Augmenting Informal Collaboration in Hospitals through Pervasive Computing

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Abstract— **Informal communication is a necessary resource to accomplish activities in hospital work. It is used for collaboration and task coordination, as well as to gather knowledge and human resources necessary for patient care. Results of a field study that we conducted in a hospital show that most informal interactions happen face to face due to opportunistic encounters; a significant amount of these interactions involve the use of information artifacts –such electronic Health record, lab results among others- on discussions about patient care. However, some of these interactions present some breakdowns. For this reason, we present the concept of On-the-move Collaborative Environment, a design concept that provides pervasive support for informal co-located collaboration through the interaction of a set of electronic services and heterogeneous devices. Finally, we present our realization of an OCE based system through the implementation of a prototype that provides four main services that allow users to access persons, artifacts and devices every time/every where.**

Keywords-component; Collaborative work, Communication systems, Medical services.

I. INTRODUCTION

Communication is an essential resource in hospital work. In this setting, users experience a high level of mobility that enables them to establish co-located interactions in order to collaborate and coordinate their activities with colleagues, involving the exchange and analysis of documents distributed in space or time [2]. It occurs because medical activities are characterized by the need for collaboration and coordination among specialists with different areas of expertise, an intense information exchange, the integration of data from many devices or artifacts and the mobility of hospital staff, patients, documents, and equipment [1, 2].

Actually, in a field study aimed at understanding mobility and collaboration among hospital workers [8], results shows that hospital workers have meaningful encounters and get work done while in the hallway or out of their base. It means that opportunities for face-to-face interactions in this case arise naturally while people move around to perform their work. However, even though the hospital provides opportunities for collaboration, workers experience some inconveniences caused by the lack of awareness on the nearness of colleagues, interruption of interactions in order to gather information artifacts necessary for the collaboration and the absence of mechanisms that facilitate to groups of users the discussion of medical information stored in artifacts.

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In this paper we present an approach to support informal co-located communication in hospitals that enhances the opportunities for co-located collaboration by providing awareness of the potential of collaboration through the estimation of the other's location and the status of collaborative activities. Additionally, this approach enables augmenting interactions through a pervasive computing environment that allows users to access persons, artifacts and devices every time/every where they need.

The rest of this paper is organized as follows: Section II describes the methodology and findings of a field study we performed in order to understand the characteristics of informal communication in a hospital. Section III presents the characterization of On-the-move Collaboration Environment (OCE), a new conceptualization on how to provide support for informal co-located communication and work in mobile collaborative environments. Section IV shows the development of an OCE based system. Finally, Section V presents the concluding remarks and directions of future work.

II. UNDERSTANDING INFORMAL INTERACTIONS IN HOSPITAL WORK

To understand informal communication in medical settings, we conducted an observational field study in a public hospital. In it, we *shadowed* five physicians and five medical interns. Each subject was shadowed for two complete working shifts, placing special emphasis in understanding how informal interactions occurred, which their purpose was, and how local mobility influences the interactions experienced by hospital workers. Our goal was to have a good sample of interactions and capture all the communication in which those workers were involved as they conducted their work. This allowed us to detect some breakdowns experienced before and while workers are collaborating and capture facets of how technological support might fit into current work practices.

A. Influence of Mobility on Informal Communication in Hospital Work.

In order to have a better understanding of informal interactions at hospital, we classified and measured the observed interactions based on the intentionality of informal interactions as proposed in [4]. This classification is as follows: (a) those in which the initiator set out specifically to visit another party (intended), (b) the ones in which the initiator had planned to talk to another participants and took advantage of a chance encounter to have a conversation (opportunistic), and

(c) spontaneous interactions in which the initiator had not planned to talk to another participant (spontaneous). According to this definition, opportunities for *opportunistic* and *spontaneous* interactions emerged from the mobility experienced by workers in their work environment.

The results of our study show that on average 22% of the observed interactions in the hospital are opportunistic and 37% are spontaneous. These findings suggest that local mobility plays an important role on informal interactions in hospital work, by allowing for the creation of opportunities for face-to-face interactions (as almost 60% of the interactions happen face to face due to opportunistic encounters).

B. Augmentable Interactions

Results of our field study show that 28% of the face-to-face interactions could be improved by augmenting them with the use of technology. By *augmentable* interactions, we mean those interactions that occur among co-located participants due to opportunistic encounters or because at least one of the participants wants to take advantage of the affordances of face to face interaction, and where adequate technological support is used to permit access to the resources at that precise moment. Thus, it allows the achievement and improvement of the goal of the interaction without deferring it.

C. Example of an Interaction that could be Augmented

From our understanding of how work gets done in a hospital, we identified breakdowns on informal co-located collaboration in real use scenarios at hospitals. We describe one of such scenarios and present the breakdowns as follows:

A physician is in the Internal Medicine office when a medical specialist arrives and asks him about an X-Ray image he is consulting.

