Agent Based Mobile Collaboration and Information Access in a Healthcare Environment

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Abstract: Hospitals are characterized by a high degree of collaborative work, mobility, and information access from many devices or artifacts. Healthcare environments are becoming ideal test-beds for pervasive and mobile communication technologies. In this paper we present the development of an agent-based mobile collaborative system to support the intensive and distributed nature which characterizes information management and collaboration in a hospital setting. We describe the methodology that was followed to conceive, design, implement and evaluate the prototype. The design is based on a grounded understanding of user needs and the identification of validated scenarios of use, which illustrate that collaboration in the hospital is highly based on a set of contextual elements, such as the location of people and devices and the timing of messages to be delivered. To facilitate the development of the system, we used the SALSA agent middleware which enables to easily integrate autonomous agents to pervasive applications. Finally, we present the results of a preliminary evaluation of the system.

1. Introduction

Information management and communication in a hospital setting is characterized by a high degree of collaborative work, mobility, and the integration of data from many devices or artifacts [11]. Exchanges of information are intense, and demand from participants to promptly extract from the artifact useful pieces of data to perform their job. In contrast with other settings such a traffic control rooms [14], information in hospitals is not generally concentrated in a single place but distributed among a collection of artifacts in different locations. For instance, patients' records are maintained and used in coordination with data on whiteboards, computers, or binders located in rooms, labs, common areas or offices.

Given the high distribution of information together with the intensive nature of the work, it results clear that tremendous coordination efforts are required from all members of the hospital staff to properly manage the information to attend and take care of patients. The right information has to be in the right place, whenever it is needed by whoever needs it, in whatever format (representation) that they need it

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2]. Hence the characteristics of artifacts containing information play a fundamental role to achieve this coordination. For instance, patient's records are easily moved from place to place and filled, checked, read and consulted in many locations like nurses' room, analysis labs, or the actual bed where the patient is being attended; nurses, physicians and other workers interact with those records and use them to support their work or to transmit instructions to be followed by others. To have the patient's records at the right place is what in part makes them successful to support coordination, as well as the fact that the information contained in them is clear, complete, accurate, and updated. Unfortunately those conditions are not always achieved. Documents get lost, instructions are not clear, or the data is not complete to support decisions. We therefore need to understand how each information item gets integrated successfully into artifacts to support the coordination required in hospitals. From that we can derive adequate information technology.

This understanding should be based on a proper assimilation of the context where the hospital's staff performs their job and this demands an active engagement of researchers in daily work through which the routines, procedures, and working practices of individuals can be captured. Therefore our designs aimed to emerge from empirical studies in hospitals and from a comprehensive analysis of the conditions where technology would be implemented.

Figure 1 depicts the process we followed in the design and implementation of a pervasive healthcare application that supports collaborative activities and information access of mobile users. Our workplace study enabled us to understand what and how contextual elements effect the information management and medical collaborative activities: (1) the location of people and devices, (2) the timing of messages to be delivered, (3) the role-oriented nature of the work and (4) the artifact-mediated nature of information gathering.

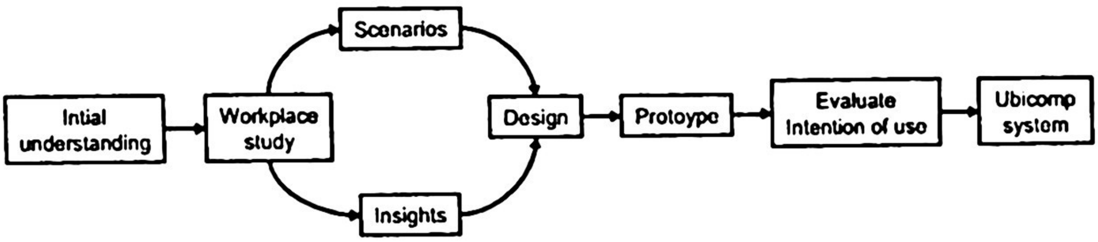


Fig. 1. The user interface of the System's Context-aware Client

We shaped our technological designs to directly address these contextual elements. Thus, our proposed technological solution is a context-aware system based on agents that enables mobile users to collaborate by exchanging messages, and access information and services when and where they need them.

Some of the system's components were identified as agents that respond autonomously in accordance to the context surrounding the activities performed at the hospital. To facilitate the development of the system, we used the SALSA agent middleware which enables to easily integrate autonomous agents to pervasive applications.

The organization of this paper is based in the sequence of steps we follow to conceive, design, implement, and evaluate the system's prototype. In section 2 we briefly review how information management in a hospital setting has been understood and what has been done to support it. Section 3 describes a workplace study performed to understand the contextual elements supporting the management of information at a hospital. Section 4 presents two scenarios derived from the study that guided the design of the context-aware messaging system. Section 5 presents the findings that resulted from this study. In Section 6 we explain the architecture and design of the agent-based mobile collaborative system, and illustrate its functionality. Section 7 presents the results of a preliminary system's evaluation. Finally, Section 8 presents our conclusions and future work.

