Context-aware and Home Care: Improving the quality of life for patients living at home

Juan A. Fraile[1], Javier Bajo[1] and Juan M. Corchado[2]

[1]Pontifical University of Salamanca, c/ Compañía 5, 37002 Salamanca, Spain
[2]Departamento de Informática y Automática, University of Salamanca,
Plaza de la Merced s/n, 37008 Salamanca, Spain
{jafraileni, jbajope}@upsa.es, corchado@usal.es

Abstract. This paper presents a multiagent system that facilitates the performance of daily tasks for people within a context-aware environment. The paper analyzes the important aspects of context-aware computing and presents a prototype that can be applied to monitor dependent individuals in their homes. The system includes computation elements that are integrated within a domestic environment with the goal of capturing context-related information and managing the events carried out by the patient. The services are support by the processing and reasoning out of the data received by the agents in order to offer proactive solutions to the user. The results obtained with this prototype are presented in this paper.

Keywords: Context-Aware Computing, Home Care

1 Introduction

The preferred characteristics when designing software applications include autonomy, security, flexibility and adaptability. In order to achieve this objective, it is necessary to have mechanisms, methods and tools that can develop systems capable of adapting to changes within the environment. The search for flexible software applications that can continually improve their ability to adapt to the demands of the users and their surrounding leads us to context-aware systems that store and analyze all of the relevant information that surrounds and forms a part of the user environment.

Context-aware systems provide mechanisms for developing applications that understand their context and are capable of adapting to possible changes. A context-aware application uses the context of its surroundings to modify its performance and better satisfy the needs of the user within that environment. The information is usually obtained by sensors. The current trend for displaying information to the system users, given the large number of small and portable devices, is the distribution of resources through a heterogeneous system of information networks. Web applications and services have been shown to be quite efficient [15] in proc-

essing information within this type of distributed system. Web applications are run in distributed environments and each part that makes up the program can be located in a different machine. Some of the web technologies that have had an important role over the last few years are multiagent systems and SOA (Service Oriented Architecture) architectures, which focus on the distribution of system service functionalities. This model provides a flexible distribution of resources and facilitates the inclusion of new functionalities within changing environments. In this respect, the multiagent systems have also already demonstrated their aptitude in dynamic changing environments [3] [9]. The advanced state of development for multiagent systems is making it necessary to develop new solutions for context-aware systems. It involves advanced systems that can be implemented within different contexts to improve the quality of life of its users. There have been recent studies on the use of multiagent systems [3] as monitoring systems in the medical care [2] patients who are sick or suffer from Alzheimer's [9]. These systems provide continual support in the daily lives of these individuals [8], predict potentially dangerous situations, and manage physical and cognitive support to the dependent person [4].

This paper presents the Home Care Context-Aware Computing (HCCAC) multi agent system that supervises and monitors dependent persons in their homes, providing the user with a certain degree of self-sufficiency. The proposed system focuses on incorporating mechanisms that facilitate the integration of web applications. The HCCAC system provides wireless communication between its elements, and integrates intelligent agents with sensors and autonomous components that obtain context-aware information and are proactive in their interaction with the users. HCCAC facilitates the automation of context devices and the ability to respond to the elements from a remote location. One of the most important characteristics of HCCAC is the use of intelligent agents as one of the principal components in its system services-oriented approach. The system proposes a new and simple method of a distributed construction where the system functionalities are modeled as services that are activated by agents, which, essentially, control and coordinate the services.

The remainder of the paper is structured as follows: section 2 presents the problems of context-aware computing and introduces the need for developing new systems that can improve the living conditions of patients in their homes. Section 3 describes the proposed system and the interaction between agents and devices, focusing specifically on context-aware capabilities and the value-add provided by HCCAC. Finally, section 5 presents the results and conclusions obtained after evaluating the prototype in a Home Care scenario.

2 The context-aware computing.

The idea behind context-aware systems began when Want et al. [19] presented the Active Badge Location System, which is considered to be the first context-aware application. It is a system for locating individuals in their office, where each per-

son 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 tour guides emerged [1] [7] offering information about the location of the user. The most commonly used context-aware feature is by far user location. Over the last few years the use of other information attributes for context-aware systems 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" appeared in Schilit and Theimer [18]. There are authors that describe context-aware as the location or identification of persons or objects [17] [12] [5]. These descriptions are frequently used during the initial research of these systems. One of the more precise definitions was provided by Dey and Abowd [10]. 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 [11] [6] [13] [16]. These systems include GPS satellites, mobile telephone towers, proximity detectors magnetic card readers, barcode readers, etc. These sensors can provide information about 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: positional information for the object or person. The use of different context attributes such as noise, light and location allows for the combination of much higher levels of context-aware objects. These elements are necessary for building systems that are more useful, adaptive and easy to use. An example of a this type of context-aware infrastructure is the system presented by Muñoz et al. [14], which improves communication by adding context-awareness to the management of information within a hospital environment. All of the users (doctors, nurses, etc.) are given a mobile device for writing messages that are sent when a determined number of circumstances are met. The contextual attributes that are included in this system are location, time, roles and the state of the user or entity that is being analyzed.

