Applying Context-Aware Computing in Dependent Environments

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Abstract. Context-aware systems gather data from their surrounding environments in order to offer completely new opportunities in the development of end user applications. Used in conjunction with mobile devices, these systems are of great value and increase usability. Applications and services should adapt to changing conditions within dynamic environments. This article analyzes the important aspects of context-aware computing and shows how it can be applied to monitor dependent individuals in their home. The proposed system logically processes the data it receives in order to identify and maintain a permanent location on the patient in the home, managing the infrastructure of services both safely and securely.

1 Introduction

The search for software capable of better adapting to a user's needs and particular situation leads us to context-aware systems. These systems store and analyze all the relevant information that surrounds them and constitutes the user's environment. Information that can be initially classified as context information is comprised of user preferences, tasks, location, state of mind, activity, surroundings, the ambient temperature of the area in which the user is located, the lighting conditions, etc. As such, a context stores data regarding the user's surroundings and preferences. Context-aware systems provide mechanisms for the development of applications that can understand their context and are capable of adapting to possible changes. A context-aware application uses the context of the subject in order to adapt its performance, thus better satisfying the needs of the user in that particular environment. The information is normally obtained by sensors. The current trend for displaying information to the system agents, given the large number of small and portable devices, is through distribution via heterogeneous systems and net-works with varying characteristics. One particular environment that requires the use of context-aware systems is the medical supervision of patients, specifically, home care. This situation involves applications that can be embedded in the homes of dependent individuals in order to improve their quality of life. With home care, it is preferable to use network sensors and

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intelligent devices to build an environment in which many home functions are automated, and devices and support services can assist with performing daily tasks. For example, a context-aware application in a home care environment could alert the hospital if the patient's blood pressure increases beyond a predetermined limit, or remind a patient to take medication. This article presents the Home Care Context-Aware Computing (HCCAC) multi-agent system for supervising and monitoring dependent persons in their homes. There have been recent studies on multi-agent systems (Ardissono et al. 2004) as a monitoring system in the medical care of people (Angulo et al. 2004), which are sick or suffer from Alzheimer's (Corchado et al. 2008b). These systems provide a continual support in the daily lives of these individuals (Corchado et al. 2008a), predict potentially dangerous situations, and manage physical and cognitive support to the dependent person (Bahadori et al. 2003). The remainder of the article is structured as follows: section 2 presents the problems of context-aware computing and introduces the need for the development of new systems that can improve the living conditions of patients in their homes. Section 3 describes the proposed system, with particular attention to the capabilities that a context-aware system can offer. Section 4 presents a case study describing how the proposed system has been applied to a real scenario. Finally, section 5 presents the results and conclusions obtained after using a prototype in a home care environment, and recommends future studies for improving the system.

2 The Context-Aware Computing

The history of context-aware systems began when (Want et al. 1992) presented the Active Badge Location System, which is considered to be the first context-aware application. It is a system for locating people in their office, where each person wears a badge that uses network sensors to transmit information signals about their location to a centralized service system. In the mid-1990s, several location-aware (Abowd et al. 1997) (Cheverst et al. 2000) (Sumi et al. 1998) tour guides emerged offering information about the user's location. The most commonly used context-aware feature is by far user location. Over the last few years, the use of other context-aware features has grown. It is difficult to describe the term context-aware and many researchers try to find their own description and the relationship among the features that are included in context-aware systems. The first written reference to the term context-aware was made by (Schilit et al. 1994). There are authors that describe context-aware as the location or identification of persons or objects (Ryan et al. 1997) (Hull et al. 1997) (Brown 1996). These descriptions are frequently used during the initial research of the systems. One of the most exact definitions was made by (Dey 1998). These authors refer to context-aware as information that can be used to determine the situation of entities (e.g., people, places or objects) that are considered relevant for the interaction between a user and an application. There are several location-aware infrastructures capable of gathering positional data (Espinoza et al. 2001) (Burrell 2002) (Kerer et al. 2004) (Priyantha et al. 2000). These systems include