[Physician] *What do you think about this?*

[Medical Specialist] *(Looking the X-Ray results) Mmm, I think that he has (disease's name).*

[Physician] *Are you sure? Because he has (medical specialist explains the symptoms of patient).*

[Medical Specialist] *Yes, I do. I had a patient with similar symptoms.*

[Physician] *Are you sure? I think (there) could be some differences between the symptoms of these patients.*

[Medical Specialist] *Well, let me review the health record of my patient and I will discuss with you later.*

Later, the physician and the medical specialist met opportunistically in the hallway and they restart their previous discussion.

[Medical Specialist] *(Showing the physician a health record) Look, these are the symptoms of the patient I mentioned. His disease has the same features as those of your patient.*

[Physician] *Ok, you are right. But, which is the treatment for this type of disease?*

[Medical Specialist] *(Medical specialist explains the treatment for the patient). I have a book in my consulting room. Please go there later, I can lend it to you.*

This scenario presents some breakdowns while workers get into collaboration, such as interruption of interaction and the absence of mechanisms that enable hospital workers to access the artifacts necessary to enrich the discussion. These and other breakdowns occurring before workers start to collaborate are addressed through our proposal of an On-the-move Collaborative Environment.

III. On-the-move Collaborative Environments

In a hospital working environment, the tendency on technological support [3, 5, 9] is towards the use of a variety of heterogeneous computing devices, ranging from handheld computers that can be used to capture and access limited amounts of information (due to limited screen size and text entry capabilities), to PCs that can be used at fixed sites for longer periods of time, and finally, semi-public displays located at convenient places, which can be used to share and discuss information with colleagues.

In order to provide support for augmented collocated informal interactions, we propose the use of OCE's, a design concept that represents a collaborative pervasive space integrating an ensemble of specialized services. The basic idea is that an OCE is composed of a set of pervasive services that are provided and used by applications in fixed -e.g., desktop personal computers or public displays- or mobile devices - PDA's, and smart phones anywhere in the hospital.

Based on the results of our study, we propose a set of design insights that must be fulfilled by OCE's based systems.

A. Use of devices that allow workers getting into collaboration while on-the-move.

Mobility is a predominant characteristic of hospital work. Results of a study on hospital mobility show that physicians spent almost 10% of their time in hallways [8]. They are there not only to move from one operation center to another, but also to actually have meaningful encounters and perform work while in the hallway. For these reason, we argue that it is very important that systems that intend to provide support for hospital workers must allow them to move around the hospital area and to interact "every time - everywhere" as required by the actual situation.

B. Have easy access to information's sources

In hospital work, we found that in almost 27% of the total number of informal interactions, physicians and medical interns need to share or exchange information to accomplish the objective of their interaction. Currently, they use physical artifacts to do this, like medical records and X-Ray images, among others. Additionally, they use external information like medical guides, digital libraries and books among others, in order to enrich the content of their interaction. For these reasons, we argue that it is very important that systems aimed

at providing support for hospital workers allow them to have easy access to digital information sources.

C. Use of devices and services that allow interactions based on medical evidence

Physicians and medical interns often discuss clinical cases. We observed that in 18% of the informal interactions they used and shared information stored in physical artifacts (medical records, X-Ray images and books among others) and electronic devices (document stored on PCs or PDAs and digital libraries among others) in order to explain to others their opinions. All these meetings were directly related to patient care. For these reasons, we argue for systems that allow hospital workers to use heterogeneous devices that help them to establish interactions based on medical evidence.

D. Awareness of the opportunities for collaboration

In informal interactions there are two main elements that trigger people to initiate collaboration with others: the availability of a communication or interaction channel (e.g. physical proximity) and the interest or need of at least one of the participants to collaborate with the other [7]. For these reasons, systems should allow hospital workers to be aware of the other's presence, identity and location, as well as of an adequate moment for getting into collaboration with them.

E. Seamless information access and sharing

Almost 18% of informal interactions hospital workers had co-located collaboration in hallways, related to patient care, based on medical information stored in physical artifacts or electronic devices, as well as on external medical information sources. While collaborating, information is transferred among these artifacts or devices. For these reasons, we argue that it is very important that systems allow hospital workers to easily share and exchange information among them.

IV. An OCE Based System

Based on the nature of hospital work, we address our vision of OCE's through the development of a system that is able to support improvised meetings among people distributed in their work area. It provides four main services described as follow:

A. Location Awareness for Co-located Interactions.

We use a location estimation component that estimates the position of users within a hospital [6]. A trained backpropagation neural network (BNN) is embedded within the component and is used to estimate the approximate location of the users. The input of this BNN is the signal strength of radiofrequency signals received by a mobile device, carried by medical staff, from at least three access points and map input sequences to output sequences (2D coordinates). It allows users identifying the other's location as a means to discover opportunities for interaction or collaboration.

B. Awareness on the Potential for Interaction.

The *awareness on the potential for interaction service (APIS)* is aimed at enhancing the opportunities for co-located encounters. This service uses the Location Estimation Service to provide to users with awareness on the nearness of those with which they need to interact opportunistically.
Using the *Location Estimation Agent* (see Fig. 1), this service obtains its own location and asks if the user needs to interact with some nearby co-worker; if so, the *Pending Task Agent* sends a voice and graphical notification to the user.