The previously mentioned case studies demonstrate that the attributes used by the majority of context-aware systems are the identification and location of people, objects or entities. Few systems can use information from different context attributes and connect different types of data to interact with users or patients. We would like to take the next step and, in addition to using different context attributes in the system that we propose, make it possible for the different types of data gathered by the system to be stored, processed and reasoned out in order to improve the quality of life for dependent persons living at home.

We would like to propose the context model-based Home Care Context-Aware Computing (HCCAC) multiagent system that offers context-aware services for patients in a dependent environment and includes a set of independent services that can gather and interpret context data. The fundamental characteristics of the system are to process and reason out data furnished by the context to improve patient care. The system allows for easy development of context-aware services and applications in a variety of contexts.

3. HCCAC multiagent system.

HCCAC can be defined by the need to control various devices and gather user information in a non-intrusive and automatic way within Context-Aware environments [5]. Additionally, HCCAC brings greater speed to the gathering, processing and storage of data, variety in the communication channels among system players, and security in the management of access and administration of information. Each of these characteristics allows users to feel safe within the context knowing that they are being monitored and that any type of unexpected incident can be prevented. Additionally, the variety of communication channels also facilitates the administration of the system and the interaction between the components within the environment. The HCCAC system also facilitates the integration and management of agents and devices. Communication between platform agents follows the standard FIPA ACL [8] (Agent Communication Language) specification. Communication protocol between agents and services is based on the SOAP [9] standard. The services that the agents invoke can be of two types: services that capture information from the context data that are obtained by the autonomous components; and services that function within devices installed in the context. All of this allows HCCAC to be a system that is easy to implement in complex environments and is not platform specific.

HCCAC makes it possible to automatically obtain information on users, their actions and environment in a distributed manner. HCCAC primarily focuses on monitoring a person in their home and sending notifications on the state of the individual or possible incidents. Additionally, it combines the management of personal information with a model of daily activities that are developed by using the data provided by the sensors through the household network. The interpretation and reasoning of the base knowledge and the daily activity models developed by the system provide an added value to the system. HCCAC makes is possible to easily use and share context-aware applications within changing physical spaces. As seen in Figure 1, the system is composed of the following agents:

- Provider agents capture and summarize the data obtained by both internal and external heterogeneous context sources so that the Interpreter and Database agents can process and reuse these data. The system is dynamic and is capable of incorporating an information Provider agent at any given moment by adding the corresponding sensor or capturing the necessary information from a server or external provider.
- Database agents store the context data obtained by the Provider agents. The organization of this information is similar for different environments. This agent is in charge of managing and exploiting the stored data. Additionally it provides the necessary information to the interpreter agent and records and updates the action plans that are determined by the interpreter agent.
- Interpreter agent provides logical reasoning services to process the contextual information. The interpreter agent reasons out the actions that must be taken by creating a plan that determines the optimal course of action for reaching an objective. This agent provides the ability to reach high level

and complex objectives and avoids errors that could result in inefficacies. It also allows for greater flexibility when dealing with new objectives.

- Resource Identification Agent (LcA) makes it possible for the provider agent and the interpreter agent to work directly with the applications and the users in order to avoid dangerous situations or particular incidents with the user. This agent is in charge of maintaining a record of the provider agents that are active in the system, in addition to allowing or denying the inclusion of new provider agents.

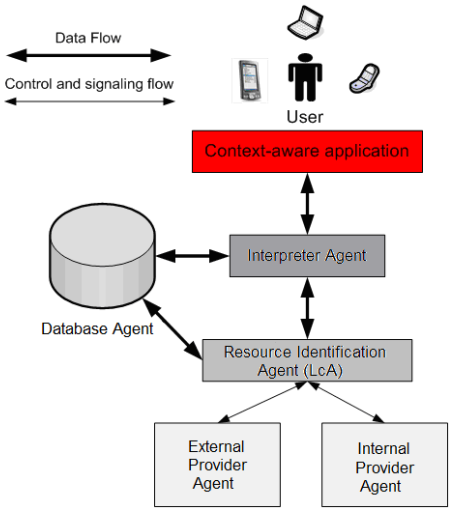

Fig. 1. Overview of the multi-agent system HCCAC.

