ELDeR: An Ontology for Enabling Living inDependently of Risks

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Abstract. We present a Context-aware Component based on agents that enables developers to build Ambient Intelligence (AmI) Systems for supporting the independent living of elders. This component uses the ELDeR ontology that we propose to model the context information inherent to the elder's daily activities and that enables agents to infer risks. Our aim is to provide an ontology flexible enough to easily enable developers to change the contextual conditions for inferring risks in order to respond to a different scenario. In this paper, we describe the functionality of the activity-aware component and the ELDeR ontology and illustrate their use by presenting the design of an application.

Keywords: Ontologies, Ambient Intelligence, Agents.

1 Introduction

For creating AmI systems, it is needed context-aware and intelligent systems that monitor the elders' activities of daily living (ADLs) and recognize when they face an abnormal situation or risk. We are following the approach of using agents as a tool for designing and implementing AmI systems [1]. We have created a context-aware component that facilitates developers to create AmI systems to infer the elders' daily activities and the risks associated with them. To reach this end, our component includes the ELDeR ontology which represents the elders' context generated while they perform their activities of daily living in their homes. Several works have proposed infrastructures for facilitating the development of context-aware systems which use the ontology-based approach for modeling context information. For instance, SOCAM (Service-Oriented Context-Aware Middleware) includes [2] common upper-level ontology for representing general concepts such as: Person, Location, Computational Entity (i.e. Devices such as TV, Fridge) and Activity (i.e. Dinner, TakingShower). Similarly, CoDAMoS provides general ontology-based context models [3] which consist of sets of extensible ontologies to express contextual information about User, Tasks, Services, Environment and Platform. I.L.S.A is an agent-based architecture for creating home-based systems for assisting elders [4]. To our knowledge, I.L.S.A is the only project that proposes an ontology for this domain: the Consolidated Home Ontology in Protégé (CHOP). CHOP is a common

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vocabulary for I.L.S.A related concepts and their relationships. Additionally, CHOP produces an agent communication interface between I.L.S.A.´s agent-based system components. The ontologies presented in this section, are general models (high-level ontlogies) for representing context information. Creating ontologies for specific domains (lower-level ontologies) is not an easy task since it requires a more profound analysis to abstract the context information that is general for any user living in the specific domain. Our aim is to create the ELDeR (Enabling Living inDependently of Risks) ontology flexible enough to enable developers to easily add and change the contextual conditions for inferring risks of elderly performing their ADLs in their homes. To reach this end, we are creating an agent-based component that enables developers to build AmI systems by encapsulating functionality for consulting and updating the ELDeR ontology to infer risks associated with ADLs. In the following section we present the ELDeR ontology. Section 3 explains the design of our context-aware component. Section 4 presents how this component and its ontology facilitates to implement an application designed for preventing elderly from not adhering to their medication routine. Finally, Section 5 presents our conclusions and future work.

2 ELDeR Ontology

The ELDeR Ontology provides a common language for agents that are involved in the context of elder healthcare. To design the ELDeR Ontology we obtained a general understanding of ADLs from medical literature [5]. The design of the ontology presented in figure 1, indicates that activities (ADL) are linked to other activities. For instance, some activities are commonly performed sequentially or in a certain order (although not necessarily all the time); for instance: hand washing, eating and teeth-brushing. An ADL is composed of at least one task or Action. For example, the hand washing ADL is composed of actions such as open the faucet, take the soap, etc. Thus, for carrying out Actions, elderly use Objects of their environment. An ADL tends to be performed at certain Times of the day and with certain Frequency. Persons tend to spend certain period of time (Duration) for executing it. Each Action can be performed at one or many Locations, and at a moment in Time. For example, opening a water faucet may be performed in a bathroom or kitchen at different times during the day. In addition, Actions may have Features which we identified as contextual variables of the elder while performing an Action that may cause a Risk. These features should be specified in Rules that infers risk. For instance the action “open the faucet” is associated with the temperature of the water which is a feature, and the Rule is that if it is 54°C or more there is a Risk of scalding. Thus, as represented in Figure 1, not only Features are specified in the Rules to infer risks but Frequency, Time, Duration, Objects and Location may be included in the Rules. Risks are linked with Notifying Agents that notify of the elder’s situation appropriately as defined by the application programmer. The identity of these agents should also be specified in the ontology. Thus, the contents of this ontology will be provided by the programmer according to the application scenario being implemented.