GPS satellites, mobile phone towers, proximity detectors, cameras, magnetic card readers, bar code readers, etc. These sensors can provide information on location or proximity, differing mainly in the precision detail. Some need a clear line of vision; other signals can penetrate walls, etc. The previously mentioned systems only use one context attribute: the information on the location of the object or person. The use of different context attributes such as noise, light, and location allow a higher degree of combination of contextual objects. These elements are necessary for building systems that are more useful, adaptive and easy to use. An example of this type of context-aware infrastructure is the system presented by (Muñoz et al. 2003) that improves communication by adding context-awareness to the management of information within a hospital environment. All of the users (in this case, doctors, nurses, etc.) are equipped with mobile devices for writing messages that are sent when a previously determined set of circumstances are met. The contextual attributes that this system includes are location, time, roles, and the state of the user or entity to be analyzed. The studies we have mentioned use the attributes common to the majority of context-aware systems: the location and positioning of the person, object or entities. Few systems use information from different contextual attributes and relate different types of data to interact with users or patients. We would like to take the next step and use different contextual attributes with the system we propose. We would like the different type of data that the system gathers to be stored and logically processed with the goal of improving the quality of life for dependent per-sons in their home. Based on the context model, we propose a multi-agent Home Care Context-Aware Computing (HCCAC) system that offers context-aware services to patients within a dependent environment, and that includes a set of independent services that can gather and interpret contextual data. The fundamental characteristic of the system is the ability to logically process the data provided by the context so that the attention provided to the patient can be improved. The system can easily develop context-aware services and applications within a variety of contexts. The system is independent because it can be applied to various types of hardware devices and operating systems, and because it includes a Java-based technology. The patients can be identified and located within the environment by the RFID JavaCard chip that they carry. HCCAC defines a light framework for executing service-oriented applications. The system functions include installation management, activation, deactivation, initiation and elimination of services, as well as the identification, control and supervision of patients at all times.

3 HCCAC Multiagent System

The number of common objectives between context-aware software and user control is continually growing. The lack of transparency between application and user activity has created a need to improve the techniques for obtaining and capturing user preferences (Jameson 2001). Using explicit information that has been captured allows users to customize their preferences if they wish, and also

provides a tool for transparently presenting the obtained information. The users are then able to understand their application activity and make adjustments as needed. The majority of context-aware applications are programmed with the traditional software engineering techniques that integrate context information directly into the code source, which in large part results in the applications performing statically, making them more difficult to maintain. The HCCAC system functions like an integrated communication platform in which the context-aware agents intervene in the selections of communication channels used for interacting among users. Each agent uses a variety of communication channels, including mobile technology, RFID, wireless networks and electronic mail, in order to manage and register data from a particular user's interaction. HCCAC is based on a home care context model that integrates context-aware applications. HCCAC makes it possible to easily use and share context-aware applications within changing physical spaces. Figure 1 identifies the following agents that make up the system:

1. Provider agents capture and summarize the context data obtained from both internal and external heterogeneous sources, so that the Interpreter agents can, based on location data, try to reuse the same data.
2. Interpreter agents provide logical reasoning services in order to process the contextual information.
3. Database agents store the context data obtained by the Provider agents. The organization of this information is similar for different environments.
4. Context-aware applications examine the information available from the context provider agents and are constantly listening for possible events that the context providers send out. They also use different levels of context information and modify their performance according to the active context. They consult the functionalities registered in the system and always know the location of the context providers within the environment. One way of developing context-aware applications is to specify the actions that will respond to changes within the context that fall within a determined set of rules and conditions.
5. Location agents provide a mechanism that allows the Provider and Interpreter agents to make their presence known, and the applications and users to be able to locate these services.

All of the HCCAC agents are interconnected and can interact with each other. The agents described function independently from the platform on which they are installed. The next section describes in general terms how the HCCAC agents function. The external provider agents obtain context information through external resources such as a server that provides meteorological information about the temperature in a specific place, or a location server that provides information on the location of a person who is not at home. The internal provider agents directly gather information from the sensors installed in the environment, such as RFID based locators installed in the patient's home, or light sensors. The Interpreter agent functionalities include both processing information provided by the database agent, and analyzing the processed information. Based on the