Context-aware applications in HCCAC also check the information available from the context providers and are in constant listening mode to deal with possible events that the context providers transmit. The applications use different levels of context information and adapt their behavior according to the active context. They check the functionalities registered in the system and have a location for all of the context providers made available within the environment. One way of developing context-aware applications is to specify actions that respond to changes in the context under specific conditions and rules.

The agents described function independently from the platform on which they are installed. The external provider agents obtain context information through external resources such as, for example, a server that provides meteorological information about the weather 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 gather information directly from the sensors installed within the environment, such as RFID based location sensors installed in the home of a patient, or light sensors. The functions of the interpreter agent include both processing information provided by the database agent, and reasoning out the information that has been processed.

The interpreter agent offers context data of high level interpretation to both the context-aware applications and the devices in which it acts, from low-level context data. Context-aware applications use different levels of context information and can adapt their performance according to the context within which they are executed. After consulting the data registered by the LcA, these applications can locate the web services handled by the context providers. Context provider agents facilitate the access of the applications and web services that provide information to the system. For example, web applications provide meteorological data to the HCCAC system. In order to obtain context data, context-aware applications can ask the Provider agent or wait for an event from the Provider agent. LcA allows users and agents to locate different context applications. LcA controls large areas where there are context providers that can be located in internal or external networks. The LcA searches and adapts to the changes that are introduced within the context when adding or deleting physical sensors or reconfiguring the actual devices. It also unfolds a mechanism that allows context providers to notify about their functionalities within the LcA.

4. Using context-aware computing to apply patient control.

Our case study developed 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 gathered by the sensors that have been installed is the location-aware for the user in the environment. The system also processes information relative to the temperature in the different rooms of the patient's home, and the lighting conditions in the areas where the user moves about. All of the access doors in the house have an automatic open and close mechanism. The house was installed with (i) passive infrared motion detectors on the ceiling and (ii) automatic door opening mechanisms. The motion detectors and door opening mechanisms, interact with the microchip Java Card & RFID [11] users to offer services in run time. Each dependent user is identified by a (iii) Sokymat ID bracelet Band Unique Q5 that has an antenna and a RFID-Java-Crypto-Card chip with a 32K Module and Crypto-CoProzessor (1024 bit RSA) compatible with the SUNs JavaCard 2.1.1 [20]. También se instalan (iv) sensores de luminosidad, que se utilizan para gestionar el nivel de luminosidad de una estancia haciendo que se mantenga entre unos valores pre-asignados modificables, (v) una pantalla TFT de superficie, que permite visualizar y gestionar los elementos principales del sistema. There were also light sensors (iv) installed to manage the level of lighting in the home, maintaining the level within a pre-determined set of values, (v) a TFT surface screen that makes it possible to see and manage the principal elements of the system. The sensors or actuators are placed in strategic positions within the home. All of these devices are controlled by agents. The sensors network is responsible for generating alarms after 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 use 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.

The main idea, which can be considered the core of the case study, is the system's ability to hide the available technological resources from the patient, ensuring that they remain concealed from the patient's daily life activities. In this way, users have only to be concerned with informing the system of their preferred living conditions and the system itself takes care of managing the resources and acting accordingly. It is necessary to apply or develop an appropriate analysis and design methodology, and to develop an organizational structure. The first step, however, is to analyze the extent of the system's performance as it is installed in the patient's home.

