Ontology Support for Home Care Process Design

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Abstract: For the implementation of home care systems, using sensors and devices to provide assistance to the patient, it is necessary to develop an easy way to configure each home, since differences between them exist and a personalized one-by-one planning is expensive. To support this configuration need we propose a Service Oriented Architecture which uses process models to create service orchestrations to personalize each environment. Process design requires a good understanding of the application domain; business analysts interview the domain experts and translate their understanding to process models. This modelling may be very complex as the vocabulary used by the domain expert is very specific and difficult to understand by process analysts. Therefore, the process model elements (such as activities and role labels) can be named with inappropriate terms. Moreover, the lack of domain understanding by business analysts increases the probability of errors in the process design. In this paper we propose a methodology in which ontologies are used to support the process design, expressing the modelling possibilities and also provides semantic to help the development process. Altogether the approach aims to facilitate the design of each service orchestrations for home care systems, by non specialists.

1 INTRODUCTION

The elderly population increased over the last years. Thus, home care strategies show to be suitable mainly because of cost and scalability reasons. Assuming that intelligent homes will be offered, a problem of scalability will appear since every patient and every environment has their own particularities. Our research challenge is to investigate how to facilitate the design task by applying ontological support to define the best suited workflows in a specific home project.

Our goal is to personalize homes from process models, abstracting technical implementation issues. This is equivalent to the Data Base development, which starts from a conceptual schema that abstracts any implementation issue. In our approach each possible action performed by the system is a Web Service (WS). For example, to an actuator turn the lights on there is an associated web service, to present some information on the TV exists another WS, for a sensor communicate the humidity of the floor and so on. Based on an ontology, which expresses the possible interactions (as turn the light on) and the involved participants (as the home system or the caregiver), the designer may model the situations for the patient context.

As example: consider that a patient has Alzheimer and sometime becomes agitated. In these cases the system could interfere trying to calm the patient or calling some related person. The first step is to detect the agitation behaviour (sensors are used in this task, with WS), then the system checks the caregiver location (WS). If the caregiver is at home, a message is sent to him (WS), in other cases the system calls an ambulance from the nearest care provider (WS). In both cases the system checks the level of agitation (WS) and if is high it suggests the use of drugs (by message, WS). Otherwise it plays a music (WS) that should calm down the patient. All tasks marked with (WS) in the example occur through web services. This model follows the process project concept and may be implemented in a residential system.

2 BACKGROUND

Engineering is an expensive task in itself, but the consequences of bad engineering are even worse, resulting, for instance, in the loss of the possibility to deploy customized home care for a large public. Information systems supporting the home care activities play a critical role in minimizing errors and delays. Computer-supported tasks require the concurrent participation of multiple designers with a broad

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range of competences and a difficult communication barrier. The design task complexity is compounded by its interdisciplinary character: the health care engineering system has to assure design consistency between teams with different specialities that must work as freely as possible. The approach, which is based on a simple yet powerful conceptual model, combines ontology and workflows to clarify the terms and concepts and to facilitate the design process. Its features are nowadays either supported by very expensive or very specialized integrated packages, or separately performed by largely disintegrated database managers, drafting systems and other software.

A home care design methodology must satisfy the following requirements:

Abstraction. design on a given conceptual level should be able to abstract design aspects concerning more detailed levels;

Design Coordination. the conceptual model should support the management of loosely coupled design groups;

Conceptual Comfort. each concept of the model should reflect established design habits naturally. In the design of an instrumentation circuit familiar instrumentation symbols must be employed. When a certain instrument is to be used at a certain location, a set of instrument classes should be presented;

Generality. conceptual foundations must support a broad scope of technologies, they must not be specific to any specific technology. Classes, types, rules, e.g., must be defined and customized by the user, not "hard" pre-programmed into the design package;

Coupling between Disciplines. The design task is multi-disciplinary: a home care environment is composed of electrical, instrumentation, architectural, leisure and other subsystems, which are designed by different teams, but interact towards a common goal;

Knowledge Reuse. a home care environment should support graphical drafting and design at large. For drafting, a graphical interface is required. Design at large includes engineering property verification, using inference analysis.

