in a real environment are presented.

1. Introduction

Ambient Intelligence (AmI) proposes a new way to interact between people and technology, where this last one is adapted to individuals and their context (Friedewald & Da Costa, 2003). The objective of Ambient Intelligence is to develop intelligent and intuitive systems and interfaces capable to recognize and respond to the user's necessities in a ubiquitous way, providing capabilities for ubiquitous computation and communication, considering people in the centre of the development, and creating technologically complex environments in medical, domestic, academic, etc. fields (Susperregi et al., 2004). Ambient Intelligence requires new ways for developing intelligent and intuitive systems and interfaces, capable to recognize and respond to the user's necessities in a ubiquitous way, providing capabilities for ubiquitous computation and communication (Aarts & Marzano, 2003). The multi-agent systems (Wooldridge & Jennings, 1995) have become increasingly relevant for developing distributed and dynamic intelligent environments. A case-based reasoning system (Aamodt & Plaza, 1994) has been embedded within a deliberative agent and allows it to respond to events, to take the initiative according to its goals, to communicate with other agents, to interact with users, and to make use of past experiences to find the best plans to achieve goals. The deliberative agent works with the concepts of belief, desire, intention (BDI) (Bratman, Israel, & Pollack, 1988), and has learning and adaptation capabilities, which facilitates its work in dynamic environment.

With the appearance of AmI-based systems, one of the most benefited segments of population will be the elderly and people with disabilities. It will improve important aspects of their life, especially health care (Emiliani & Stephanidis, 2005). There is an ever growing need to supply constant care and support to the disabled and elderly (Nealon & Moreno, 2003) and the drive to find more effective ways to provide such care has become a major challenge for the scientific community. Today, the number of Europeans over 60 years represents more than 25% of the population and it is estimated that in 20 years this percentage will rise to one third of the population (Camarinha-Matos & Afsarmanesh, 2002). In the United States of America it is expected that in 2020 people over 60 will represent about 1 of 6 citizens (Kohn, Corrigan, & Donaldson, 1999). Furthermore, over 20% of people over 85 years have a limited capacity for independent living, requiring continuous monitoring and daily care. The Institute of Medicine has studied the role of information technology in improving health care delivery in the US. In Kohn et al. (1999), the Institute presents a strategy and an action plan to foster innovation and improve the delivery of care. The need to reinvest in the system is underlined and as such six health care aims are defined; to be safe, effective, patient-centered, timely, efficient and equitable. Ten guidelines for the redesign of the system are given attention on the role of the patient and improvements in knowledge, communication and safety mechanisms. Moreover, the Institute proposes a strategy to improve safety in health care based on the study of medical errors. The proposed system presented here has been conceived and developed taking these considerations into account.

* Corresponding author. Tel.: +34 923277100.
E-mail addresses: jbajope@upsa.es (J. Bajo), fcofds@usal.es (J.F. de Paz), yanira@usal.es (Y. de Paz), corchado@usal.es (J.M. Corchado).

0957-4174/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2008.07.029

The importance of developing new and more reliable ways to provide care and support to the elderly is underlined by this trend (Camarinha-Matos & Afsarmanesh, 2002), and the creation of secure, unobtrusive and adaptable environments for monitoring and optimizing health care will become vital. Some authors (Nealon & Moreno, 2003) consider that tomorrow health care institutions will be equipped with intelligent systems capable of interacting with humans. Multi-agent systems and architectures based on intelligence devices have recently been explored as supervision systems for medical care for the elderly (Cox, Muñoz-Avila, & Bergmann, 2005). These intelligence systems aim to support them in all aspects of their daily life, predicting potential hazardous situations and delivering physical and cognitive support.

Radio Frequency IDentification (RFID) (US Department of Commerce, 2005) is an automated data-capture technology that can be used to electronically identify, track, and store information about products, items, components or people. It is most frequently used in industrial/manufacturing, transportation, distribution, and warehousing industries, however, there are other growth sectors including health care. The proposed system uses microchips mounted on bracelets worn on the patient's wrist or ankle, and sensors installed over protected zones, with an adjustable capture range up to 2 m. The microchips or transponders help locate the patients, which can be ascertained by consulting the CBR agents installed in personnel PDAs.

