# THE MAGIC WINDOW:

# BALANCING PRIVACY AND AWARENESS IN OFFICE SETTINGS

A Thesis Submitted to

The College of Graduate Studies and Research

In Partial Fulfillment of the Requirements

For the Degree of Master of Science

In the

Department of Computer Science

University of Saskatchewan

Saskatoon, Canada

By

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Keywords: Privacy, awareness, availability, casual interactions, iterative design, augmented office window, co-present media space system.

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ABSTRACT

Co-workers who are physically distributed in the same building often obtain information about others through the windows in office doors. Using the information gathered by looking through the window, they can determine whether it is a good time to initiate a conversation with the occupant. There are, however, two problems with ordinary glass windows. First, there are times when the window does not provide enough information, such as when the occupant is away. Second, there is potential to violate the occupant's privacy; as a result of the privacy risk, people often cover their windows entirely. If office windows are to work efficiently as a support for collaboration, there must be a balance between awareness and privacy. In this research, I augmented the functions of a physical office window with a computer-mediated replacement called the Magic Window. The Magic Window collects video of the occupant, mediates the signal in various ways, and then presents the altered view on a screen that replaces the glass window. The Magic Window provides a better balance of awareness and privacy in office settings by allowing occupant to differentiate the amount of awareness information based on the viewer. The Magic Window system was tested in an eight-month field trial. The trial showed that the augmented window did provide a balance of privacy and awareness, and also raised a number of issues that will aid the design of future design of co-present media spaces.

ACKNOWLEDGEMENTS

Thanks to God who provided me with courage, strength, and wisdom to complete this research.

Thanks to my family in Korea for their support and prayer. Special thanks to my wife, Jean for her patience and ongoing support for me.

Thanks to my supervisors, Dr. Carl Gutwin and Dr. Sriram Subramanian for their guidance, support, advice, and confidence in all aspects of this research.

Thanks to Merlin Hansen and Seth Shacter who were the primary users of the Magic Window prototype for a number of useful feedback, enthusiasm and interest in the system.

Thanks to all the people who participated in this study and provide useful feedback during interviews.

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# CHAPTER 1

# INTRODUCTION

Co-workers who are physically distributed, but are in close proximity regularly interact with one another. This casual or informal interaction is spontaneously initiated by one person (Kraut, 1988). Through chance meetings in a hallway or informal discussions between two or more co-workers, casual interactions are initiated based on informal awareness: the general sense of who is around, what others are doing, and whether people are available for collaboration (Dourish and Bly, 1992).

Informal awareness plays an important role in initiating casual interaction. Informal awareness can be easily obtained from the environment without paying specific attention:  it can be gathered by glancing around a common area, by peeking into an office through the window or the door, or by hearing ambient sound coming out of an office. These pieces of information help people to interpret their co-workers' state and find an opportune time to start an interaction with the other person. Without awareness of others, initiating interactions becomes difficult because people are prone to inappropriate interruptions and privacy violations.

As an example of how people use awareness information in the real world, imagine an office visitor standing near an office door, wondering whether he can start an informal meeting about a project on which he and his co-worker, who is the office occupant, are currently engaged in. First, he notices that her office door is ajar and convinces himself that she is currently in. Next, he tries to see whether she is busy or not. He peeks into the office through the office window and sees her talking on the phone. At that moment, he understands that this is not a good time to start an interaction with her because it is not socially acceptable to interrupt others while they are engaged in conversation.

However, there are two main problems when information is obtained through a conventional glass office window. First, in some cases, such as when the occupant is not currently in the office, the viewer gets very little awareness information about the person. The viewer might want to know whether the occupant will return or has left for the day. Second, the occupant may feel that privacy is compromised when people look through the window.

Providing richer awareness means better chances of successful interactions, but it also means more chances of violating privacy. However, strict control over privacy reduces the amount and fidelity of awareness information. As a result, preserving too much privacy makes initiating casual interactions difficult. The nature of the trade-off is as follows: the more awareness that is provided, the more appropriate initiation of interactions can be achieved; yet, the more awareness that is provided, the more threats to privacy are created (Hudson and Smith, 1996). This fundamental trade-off must be resolved for effective collaboration because initiating interactions will be awkward and difficult without a balance between awareness and privacy.

## 1.1 Problem

The problem to be addressed in this thesis is that *it is difficult to balance privacy and awareness depending on context in current office settings*.

In current office setting, the viewer obtains informal awareness about the occupant by looking into a physical office window. This action can violate the occupant's privacy. On one hand, there must be efficient ways to control privacy. From the occupant's point of view, some people should be able to gather richer awareness than others, but this kind of control is extremely difficult with an ordinary office window. On the other hand, if the occupant controls the privacy information too much, very little awareness will be provided. This will cause improperly timed interruptions, and collaboration will rarely happen. Therefore, there must be a balance between awareness and privacy for successful start of interaction. There are two specific problems in interactions in current office setting, one problem for the occupant and one problem for the viewer.

### 1.1.1 Problem for the occupant (problem of privacy)

The occupant wants to preserve as much privacy as possible, but the occupant's privacy may be violated when a viewer peeks into an office window for awareness information. This problem occurs because the occupant cannot control privacy with a physical window in a fine-grained and lightweight manner- everyone gets the same level of awareness regardless of their relationship with the occupant. With an office window, the occupant has only two options, either coarse-grained control in a lightweight manner (e.g., leaving window blinds shut or open all the time) or fine-grained control in a heavyweight manner (e.g., using door to indicate different levels of availability).

### 1.1.2 Problem for the viewer (problem of awareness)

The viewer wants to obtain as much awareness as possible, but a physical window can only provide limited information for the viewer. Insufficient awareness may lead the viewer to interrupt on inappropriate occasions or may not be beneficial to the viewer at all. This problem for the viewer occurs because ordinary office windows are unable to provide important additional information, such as asynchronous awareness (information about what has happened in the past). For example, the viewer obtains very little information about the occupant when the occupant is not in. Thus, they do not usually know when the occupant will become available. Knowing what has happened in the recent past might be very important in determining the occupant's current availability.

## 1.2 Motivation

The main motivation for solving the problem of balancing privacy with awareness is to improve collaboration for co-workers by assisting and encouraging casual interactions.

Unless a balance between awareness and privacy is achieved, both safeguarding privacy and providing awareness will not happen at the same time. The office occupant will not be willing to disclose information without a mechanism that safeguards privacy. This will result in insufficient awareness, and the viewer will interrupt the occupant even when the occupant is not available. In contrast, a good balance between awareness and privacy will make the occupant feel comfortable in disclosing information and will assist the viewer in finding good times to initiate casual interaction, leading to more efficient interactions.

## 1.3 Solution

The solution explored in this thesis is to build a computer-mediated augmented window system, the Magic Window, which allows for f*ine-grained control* over privacy in a *lightweight manner* by differentiating the amount of awareness disclosed according to the viewer's relationship to the occupant. The Magic Window is based on video, but the signal is intercepted, altered, and displayed by a computer. The system provides the office occupant with fine-grained control over privacy and provides the viewer with an appropriate amount of awareness depending on the context.

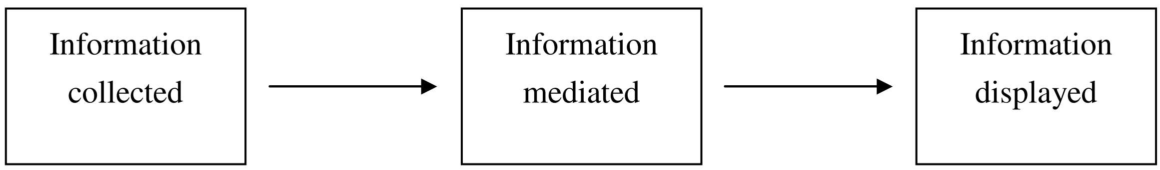



**Figure 1.1: Framework of Augmented Window**

Figure 1.1 presents a basic framework of the Magic Window. The collected information mainly consists of the current activity of an occupant in the form of video captured by a video camera. The captured data is processed to protect the occupant's privacy by various techniques (e.g., image processing techniques). The altered video signals are then displayed on a screen that replaces the glass window.

## 1.4 Steps in the solution

The research project was carried out in five steps:

1. *Determine which information to be provided through the augmented window*

This step brought together and organized the information that would be useful for the viewer, based on what the viewer would want to know. Gathered information included informal awareness and privacy-sensitive information from the occupant's perspective. Informal awareness was then categorized into synchronous and asynchronous information and sorted according to its sensitivity.

2. *Determine how to control privacy information*

This step used the results of the previous step to determine what kind and what amount of information would be disclosed according to the occupant's privacy setting (global privacy setting) and current viewer (local privacy setting) in order to minimize privacy violation while maximizing awareness.

More importantly, the relationship of the viewer to the occupant was used to determine the amount of awareness to be provided, since fine-grained control over privacy was expected by using relationship (Davis and Gutwin 2004). The results of this step were user interfaces that allowed the occupant to control privacy information in an efficient manner, and a set of rules and control techniques that coordinated awareness information with privacy information.

3. *Determine how to gather and display awareness information*

In this step, a set of candidate techniques were considered and developed for gathering the awareness data determined in Step 1, and for visualizing this information through the Magic Window. Some of them were difficult or impossible to visualize the information through the Magic Window. The result of this step was a list of sensors to be used to gather awareness information and techniques for visualizing gathered awareness information through the Magic Window.

*4. Implementation of working system*

A system was implemented to demonstrate the feasibility of a co-present media space system and to provide a working prototype for field evaluation. The results of the previous two steps, which are methods to control privacy in Step 2 and methods to gather and display awareness information in Step 3, were used to design the Magic Window system that mediated the inflow and outflow information between an office and a hallway. The result of this step was a working system that balanced privacy and awareness and that was used for the evaluation to identify usability issues in co-present media spaces.

## 1.5 Evaluation

The evaluation was based on user experience with a focus on its usability in a real world situation. The first main question to be answered was whether the system worked in practice. The second main question to be answered was what design issues and problems would likely happen in real system use.

The questions were answered with an iterative usability evaluation of the Magic Window. The Magic Window prototype was deployed in real office settings for evaluation for an eight-month time period. Users' experience was explored through observations on a regular basis, frequent informal interviews and semi-structured interviews followed by questionnaires. Both the viewers and the occupants found that the system was useful and were satisfied with the system (see Section 4.2.3). We also identified a set of design issues and problems that had impact on system usability (see CHAPTER 5). The results of such evaluation were a list of issues that affected the design of co-present media spaces, a set of possible solutions to the problems raised by issues, and different versions of Magic Window prototypes.

Another question that could be asked in the evaluation is if the Magic Window is better in terms of facilitating interruption and encouraging interactions for collaboration than an alternative (e.g., glass window) in a real situation. To answer such questions would require deploying several final versions of the Magic Window system in a real office environment and tracking of occupants and viewers' experience as well as interaction episodes by observation and system log. This is out of the scope of the M.Sc. thesis and is possible future work to be explored.

## 1.6 Contributions

There are two major contributions of this research. The first major contribution is a working system that showed the feasibility of a co-present media space system, which mediates information in a way that privacy and awareness are balanced in an office-hallway setting. The second major contribution is a set of identified issues that will aid the design of future design of co-present media spaces. Minor contributions include implementation of relationship based privacy regulation techniques, information gathering techniques using hardware sensors, a set of techniques for balancing privacy and awareness.

## 1.7 Overview of Thesis

The remainder of this thesis is organized a follows:

Chapter 2 outlines the foundation areas that are needed in order to know to design and build a co-present media space system to achieve a balance between privacy and awareness.

Chapter 3 describes the underlying design principles of the system as a mediator between privacy and awareness. System evolution of over a period of time and technical implementation details are also discussed in this chapter.

Chapter 4 describes methods of evaluation performed over the course of system deployment. Specific deployment context, evaluation details, evaluation timeline and findings including how users used the Magic Window system are presented and discussed in this chapter.