A home care engineering project is an incremental process starting from a coarse specification and arriving at a detailed project. As projects are expensive the reuse of former work is a necessity. The problem is well suited for knowledge based and ontological supported solutions.

An ontology is a formal explicit specification of a shared conceptualization (Gruber, 1993). Conceptualization refers to a model which describes concepts (e.g. Patient, Caregiver, Room, etc.) and relationships between these concepts of some domain (e.g. Assists, hasCaregiver). The term "formal" means that it has logics applied, which allows to avoid ambiguities, also allows to apply inference mechanisms and to check the model consistency. Furthermore, "shared" means that this model is accepted by a group of people. The ontologies are used to make the modelling of business process easier, using its expressiveness to restrict the model designer in some aspects. We use the Web Ontology Language (OWL), which is a W3C pattern.

A business process consists of a set of related activities which are performed in a coordinated way. These activities jointly execute a business goal. Each business process is enacted by a single organization, but it may interact with business processes performed by other organizations (Weske, 2007). We understand that situations of home care can be seen as a set of activities that occurs in some sequence and in some context, as well as business processes. For example, if the patient gets agitated and a message is sent to the caregiver it is a situation. If the patient gets agitated and an ambulance is called, it is other situation. Both occur in the same scenario, but in different contexts. The scenario presents all possibilities, the context drives the execution performing a situation.

We use the Business Process Modelling Notation (BPMN), which is a pattern developed under the coordination of the Object Management Group (OMG, 2009). The business process will be used to create service orchestrations, which controls the web services execution. It allows personalized orchestrations, based on the patient, environment and so on.

Web services can be defined as a capacities provider, composed by a body of logic which executes them and by a service agreement, which expresses the available capacities (Erl, 2007). Service orientation comprises basically the use of independent services as components to construct one composition with the goal of accomplish some objective (Erl, 2007). In this research, the home care environment includes a variety of services such as: call an ambulance, send a message to a caregiver, detect behaviour and so on.

3 RELATED WORK

Research on process design and ontologies have been developed for more than ten years. One of the reasons is that ontologies and structured vocabularies in different domains help to make data understandable by machines (Manzorr et al., 2007). However, most of the existent approaches focus on building ontologies for the business process management domain as well as in the use of ontologies to add more semantics for the existent process model notations and execu-

tion languages. Related to these points (Haller and Oren, 2006), present an ontology that unifies both internal and external business processes, based on various existing reference models and languages from the workflow and choreography domain. The authors argue that the interoperability problems in this domain require an intermediate ontology to reduce the number of needed mappings.

An interesting approach regarding the semantics of process design is proposed in the SUPER Project, which has developed the Business Process Modelling Ontology (BPMO) (Norton et al., 2009). The BPMO enables the semantic annotation of high-level business process models and it includes concepts to describe process behavior (workflow), activities and related organisational data. In the context of the SUPER project it was also proposed the Core Ontology for Business pRocess Analysis (COBRA) which comprises a core terminology where business practitioners can map domain-specific knowledge in order to analyse their business processes (Pedrinaci et al., 2008).

For the intelligent homes there are many ongoing researches as the Gator Tech Smart House (Helal et al., 2005) which presents a service-oriented approach that allows to deploy new sensors, actuators and devices in the home easily. They use the OSGi (Open Services Gateway Initiative framework) to provide means for deploy new Java services. In our approach the difference is that we use the service-oriented approach based on SOAP, allowing the service providers to choose how to implement the services. Yet, we propose to use workflow managers to execute the services and service compositions from different providers, not only from the home.