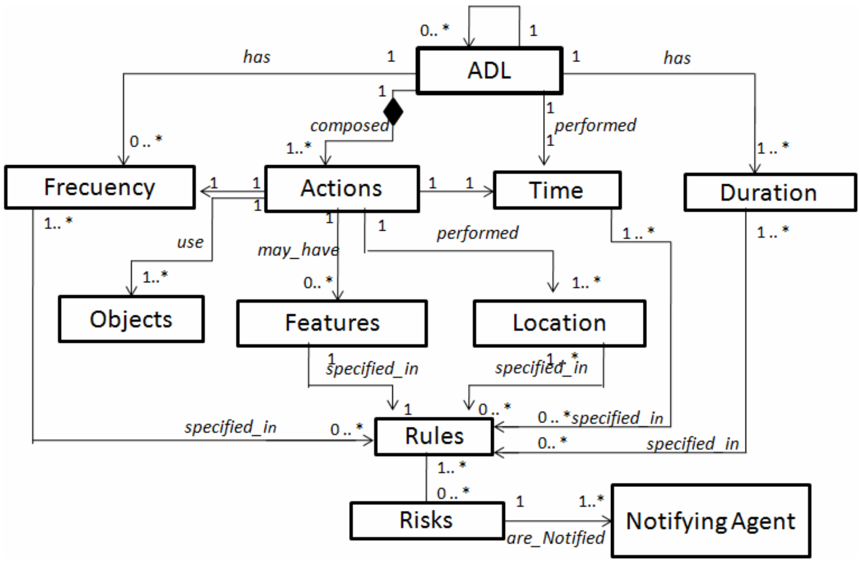

Fig. 1. ELDeR Ontology

3 Context-Aware Component

The Context-aware Component, illustrated in figure 2, contains agents that provide the characteristics of intelligence and context-awareness required for inferring the elders' activities and predicting if they are facing a risk. These agents were designed based on the types of agents proposed in the SALSA middleware [1]. SALSA provides a library of classes for implementing and handling the execution model of agents, which consists of perceiving information, reasoning, and acting. Further information regarding SALSA is found in. The Context-aware Component contains agents that provide the following functionality:

- *Gathering context information.* The component contains agents that perceive the time, duration and frequency of carrying out an activity (Time Agent, Duration Agent and Frequency Agent). The Features Agent gathers context information (Features) that developers identify as relevant for inferring risks associated with the elderly activity. Other agents act as proxies to external components, such as information resources, devices or other agents, which capture the elderly context. For instance, the Location-proxy Agent perceives the elder´s location from an external component (i.e. Location-estimation agent); and the Objects-proxy Agent perceives information related the elderly interaction with their environment objects used for the activity. Developers should implement the external components for gathering context information and attach them to the context-aware component by using the SALSA communication protocol.

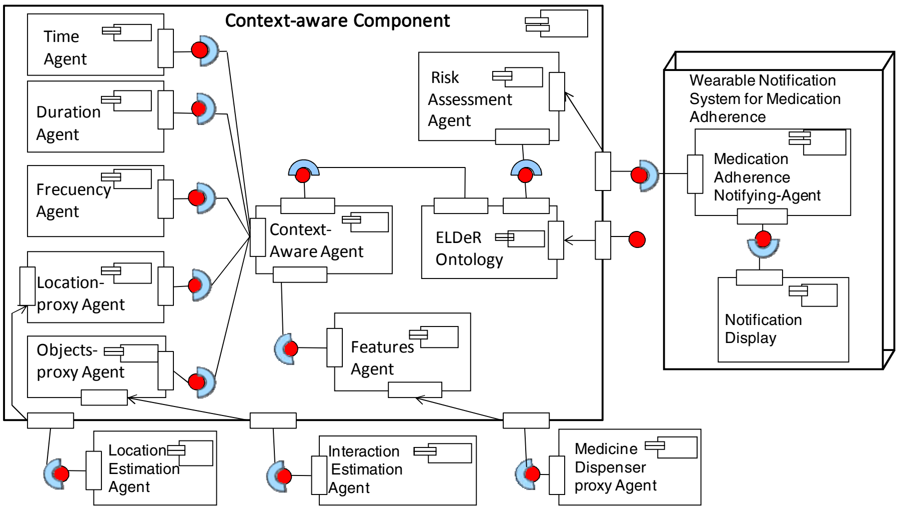

Fig. 2. Context-aware Component for inferring risks

- *Representing and inferring the elderly contex,* The aforementioned agents communicate the gathered context-information to the Context-Aware Agent by using SALSA messages extended for conveying this information. The context perceived by the context-aware agent will be used for updating the ELDeR ontology. When the older adult context changes, the Context-aware Agent notifies it to the Risk Assessment Agent, which will consult the ontology to verify if a risk condition has met. The Risk Assessment Agent informs the elder's situation to the appropriate Notifying Agent specified by the developer in the ontology. Developers implement a Notifying Agent to take the appropriate measures for the risk such as warning the elder or notifying the elder's caregivers.