Chapter 5 discusses fundamental issues and the design implications for co-present media spaces, which were identified and analysed based on the findings during the deployment phases.

Chapter 6 concludes the thesis and describes its contributions and future work that may be carried out.

CHAPTER 2

# REVIEW OF LITERATURE

This chapter reviews previous work in several areas that underlie this research. These areas include group awareness and informal awareness, casual interaction, privacy, awareness support systems, techniques for safeguarding privacy in such systems, and visualization of awareness histories.

## 2.1 Group Awareness and Informal Awareness

Awareness is knowledge about the state of a dynamically changing environment, a setting bounded in time and space (Endsley, 1995). There are four basic categories of awareness: *who*, *what*, *where,* and *when* categories (Gutwin and Greenberg, 2002). For example, the basic set of awareness includes *who* is doing *what,* and *where* and *when* events happen. In particular, the *when* question can be applied to *who, what,* and *where* questions. Awareness can also be categorized into synchronous awareness and asynchronous awareness depending on the *when* question. Synchronous awareness is information about state of environment we continuously receive in real time. On the other hand, asynchronous awareness is information about what has happened in the past.

Knowledge about a state of the environment can be called group awareness if it is focused on other people. In computer supported cooperative work (CSCW) research, several kinds of group awareness have been investigated: conversational awareness, workspace awareness, structural awareness, and informal awareness (Gutwin, 1997). Conversational awareness is the understanding of visible or audible cues of others provided during a conversation. They include facial expressions, eye contact, and verbal cues, and they are crucial in maintaining conversation. Workspace awareness is the up-to the moment understanding of another person's interaction with a shared workspace (Gutwin, 1997). Workspace awareness helps distributed users to collaborate efficiently through real-time groupware. Structural awareness is knowledge of a group's organization and understanding of the working relationships. Being aware of roles and relationships, a group of members within an organization can operate smoothly without much need for coordination (Leland et al. 1988). Lastly, informal awareness is the general sense of who is around, what others are doing, and who is available for collaboration (Dourish and Bly, 1992), and it helps people to determine a good time is to initiate casual interaction. Lack of informal awareness can cause people to interrupt others improperly at inappropriate times. Among the several kinds of awareness, informal awareness is the most important factor in casual interaction. This thesis will focus on informal awareness in particular.

Gathering informal awareness in co-located environments can be done subconsciously without paying specific attention to the information source. For example, it is gathered by walking down the hallway, peering in an open office, looking into an office window, or overhearing conversation (Kraut et al., 1993). People obtain informal awareness through the process of "browsing the social environment," and people move into informal conversation based on the information they gather. Kraut et al. found that this awareness information plays an important role in determining others' availability for casual interaction.

## 2.2 Casual Interaction

Casual interaction is unplanned, frequent, and opportunistic interaction or conversation, such as a chance meeting in a hallway or unplanned informal meeting in one's office, which occurs in a serendipitous manner (Kraut et al., 1988). Its purpose, duration, and degree of involvement are not usually planned in advance, but are negotiated during the interaction (Borning and Travers 1991; Kraut et al., 1993).

Physical proximity is a major function in the frequency of casual interaction. Kraut at al. (1988) found that physical proximity is extremely important for successful collaboration initiation; co-located workers are more likely to communicate frequently. Furthermore, they found that the quality of communication is better, and the cost of communication is cheaper than communications between remotely distributed members because among closely distributed workers, face-to-face interaction is more common, and there is no need for long distance calls. According to Kraut's observations, the probability of collaboration significantly decreased from 10% to 2% if people are not located in the same corridor but on the same floor. If collaborators are on different floors, collaboration rarely happens with (0.3% of collaboration).

Casual interaction supports the execution of work-related tasks, coordination of group activity, and the build-up of community among co-workers (Dourish and Bly, 1992; Kraut et al., 1988). It also accounts for a large portion of the work day. Whittaker et al. (1995) found that 31% of work time was spent in casual interaction and observed that the unplanned interactions led to detailed task oriented discussions. Removing such interactions significantly decreases effective collaboration (Kraut et al., 1988). It suggests that casual interaction is an area where technical support can assist effective collaboration.

As the role of physical proximity in casual interaction suggests, remote workers have difficulties collaborating with other members. In an attempt to emulate physical proximity, CSCW researchers have built several types of systems to support casual interactions among distributed groups: e.g., (Dourish and Bly 1992; Tang and Rua 1994; Hudson et al. 1996; Obata and Sasaki 1998; Crowley et al. 2000; Fogarty et al. 2004). When implementing technology to support collaboration, Kraut et al. (1988) suggested that two requirements must be met. First, the cost of initiating casual interactions must be low. Potential collaborators should be able to easily contact each other before committing to an elaborate work task. Second, the quality of interaction must be high: the interaction should occur in real time so that during the interaction, people should be able to receive dynamic feedback as in face-to-face interaction. These two requirements suggest the need for video in collaboration. Always-on video is effective in supporting collaboration because it can support low-cost, frequent, and spontaneous interactions through visual cues that provide rich informal awareness. Thus, many awareness support systems for casual interaction among remotely distributed members use live video (see Section 2.4.1).

However, video-based systems have privacy implications since someone has access to live video of a person. There are also problems with the distraction created by such systems. The nature of privacy and techniques to protect users' privacy will be discussed in the next section.

## 2.3 Privacy

There are many definitions of privacy. The general definition of privacy is the interest that individuals have in sustaining a "personal space," free from interference by other people and organisations (Clarke, 1997). In this section, privacy will be discussed as a *control process* over information (Altman, 1975): privacy is the ability of an individual to control the information about the self available to others, and the ability to control access to the self. In Altman's theory (1975), privacy is described as a boundary control process regulating access to the self, and this control over information needs to be available for computer mediated communication (Boyle and Greenberg, 2005). Three main types of control over privacy are solitude, confidentiality, and autonomy (Boyle and Greenberg, 2005); however, this thesis will focus on the first two types in a situation where an office occupant controls the information available to office visitors and controls the office visitor's interruptions in the current office setting.

*Solitude* is control over information moving toward the self: that is, one's control over interactions requested by incoming interruptions. When a person is interrupted for interaction, the person pays attention to the interruption. The attention to interruption is closely related to solitude violation. In current office settings, the visitor's interruption violates the occupant's solitude if the interruption occurs when the occupant is not available (e.g., when busy or when engaged in a meeting). As shown in Figure 2.1, inflow of information from the hallway has the potential to violate the occupant's solitude. The office door is an example of how people currently control solitude. For example, a wide open office door can suggest willingness to be interrupted. Thus, it can be inferred that the occupant is currently available for interaction.

*Confidentiality* is control over information moving outward from the self to others. It is the ability to regulate what information is disclosed, and to what extent, in different situations. In a typical office setting, the outflow of information has the potential to violate the occupant's confidentiality (Figure 2). Two important points in confidentiality to be considered are information fidelity and sensitivity (Boyle and Greenberg, 2005). For instance, disclosure of high fidelity information can increase the chances of violating one's confidentiality. Also, highly sensitive information, such as credit card information, may need to be more carefully controlled. One should take into account these aspects of confidentiality in order to effectively control one's privacy. For example, an office occupant can make sure privacy is protected by disclosing high fidelity of non-sensitive information (e.g., presence information) but low fidelity of highly sensitive information (e.g., current computer activity).

The fundamental tradeoffs between privacy and awareness (Hudson and Smith, 1996), mentioned in the introduction section can be further explored in terms of solitude and confidentiality. The more information that is transmitted, the greater potential for invasion of one's confidentiality. However, providing more information can actually lead to better protection of solitude because office visitors who are able to better determine the occupant's availability with richer awareness will not interrupt at inappropriate times (Dabbish and Kraut, 2004). This suggests that there must be a balance not only between confidentiality and awareness, but also between confidentiality and solitude.

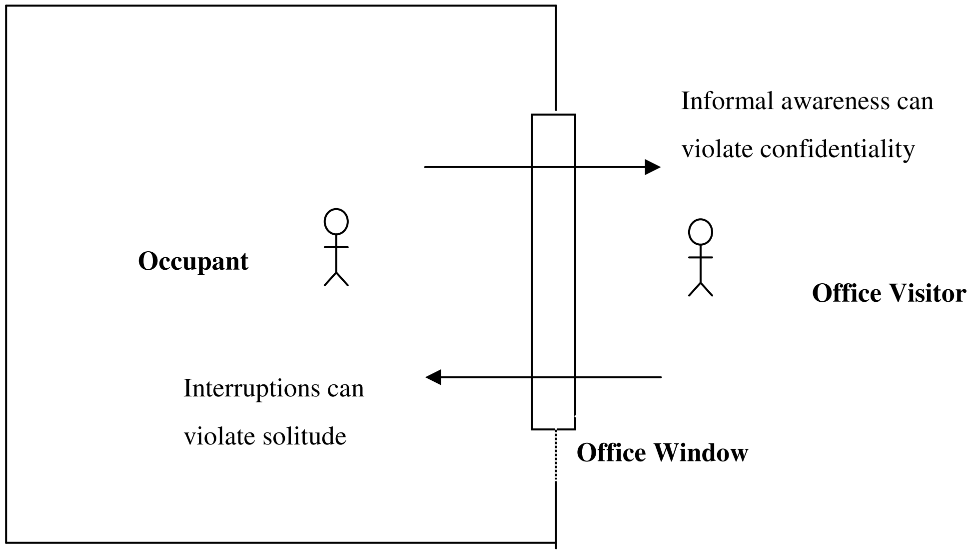



**Figure 2.1: Inflow and Outflow of Information through an Office Window between Office Occupant and Office visitor**

## 2.4 Awareness Support Systems

Awareness support systems, also called “media spaces” emerged from efforts to support the social practices of collaborative work (Bly et al., 1993). They use video, audio, and other media to create a virtual shared space between users with the goal of encouraging casual interactions and improving informal awareness of activities among distributed group members (e.g., Fish at al., 1993; Dourish and Bly, 1993; Tang and Rua, 1994). Media spaces can be categorized into video-based and non-video-based media spaces, and they are discussed in the following two subsections.

### 2.4.1 Video-based Media Spaces

The main motivation of using video for communication based media spaces is to reconstruct rich interactions in situations where face-to-face conversations are difficult (e.g., when people are remotely distributed). Video can not only provide rich awareness, but also substitute for physical proximity. Video can also increase spontaneity of interaction, support social interactions, and cope with complex and equivocal communication (Kraut et al., 1993). There are three interaction models in video-based awareness support systems: the *telephone* (e.g., video conferences), *overview* (e.g., Borning and Travers, 1991; Dourish and Bly, 1992; Lee et al. 1997) and *hallway* models (e.g., Tang and Rua, 1994; Obata and Sasaki, 1998). They differ from one another in terms of initiating interaction, but the boundary between the last two models can be blurred by adapting a hybrid approach of the overview and hallway models. Figure 2.2 shows a typical video-based media space environment.


**Figure 2.2: Typical Setting of Video-Based Media Spaces**

The *telephone* model (e.g., video conferencing) allows a caller to interrupt the recipient of the call whenever the caller wishes to contact the person. This model requires the recipient to respond to a call actively. It can be ensured that one's confidentiality is not violated by not disclosing any video and audio information to the potential callers, but the caller can invade solitude by calling at inappropriate times.

The *overview* model helps a user to quickly and continuously assess what is happening to other users at different locations through periodically updated multiple video images (Figure 2.3). Polyscope (Borning and Travers, 1991), Portholes (Dourish and Bly, 1992), and NYNEX Portholes (Lee et al., 1997) are good examples of overview media spaces. In such systems, users can determine an appropriate time to interact with others without explicitly interrupting call recipients, and there is no need for explicit action for a user to let others watch one's image. Users of Portholes (Dourish and Bly, 1992) showed that the system not only provided awareness of others but also worked positively towards building a sense of community among remotely distributed members. However, several people felt uncomfortable about having their images broadcast without knowing who was watching. One's confidentiality can be easily violated in the overview model if users are not able to know who is watching. Lee et al. (1997) further explored the overview model through an improved version of Portholes prototype called NYNEX Portholes. It allowed a user to control privacy by providing different fidelity of video images. They suggested that porthole-based video awareness tools must support reciprocity (see Section 2.5.3), provide an easy way to control privacy, and give immediate feedback on user control over privacy.


