The Journal of Systems and Software 111 (2016) 34–48

Contents lists available at ScienceDirect

The Journal of Systems and Software

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

A model-driven approach for constructing ambient assisted-living multi-agent systems customized for Parkinson patients

Iván García-Magariño [a,*], Guillermo Palacios-Navarro [b]

[a] Department of Computer Science and Engineering of Systems, University of Zaragoza, Escuela Universitaria Politécnica de Teruel, c/ Ciudad Escolar s/n, 44003 Teruel, Spain

[b] Department of Electronic Engineering and Communications, University of Zaragoza, Escuela Universitaria Politécnica de Teruel, c/ Ciudad Escolar s/n, 44003 Teruel, Spain

ARTICLE INFO

Article history:
Received 26 June 2015
Revised 9 September 2015
Accepted 11 September 2015
Available online 24 September 2015

Keywords:
Agent-oriented software engineering
Model-driven engineering
Parkinson disease

ABSTRACT

The Parkinson disease affects some people, especially in the last years of their lives. Ambient assisted living systems can support them, especially in the middle stages of the disease. However, these systems usually need to be customized for each Parkinson patient. In this context, the current work follows the model-driven engineering principles to achieve this customized development. It represents each patient with a model. This is transformed into an agent-based model, from which a skeleton of programming code is generated. A case study illustrates this approach. Moreover, 24 engineers expert in model-driven engineering, multi-agent systems and/or health experienced the current approach alongside the three most similar works, by implementing actual systems. Some of these systems were tested by Parkinson patients. The results showed that (1) the current approach reduced the development time, (2) the developed system satisfied a higher percentage of the requirements established for certain Parkinson patients, (3) the usability increased, (4) the performance of the systems improved taking response time into account, and (5) the developers considered that the underlying metamodel is more appropriate for the current goal.

1. Introduction

According to a recent study Gómez-Garre et al. (2014), Parkinson disease (PD) is affecting the population with many variants due to the different mutations of the gene that encodes the F-BoX Only protein 7. In particular, 17 variants were detected in the southern of Spain. Although some factors can influence the risks of suffering this disease, such as smoking, there is a percentage of people with a certain gene that unavoidably suffer PD in the last years of their lives (Miyake et al., 2010). In these cases in which the most advanced medicine research cannot avoid the symptoms, patients need other kinds of assistance for getting along with their disease. The social environment including the family members usually becomes a pillar of support for overcoming the needs of patients (Jenkinson et al., 2012). However, in some cases there is not any member that can exclusively dedicate their life to take care of a patient. In these cases, the different familiar caregivers have to coordinate for taking care of the patient, and in some hours of the day the patient may not have any human company.

In this context, this work proposes customized multi-agent systems (MASs) as a solution for coordinating partial human caregivers and assisting patients in some needs. This work proposes MASs as these have proven to be effective for coordination and collaboration. This can be observed in the later works about MASs such as the real-time order-driven approach for collaborative production planning and scheduling (Ni and Wang, 2015). In particular, the current approach develops the customized MASs with a model-driven engineering (MDE) approach. This approach includes a metamodel for defining a Modeling Language (ML). In this, each model determines all the features of a patient including (a) their social environment with home members and other caregivers, (b) their symptoms, (c) the skills in which the patient needs assistance, and (d) their economical circumstances. In addition, there are some Model Transformations (MTs) from the mentioned ML to initial MAS models. MASs can be developed from these models after refining these. In particular, the remaining development of each MAS is recommended to follow the Ingenias methodology, which was previously introduced in Pavón and Gómez-Sanz (2003). This methodology has been selected because it already follows an MDE approach including the generation of programming code. This methodology has also been chosen because the underlying metamodel of its tool support, i.e. the Ingenias Development Kit (IDK), had already been defined with the ECore

* Corresponding author. Tel.: +34 978645348; fax: +34 978618104.
E-mail addresses: ivangmg@unizar.es, ivangmg32@gmail.com (I. García-Magariño), guillermo.palacios@unizar.es (G. Palacios-Navarro).

http://dx.doi.org/10.1016/j.jss.2015.09.014
0164-1212/

language. In this manner, this work can use the Atlas Transformation Language (ATL) to define MTs from the current metamodel to the Ingenias metamodel.

The current work introduces the development of a complete functional ambient assisted living (AAL) MAS with an application for mobile devices (i.e., smartphones and tablets) as a case study. In addition, the current approach has been compared with the most relevant and similar ones, which are presented by (1) Calvillo et al. (2013), (2) Lopez and Blobel (2009), and (3) Raghupathi and Umar (2008). For this comparison, 24 engineers expert in MDE, agent-oriented software engineering (AOSE) and/or health experienced the current one and the others. They developed applications customized for particular PD patients with each approach. Some of these applications were tested by real PD patients. In particular, the evaluation of the present work compares the development time, the satisfied requirements, the usability, the response time and the perceptions of experts.