Nowadays, a great amount of problems can be considered as planning problems. In this kind of problems the aim is to obtain a plan, as well as obtaining a scheduling of the actions along the time, assigning the necessary resources and taking into account the restrictions within the problems (possibly using optimality criteria and guarantee of the execution). Planning has experienced significant progresses since its origins in the decade of 1970 in terms of efficiency and sophistication of the algorithms and representations used. Moreover, planning has been adapted to real problems and talking about practical planning. Practical planning has been applied in many different fields and has been combined with different artificial intelligence techniques, i.e. neural networks. One of the main challenges has been the development of intelligent systems focused on the improvement of health care sciences that can be applied to hospitals, residences, etc. (Foster, McGregor, & El-Masri, 2005). Most of the applications developed try to use practical planning techniques in order to monitor patients, supervise treatments or to obtain knowledge from the data handled. Lanzola, Gatti, Falasconi, and Stefanelli (1999), for instance, presents a methodology that facilitates medical applications and proposes a generic computational model for its implementation. Such a model could be specialized to manage all kind of information and knowledge in a hospital environment. However, the method proposed by Lanzola et al. (1999) is very abstract and doesn't take into account the possibility of modelling certain technologies common in hospital environments (as shown in this paper) as wireless or RFID. Another lack of the method is the use of dynamic planning, commonly required in this kind of applications. Others such as Decker and Li (1998), propose a system to increase hospital efficiency using global planning and scheduling techniques. They propose a multi-agent solution using the generalized partial global planning approach that preserves the existing human organization and authority structures, while providing better system-level performance (increased hospital unit throughput and decreased patient stay time). To do this, they extend the proposed planning method with a coordination mechanism to handle mutually exclusive resource relationships, using resource constraint scheduling. This system does not use dynamic planning, it uses a static task assignment, and it does not work on wireless devices and does not use location information or RFID technology.

In this work, we propose CBPMP, a dynamic planner which is integrated within AmI-P intelligent environment, which is a dynamic system for the management of different aspects of a geriatric center. This distributed system uses Radio Frequency IDentification (RFID) US Department of Commerce, 2005 technology for ascertaining patients' location in order to maximize their safety or to generate medical staff plans. The development of such intelligent environment has been motivated for one of the more distinctive characteristics of hospital environment, which is their dynamism, in the sense that the patients change very frequently (new patients arrive and others pass away), while the staff rotation is also relatively high and they normally work in shifts of eight hours. AmI-P provides the personnel of the hospital with updated information about the center and the patients, provides the working plan, information about alarms or potential problems and keeps track of their movements and actions within the center. Dynamic problems require the dynamic solutions provided by this technology. From the user's point of view the complexity of the solution has been reduced with the help of friendly user interfaces and a robust and easy to use technology.

The proposed planner CBPMP uses a case-based reasoning (CBR) (Aamodt & Plaza, 1994) architecture, that allows it to respond to events, to take the initiative according to its goals, to communicate with other agents, to interact with users, and to make use of past experiences to find the best plans to achieve goals. This particular planner uses a special type of CBR systems which we call case-base planning (CBP) system, specially designed for planning construction. Case-based planning allows us to retrieve past experiences when a new plan is created which lends the system a large capacity for learning and adaptation (Glez-Bedia & Corchado, 2002). The planning mechanism has been implemented by means of a novel RPTW (routing problems with time windows) neural network. The neuronal networks proposed within this research framework are self-organised, based on Kohonen networks (Kohonen, 2001), but which present certain improvements (RPTW neural neural network) (Martín, Santos & de Paz, 2005). These improvements allow the network to reach a solution much more rapidly. Furthermore, once a solution has been reached, it makes it possible to make new modifications taking restrictions into account (in this study, specifically time restrictions). In this way, the CBPMP palnner has learning and adaptation capabilities, which facilitates its work in dynamic environment and allows it to learn from initial knowledge, to interact autonomously with the environment as well as with users and other agents within the system, and to have a large capacity for adaptation to the needs of its surroundings.

This chapter is organized as follows: the following section presents the new RPTW neural network. Section 3 shows the new planning mechanism, obtained by means of integrating case-based planning and RPTW neural networks. Section 4 presents a case study in a hospital environments and, finally, Section 5 presents results and conclusions obtained after the implementation of a prototype into a real scenario.

2. Defining self-organising neural networks in a novel way: RPTW neural networks

The basic Kohonen network (Kohonen, 2001) cannot be used to resolve dynamic problems since it attempts to minimize distances without taking into account any other type of restriction, such as time limits. In the present study a planner based on Kohonen networks is described but with a number of improvements (RPTW neural network) (Martín et al., 2005) that allow us to reach a solution more rapidly. Furthermore, once a solution has been reached, it is re-modified in order to take restrictions into account.