**Figure 2.3: Overview Model: Portholes (Dourish and Bly, 1992)**

Last, the *hallway* model (Figure 2.4) simulates what happens when a person walks down a hallway. The "glance" functionality allows for a short-time-period video connection so that the caller can see whether the recipient is available for interaction prior to conversation. Upon the recipient's acknowledgement, a full video and audio connection is established. Otherwise, the glance connection times out. The hallway model requires the caller to initiate brief, reciprocal glances in order to obtain awareness of the recipient, whereas in the overview model, the caller can gather awareness without explicit actions. Systems such as CRUISER (Fish et al., 1993), OfficeWalker (Obata and Sasaki, 1998), and Montage (Tang and Rua, 1994) adopt the hallway model. In the CRUISER system, the "glance" feature proved to be abrupt and intrusive like a telephone. Thus, most participants felt their solitude was threatened. To address this problem, Montage (Tang and Rua, 1994) introduced a fade-in video effect to reduce the perception of abruptness. However, users still commented that a glance was still more disruptive than someone in a hallway looking into the office. Obata and Sasaki (1998) claimed that the intrusiveness of the "glance" feature comes from breaking down the sense of distance which people maintain before initiating conversation. They created a virtual hallway where a user and the user's neighbours can see the only users who enter the virtual hallway. The idea of creating a virtual hallway seemed to be beneficial because a glance at recipients in the same virtual hallway did not interrupt the activities of recipients but supported unintended interactions by enabling participants to glance without reluctance.

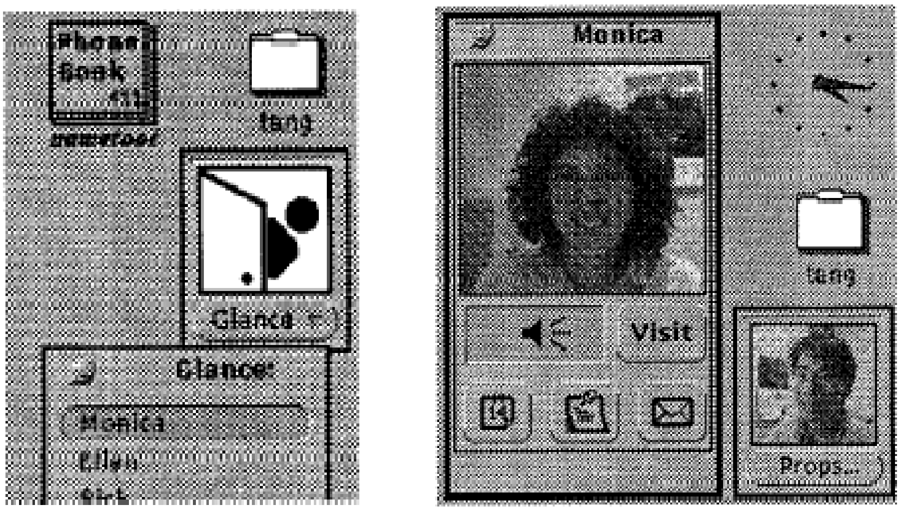



**Figure 2.4: Hallway Model: Montage (Tang and Rua, 1994)**

### 2.4.2 Non-Video-Based Media Spaces

Despite many advantages of using video for supporting awareness among distributed members, video still has two main problems. First, users are concerned about privacy issues because they do not feel comfortable with a camera watching all the time (Friedman et al., 2004). Second, video requires too much bandwidth to be transmitted on many real-world networks. An awareness server such as an instant messenger (IM) is a good example of an awareness support system that does not use video and has less potential to violate confidentiality. Some examples of IM systems are MSN Messenger (Figure 2.5) and Peepholes (Greenberg, 1996) (Figure 2.6). Such systems adapt a minimalist approach to address problems with video. Instead of using video for awareness, Peepholes uses iconic representations of users as an indicator of the presence and availability of a user. In efforts to attenuate privacy threats, these systems hide context details and present abstraction of the prospective recipient's availability. However, it is sometimes hard to assess one's activity accurately (e.g., distinguishing between inactivity and absence for another user.)

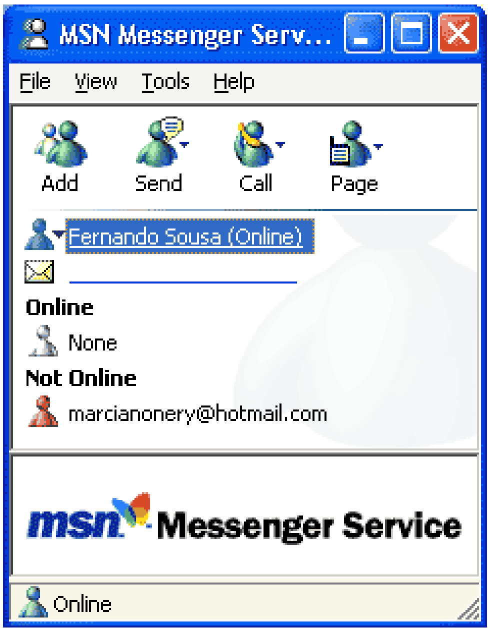



**Figure 2.5: MSN Messenger (Microsoft Corp., 2005)**

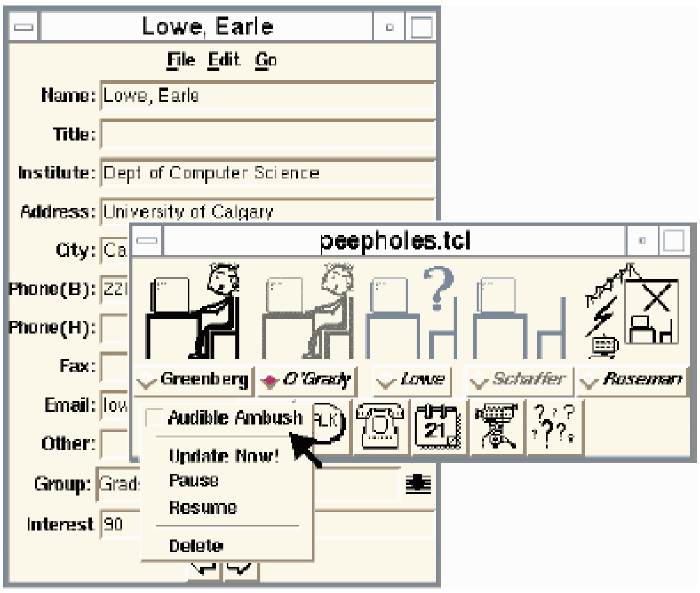



**Figure 2.6: Peepholes Activity Icons (Greenberg, 1996)**

Lilsys (Begole et al., 2004) is an instant messenger application similar to Peepholes. The system determines a user's availability by detecting a user's motion, sound, phone usage, and door state. Other users can decide to initiate conversation with the user according to the machine-determined availability of other users. To ensure and protect privacy, the system also provides explicit controls over privacy such as an on/off switch. After a user study, Begole et al. (2004) found interruptions still occurred even though the user appeared unavailable. It can be inferred that users of IMs consider that an intrusion through such systems can be excused, whereas such interruptions would be unacceptable in a face-to-face situation (Fogarty et al., 2004).

Kuzuoka and Greenberg (1999) tried to minimize distraction caused by awareness systems by using ambient output. They argued that window-based notification can be intrusive and often clutter the display. Thus, they redirected the output from display to physical surrogates. A surrogate represents a distant user, and its state is an indicator of other's state (e.g., busy or absent). For example, the peek-a-boo surrogate (Figure 2.) faces the wall when the other user is absent, but faces the user when the remote user's activity is sensed. Also, the dragonfly surrogate flaps it wings when a remote person becomes active. By glancing at or hearing ambient sound from surrogates, a user can naturally be aware of others' state easily (Figure 2).

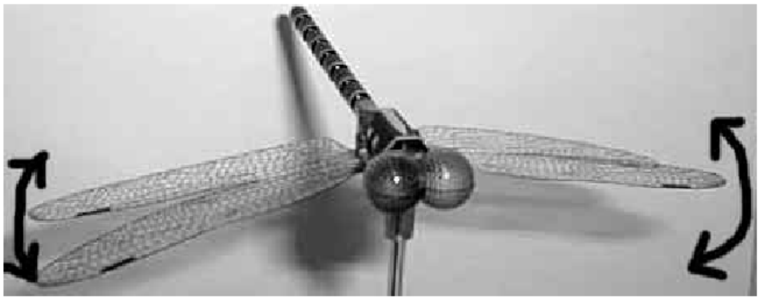


**Figure 2.7: The Dragonfly Surrogate (Greenberg, 1996)**

**Figure 2.8: The Peek-a-boo Surrogate (Greenberg, 1996)**

Sound can also be used to provide awareness and reduce the threat to confidentiality invasion. Hubbub (Isaacs, 2001), a sound-based instant messenger application for mobile devices, uses "earcons," which provides a unique sound ID for each user. When a user becomes available, the system plays an active sound associated to a particular user. Thus, users can receive awareness of others with minimal effort at any place.

## 2.5 Techniques for Safeguarding Privacy

Privacy has always been a major concern in awareness systems because awareness provided by such systems can always include privacy-sensitive information. Many video-based system users have reported that video is highly invasive (e.g., Bellotti and Sellen, 1993; Lee et al., 1997). The main reason for video being too intrusive is that there is no clear distinction between public and private space in the virtual places created by media space. For example, while an office in the real world is considered the occupant's private space, it is not clear whether an office that can be viewed by many users through a media space system should be considered a public space. This section will discuss techniques to address privacy issues that arise in awareness systems.

### 2.5.1 Control Over Privacy

Awareness support system users can safeguard their privacy through explicit and implicit controls. Explicit control is performed by a user's explicit actions such as setting the current privacy level or configuring privacy preferences, while implicit control is done by a machine that senses a user's availability.

The simplest, yet most effective explicit control over privacy is using an on-off toggle switch. It allows lightweight control over privacy and requires very little effort in performing the task. Many prototypes, such as CoMedi (Coutaz et al., 1999), and NYNEX Portholes (Lee et al., 1997), have this feature. However, although it is an easy way to protect privacy, the on-and off switch cannot allow fine-grained control over privacy. Also, a user study showed that users rarely used it for safeguarding privacy except during the early stage of the system deployment (e.g., Begole et al., 2004;

Fogarty et al., 2004). They seemed not to be able to keep track of their current preferred privacy level all the time, and therefore often forgot to trigger the control.

Relationships can be used as an effective tool for explicit control over privacy. Davis and Gutwin (2005) found that people differentiate in disclosing privacy information by their relationships to the observer. Privacy can be controlled in a fine-grained way using relationships, by giving different people different fidelity and accuracy of information; that is, people are more willing to disclose more sensitive information to spouses or friends than acquaintances. Lederer et al. (2003) also showed that people are consistent in providing information according to relationships. People are more likely to apply the same privacy preference policy to the same inquirers in different situation than to apply the same privacy preferences to different inquirers in the same situations. For instance, for particular information about the occupant's current mood, the information holder will always tend to provide the exact state of the current mood to family members but no information to acquaintances, no matter how happy or unhappy the person is. Furthermore, providing a grouping functionality can reduce the user's configuration load (Patil and Lai 2005). They found that defining permissions for information access at the group level appears to provide the flexibility needed to appropriately manage the balance between awareness and privacy. These findings suggest the effectiveness of using relationships at the group level as a way to provide privacy control.