The current approach was previously introduced in García-Magariño (2013), but it has been extended in several ways. The metamodel has been enhanced by including new concepts such as the ones related with treatments, tests, caregiver symptoms, timetables, other diseases, other patient symptoms, dressing and going out. The MTs have been refined to obtain more useful output models. The paper now graphically presents some of these MTs. The development of the case study now shows a complete functional system. The paper now also includes the aforementioned experimental comparison evaluation.

The remaining of the paper is organized as follows. The next section briefly introduces the background comparing some related works to the current one. Section 3 presents the model-driven approach for developing and customizing MASs for PD patients. Section 4 presents the modeling of a particular PD patient and the development of a customized MAS for its assistance, as a case study. Section 5 compares the current approach with others by analyzing the experience of the group of experts and PD patients. Lastly, Section 6 mentions the conclusions and future lines of research.

2. Related work

2.1. MDE and MDA

There are several works that use MDE approaches for developing ambient intelligent systems. In particular, the FamiWare (Gamez and Fuentes, 2013) framework uses an MDE approach for developing ambient intelligent systems, with models determining the cardinality-based features. Their process propagates the changes made in the feature level to the different components of the FamiWare middleware. In particular, this framework can be used to evolve AAL intelligent systems. In addition, Reubi (Ruiz-López et al., 2013) is a method for acquiring requirements and then following an MDE approach for constructing ubiquitous systems. Their authors present this method by developing an AAL healthcare system.

In the literature, several metamodels have been defined for modeling patients in general. For example, Calvillo et al. (2013) present a metamodel that is integrated in a healthcare system. In this system, each patient can determine who can access their information such as demographic data, health, well-being and social conditions. This metamodel defines the information regarding each patient considering three main groups of actors: people (e.g., nurses, relatives and friends), organizations and healthcare devices. In addition, Lopez and Blobel (2009) have developed a framework for achieving semantical interoperability in health information systems. This framework uses the model-driven architecture (MDA) approach, defining the corresponding metamodels for the computation-independent models, platform-independent models and the platform-specific models. Moreover, Raghupathi and Umar (2008) apply the MDA approach for developing healthcare systems. Their metamodels are mainly focused on defining the models of the health clinics. In particular, a platform-independent model is created for each clinic, and this is transformed into several platform-specific models.

Kevoree (Fouquet, 2013) is a framework for designing and deploying distributed adaptive systems following the Model@Runtime paradigm. It has a layer to manage different types of nodes such as sensors and mobile devices that are close to the users. It also considers that some nodes may only be connected sporadically, in order to manage the differences between the states of the sub-systems. In addition, EntiMid (Nain et al., 2009) is a middleware that manages certain nodes in house automation for assisting elderly people. This middleware satisfies a list of requirements desirable in distributed applications for the aging population.

Nevertheless, all these works do not generate programming code for impersonating real users and coordinating them. By contrast, the current work generates programming code for this coordination in which some agents impersonate real people according to their preferences and circumstances. In particular, MASs are an appropriate choice for impersonating people that coordinate between each other, like in the current approach.

2.2. MASs

There are several MASs that have been developed for AAL for elderly people or people suffering a disease. For instance, Kaluža et al. (2010) present an MAS that assists elderly people that are living on their own at home, in order to prolong their independence. This system can detect an emergency situation in real time by means of several sensors. The system detects domestic accidents with several facts such as vertical acceleration or a frozen weird position for a long time. This MAS was tested in a nearly-realistic room with several movements. This MAS could be used for people who suffer PD.

Moreover, Nefti et al. (2010) present an MAS for AAL of people suffering the dementia disease. In fact, this MAS keeps patients observed in an unobtrusive way, and warns them of possible risks. It alerts the local authority when a risk is ignored. Furthermore, Su (2008) introduces a framework for e-health monitoring in wide areas such as metropolitan and national. This framework contains mobile agents conforming MASs. These MASs allow caregivers to monitor the patients with light-weight portable devices, without interfering their daily activities.

Furthermore, Benhajji et al. (2015) present an MAS that coordinates all the hospitals resources and control the patients flow. Their aim is to improve the planning of healthcare resources for patients and to efficiently manage unpredictable disruptions.

All these works present MASs that assist healthcare in different ways. However, these works do not provide a proper interface that actually lets patients to guide their assistance. For instance, these works do not include interfaces with speech recognition for patients with hand shaking. These neither offer immediate technological treatments for psychological aspects. These neither allow patients to establish their own timetable to coordinate with their caregivers. To the best of authors' knowledge, the current work is the first one that takes all these aspects into account.

2.3. MDE for MASs

Gascueña et al. (2012) use a model-driven approach for developing MASs, using the set of the Eclipse modeling tools. In particular, this work defines the Prometheus metamodel with the ECore language, and generates the corresponding graphical modeling tool by means of the Graphical Modeling Framework. In addition, Ghorbani et al. (2014) present a model-driven approach for developing agent-based simulators. Their work formalizes knowledge of social sciences, and represents collaborative relations among individuals. In their