2. Initial Understanding of Medical Work Practices

Hospital settings have been a subject of study by many researchers in recent years [3], [11], [12]. Those studies have identified the intensity of the information exchange and its distributed nature. Members of hospital's staff might be distributed in space (i.e. different location within the settings) or time (i.e. working different shifts). Such conditions are clearly not likely to change and are absolutely essential to provide full time coverage for patients.

Consequently given that many people can interact with a patient across the day, all those individuals have to rely on artifacts that serve as containers of relevant patient's data, as well as a channel of communication with other individuals. In her study of a hospital ward, Bossen identified some characteristic artifacts which resulted to be central for the coordination of staff's actions [3]. Elements such as whiteboards hanged on walls, helped to communicate information regarding patients' conditions and locations. Other *mobile* artifacts such as clipboards with individual patient's records provided more details of patients such as the medicine and doses that was administered to each of them. Bossen also emphasizes the importance of having the information in the right place [3].

The effectiveness of information artifacts is highly dependent on their location but also on being able to provide adequate information to the reader. It has been pointed out that due to their different professional background, hospital's personal is likely to experience communication problems or to define and agree on what is the most useful way to represent information contained in artifacts [12]. For instance, physicians and nurses can pull different bits of data from a patient's record in order to do their work (e.g. a diagnostic vs. the administration of medications). Therefore in order to be effective an information artifact has to be *elastic* enough to provide with different levels of representations for each possible reader in such a way that it results meaningful for all of them.

Limited work has been done to directly address the information management needs of hospitals with context-aware technologies that support contextual variables such as where the artifact is located, who reads it, when it is read and for what purposes it is read. Previous efforts have focused on supporting communication among individuals working in hospitals by using video conference [9] or 2-way pagers [7]. Unfortunately those designs do not contemplate that tasks in hospitals are usually handed among people working different shifts [3] and the fact that even when people are collocated they often rely on information artifacts to transmit data to other members instead of contacting them directly minimizing with this articulation efforts.

Other design efforts have intended to support the mobility inherent in many of the information artifacts used in a hospital. For example the Ward-in-Hand system is a handheld system that provides access to patient's records, hospital information and communication with other patients through a wireless infrastructure [1]. In spite that this solution seems to be pointing to the right direction we believe that it is limited because it conceives information artifacts as being personal devices, which is clearly not the case. Information artifacts in hospitals are in essence shared by many people and consequently we must focus or design on supporting the roles that individuals play and not the individuals themselves.

With the aim of acquiring a robust understanding of what are the essential contextual elements that support the management of information and collaboration in a hospital setting and how they interact with each other, we conducted a workplace study which is described in the next section.

3. Workplace Study

In order to design the agent-based mobile collaborative system we conducted a field study at the IMSS General Hospital (H.G.Z. IV. No.8) in the city of Ensenada, Mexico. This is a public health institution providing medical services for a potential population of 175,000 inhabitants. Our approach was to use qualitative methodologies to gain understandings beyond requirements gathering and understand how routine and non-routine work is performed in a daily basis.

To understand IMSS General Hospital's people, setting, and practices, we studied three of its high-traffic departments: Urgencies, where more than 70 percent of the patients enter the hospital; Internal Medicine; and Laboratory Analysis. Most patients enter through Urgencies and go to Internal Medicine, and they typically require laboratory services. For three months, we observed work practices and conducted interviews with 20 staff, including physicians, nurses, social workers, assistants, a chemist, and lab workers. We took care to select people with different roles, experience, and expertise. We then assimilated our results to gain a deeper understanding of how contextual elements affect information management. From interview transcripts and our written observations, we identified characteristics that context-aware technologies should support. We also identified the processes in which the hospital workers were most likely to interact frequently, change location constantly, and access patient information. We then sorted out activities that depend on contextual variables such as location, identity, role, or time. We modeled these processes and validated them in another set of interviews with workers.

Once we clearly understood the processes, we identified use scenarios —situations that exemplify a distinct and typical use for a context-aware support system. The scenarios below show the kind of contextual support hospital work requires and give a flavor of how technology can enhance hospital practices.

4. Scenarios of Use

The scenarios let us translate our findings into specific vignettes that captured facets of how context-aware and mobile computing technology might fit into current work practices. The scenarios were sketches of user activities. They did not contain details about how the tasks would execute or how the system would enable the required functionality [4]. Rather, the scenarios helped us frame our understanding of hospital work practices and gave us insight into how mobile and context-aware computing could augment the work. This section presents two of the seven scenarios we used to design the system, which are the most representative examples of daily medical work.