Implicit control can be accomplished by various sensors of a system that automatically collect data to determine an office worker's presence and availability. The system lets other people know the current availability level of the user (e.g., Hudson, 2003; Begole et al., 2004; Fogarty, 2004). By providing information about the occupant's current state, a system can deter office visitors from interrupting inappropriately.

Whether an office worker is present or not is the most important factor in availability information, but it alone does not suffice in determining if a person can be contacted, because being present does not necessarily mean the person is available for interaction. For a person to become available, both presence and receptivity (a person's willingness to be interrupted) must be satisfied since interruption depends on the context of both the caller and the person being interrupted (Begole et al., 2004).

In order for implicit control over privacy to be successful, the system must accurately determine one's availability. Hudson et al. (2003) performed a 'Wizard of Oz' study to measure human interruptability based on several variables using a variety of sensors. The variables included environmental variables (e.g., time of day, day of week, and door state) and user variables (e.g., activity of mouse and keyboard, the number of guests, activity of guests, and sound level). Their results showed that a person's availability can be measured by sensors with overall accuracy of 78%. In particular, speech is found to be a very good indicator that an office worker is busy and should not be interrupted (Hudson et al., 2003). Sensing human speech for availability is also performed in Fogarty et al.'s study (2004). They used a laptop microphone along with other sensors in an IM system, called MyVine, and measured human availability. Although availability information seemed to be provided accurately through MyVine, users still interrupted at inappropriate times. This result is the same as in the user study by Begole et al. (2004) (see Section 2.4.2).

### 2.5.2 Control Over What Others See

In video-based awareness support systems, image processing and computer vision techniques have been used to protect a person's privacy. In particular, privacy filters that alter the fidelity of live video are used so that the system provides just enough amount of awareness information while still protecting confidentiality.

The most widely used privacy filter is a blur filter (Figure 2.9), and this technique has been used in many systems (e.g., Lee et al., 1997; Neustaedter et al., 2003). Depending on the size of convolution filter applied to the video image, the filtration effect on video varies. For example, Boyle and Greenberg (2000) found that balance between awareness and privacy can be achieved when an image is blurred with a 15x15-pixel box filter. With this blur level, the viewer can assess if a person is busy or not (Boyle and Greenberg, 2000). If the size of convolution filter grows to 41x41, assessing a person's busyness becomes difficult. Of course, there are other parameters that must be considered, such as the location and the frame rate of a camera, and they can affect the results. Other manipulation effects such as the Venetian blind effect (Crowley et al., 2000) can also be used to mitigate privacy concerns in video-based media spaces (Figure 2.10).

**Figure 2.9: Blur Filter Effect (Lee et al., 1997)**

**Figure 2.10: The Venetian Blind Effect (Crowley et al., 2000)**

While a blur filter alters the whole image including the background and foreground, there are other techniques that alter only the foreground image. In such techniques, the background remains unchanged but the foreground image is altered. In most cases, a moving object in an office is the occupant or a visitor, and high-fidelity video images of these people often convey too much sensitive information. Hudson and Smith (1996) introduces a technique called the shadow view (Figure 2.11) that hides details about the occupant while providing important awareness information, such as an office occupant's presence or movement. For this technique, each video image is broken into 8x8 pixel regions, and the regions are made darker or lighter based on the occupant's movement.

Crowley et al. (2000) presented the Eigenspace filter that always shows "socially correct" images. They used principal component analysis (PCA); an orthogonal set of basis images are determined by PCA of a set of "socially correct" images. For example, in Figure 2.12, the source image (left) appears as a socially corrected image (right) since the socially incorrect image gestures (left) are not found in the basis space. Although the Eigenspace filter can safeguard the privacy in certain situations, there is room for misuse of the feature that might raise ethical issues (e.g., masquerading as another user).

Another interesting technique is the Synthetic Group Photo (Hudson and Smith, 1996). The motivation behind this technique is to reduce disturbance and resource utilization. Even small video images will quickly fill the display if one image is used for each member; also, the CPU utilization can become high if multiple video images need to be displayed. The Synthetic Group Photo (Figure 2.13) uses previously captured "head and shoulder" still images of co-workers and partially overlays them in a compact way. Whenever any user becomes present in their office, the person's image is moved to the front, and the size of the image becomes bigger. This technique lets the user understand who is present and absent currently like in the overview model (see Section 2.4.1). In Figure 2.13, 123 people's images are presented in a compact and meaningful way.

**Figure 2.11: The Shadow View (Hudson and Smith, 1997; Zhao and Stasko 1998)**

**Figure 2.12: Eigenface Filtering for Privacy Protection (Coutaz et al., 1999)**


**Figure 2.13: The Synthetic Group Photo (Hudson and Smith, 1997)**

In a potentially risky situation, such as at home, Neustaedter et al. (2005) argues that a blur filter fails to safeguard privacy. The main reason for their system's failure to balance privacy and awareness is that users can not trust the system for their privacy protection in a situation where they are very concerned about their privacy. It can be inferred that not only the blur filter, but also other image processing techniques do not work for privacy protection in extreme situations. This problem could be addressed by making the system more trustworthy. Users will have more confidence in systems if they are allowed to control their privacy directly in a lightweight and fine-grained manner (Bellotti, 1998), and explicit and immediate feedback about user's direct manipulation of the system (Neustaedter et al., 2003) can make the system more trustworthy.

### 2.5.3 Reciprocity

Reciprocity (or symmetry) is a simple social principle that states “I can see you only if you can see me” (Borning and Travers, 1991, Boyle and Greenberg 2005). In order for this concept to work well in media spaces, it should be comparable (Borning and Travers, 1991). For example, if user A can see the full live video of user B, then user B should be able to see the full video of the user A as well. Reciprocity does not protect privacy by altering any information. Instead, it makes users feel more confident in using the system. Many researchers (e.g., Lee et al, 1997; Borning and Travers, 1991; Boyle et al., 2000) suggest the idea that reciprocity is necessary in media spaces for its positive effect of deterring people from misuse (e.g., surveillance) and for the increased user trust in systems. However, there is a problem of disruption that can occur when a system notifies a user of someone’s information access. Given that reciprocity does not always hold in the real world, sometimes breaking it can be beneficial (Boyle and Greenberg, 2005). For example, assessing the office occupant’s availability by a quick look without interruption might be beneficial both for the observer and the occupant.

## 2.6 Visualization of Past Activity

Interaction history is the record of the interactions of people and objects (Wexelblat and Maes, 1997). People can asynchronously interact with each other by being aware of what interactions have happened in the past. In many cases, interaction history is provided as a form of visualization that can be perceived easily by users (Hill and Hollan, 1992; Wexelblat and Maes, 1997). Visualization of Past Activity can help people see past patterns of use that often provides useful information (Wexelblat and Maes, 1997) and improves usability of a system. Hill and Hollan (1992) developed interaction history visualization techniques called *Edit Wear* and *Read Wear*. These are graphical visualizations of the amount of reading and editing that multiple users made in each line of a sharable electronic document. The term "wear" comes from an analogy of physical wear- that is, as objects are used more and more, they get visibly worn out. Also, in Babble (Ericson and Laff, 2001), an online conversation system, the past chat activity of a user is visualized, and users can get awareness information of other chatters' activity such as how recently a chatter has either spoken or listened.

Visualizing recent past activity can provide useful information for casual interaction. In a 2D groupware context, Gutwin (2002) maintains that recent traces of a telepointer's movement can provide useful awareness information. Traces of past movement of a telepointer can tell where it has been and is going to move. By the same token, traces of a person's past activity can provide clues about the future. For example, five overlaid snapshots taken during the past five minutes can show what the occupant was doing and provide some indication as to what is going to happen next. For instance, from the image in Figure 2., one can infer that the occupant was present and that the person stepped out after talking on the phone. It is not difficult to understand why the occupant is not currently in (e.g., attending an informal meeting after an important call) and determines if the occupant might come back soon given some additional information (e.g., the last time the occupant left and the current state of computer screen).

**Figure 2.14: Composite Image with Shutter Blur Captured in the Last Five Minutes (Gutwin, 2002)**

In addition to visualizing recent past activity, showing longer-term past activity can give useful information about the current and future activities of a person. Begole et al. (2002) explored visualization of long-term past activities of office workers by gathering and analyzing information about work patterns. The authors visualized pattern information such as time-of-day and day-of-week patterns to provide awareness in distributed work groups. By examining such visualizations, one is able to answer a question like "When is the person likely to be at the office?" Figure 2.15 presents a visualization of a typical worker's computer activity detected by keyboard and mouse use for several months. It can be easily inferred that the times before 8:00 AM, after 6:00PM, and between 12:00PM and 1:00PM are not good to contact the person, but times between 9:30AM and 12:00PM and between 1:30PM to 5:00PM are good to contact the person. However, given this particular dataset, it is difficult to determine if it is an appropriate time to interrupt a person because as mentioned before, being present does not mean being available for interaction. Yet, the visualization still provides useful information. For example, one can guess the approximate time when an e-mail will be read by the user according the work patterns.

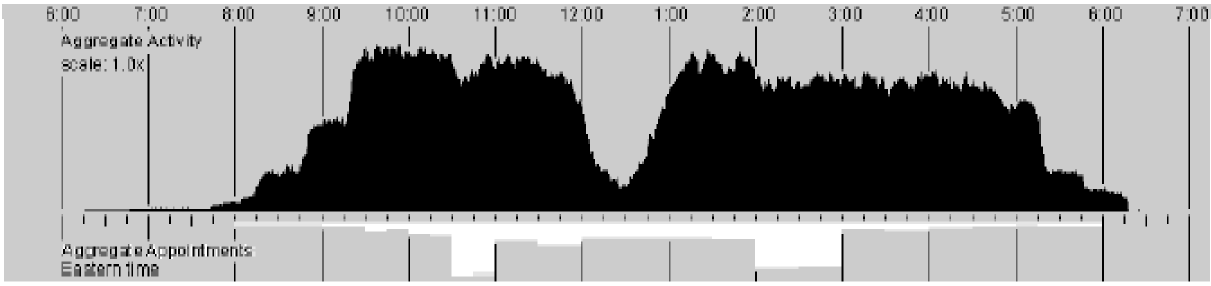



**Figure 2.15: Visualization of Aggregate of Activity and Appointments over Several Months (Begole 2002).**

CHAPTER 3

# DESIGN OF THE MAGIC WINDOW

This chapter describes the underlying design principles of the Magic Window system, the evolution of the system over a period of time and technical design and implementation details of the Magic Window.

## 3.1 Overview of the Magic Window System

The Magic Window is a co-present media space system (i.e. visitors must be physically collocated to use the system) designed to support interactions between an office occupant and office visitors. The system provides awareness information about the occupant in a way that the occupant's privacy is safeguarded, so that awareness and privacy are balanced by the system. The system has a two-way information channel from the office to the hallway and the hallway to the office, created by two PC cameras (hallway camera and office camera). Through this channel, the visitors can see the video of the office on the Magic Window main display, and the occupant can see video of the hallway on the hallway view display. The occupant can control what is displayed and how it is displayed by using a physical user interface as well as a 2D graphical user interface.

A diagram of the Magic Window system is presented in Figure 3.1. The video captured by the office camera is displayed on the Magic Window display (in the hallway), on the office view display (in the office), and in the 2D GUI on the occupant's desktop computer in the form of periodically updated images. The video captured by the hallway camera is displayed on the hallway view display (in the office) and in the 2D GUI on the occupant's desktop computer (also in the form of periodically updated images). Images that appear in the 2D GUI are transferred from the main machine through TCP/IP connections. Other components such as the doorbell, the fingerprint reader, the privacy controls and PC cameras are connected to USB ports in the main machine. Also, three LCD panels are connected to the main computer through one dual head video card and an extra video card. For details about how the system works, see Section 3.4.