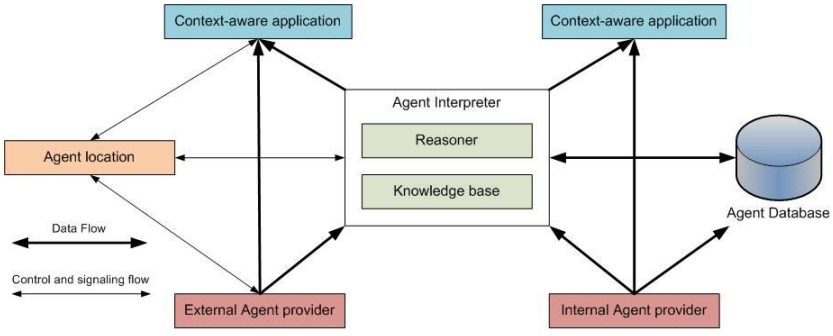

Fig. 1. Overview of the HCCAC multi-agent system

low level context data, the Interpreter agent offers high interpretation level context data to the context-aware applications. The context-aware applications use different levels of context information and can adapt their performance to the context within which they are executed. After consulting the data registered by the Location agent, these applications can locate the services from all of the context providers that they are interested in. The context-aware applications can obtain context data by asking a provider agent or waiting for an event from the provider agent. The Location agent allows the users and agents to locate different context applications. The primary characteristics of the Location agent include scalability, adaptation, and multiple processing capabilities. It controls large areas in internal or external networks where the context providers could be located. The Location agent searches and adapts to the changes that are introduced within the context when it adds or eliminates physical sensors or reconfigurations for the same devices. It also lays out a mechanism that allows the context providers to communicate their functionality in the context to the system. Figure 2 illustrates a general description of the system infrastructure. The image shows how different devices connect to the system via the Internet. All of the devices are interconnected through wireless communication networks, mobile devices or RFID technology.

4 Using Context-Aware Computing to Apply the Patient Control

Our case study developed a prototype for improving the quality of life for a patient living at home. The system gathers information from the sensors that capture data and interact with the context. The primary information that the installed sensors gather is the location-aware for the user in the environment. The system also processes information relative to the temperature in the in the different rooms and the lighting in the areas where the patient moves about. All of the access doors in the house have automatic open and close mechanisms.

HCCAC was used to develop a multi-agent system prototype aimed at enhancing assistance and care for low dependence patients at their homes. The house

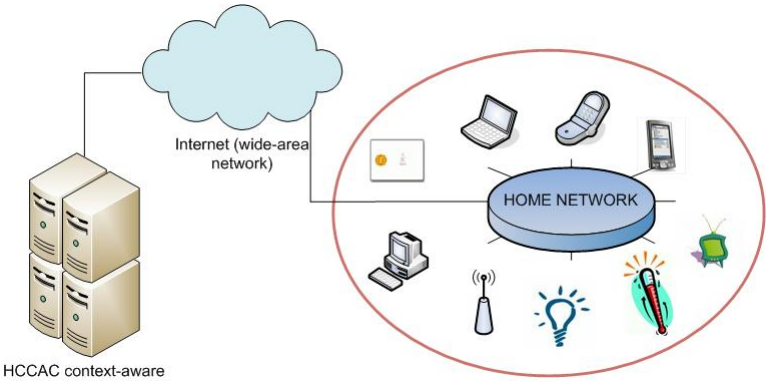

Fig. 2. Overview of the HCCAC context-aware infrastructure

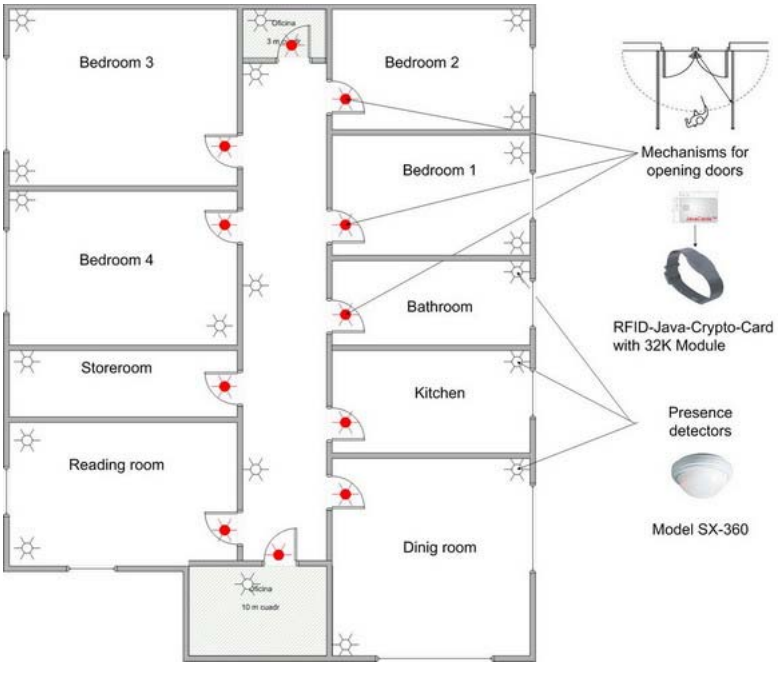

Fig. 3. Home plane

measured 89 m and was occupied by one dependent person. As shown in Figure 3 20 passive infrared SX-320 series motion detectors were installed on the ceiling, as well as 11 automatic door opening mechanisms. The movement detectors and door opening mechanisms interact with the microchip Java Card and RFID (Espinoza et al. 2001) users to offer services in run time. Each dependent user is identified by a Sokymat ID bracelet Band Unique Q5 which has an antenna