Also an European project called Sm4all (http://www.sm4all-project.eu/) which is in certain aspects very similar with our research. They work in the domotics idea, using web services (Catarci et al., 2011) to execute every available action in the house, the actions (e.g. open the window blinds) are provided by sensors, actuators and devices in general. Furthermore, they work with the idea of service compositions, the composition is made automatically by the system that runs de residence, from goals. They use the web service itself in the composition, the abstraction that we use allows using different services to execute the same action, providing high decoupling and availability.

Considering these approaches, we consider that the use of ontologies might facilitate the understanding of the process domain, however, the process design and execution still constitutes a challenge.

4 ONTOLOGIES SUPPORT FOR THE BUSINESS PROCESS DESIGN

The proposed home care system consists of (i) care providers (e.g. hospitals, general practitioners, physiotherapy clinics, etc.), (ii) the residences of the elderly persons and (iii) any other entity that have interest in providing services for those environments. All participant entities communicate through web services. So, the communication is possible directly between the participants or one of them (e.g. a home care system provider) can act as intermediary, integrating services provided by others. Examples of services are:

- The residential system can provide a service for patient localization;
- An intermediary system can provide a service for choose the best care provider to call, based on information such as location, health plan, and so on;
- The hospital can have a service to inform the ambulances availability.

The available services require an orchestration to accomplish the desired goals, process models will be employed in this task. Having a knowledge model (ontology) as base for creation of business process models will make easier this task.

4.1 Methodology

To illustrate our proposal let's consider the follow example: (1) the patient goes to an appointment with his physician that does the necessary prescriptions; (2) The prescriptions are sent to the modelling department, where a non specialist person creates the process model based on the prescriptions and a pre-existing ontology; (3) The process(s) model(s) are sent to the home system of the patient; (4) The residential system adapts itself to the received model. During the remain of the paper the second step will be explained in more details.

Our methodology consists of two steps: to build the ontology (by the home care system vendor) and to design the business processes (by the process designer) based on the former ontology. This paper does not discuss the ontologies design, we assume that it is already defined and available in the web. The responsible for the ontology maintains the model well-formed and consistent, and the updates are accessed by the clients. The client's users may be, for example, a person who implements the prescriptions of physicians to the automated residential context. In

this case, the person will probably have some domain knowledge, but needs of an easy way to model it.

The ontology describes the concepts (eg. ResidentialSystem, Caregiver, Patient, etc.) and the possible interactions between them in the environment (e.g. DetectsAgitation, Alerts, Assist, etc). These interactions are relationships between the concepts in the ontology model, for example, the Caregiver (concept) assists (interaction) the Patient (concept). This way, the modeller selects the concepts and interactions from the ontology, to create the activities, it is not necessary to create them during the process design. Furthermore, the interactions that are computationally executed are linked to abstract representations of web services which allow to get information about this action as the inputs, outputs and so on.

4.2 Activities

An activity is a unit of work that can be executed manually or with the support of a business process management system. BPMN supports atomic activities (tasks) or sub-process, that are flows of activities.

According to (Mendling et al., 2010), little attention has been devoted to labelling the graphical constructs of a business process, in particular to activities, which are an essential part in this kind of modelling. One of the main focus of our research is on the atomic activities of business processes. Our concerns are about the semantic of the labelling task of activities. We propose a mark-up strategy instead of free text labelling, which will make easier to understand (computationally) the output generated from the model. The activity will be composed of a triplet:

- **Subject:** performs an action (e.g. HomeSystem);
- **Action:** the action itself (e.g. notifies);
- **Object:** suffers an action (e.g. Caregiver);

The examples create an activity for the residential system (that manages the home) notifies the caregiver (person who takes care of the patient) about something that happened. The possible triplets are expressed in the ontology, the *subjects* and *objects* are concepts, while the *actions* are relations between the concepts. The process designer simply select the *subjects*, *actions* and *objects* from the ontology to create the triplets that are needed for the current modelling task.