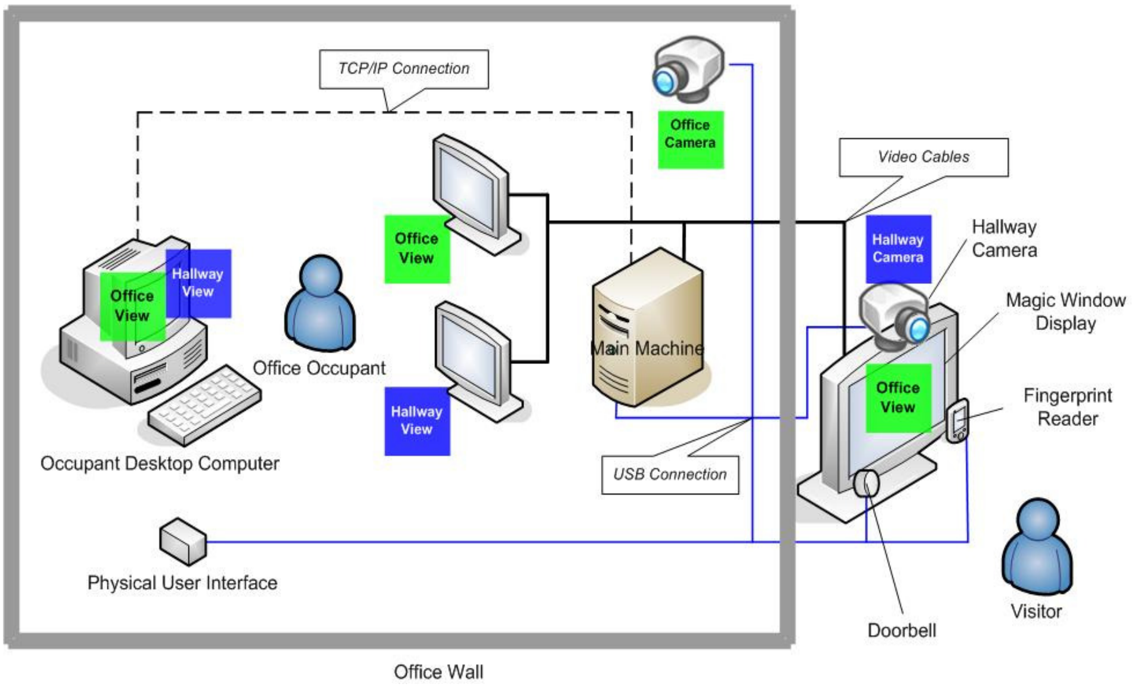



**Figure 3.1: Simplified Diagram of Magic Window System**

### 3.1.1 System Functions

The system provides several functions to its users. A list of functions which are available to the occupant includes:

- Ability to register and un-register a visitor's name and set a priority to configure the relationship-based privacy control
- Ability to increase or decrease the quality of the office view on the Magic Window display
- Ability to select and display the message regarding current availability level
- Ability to identify and browse names of visitors who visited the office with the time of visit while the occupant is absent, so the occupant can maintain awareness of visitors who visited while away
- Ability to notify the occupant who the current interrupter is
- Ability to set a customized message such as "back in 5 minutes" on the Magic Window display
- Ability to manage the interruption by dynamically posting a message when
- interrupted as a lightweight way to handle interruption control mechanism

A list of functions which are available to the visitors includes:

- Ability to obtain awareness in order to determine availability from the Magic Window display
- Ability to obtain short-term and long-term asynchronous awareness about the occupant so as to determine a good time to visit or the time the occupant may come back
- Ability to quickly determine if the occupant is in or not with little effort
- Ability to authenticate with a fingerprint and get different fidelity of awareness information depending on user priority
- Ability to indicate interest in interaction by pressing a doorbell

### 3.1.2 Scenarios of use

The following scenarios describe a typical use of the Magic Window. Suppose James wants to contact Carl to ask about a paper that they have been working on together. James takes the draft and walks to Carl's office which is located at the end of the hallway on the same floor as James' office. James looks up on the Magic Window display that is mounted on Carl's office door, where the default view of the occupant is displayed. It is somewhat difficult to tell if he is in or not since the default view is blurred for privacy reasons, but James becomes confident that he is in the office as he looks at the In-Out display clearly saying he is currently in. So James decides to log into the system by placing his finger on the fingerprint reader for further information.

Upon log-in, the default video view on the Magic Window display changes to clearer video along with an availability message on the screen. The message says "I am talking on the phone," and Carl is also on the phone in the video. James realizes that now is not a good time to interrupt him. If James was set to higher priority, he would see much clearer video than what he is seeing currently. James, even though he is a high priority viewer, would have seen blurry video if Carl dynamically had set the global privacy setting to high. A few minutes later, James tries the system out again. Given the clearer video on the display, now the occupant seems available sitting at the computer, and the availability message says "I am available." So James decides to interrupt him by pressing a doorbell wired to the system while still being logged in the system. A few seconds later, James hears Carl say "Come In!", so he opens the door and walks into the office.

When a visitor presses the doorbell, the occupant gets notified by a ringing sound and a pop-up window on the desktop computer display. The number of rings varies based on the viewer's priority. (e.g., for highest priority viewer, it rings 4 times).

The occupant can see who is interrupting by looking at the hallway view display. From the pop-up window, the occupant has three choices to handle the interruption by clicking one of three buttons-"Come in," "Hold on," or "Ignore" and by putting such message on the display (for "Ignore", no message is posted). Seeing the message posted dynamically by the occupant, the visitor can decide to walk into the office or wait for a short time until the occupant answers the door.

## 3.2 Design Principles

The Magic Window system was designed based on several principles. Design principles include using relationship for privacy control, minimizing user effort, ensuring user trust and using user context. This section discusses these underlying design principles of the Magic Window system.

### 3.2.1 Using Relationship to Regulate Privacy

The system was designed so as to take advantage of relationships between co-workers. Relationship-based privacy control can facilitate lightweight and fine-grained privacy control. According to a visitors' priority as preset by the occupant, the quality of the awareness information provided thorough the system varies. Figure 3.2 presents the 2D user interface though which the occupant can set the visitor's priority. The images on the right side of the interface indicate the levels of quality of video that each group of people would see.

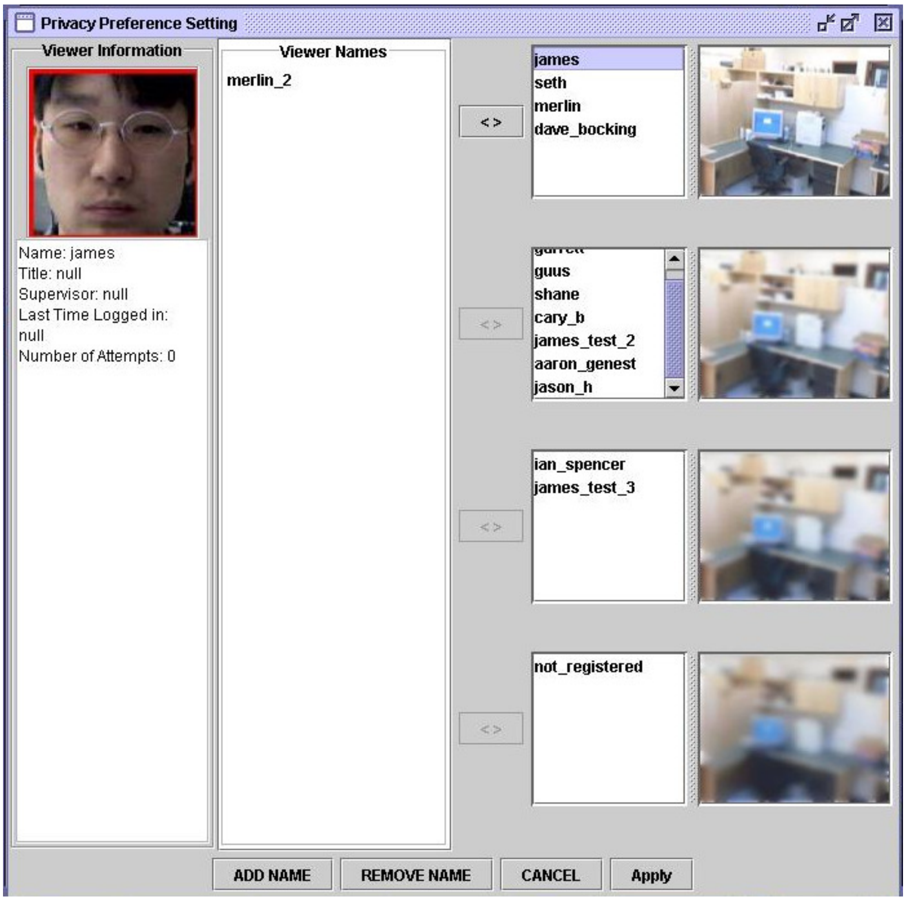



**Figure 3.2: 2D GUI for Occupant's Privacy Control Based Relationships**

***Lightweight Control over Privacy:*** Human-to-human relationships remain static in real world situations. They do not change over a short period of time, once people form relationships with others, regardless whether they are formal or informal. For example, the supervisor – student relationship remains the same until the student graduates and this does not occur within a few days, not even in a few months. Such characteristics of human relationships suggest that if we are able to preset a privacy level based on relationships with potential information requestors, we do not need to set the privacy level over and over again. From the occupant's perspective, this relationship-based privacy control can eliminate the need to remember to regulate privacy settings repeatedly depending on the situation. Thus relationship-based privacy setting can enable lightweight privacy control.

***Fine-grained Control over Privacy*: **The 2D graphical user interface (Figure 3.2) allows the occupant to group potential viewers into four different groups to which the occupant can add a person's name. The occupant can preset one of four different fidelities for a specific individual. This means the occupant can adjust privacy on a person-to-person basis. The fidelity of video can also be adjusted through an explicit control by the occupant (see Section 3.2.3).

Often too much fine-grained control can leave system unused and ignored because it makes the control too heavyweight. However, relationship based control does not require the user to change privacy setting often. Therefore, the system still allows fine-grained control over privacy in a lightweight manner.

### 3.2.2 Low Effort System

The Magic Window system was designed in a way that the system requires minimal effort to use. Both the occupant and the viewer were taken into account in design of low effort system. However, there was a lot more focus on minimizing the occupant's effort to control privacy.

***Low Effort System for Occupant:*** From the occupant's point of view privacy control can be done in an easy way through a physical user interface (Figure 3.3).There is no need to open an application to set the current privacy level but the occupant can simply manipulate the physical gadgets to regulate privacy control instead. The interface includes two physical sliders for confidentiality and solitude control, an on-off switch, a joystick to pan and tilt the camera position, and a three-way switch to change the display mode of the system. (see Section 3.3.1) Through the physical user interface, the occupant can save space on the screen and adjust privacy level separately from the viewer's current tasks on the PC.


**Figure 3.3: Interfaces for Occupant's Privacy Control**

***Low Effort System for Viewers*:** The goal is to develop a walk-up-and-use system given how people obtain and maintain awareness of an office occupant. To support the idea of using relationships, the system should be able to determine the viewer's identity. However, conventional mechanisms to gather viewer information through a mouse and a keyboard do not meet ease-of-use system requirements. Instead, the system adapted biometric approaches; it is found that this approach is effective in minimizing viewer's efforts. It was intended to use computer vision techniques such as face recognition and face detection but due to the limitation of the accuracy and implementation learning curve, we switched to fingerprint recognition using an existing commercial standard development kit for fingerprint recognition.

### 3.2.3 Ensuring User Trust

User trust is one of the major issues in media space systems. Many researchers have found that people become reluctant or even refuse to use a system that is incapable of winning user trust.