Scenario 1:
Rita is a doctor in a local hospital. As she makes her final round, she notices that a patient, Theresa, is not responding well to her medication. Rita wishes to leave a note to the doctor who will be reviewing Theresa in the afternoon shift. She doesn't know who that will be, so she writes a message to the first doctor to check the patient after her.

Scenario 2:
While Dr. Diaz is checking the status of a patient (on bed number 1 of room 222), he realizes the needs to request an ordinary laboratory study for her. Through his PDA, he adds this request to the patient's clinical record of the Hospital's Information System. The chemist (responsible for taking the samples for the analysis) visits the internal medicine area every morning. His PDA informs him that inside room 222 there are three patients that require a medical analysis. When the chemist stands in front of the patient, his PDA shows him the samples that have to be taken and the type of analysis to be performed. He labels the samples and at the end of his round he takes them to the lab to perform the analyses. The results are added to the patient's clinical record. When the doctor is about to finish his shift and while walking through the corridor, his PDA alerts him that the test results of the patient on bed number 1 in room 222 are available. Dr. Diaz goes back to the patient's room and when he stands near the patient's bed the results of the analysis are displayed on his PDA. At that point, the doctor revaluates the patient and based upon the results just received, decides to prepare him to be surgically intervened.

5. Insights from the Study

We group the findings from our study into four different aspects that let us to understand the fundamental contextual elements that have to be considered to support the management of information and coordination of activities

5.1 Location of people and devices

We noticed that the location of hospital's staff is useful to determine the type of information that they might require. Access to patient's medical records is most relevant when the doctor or nurse is with that particular patient. It is in the context of the patient's bed when detailed information should be revealed to the adequate person. For instance a nurse might notice that a particular medicine has to be administered to a patient and she must know the appropriate doses to apply to the patient. Location then becomes relevant when considering what information to deliver. This information should be sent to the place where it will be useful rather than to a particular person. We conclude that an approach that emphasizes the role of location and integrates it into its design will protect against overloading the hospital's staff with information which is neither useful nor relevant at that particular location.

5.2. Timing for the delivery of information

Communication exchanges in an intensive working environment such as a hospital tend to be time-sensitive. There is a period of time during which a message is relevant to be delivered. For instance, a doctor might wish to leave a message providing recommendations for the treatment of a patient, to any nurse of the next shift. The message might not be relevant if delivered before the next shift since not enough time has passed to evaluate the evolution of the patient's symptoms, nor will it be relevant the following morning. We conclude that an approach that lets users specify the time where messages are delivered will facilitate the coordination of activities in a hospital where services are provided 24 hours a day, 7 days a week.

5.3. Role-oriented nature of work

Communication needs to be established between parties that might not know each other a-priori or which rarely meet. For instance, we noticed that due to the work-shifts and the constant turnover of personal, a single patient might be attended by two different physicians and three different nurses in the same day. In such conditions communication of messages is not addressed to particular individuals but to the nurse in the afternoon shift, the next doctor to visit the patient, etc. There is not certainty about who will be that person, only about the role that he/she will play in the attention of the patient. Therefore information is often sent to roles and not particular individuals. We conclude that an approach that complements communication with specific role-based support will be more appropriate for hospital work.

5.4. Artifact oriented nature of information gathering

Awareness of the state of an artifact (e.g. patients' records) facilitates the communication among coworkers and reduces the chances of misunderstandings. For instance, the state of devices (temperature reading) and documents (availability of lab results) can be important triggers for information exchanges. The sudden availability of a bed could trigger the transfer of a patient waiting in the corridor of the emergency room to the next bed to be freed. Medical staff might need to communicate directly with documents and/or devices. For instance, a doctor might wish for the patient's lab analysis to be shown on the large display of his office as soon as they become available. We conclude that through the monitoring of relevant artifacts we can support the timely delivery of pertinent information to hospital workers.

6. Supporting Mobile Collaboration and Information Access in Hospitals

In this section we present the design of an agent-based system to support context-aware collaboration and information access of mobile users. Thus, we first introduce the concept of context-aware computing, and present the system designed to support the scenarios described on the previous section.

Context-aware computing has been closely associated to pervasive computing [6] Context-aware computing refers to an application's ability to adapt to changing circumstances and respond based on the context of use. Mobile users are constantly changing their context, most notably their location. Additionally, context-awareness often requires the use of sensors and computing devices set in the environment in order to establish the context of use.

As noted in the scenarios presented in Section 4 there are circumstances, in a hospital setting, that require the sending of messages to a person or device that might depend on contextual information (location, time, availability, etc.). For instance, the doctor in the first scenario described might wish to send the message to the first doctor to be at a particular location (around a patient's bed) during the afternoon shift and once the results of his medical analyses have been reported. Another scenario might involve a doctor wishing to send the lab results to the first printer to become available or to be visualized in a public display for consultation with another doctor.