4.3 Actions

An *action* is something performed manually or computationally during an atomic activity of a process. Each *action* of the process model that is performed for a computational entity will have an abstract representation of a service or of a service capacity. For the execution, the system can choose from the service inventory the services that match with this representation. This strategy separates the model of the concrete (program codification), providing dynamicity for the home care system. If a service becames unavailable, another one can be selected from the inventory and so on. In order to describe the services, it is possible to use the OWL-S ontology. Thus, describing the web services with OWL-S ontologies enables the use of matching strategies as the one described in (Maamar et al., 2011). Furthermore, other aspects can be achieved by using these abstract representations of services. For example, let's say that the home system needs to present some information (text) to the patient. If the devices of the residence provide web services, it is possible to match the abstract representation of the needed action against the services in the home inventory.

An example refers to the similarity comparisons of the abstract representation, verify if it is possible to use services presenting different characteristics but achieving similar goals. A problem occurs within the TV, and the system needs to find alternative ways to present the information to the patient. The similarity step does not found any other device that displays information in the room, but found a service that receives text as input and reads it using a speaker, allowing passing the message to the person. The composition remains the same because of the abstract representation. During the model execution, the methods can search the most suitable services, this provides a high decoupling.

4.4 Ontology Advantages

In the present approach, ontologies support the creation of business process. The main advantages are (1) To better understand the process model; (2) To support business process reuse; (3) To facilitate discussion with other designers or specialists of the process model domain; (4) To develop tools which can make easier the process modelling task; (5) To reason over the ontology and process to verify aspects as most suitable activities for the patient; (6) To provide characteristics of the *actions* (OWL-S), given more control to the designer, over the activities; (7) To provide tracing capability as the activities have associated mark-ups. These advantages of ontologies add more semantics for the process models. Also, they help abstracting the technical issues in configuring the homes, since the designer selects the triplets from the ontologies instead of program the services.

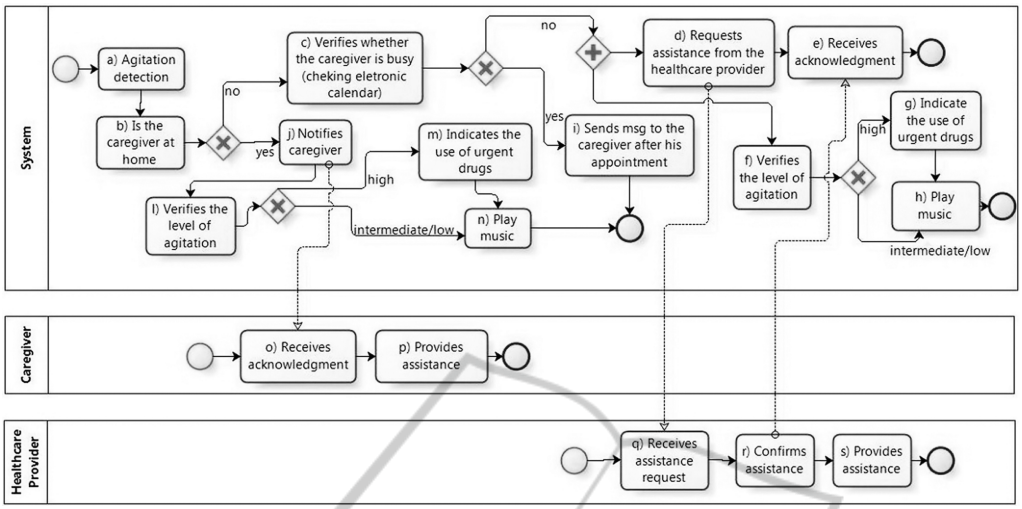

Figure 1: BPMN Model of agitation behavior.

5 CASE STUDY

The scenario is presented by means of a process that describes agitation behaviour. The process describes an elderly person that presents mood and behaviour changes, besides disorientation. Note that this process is illustrative, was designed based on the literature and in group discussions of an Ontology Class of a Public University located in Brazil (Siang Fook et al., 2006). In real life this process can present different behaviour, the sample process present the situation discussed in late of Section 1. The whole scenario of agitation in a BPMN model is presented in Figure 1. In our research we will change the free text describing an activity for a markup strategy, this make easier the task of read the process computationally.