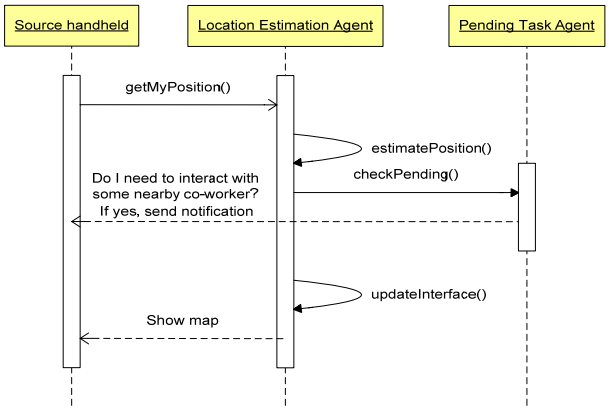

Figure 1. Potential Collaboration Awareness Service

The capture of pending interactions could be done automatically by the system at the time of detecting the occurrence of particular events that triggers the user's need of interacting with others, such as the availability of lab result or the change of treatment of patient (indicated in a medical electronic record) that need to be discussed among the hospital workers. Otherwise it could be done explicitly by the user.

C. Seamless Information Transfer among Heterogeneous Devices.

We designed and implemented a migration component that allows the seamless transfer of information among heterogeneous devices [6]. It allows users to transfer information, such as digital files and URL's, to any device in the vicinity, such as a PDA, a PC or a public display, from a handheld computer.

This service addresses the need for information transfer between heterogeneous devices. The command is activated from the file system menu that is displayed with a right-click or triggered. Once the menu appears, the user needs to select the *Transfer To…* option and a list of target devices in the vicinity is displayed. The user needs to choose a target device to start the transfer of the information. Once the information has been transferred, a notification is sent to the source device and the file is opened by an application in the target device, according to its file type.

D. Remote Control of Heterogeneous Devices.

The idea consists of displaying the screen of any device in the vicinity, such as a PDA, a PC or a public display, on a handheld computer, and being able to remotely share the control of the device with its owner and/or other users [6].

Figure 2. Remote control of a large display. (a) A physician interacts with a public display while a colleague remotely interacts with the public display from his PDA. (b) A close up of the PDA's remote control application.

Thus, this service allows a group of physicians to remotely control a public display with their handhelds (see Fig. 2a). The user that has control of the floor is able to move the cursor as well as type on the device being controlled, while the others are only able to point at the screen using a telepointer.

E. Sample of an Interaction Augmented through a OCE-based System

A physician is in the Internal Medicine office consulting an X-Ray image in a public display when a medical specialist arrives and asks him about it.

[Physician] *What do you think about this?*

[Medical Specialist] *(Looking the X-Ray results) Mmm, I think that he has (disease's name).*

[Physician] *Are you sure?*

The physician uses his PDA to display the patient's electronic personal record in the public display (seamless information transfer service) and shows to the medical specialist the medical history of the patient that he thinks is relevant for the diagnosis of the patient's disease.

[Medical Specialist] *Yes, I do. I had a patient with similar symptoms.*

The medical specialist uses his PDA to display the X-Ray image of another patient in the public display (seamless information transfer service) in order to explain to the physician the similarities between these patients (remote control of heterogeneous devices

[Medical Specialist] *Look, these are the symptoms of the patient I mentioned. His disease has the same features as those of your patient.*

[Physician] *Ok, you are right. But, which is the treatment for this type of disease?*

[Medical Specialist] *(After explaining the treatment for the patient, using the remote control of heterogeneous device service), the medical specialist accesses his office's computer to retrieve information from a medical guide related to the medication and to the patient's condition, and transfers it to the physicians' PDA). I have this information that could be useful to you*

[Physician] *Ok, thank you.*

V. CONCLUSIONS

The nature of hospital work provides opportunities for co-located informal communication. Nevertheless, co-located communication among hospital workers presents some inconveniences as previously discussed in this paper.

Further research in pervasive computing [3,5,8] has been focused on exploring novel interaction paradigms aimed at seamlessly integrating heterogeneous devices to support face-to-face encounters. Based on results of a field study that we conducted in a hospital, we propose the concept of On-the-move collaborative environments, a collaborative environment that supports informal co-located collaboration through a set of pervasive elements, such as heterogeneous devices and four electronic services; i) location estimation, ii) awareness of potential collaboration, iii) seamless information transfer among heterogeneous devices, and iv) remote control of heterogeneous devices.

The main strengths of our proposal consist on the integration of independent functionalities that provide hospital workers with an ensemble of cooperating services under one single platform, and that it allows them using these services to enhance their co-located informal work interactions, as well as that the actual design of the environment was informed with requirements that emerged directly from observations of the real hospital work situations that we intend to support.

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