Based on these scenarios we decided to use the Instant Messaging (IM) paradigm to support what we refer to as context-aware communication. In particular we look to support context-aware messaging. This concept extends the traditional instant messaging paradigm by allowing users to specify a set of circumstances that need to apply for a message to be delivered; we refer to this as context. For example, the sender can indicate that the message will be delivered to the specified recipient when she enters the emergency room; or for the message to be sent to the last person to leave the laboratory when the air conditioning is on.

Some of the key computer-based components of the proposed scenarios can be envisioned as agents that have capabilities to make their own decisions about what activities to do, when to do them, what type of information should be communicated and to whom taking into account the situation's context. Such capabilities have been identified as features highly related with autonomy [8]. We also observe in these scenarios, that a user could interact seamlessly with a range of different agents that can assist the user in his activities. These autonomous agents enrich context aware computing environments by introducing capabilities for negotiating services with other agents and wrapping complex system functionality. For instance, autonomous agents can monitor the medical information system in order to notify to a doctor when the results of a medical analyses are available; find out what is the nearest public display where a doctor may discuss the analyses results with a medical specialist; control and allow access to the hospital's devices/services taking into account priorities or security restrictions; estimating users' localization; and monitoring the environment to control the sending of contextual messages.

6.1 System's Architecture

The functionality of the agent-based system is illustrated in Figure 2. It uses a client-server architecture as a basis for its implementation. Wireless connectivity between servers and mobile clients is achieved through 802.11b access points. We incorporated autonomous agents into our system architecture, along with a context-aware client and an IM server, which are explained next.

Instant Messaging Server

We used and extended the Jabber open-source IM server (www.jabber.org) and its Extensible Messaging and Presence Protocol XMPP (currently an Internet Engineering Task Force draft). This server is used to notify the state of people and agents, and to handle the interaction between people, agents, and devices through XML messages. All communication between the Context-aware Client and the Context-aware Agent will go through this server. The information in the user's handheld is synchronized with the server every time the device is connected to a point of access.

Context-aware Client

In traditional IM systems messages are sent as quickly as possible. In these cases, of course, the identity of the recipient is known a-priori. This won't work for context-aware messaging where the recipient's identity won't be known until a specific state is achieved. One of the components of the Context-aware Client is a lightweight interface for users to compose the message and to easily specify the context of delivery, which is record by the Context component, also responsible for requesting the user's location to the Location-estimation Agent. Given that the messages are not necessarily sent immediately after they are composed, the system should allow users to go back, consult the messages they have sent, and modify or delete them. From the perspective of the user that receives a context-aware message, it might be important to be aware of the context specified for message delivery, since this information could be useful for him to make sense of the message. For instance a message that states "medicate this patient when his analyses are completed" might not be fully understood if the user is not aware that the message was meant for delivery at a specific location, the patient in certain room in this case.