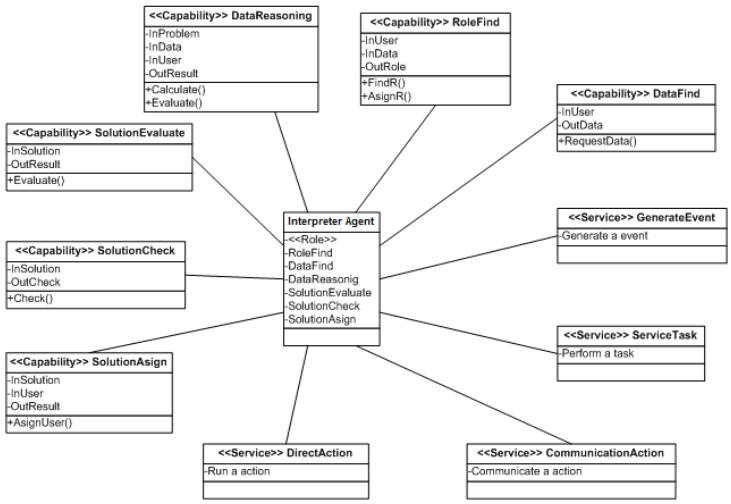

Fig. 2. Diagram of the different types of Interpreter Agents

The agent on which the HCCAC system is based is the Interpreter Agent. The diagram in Figure 2 shows the different types of Interpreter Agent, which involve a variety of roles or capacities: (i) RoleFind, assigns a role or finds a valid role for a user based on the identification of the user and the data assigned to him or her; (ii) DataFind, obtains information associated with a user; (iii) DataReasoning, detects any problem and the information associated with a user, evaluate the information and determines a solution to the problem; (iv) SolutionEvaluate, evaluates and transmites the result of a solution; (v) SolutionCheck, checks the solution and gives an assessment; and (vi) SolutionAssign, assings a solution to a user. The Interpreter agent can also initiate a series of services: (i) DirectAction, executions an action for a user; (ii) CommunicationAction, communicates an action that must be taken by a user; (iii) ServiceTask, initiates a task in the system; and (iv) GenerateEvent, generates an event after calculating or evaluating the data.

The interaction between agents and the sensors installed in the home for the prototype presented in this paper can be described by using an example, as shown in Figure 3, where the internal Provider Agent (Situ Ag) executes web services to send signals to the sensors, and communicates with the Interpreter agent to inform it of the user's situation. Situ Ag also receives signals from the Interpreter Agent in order to, for example, allow or prohibit user access to controlled areas. The LcA agent registers each of the services offered by the Situ Ag. The LcA agent continually updates the list of services provided by the Situ Ag so that it can be transferred through web services to the active applications in the context. Furthermore, the Database Agent manages the context information based on the data provided by the Interpreter Agent.

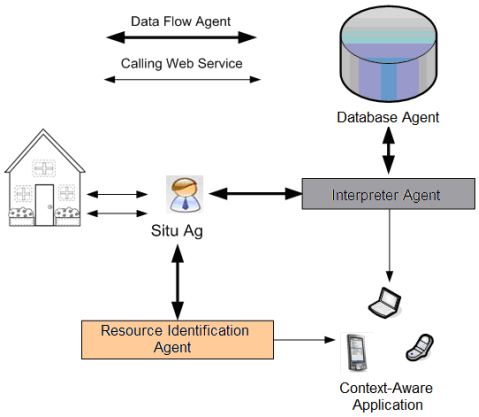

Fig. 3. Ejemplo de interacción entre agentes, recursos y aplicaciones Context-Aware.

It is also important to consider the transformation of the information that is produced within the system. First of all the system gathers data from the components of the context, which is then stored in the information system. Information on the context is taken from these data and subsequently reasoned out. To do so, the agents use case based reasoning (CBR) in a computational environment with intelligent processing capability. The CBR systems use the experience from similar previous situations in order to solve a new problem. This makes it possible to personalize the context of any accounting for user data and preferences that are pertinent to similar previous cases. The information Provider agents work together with the Interpreter agent to carry out this task.

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 automatically sensing stimuli in the environment in execution time. As such, it is possible to customize the system performance, adjusting it to the characteristics and needs of the context for any given situation. Different studies related to context-aware systems, such as [11] [6] [13] [16], focus exclusively on gathering positional data on the user. The authors of these papers gather the positional data on the users through GSP signals, mobile telephone towers, proximity detectors, cameras and magnetic card readers. Many of these signals work with a very wide positioning range, which makes it difficult to determine the exact position of the user. In contrast, the system presented in this paper determines the exact position of the user with a high level of accuracy. To do so, the system uses JavaCard and RFID microchip located on the users and in the sensors that detect these microchips in their context. Others studies, such as [14], in addition to locating the users in their context, try to improve the communication between patients and medical personnel in a hospital center by capturing context attributes such as weather, the state of the patient or role of the user. In addition to capturing information from various context attributes such as location, temperature and lighting, HCCAC also incorporates the Interpreter agent reasoning process to provide services proactively to the user within a Home Care environment. HCCAC incorporates new information Provider agents in execution time. In this respect, HCCAC proposes a model that goes one step further in context-aware system design and provides characteristics that make it easily adaptable to a home care environment.

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, web services, 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.

Acknowledgements. This work was supported JCYL SA071A08 project.