5.1 Modelling the Business Process

The modelling process is extended with our methodology; first of all, there will be an ontology providing the possibilities for the whole process modelling task. The components used to form an activity are taken from the ontology by selecting the desired concepts or actions. To clarify the method Figure 2 presents an illustrative image of an interface, in which the user is developing the same model of Figure 1 using our methodology.

As we can see in Figure 2, the ontology hierarchy is loaded at the left, when the user creates a new activity, he should choose a *subject* (concept) from the tree, this concept will provide some possible *actions*, which are presented on the top of the interface. After chosen the *action*, only the concepts that make part

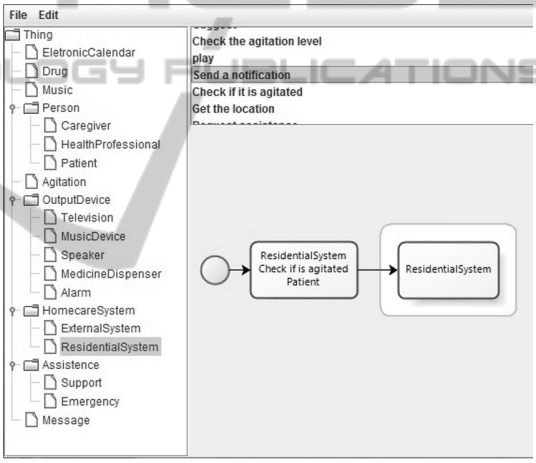

Figure 2: IIlustrative interface of a modelling tool.

of this *action* (*objects*) will be available on the hierarchy. These possibilities of representation of concepts and interactions are expressed in the ontology and are loaded by the modelling tool. In the figure it is possible to realize that a new activity was created (is highlighted), the *subject* chosen was “ResidentialSystem” and the possible *actions* were loaded in the list on top (the *action* “Send a notification” is highlighted). The texts that present the *actions* in the interface are labels of the relations in the ontology.

The ontology provides the concepts and relations for the domain in small granularity and the interface provides the ability for aggregating those concepts and relations to create activities (triplets). Also, the modelling tool provides a manner to request new concepts and relations to the ontology developers. The compositions can be reused in various residences, not all process must be personalized.

As the quantity of concepts and relations can grow fast, depending on the domain, strategies based on patterns for suggesting the next process creation step will be included. In another paper is described a set of workflow activity patterns which refers to descriptions of recurrent business functions (Thom et al., 2009). Some of these patterns can imply in the restriction of the next possible activities, for example, after the use of the pattern X, only activities of the pattern Y can be used. The modelling tool exports an XML file that may be processed by the residential control system.

6 CONCLUSIONS AND FUTURE WORK

It is very important for the home care idea that the systems developed are scalable in the dimension of multiple locals since one of the main problems for deploying home assistance is the increasing number of elder people living alone. If the developed home care systems will require the same number of people as the present systems, the implementation of wide spread home care will be compromised.

This paper described an approach that intends to reduce the need of a huge number of new personnel for the design and implementation of home care systems. The proposed methodology provides activities with more semantic to be employed in the process model, making easier to understand this model for persons as well being interpretable by automated devices. This modelling approach can also be applied for other domains; we focus on home care in this work. The use of a service-oriented system is also interesting since services can be added, removed or updated enabling the system to be context aware.

We are working to finish the prototype of the tool for modelling the processes based on ontologies. After that, we will work in a prototype for executing the processes, probably based in an execution language as the Business Process Execution Language (BPEL).

As future work, we intend to apply more deeply the BPMN notation, in order to verify how much inheritance from ontologies may be applied to model the process. Moreover the BPMN notation doesn't impose much focus in the process execution and a related study should be done.

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