4 AmI System for Supporting Medication Adherence

We illustrate the functionality provided by the Context-aware Component by presenting a hypothetical scenario of a system that reminds elders to take their medicines. We elected to study the medicating activity since persons who are over-65 years face frequent problems associated with non-adherence to their medication routine. Different studies, analyzed in [6], have reported noncompliance, non-adherence or medication errors rates in the elderly population that range from 26% to 59%. Non-adherence may aggravate health and lead to hospitalizations. An AmI system may support elders in this ADL by: providing reminders before the time for medicating; making older adults aware that the medicine was not taken; and notifying older adults that the medicine has run out. For implementing the aforementioned system functionality, the following components were created and attached to the Context-aware Component as presented in figure 2. The Wearable Notification System for Medication Adherence is a node representing the wearable device that contains the Medication Adherence Notifying-Agent. This agent receives the

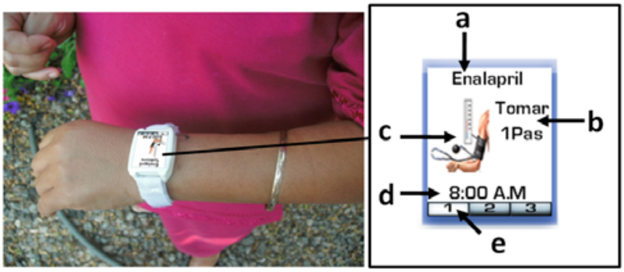

Fig. 3. Wearable Notification System for Medication Adherence. Elements of the user interface are: a) Medicine name, b) doses, c) icon representing the disease or health problem treated by the medication, d) current time, e) number of pills to take.

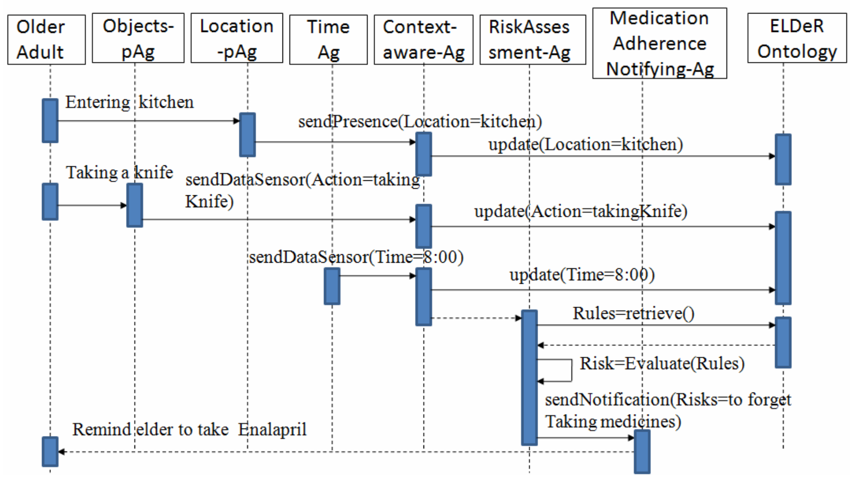

Fig. 4. AmI System's agents interacting to remind an older adult to take his medicine

notification messages to be displayed on the wearable device (see figure 3) by the Notification Display. The Medication Dispenser proxy-Agent is attached to the component to be aware of the medicines and doses taken by the elder as indicated in his medicine prescription. The Interaction-estimation Agent uses sensing technology for perceiving the elder's interaction with the objects around. The following scenario illustrates the interaction among the Context-aware Component and components of the Wearable Notification System for Medication Adherence as illustrated in figure 4.

Pablo enters to the kitchen since he wants to prepare his dinner at 8:00 pm. The Context-aware Agent updates the ontology to specify the elder's context: Pablo is in the Kitchen and he takes a knife since he plans to prepare his dinner. The Time Agent informs the Risk Assessment Agent that the current Time is 8:00pm, which is the time that Pablo should take his last medicine of the day. The Risk Assessment Agent consults the ELDeR ontology to get the rules and the context of Pablo. Then, the reasoning sub-component of the Risk Assessment Agent uses a Bayesian Network formed from the context information of Pablo to estimate the probability that Pablo forgets to take his medicine given that he is in the kitchen doing other actions related to the cooking activity at the same time he needs to take his medicine. To apply the Bayes Rule we used Conditional Google Probabilities (CGP) [7] to obtain the a-priori conditional probabilities. In this case, the CGP enabled us to estimate that the probability that Pablo takes his medicine given that take a knife is 2%. Thus, by using this CGP and by knowing that at least 26% of the elderly may forget to take their medicines, the Risk Assessment Agent determined that Pablo needs to be reminded to take his medicine. Finally, the Risk Assessment Agent informs of this to the Medication Adherence Notifying Agent by sending a sendNotification() SALSA message. The Medication Adherence Notifying Agent generates the appropriate message to be presented on the wearable device by the Notification Display component. Thus, advance inferring of this risk enables the Wearable Notification System for Medication Adherence to appropriately and opportunistically remind Pablo of taking his medicines without disturbing sending unnecessary reminders.

5 Conclusions and Future Work

To facilitate the implementation of Ambient Intelligence (AmI) systems that support the activities of daily living of older adults, we designed an agent-based component for inferring elders' context and predicting whether they need help to carry out their activities of daily living. For inferring users' context, we have designed the ELDeR Ontology which is a representational model of the elders' context information that is captured by pervasive technology. We are designing the ELDeR ontology general enough that it can be used for inferring any risk associated with Activities of Daily Living. We plan to carry out a case study for validating the ontology with older adults and healthcare professionals. And finally, we plan to implement different application scenarios to evaluate the ease of use of the Context-aware Component and the flexibility of the ontology for instantiating it according to the scenario supported.

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