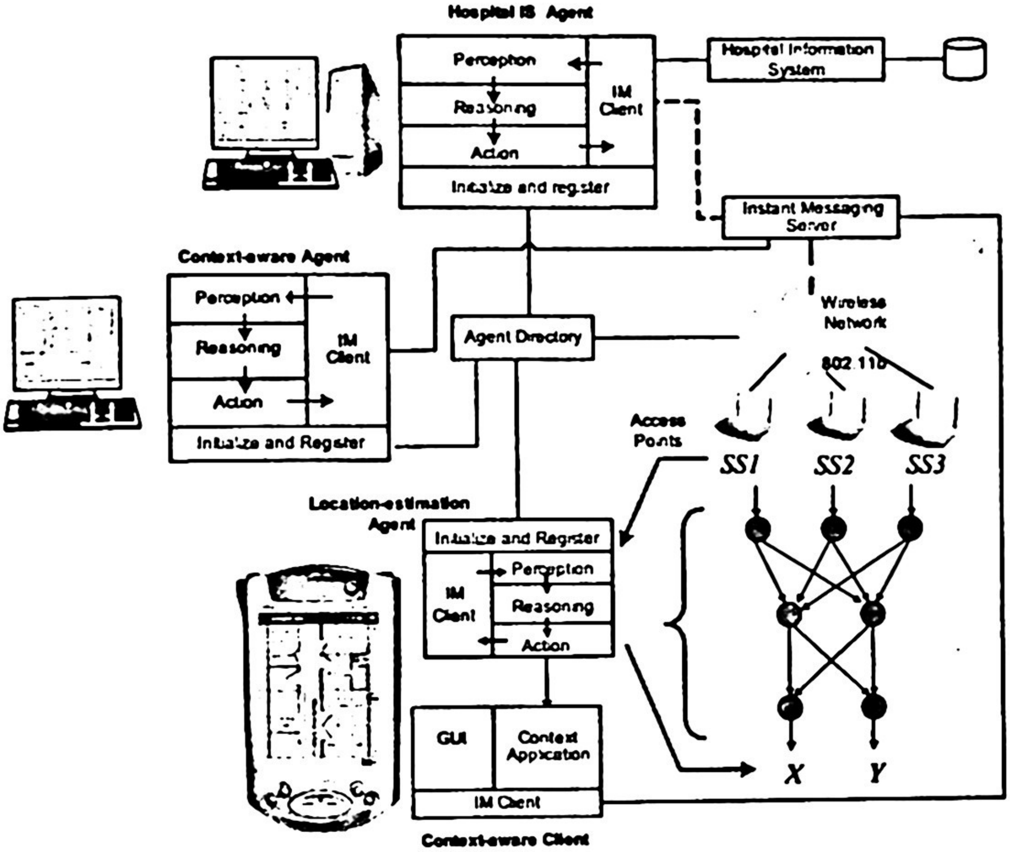


Fig. 2. Architecture of the agent-based system to support context-aware medical work

Agents

Several software components of the system are agents that autonomously act according to the perceived context information. In order to facilitate the implementation of autonomous agents for this pervasive system, we used a development framework called SALSA (Simple Agent Library for Seamless Applications). This framework provides a set of abstract classes and mechanisms to develop autonomous agents that act on behalf of users, represent services or wrap a system's functionality [13].

A SALSA agent can be launched explicitly by the user or automatically when certain conditions are met. Agents might run in a user's PDA, a trusted server, or any other computer with connectivity to the access point. A SALSA agent contains several components: a protocol to register it with an Agent Directory; a Jabber client through which users, user's agents, and services' agents interact by sending XML messages; and finally, the subsystem that implements the agent's autonomy that includes components for perception, reasoning, and action. The perception module gathers context information from the environment's sensors or directly from the users, other agents, or services through an IM client. The reasoning subsystem governs the agent's actions, including deciding what to perceive next.

Figure 3 shows the main classes provided by SALSA which enables to implement the internal architecture of an agent. The Agent class provides the methods to create and control the agent's life cycle. The agent's perception module consists of several Perception objects which sense the environment to gather context information. The framework provides the EntityToPerceive class that allows getting information directly from a sensor or the memory of a computer system. When an entity has new data, then it notifies to all Perception objects attached to it. The implementation of this perception module is similar to the Observer software pattern, which can be used when an object needs to notify other objects without making assumptions about who these objects are [15]. The Reasoning class contains abstract methods that will be implemented by the developer. Its implementation depends on the complexity of the agent's behavior. Finally, the Acting class provides an abstract method that a developer will implement to specify how the agent should react.

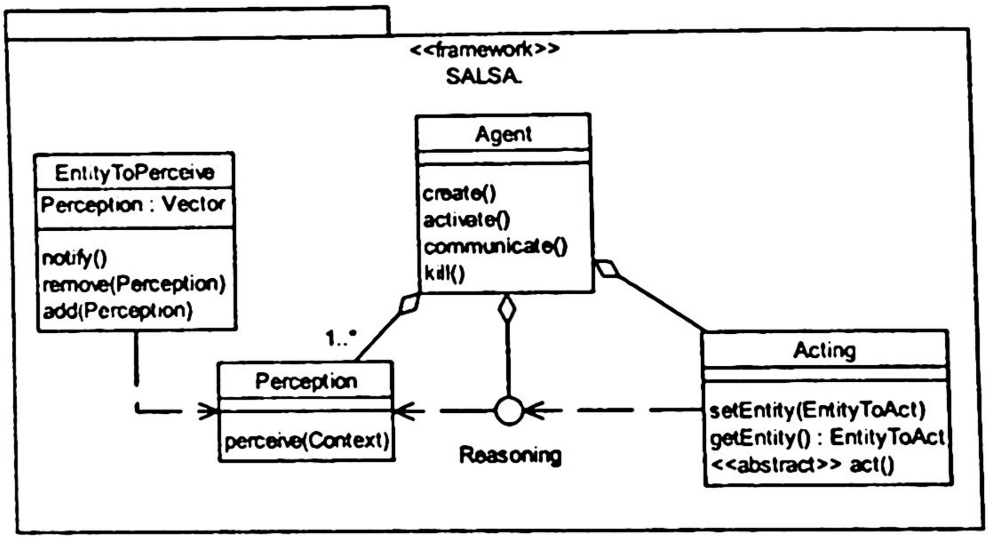


Fig. 3. Architecture of SALSA development framework

The system includes the following Agents:

- *Context-aware Agent* that supports the delivery of messages that are dependent on context. This is an entity to which all context-aware messages will be sent. The Context-aware Agent will monitor the environment to determine whether conditions are met for the delivery of the messages it retains. Its perception module registers the contextual information by monitoring the environment through the context interface. The context interface consists of a component to configure the environment (devices available, groups of users, map of the site, etc.) and mechanisms to detect changes in contextual information, such as, devices' state, users' position, etc. The reasoning component analyses the contextual information to determine if the conditions specified by messages it stores are met. If this is the case, the action module triggers the event specified by the user, which can consist of sending a message to any user with a specific role, or sending a message to a device in order to use its service or change its state. Thus, the Context aware Agent is a first class entity registered in the instant messaging server and with an IM roster that includes all people and devices of whose state it needs to be aware in order to deliver the messages it receives.