#### 3.2.3.1 Mix of Implicit and Explicit Privacy Control (occupant)

One way to ensure the occupant's trust in the system might be to leave full explicit control to the occupant. However, this approach has potential to overload the occupant with a lot of tasks to manage the control of the system. To address this issue, the design supports overriding implicit privacy control with explicit privacy control. While the system provides different fidelity and amount of awareness based on relationship, the occupant is also able to increase and decrease privacy levels dynamically. The implicit control mechanism (using relationship) remains unchanged even though the occupant changes the global privacy level (explicit control) but the average fidelity and amount of awareness information for levels of viewers will change according to the explicit privacy setting.

#### 3.2.3.2 Rich Feedback (viewer and occupant)

Another way to ensure user trust is to provide rich feedback. The feedback should reflect any immediate change to the system and any potential to threaten privacy. Audio and video feedback and feedback on system state change increase the user's trust and decrease potential to violate privacy. There are several feedback mechanisms supported by the design.

***Hallway View:*** If the system detects any viewer's face (e.g., when attempting to use the system) the image of the viewer (left image in the Figure 3.4) is displayed through the occupant's desktop computer display. The occupant also gets direct audio feedback with a pop-up window when a viewer logs in. This is the moment when the occupant's privacy could be violated (e.g., the viewer sees a clear live video.) So the system lets the occupant know how much fidelity of information is being given. While a face is detected, the Hallway View gets updated every two seconds; otherwise it shows the person who was detected last time, so the occupant can be aware of who was observing them.

***Mirror View/Office View:*** Upon change of dynamic privacy setting, the image that a highest priority viewer would see after log-in gets updated and then displayed (right image in the Figure 3.4) through occupant's desktop computer. Therefore, the occupant can perceive and understand the current privacy setting change by looking at the image provided. Any change of privacy setting through the physical user interface (solitude and confidentiality level change, camera pan/tilt position change) triggers the update of the office view; otherwise it gets periodically updated (every 30 seconds) to show what fidelity of the office view will be provided to observers.

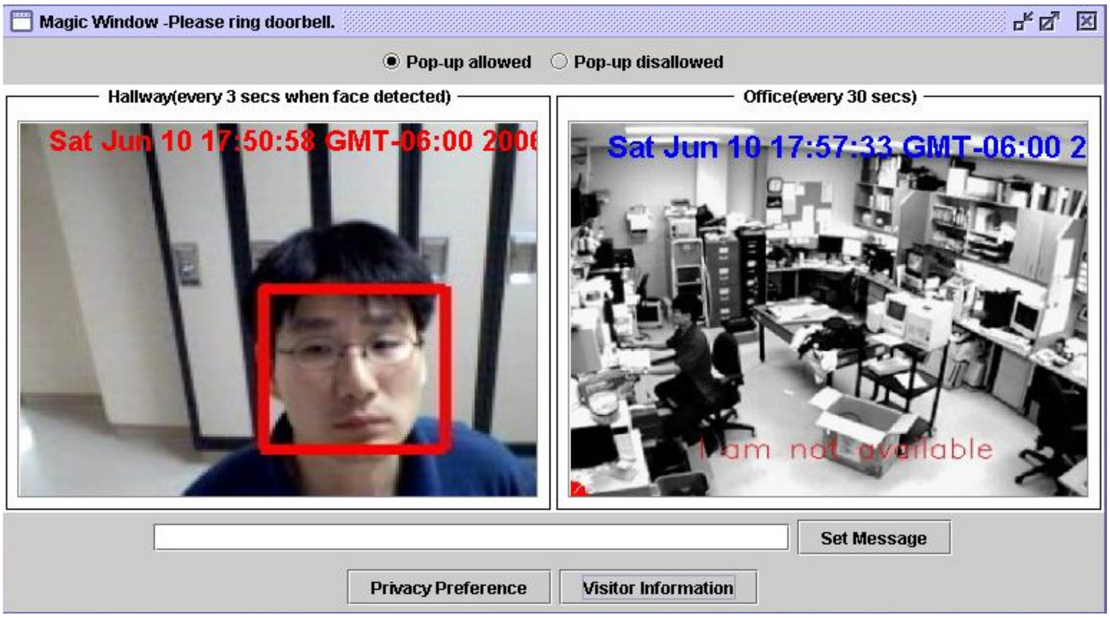



**Figure 3.4: 2D GUI for Hallway View(left) and Mirror View(right)**

***Feedback through Physical Display and Physical User Interfaces:*** The physical user interface (Figure 3.5) provides direct feedback on current privacy levels. For example, the position of sliders can be perceived as current privacy setting without the need for opening a 2D GUI. The physical user interface provides affordance as well as feedback. Two physical displays include the Time Clock display and the In-Out display (Figure 3.6). The In-Out display simply indicates whether the occupant is currently in the office or not. From the viewer's perspective, the In-Out display can decrease and get rid of the need for logging in when the viewer wants to simply check whether the occupant is present or not. The Time Clock display ensures the occupant by notifying when an image is taken in order to be displayed through Past Activity view. This decreases the occupant's privacy concerns about images to be displayed in a public space.

**Figure 3.5: Physical User Interface**


**Figure 3.6: Physical Display (In-Out Display and Time Clock Display)**

### 3.2.4 Using User (occupant) Context

The most important piece of information in a co-present media space system is the occupant's presence/absence information. Showing an empty office when the occupant is out is a very important piece of information itself, indicating the occupant is currently not available for interaction at the moment, but such piece of information can be more valuable if it is used as a context. For instance, suggesting whether the person left for the day or not in the case of being absent, can be useful for the viewer, who urgently needs the occupant's help, to determine what to do (e.g., contacting by phone or waiting for a while). Therefore, the system was designed to detect presence-absence context and behaves completely differently (showing a live video vs. visualizing Past Activity) depending on context.

## 3.3 Evolution of Magic Window

Over a period of eight months, the system evolved considerably; some functionality and features of the Magic Window were improved and added based on design evaluations. This section describes and discusses the evolution of the Magic Window prototype over the eight-month period.

### 3.3.1 Initial version of Magic Window

This section outlines the detailed elements of the Magic Window system that was initially implemented based on the design principles described in Section 3.2. There are a number of elements of the Magic Window that support lightweight privacy control and rich feedback on system state. The first version of the Magic Window was designed mainly from the occupant's perspective, and the sections below give details on how each of the design principles was put into the system. Some issues were found after system deployment and addressed at later versions of the system. The first version of the Magic Window, as deployed in a real office setting, is presented in Figure 3.7.

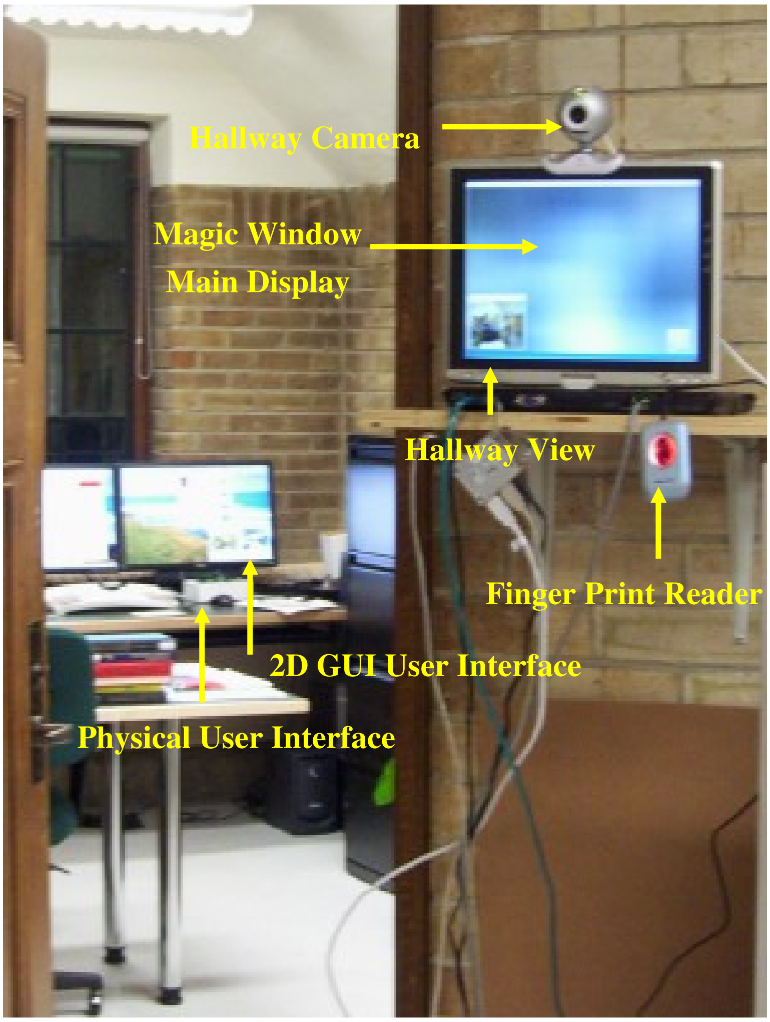



**Figure 3.7: Initial Version of Magic Window Deployed in First Office Setting**

#### 3.3.1.1 Different Views in Different Modes

The Magic Window provides a variety of different views depending on the situation. As presented in the block diagram in Figure 3.8, there are two main modes in the Magic Window; synchronous and asynchronous mode. In synchronous mode, the viewer sees one of three views (the moving ghost view, the shadow view or the filtration view) according to the occupant's preset preference. In asynchronous mode, the Magic Window always shows the Past Activity view to the viewers. Switching between the synchronous and asynchronous views is automatically done by the system through image processing techniques.

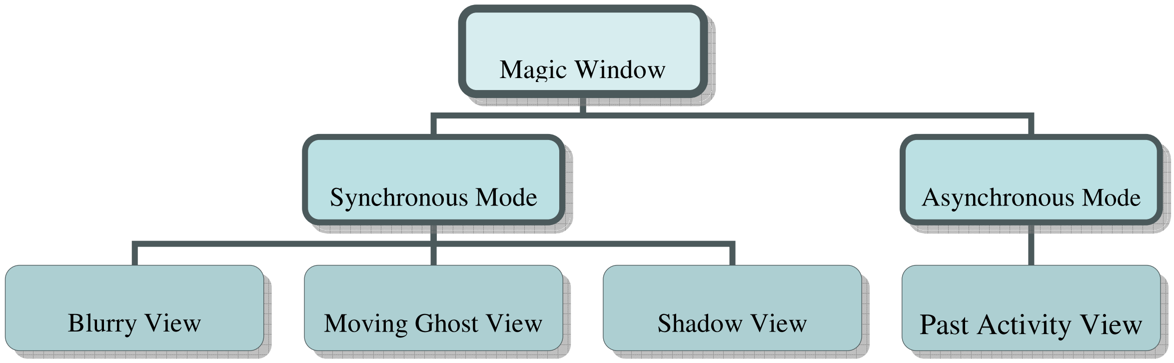
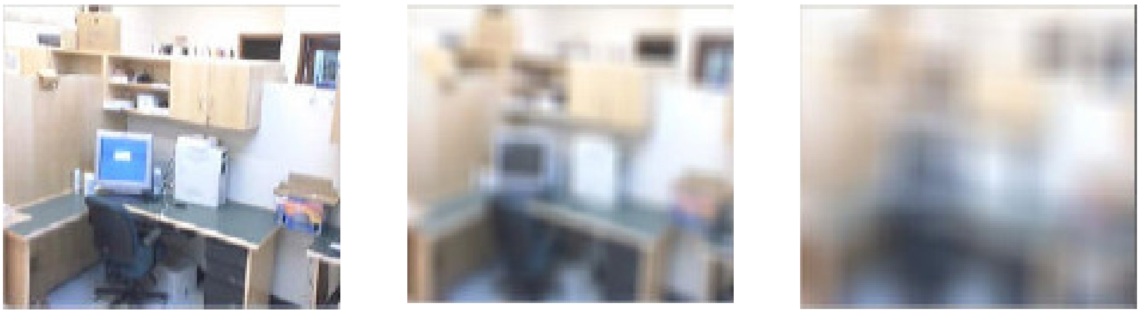



**Figure 3.8: Modes and Views in Magic Window**

In synchronous mode, the occupant can choose one of three different views of live video to display; the three views are the blurry view, moving ghost view and shadow view and described in the following sections.