References

1. Abowd, G. D., Atkeson, C. G., Hong, J., Long, S., Kooper, R., and Pinkerton, M. (1997). Cyberguide: A mobile context-aware tour guide. Wirless Networks, 3(5).
2. Angulo, C., & Tellez, R. (2004). Distributed Intelligence for smart home appliances. Tendencias de la minería de datos en España. Red Española de Minería de Datos. Barcelona, España.

3. Ardissono, L., Petrone, G. and Segnan, M. 2004. A conversational approach to the interaction with Web Services. Computational Intelligence, Blackwell Publishing. Vol. 20. pp. 693-709.
4. Bahadori, S., Cesta, A., Grisetti, G., Iocchi, L., Leone1, R., Nardi, D., Oddi, A., Pecora, F. & Rasconi, R. (2003). RoboCare: Pervasive Intelligence for the Domestic Care of the Elderly. In AI*IA Magazine Special Issue, January, 2003.
5. Brown, P. J. (1996). The stick-e document: A framework for creating context-aware applications. In Proceedings of the Electronic Publishing, Palo Alto, pages 259–272.
6. Burrell, J. and Gay, G. (2002). E-graffiti: evaluating real-world use of a context-aware system. Interacting with Computers – Special Issue on Universal Usability, 14(4):301–312.
7. Cheverst, K., Davies, N., Mitchell, K., Friday, A., and Efstratiou, C. (2000). Developing a context-aware electronic tourist guide: some issues and experiences. In Proceedings of the SIGCHI conference on Human Factors in Computing Systems, pages 17–24, New York, NY, USA. ACM Press.
8. Corchado, J.M. , Bajo, J. , de Paz, Y. & Tapia, D. (2008). Intelligent Environment for Monitoring Alzheimer Patients, Agent Technology for Health Care. Decision Support Systems. ISSN 0167-9236.Vol 34 (2) pp. 382-396.
9. Corchado, J.M., Bajo, J. & Abraham, A. (2008). GERAmI: Improving the delivery of health care. IEEE Intelligent Systems. Special Issue on Ambient Intelligence - Mar/Apr 08.
10. Dey, A. K. (1998). Context-aware computing: The CyberDesk project. In Proceedings of the AAAI, Spring Symposium on Intelligent Environments, Menlo Park, CA.
11. Espinoza, F., Persson, P., Sandin, A., Nyström, H., Cacciatore, E., and Bylund, M. (2001). GeoNotes: Social and navigational aspects of location-based information systems. In Proceedings of the 3rd International Conference on Ubiquitous Computing, Atlanta, Georgia, USA, pages 2–17.
12. Hull, R., Neaves, P., and Bedford-Roberts, J. (1997). Towards situated computing. In Proceedings of the International Symposium on Wearable Computers.
13. Kerer, C., Dustdar, S., Jazayeri, M., Gomes, D., Szego, A., and Caja, J. A. B. (2004). Presence-aware infrastructure using web services and RFID technologies. In Proceedings of the 2nd European Workshop on Object Orientation and Web Services, Oslo, Norway.
14. Muñoz, M. A., Gonzalez, V. M., Rodriguez, M., and Favela, J. (2003). Supporting context-aware collaboration in a hospital: an ethnographic informed design. In Proceedings of Workshop on Artificial Intelligence, Information Access, and Mobile Computing 9th International Workshop on Groupware, CRIWG 2003, pp. 330–334.
15. Oren, E., Haller, A., Mesnage, C., Hauswirth, M., Heitmann, B., Decker, S.: A Flexible Integration Framework for Semantic Web 2.0 Applications. IEEE Software, vol. 24, no. 5, pp. 64-71, (2007)
16. Priyantha, N. B., Chakraborty, A., and Balakrishnan, H. (2000). The cricket location-support system. In Proceedings of the 6th Annual International Conference on Mobile Computing and Networking, pages 32–43. ACM Press.
17. Ryan, N., Pascoe, J., and Morse, D. (1997). Enhanced reality fieldwork: The context-aware archaeological assistent. Computer Applications in Archaeology.
18. Schilit, B. and Theimer, M. (1994). Disseminating active map information to mobile hosts. IEEE Network, 8(5):22–32.
20. Want, R., Hopper, A., Falcao, V., and Gibbons, J. (1992). The Active Badge Location System. ACM Transactions on Information Systems, 10(1):91–102.
21. ZhiqunChen (Sun Microsystems). Java Card Technology for Smart Cards. Addison Wesley Longman. ISBN 0201703297.