and a RFID-Java-Crypto-Card chip with a 32K Module and Crypto-CoProzessor (1024 bit RSA) compatible to with the SUN JavaCard 2.1.1 (ZhiqunChen). The sensors and the actuators are placed in strategic positions within the home, as shown on the plans in Figure 3. All of these devices are controlled by agents. This sensor network uses an alert system to generate alarms by comparing the user's current state with the parameters of the user's daily routine which has been stored in the system. The system can generate alarms if it recognizes a significant change within the parameters of the user's stored daily routine, such as if the user gets up prior to a specific hour on a non-work day, if the user spends more time than normal standing at a door without entering, or if the user remains motionless in the hallway for an extended period of time. As shown in Figure 4, the Provider agents are directly connected to the devices that capture the information. All of the data is stored in the system and interpreted by the Interpreter agent. In this case, the application consists of three modules: (i) one for controlling the location of the patient, (ii) one for controlling the lighting within the home, and (iii) another for controlling the temperature. The Location agent is in charge of identifying and either accepting or rejecting the data submitted by the information providers. It serves as an overseer of the agents that integrate into the system.

It is also important to note the transformation of information that takes place in the system. On the one hand, lower level data is gathered within the patient's environment; the information is subsequently stored in a data base as high level data so that it can be more quickly interpreted and easier to use. This task is carried out by the Provider agents as well as the Interpreter agent. Additionally, the patient can interact with the context at all times in order to

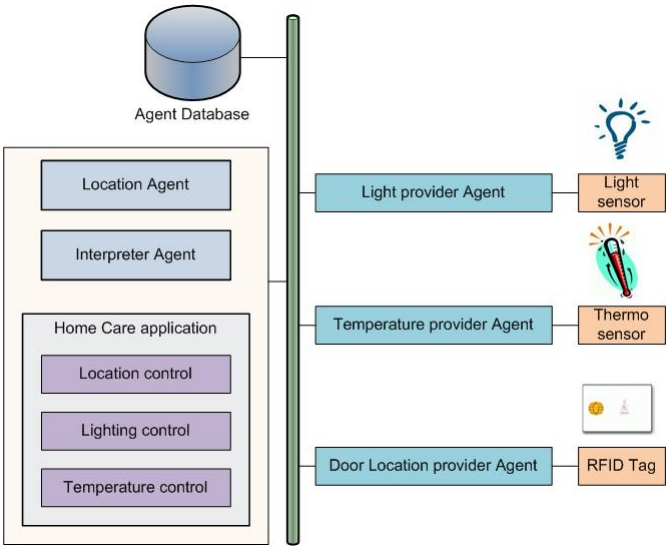

Fig. 4. Home Care context-aware application

establish the parameters that determine the functionality of the application. Just as the Provider agents gather context information, they can receive execution orders for events via the devices that they control. That is how, for example, the patient can decide which users can be controlled by the system, or control user access for the family members. The system can also store exterior temperature preferences for each one of the users that are in the system, thus making their stay more comfortable.

5 Results and Conclusions

HCCAC was used to develop a prototype used in the home of a dependent person. It incorporates JavaCard technology to identify and control access, with an added value of RFID technology. The integration of these technologies makes the system capable of sensing stimuli in the environment automatically and in execution time. As such, it is possible to customize the system performance, adjusting it to the characteristics and needs of the context with any given situation. HCCAC allows new Provider agents to be incorporated in execution time, thus proposing a model that goes a step further in context-aware system design and provides characteristics that make it easily adaptable to a home care environment. Furthermore, the proposed system offers a series of characteristics that facilitate and optimize the development of distributed systems based on home care. The functionalities of the systems and the actual agents are modeled as independent applications. As such, the agents are much lighter in terms of computational load, which can extend the possibilities for developing the system on mobile devices that have much more limited processing capabilities. Because they are independent, the applications can also be used for different developments, and with slight adjustments adapt to the needs of each environment. With its distributed focus, the system can independently launch and restrain applications and agents without affecting the rest of the system components. Although there still remains much work to be done, the system prototype that we have developed improves home security for dependent persons by using supervision and alert devices. It also provides additional services that react automatically in emergency situations. As a result, HCCAC creates a context-aware system that facilitates the development of intelligent distributed systems and renders services to dependent persons in their home by automating certain supervision tasks and improving quality of life for these individuals. The use of a multiagent system, RFID technology, JavaCard and mobile devices provides a high level of interaction between care-givers and patients. Additionally, the correct use of mobile devices facilitates social interactions and knowledge transfer. Our future work will focus on obtaining a model to define the context, improving the proposed prototype when tested with different types of patients.

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