***Blurry View:*** Different effects and different fidelity of video are generated by different sizes of blur filter (box filter). For example, in Figure 3.9, the left image is the original office scene without the filtration effects. The image in the middle is blurred by a 15 x 15 box filter. This filter can safeguard most privacy information; yet it still conveys good awareness. The image on the right is blurred by a 41 x 41 box filter. It seems hard to tell whether the occupant is in unless there is significant occupant movement. The occupant can choose to increase or decrease the size of the box filter using confidentiality control slider.



No Filter 15x15 Box Filter 41x41 Box Filter

**Figure 3.9: Blurry View**

***Moving Ghost View:*** The moving ghost view (Figure 3.10) displays the background image of the office and any traces of moving objects on top. If the occupant is not moving, the viewer will see only the background office without the occupant. If the occupant moves, a silhouette of the occupant appears on the top of the background image. This view was developed to provide the occupant with more flexible control; using this view, the office occupant might be able to prevent unnecessary incoming disruption by pretending that he is not in the office. (see also Section 3.4.2.2 for technical details)

**Figure 3.10: Moving Ghost View(left) and Shadow View (right)**

***Shadow View:*** The shadow view (Figure 3.10) displays the background image of the office and any foreground moving objects in a pixelized form. Similar to the moving ghost view, the shadow view hides any details of the occupant but tells whether the occupant is present and actively moving inside the office. Therefore, it provides very basic awareness information about the occupant (and possibly the number of people).

In asynchronous mode, there is only one view – the *Past Activity View.* Using system logs of the occupant's presence and absence, the system visualizes what happened in the office over a short time period in the past. The system always keeps capturing image sequences of the occupant and stores the last 10 images (reduced to four images in a later version of system). Once the system falls into asynchronous mode (that is, when the occupant is out) the most recent 10 images are displayed (when the highest priority viewers log in). The number of images a viewer can see varies depending on their priority. Also, the Amount of Activity view visualizes how much the occupant was active in the office. It was found that viewers had difficulties in interpreting this view, so the Past Activity view was re-designed and implemented in a later version of the Magic Window. The initial version of the Past Activity visualization is presented in Figure 3.11.

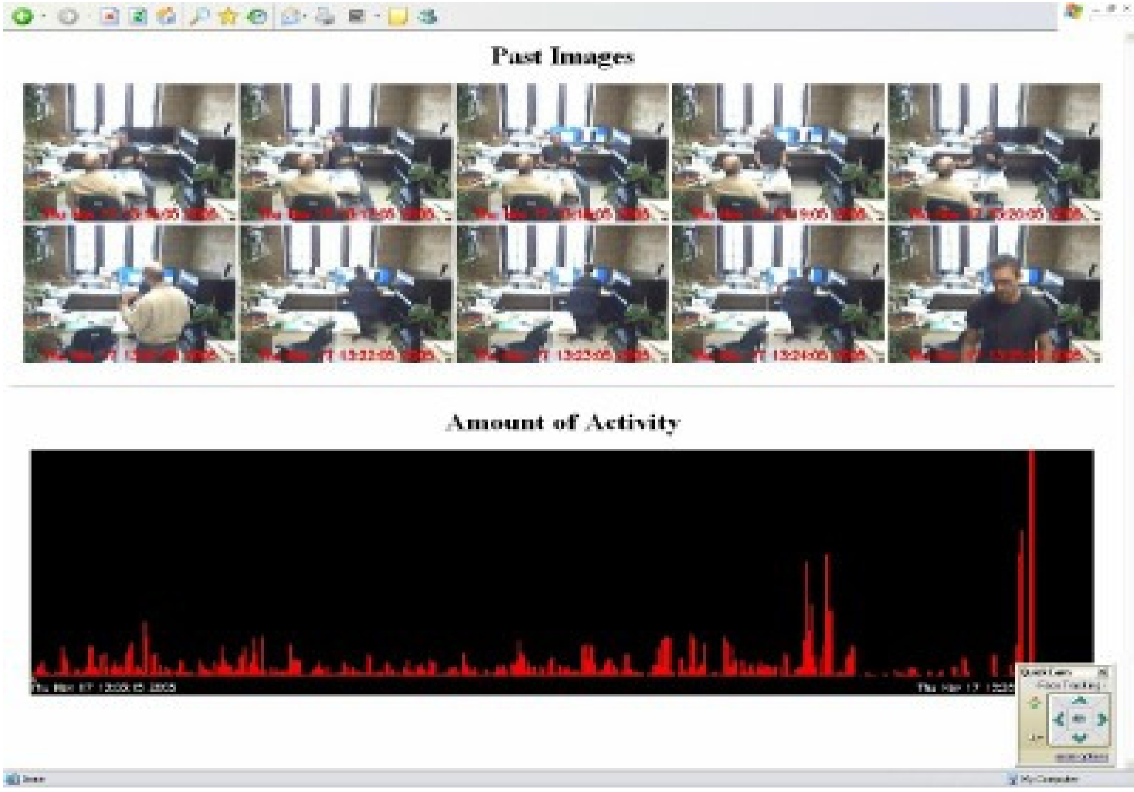



**Figure 3.11: Initial Past Activity View**

#### 3.3.1.2 Physical Controls

Physical control can be done through the confidentiality control slider, the solitude control slider, the camera pan/tilt joystick, the on-off switch, and the shadow-burry-ghost view switch. The interface of physical controls is presented in Figure 3.12.

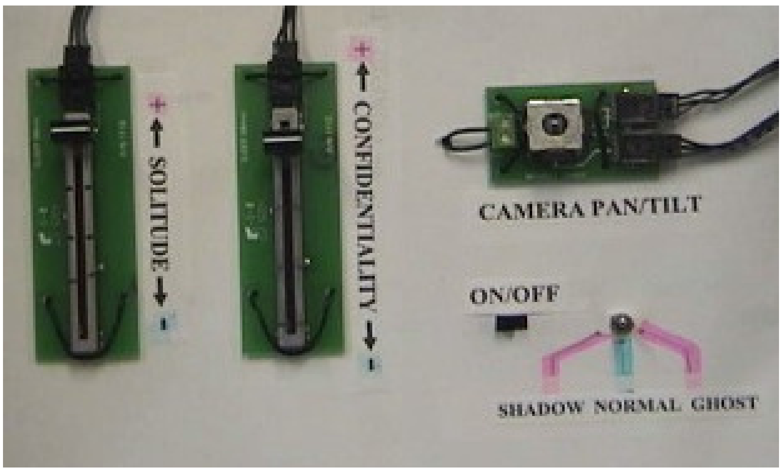



**Figure 3.12: Physical User Interface (Detailed View)**

***Confidentiality Control Slider (Control over Video Fidelity):*** For confidentiality, a blur filter is used to manipulate the fidelity of video. The occupant can set a privacy level from 1 to 10 where 10 is the highest privacy level. The system then blurs the live video with a certain size of box filter. With level 10 setting, all viewers ranging from low to high priority see about the same fidelity of video that is severely blurred, so the occupant can make sure minimal awareness is provided through the video. However, with level 1 setting, high priority viewer can see clearer video than low priority viewers, so the occupant can take full advantage of relationship based privacy setting.

***Solitude Control Slider (Video Color and Availability Bar):*** In real world situations, people regulate their solitude in many different ways. Social norms play an important role in solitude regulations. For example, knowing a person is currently busy, another person who interrupts the unavailable person is considered rude. So, people use such social norms to regulate their solitude by implicitly or explicitly letting others know their availability. One of common ways to do it is to hang on a "Do not disturb" sign meaning the person is not available. The design of Magic Window adapts such solitude control mechanisms by providing a way to control solitude level. The Magic Window system provides a way to set a continuous solitude level shown by an availability bar in the video, which shrinks and grows depending on the occupant's solitude level setting (full size being fully available and small size being not available). Also, the color of live video changes from black and white image to full color image as the occupant becomes available.

***Camera Position (Pan/Tilt Control by Joystick):*** The camera inside the office is placed on the top of bookshelf since it needs to capture the whole office so it is difficult the occupant the reposition the camera. Two servo motors attached on the web camera inside the office rotates 180 degrees each in a way the camera can be panned and tilted. The occupant can remotely tilt and pan the camera using a mini joystick. When the occupant is setting the camera position remotely, the image of the office gets updated accordingly on the occupant's desktop computer, so the occupant can set the camera position. To return the camera to default position, the occupant can simply click the joystick button. The LED will be on indicating the camera is at home position.

***Easy On-Off button:*** The design provides an easy way to protect privacy in an urgent situation. The occupant can turn off the system display using an on-off switch. When turned off, the Magic Window shows a black screen with a message of "No Signal-turned off by user."

#### 3.3.1.3 Detecting and Identifying User

***Face Detection***: For the system to be notified when there is a viewer looking into the system, the Magic Window hallway camera detects any human faces thorough the camera placed outside the office. Upon detecting a human face, the Magic Widow eliminates the viewer's effort to log in again and informs the occupant that someone is trying to get information about the occupant by showing the detected face image. The system recognizes a human face only if the face image appears big enough, which means that the viewer is close enough to the Magic Window (Figure 3.13).

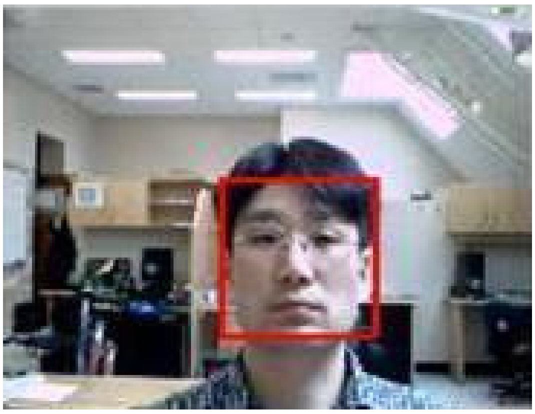


**Figure 3.13: A Viewer's Face Detected by Camera**

Upon detecting a face, the system does two things. First, it transfers the detected face images to the occupant's desktop computer, and the image is displayed through the user interface. The image is transferred at a certain rate (every 2 seconds) if the face keeps being detected. Second, the system waits to read a user's fingerprint, and if the user logs in, the Magic Window assumes that the user remains logged in as long as there is a face detected by the camera. Otherwise, the system logs the user out 10 seconds after the viewer logs in. So, by presenting a person's face in front of camera after log-in (that is, they keep looking at the Magic Window) a viewer can remain logged in without having to log in again after the log-in session times out (10 seconds).

***Occupant Detection***: When the occupant is detected, the system displays a live video of the office upon log-in by a viewer. The fidelity of live video is also altered by privacy filters according to the viewer's identity and the occupant's current privacy setting. When the occupant is not detected (asynchronous mode; see 3.3.1.1), the system displays a visualization of past activity upon the viewer's log-in. The visualization includes snapshots of the occupant, and visualization of presence and absence information. For technical details, see Section 3.4.2.

***Viewer Identification**:* The system provides a lightweight mechanism to log into and out of the system. A simple database file is maintained with fingerprint images associated with user names. Once a user places his finger onto the fingerprint reader, the system looks for the associated name. If a name associated with current viewer's fingerprint is found, the system further checks which privacy level is assigned to the viewer's name and displays the appropriate view of the office occupant. If the user's name is not found, the system treats the viewer as a non-registered user. The viewer will see a default view of the occupant in this case. In a later version of the Magic Window, non-registered users also see the occupant's availability message if they log into the system.