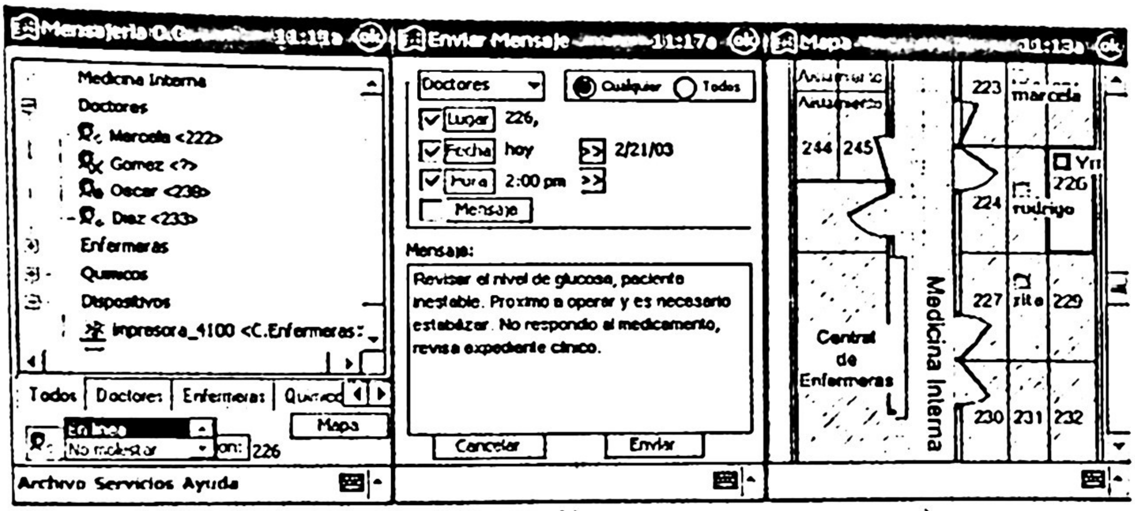
- In the user's PDA resides a *Location-estimation Agent*, which obtains the user's position by triangulation of at least three 802.11b access points [2]. Its reasoning component wraps a back propagation neural network, previously trained to map the signal strength obtained through the agent perception module from each access point to the user's location. Thus, the Context-aware Client updates its user's position information by communicating with the Localization-estimation Agent.
- The *Hospital IS Agent* provides access to, and monitors the state of, the Hospital's Information System which stores the patient's clinical records and other data relevant to the hospital, such as what patients are in what beds. For instance, considering the second scenario of Section 4, when the agent detects that the IS has been updated with the results of the user's laboratory analysis, the Hospital IS Agent notifies the doctor. It is also used to provide patient's information to the medical staff, based on their role and location.
- *Agents as proxies of devices*. Devices are appliances that offer services and are connected to the local network. Devices define possible states, the services they offer, and the protocol used to interact with them. Communication with a device is made through its agent, which runs as a daemon on a computing device with connectivity to an agent directory and a Jabber server. Agents provide a standard mechanism to initialize and register the agent with one or more agent directories, which contain information of all services offered in the environment.

6.2 A Sample Application Scenario

We illustrate the use of the context-aware messaging system revisiting the first scenario presented in Section 5. As Rita, the physician in turn checks her last patient, she decides to send a message to the doctor who will be reviewing the patient in the afternoon shift. She turns to her PDA showing the Context-aware client, which lists the staff and devices available in the hospital, to send a message to the first doctor to check the patient during the next shift. As illustrated in Figure 4a, this client is able not only to notify the status of other users (e.g. Online, Busy, Disconnected, Away, etc.), but also to show resources available in the vicinity (such as printers, air conditioning systems, etc.) and their status as well as the services they can provide to the user. In addition to the information provided by an instant messaging system, the Context-aware Client also shows the location of users and devices if known. This information is shown parenthesis after the user's name as shown in Figure 4a.

In contrast with traditional instant messages, when a context-aware message is created the sender needs to specify the circumstances that need to be met for the message to be delivered. Figure 4b shows the interface used by Rita to write the message and specify the context for its delivery. Rita writes the message and specifies that it should be sent to *any doctor* to be in *Room 226*, *after 2pm*, *today*. Through the interface shown in Figure 4b users can specify the following information to provide adequate context for the delivery of the message:

Recipient. The user can send a message to a specific user; to all users that meet the additional criteria; or only to the first user that satisfies the criteria. In our current prototype the sender specifies the recipient's identity by role (such as, a doctor, nurse, etc.) in the case of the scenario; Rita sends a message to any doctor in the next shift.



a) b) c)

Fig. 4. The user interface of the System's Context-aware Client

Location. The sender specifies an area where the user needs to be located for the message to be delivered. For this purpose a sensitive hospital map is displayed for the user (Figure 4.c), where she selects the designated area, for instance, Rita selects the room where she is currently located, patient's room 226.

Time and date. The sender can specify a lower and upper bound of time and date for message delivery. He could specify either one or both. The message won't be sent before the minimum date indicated and will expire without delivery after the maximum time. As Doctor Rita wishes to send the message to the doctor in the next shift, she specifies the period of time of delivery to be after 2pm.

State of a device. This is another context variable that a user can specify. Devices define the set of all possible states in which they can be at a given time. This list of states for all registered devices is presented to the user if he wants to specify that the device needs to be at a given state as a constraint for message delivery. For instance, send the message if the lights are on; the printer is jammed; the camera has detected movement; etc. We have already integrated only two devices in the system, a laser printer, and remote-controlled video camera.

Now that Rita has sent the message we describe how the components of the system's architecture interact for its delivery. Figure 5 presents a sequence diagram illustrating this process.

Doctor Gomez, the physician in that afternoon's shift, begins his daily routine by visiting each one of his patients. While he moves around the patient's rooms, the Context-aware Client in his PDA communicates with the Location-estimation Agent, to constantly update his position. When his location changes the Context-aware Client sends, trough the IM server, the doctor's presence to all users and agents who have him registered in their rosters. When doctor Gomez enters Theresa's room, the Context-aware Client updates his presence and notifies this to the Context-aware Agent. As the message's delivery conditions match the new context, the Context-aware Agent sends doctor Gomez the message written by Rita.

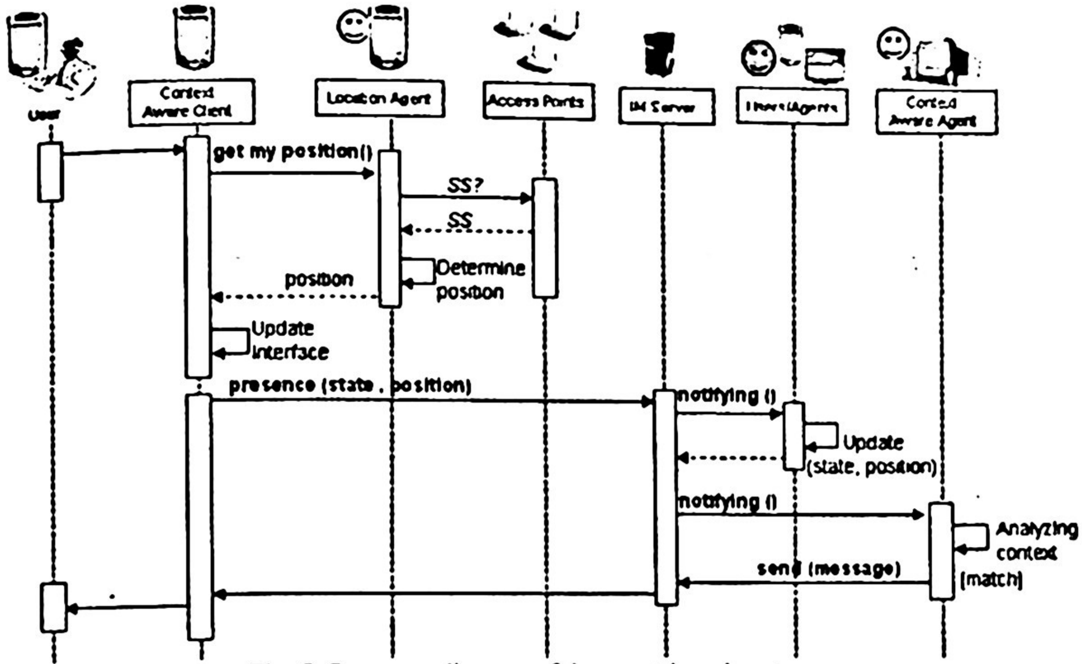


Fig. 5. Sequence diagram of the agent-based system

Figure 6 illustrates how the contextual message is displayed in the doctor's PDA. The recipient of the message can also request the conditions that were defined for the message to be delivered which should provide him with additional context to understand the message received.

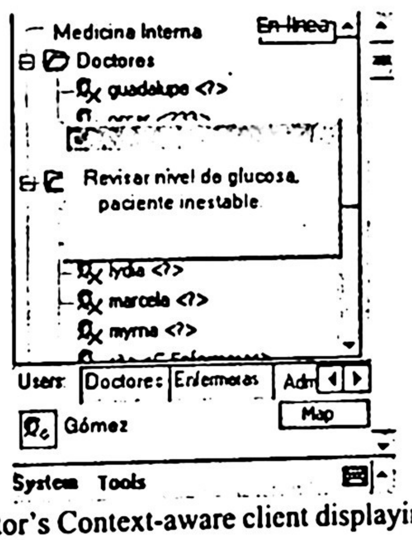


Fig. 6 Doctor's Context-aware client displaying a message

7. Preliminary Evaluation

A preliminary evaluation of mobile and pervasive technology is important before actual deployment and investing on the required infrastructure. Our approach was to conduct a session (Fig. 7) with personal from the General Hospital of Ensenada where we could evaluate the system's core characteristics, the staff's intention to use the system, and the staff's perception of system utility and ease of use. According to the Technology Acceptance Model [5], these aspects are fundamental determinants of system use.

The session's participants (28 medical staff) validated both scenarios and provided us with additional insights and opportunities for applying our technology. The results of the TAM questionnaire show that 91 percent of the participants would use the system. Additionally, 84 percent believe that using the system would enhance their job performance -a high degree of perceived usefulness- and 78 percent perceived the system would be easy to use.

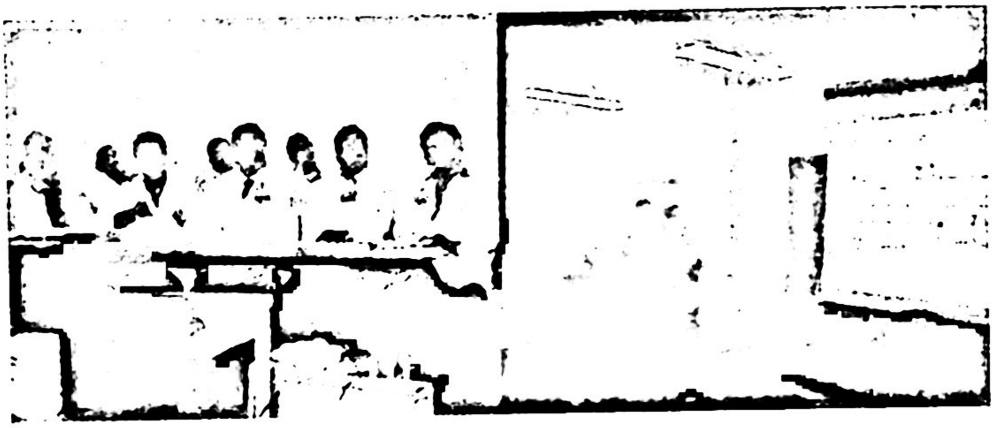


Fig. 7. Evaluation session of the system.

8. Conclusions

This paper presents and describes a context-aware messaging system which was specifically designed to support the contextual elements defining information management and collaboration at hospital settings. Ethnographic methods (namely participant observation and interviews) and scenario evaluations were used to define and clarify how contextual elements shape artifacts and influence work practices at hospitals. We found that hospital workers are highly mobile, working at different locations and shifts. The intensive information exchange between hospital's workers and their interaction with artifacts is highly dependent on situational information, or context [6], which can change unexpectedly. The above issues were addressed with the design of a context-aware collaborative system based on the instant messaging paradigm, which has proven to be an efficient interface to support collaboration and opportunistic interaction. It provides an adequate balance between awareness, privacy and disturbance.

The system we have presented allows mobile users to send contextual messages and access services by taking context into account. We used an agent-based architecture to facilitate the system's implementation. These components are autonomous agents that wrap complex system functionality, such as calculating the user's location, or deciding when to deliver a message; and introduce capabilities for negotiating services with other agents. Developers that wish to add a new device to the context-aware messaging system need only to program an interface to the device and define an XML document to specify the interaction with the services it provides. No changes are required to the Context-aware Client application used to interact with the environment. Furthermore, the states defined by these devices can also be used to specify the context required for message delivery.

The context-aware messaging system could be easily adapted to support scenarios in other areas, such as, in an educational environment. The system provides configuration options that allow users to initialize and modify the contextual space in order to specify the roles defined for its users (teachers, students, etc), a map of the location (a library, a school department, etc), and the services relevant to the application domain.

We believe that further research has to be conducted to understand how contextual elements could be supported in other settings and also to understand the evolving processes defining the relationships between those elements. Our future work will explore those issues. The work presented here is a first effort to understand those aspects within a hospital setting. However this initial work paves the way to define a robust technological architecture to support the contextual characteristics of work practice whenever it is conducted.

Acknowledgments

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