### 3.3.2 Second version of Magic Widow

One of the key goals of the second version of the Magic Window was to improve usability of the system from the viewer's perspective as well as to mitigate identified privacy concerns for the occupant. A major change to the first version of the Magic Window was to improve and modify the Past Activity view. After interviews with several users (viewers), it became clear that the Past Activity view had a potential to violate the occupant's privacy and was difficult to use effectively. The second version of the Magic Window is presented in Figure 3.14. Note that three new features- In-Out display, discrete availability message, and LCD text display- were added to the viewer side of the Magic Window interface. This section will describe how the Magic Window was enhanced to improve the usability of the system.

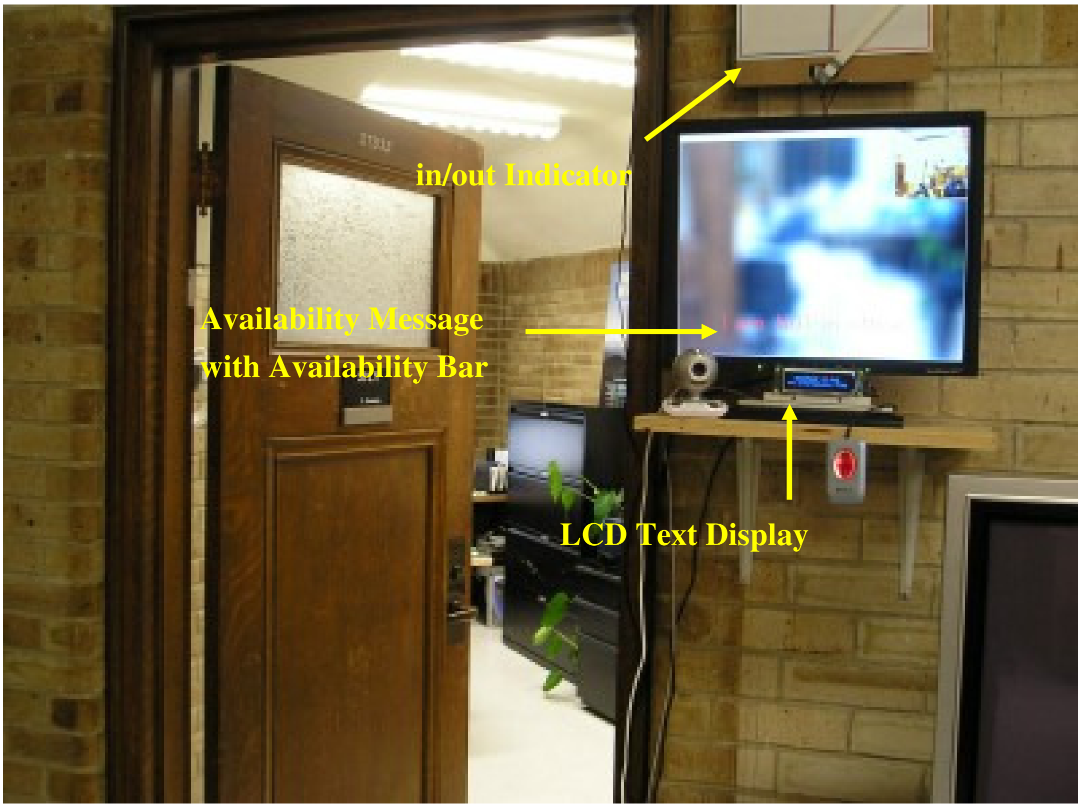
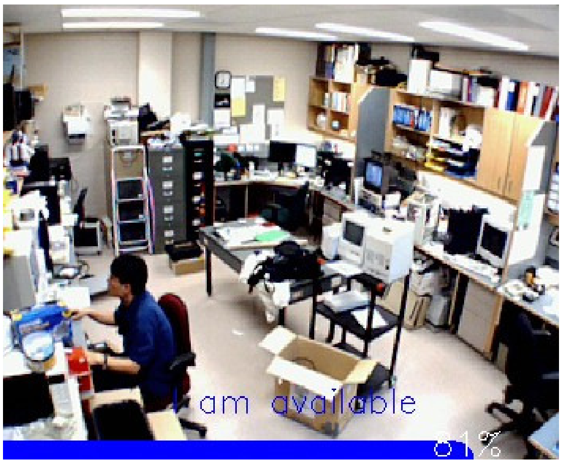


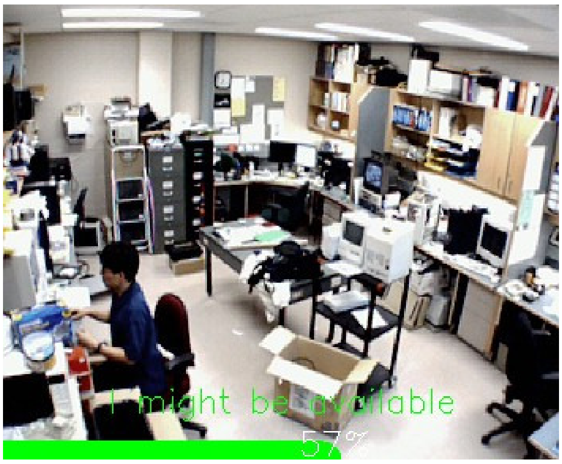

**Figure 3.14: Second Version of Magic Window Deployed in First Office Setting**

#### 3.3.2.1 Supporting Explicit Solitude Messages

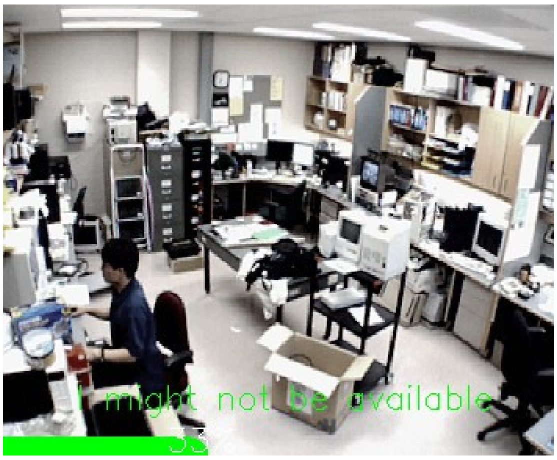
It was found that the continuous solitude level was not intuitive to understand. So, in the second version, the Magic Window was designed to provide four different discrete solitude messages, which the occupant can choose from, with solitude level 1 being available and solitude level 4 being not available, along with the existing abstract representation of solitude level. The corresponding four messages are displayed as "I am available," "I might be available," I might not be available," and "I am not available." (Figure 3.15) The corresponding text is then displayed through the Magic Window.




"I am available"




"I might be available"




"I might not be available"


"I am not available"

**Figure 3.15: Four Discrete Availability Messages**

Another interesting message was "I am talking on the phone" message (Figure 3.16). A light sensor was placed on the phone base so the system could be notified whenever the phone is picked up. This message overrides all the other four messages since it is usually well recognized that when other people are on the phone, they are not available for interruption. Regardless of the current solitude level, only the phone usage message "I am talking on the phone" is displayed when phone is picked up. When the phone is hung up, the previously set availability message is displayed again.

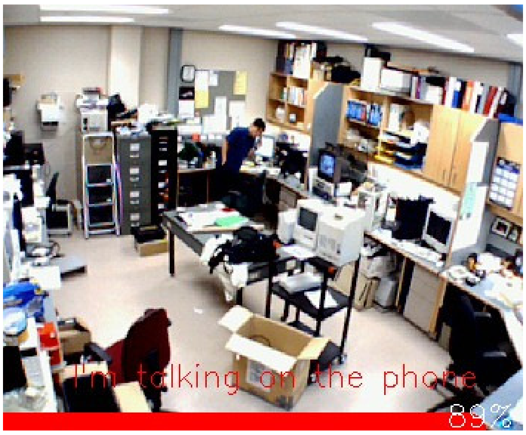



**Figure 3.16: "I am talking on the phone" Message.**

#### 3.3.2.2 How long the occupant has been gone - Past Activity View

It was found that the initial Past Activity view was difficult to understand for many viewers. Many users preferred knowing how long the occupant has been gone or if he has been in today, to interpreting time stamps on a sequence of images. To design improved Past Activity view, first, a simple prototype design was created using MS Power Point as a rapid prototype (Figure 3.17). The real application was then developed using HTML and JavaScript, and they are integrated in the Magic Window system (Figure 3.18).

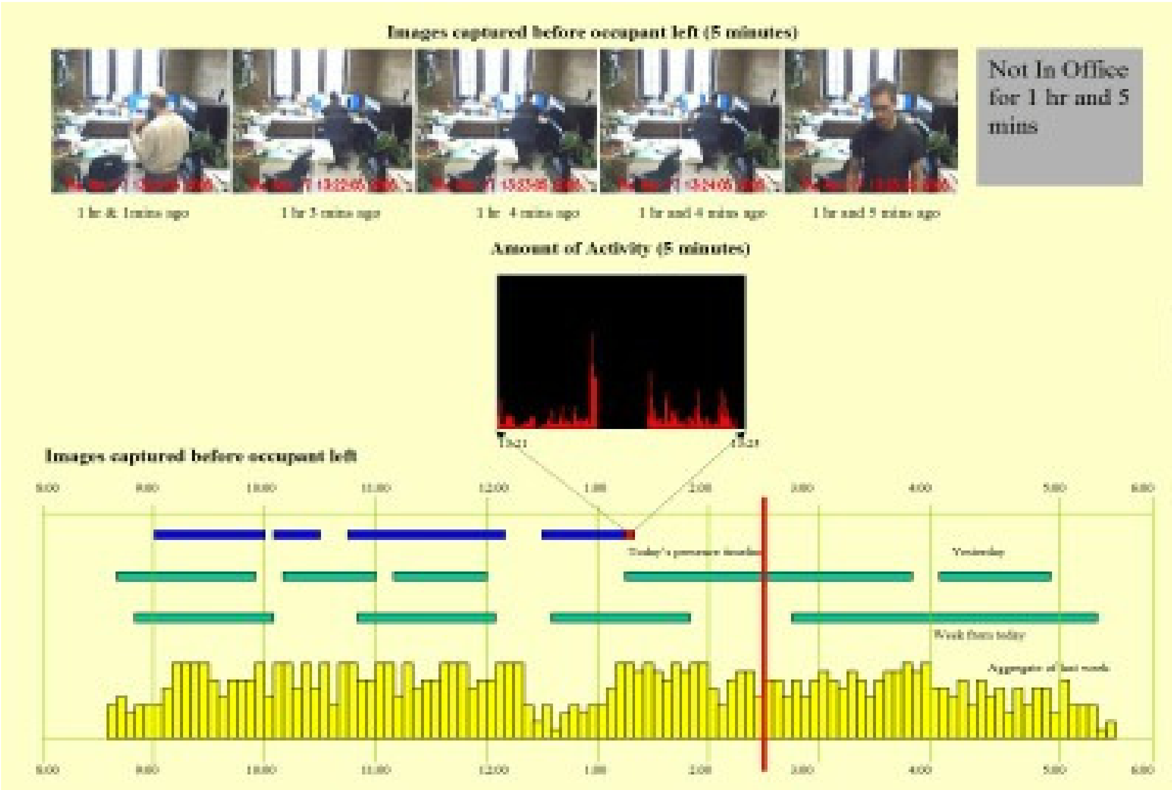



**Figure 3.17: Mock-up Past Activity View Prototype**

In Figure 3.18, there are four images captured while the occupant was in the office. The last image displays how long it has been since the occupant went out of the office. The big rectangle at the bottom represents long term and short term presence information. There are 13 columns, each of which represents a one hour time span between 7:00AM and 7:00PM. There are also four rows which represent presence time lines. The first row is for today's timeline, the second row is for yesterday's time line, and the third row is for the previous week's time line. The vertical line represents current time. The last row represents an accumulated aggregate time line over a longer period (Beogle et. al. 2001). In the aggregate time line, a valley indicates that there are relatively low chances of the occupant being present; a high peak represents high chances of presence at a given moment. Therefore, by looking at the aggregate time line, the viewer can analyze the presence pattern over the time period. In some sense, the viewer can determine the good time to interrupt the occupant by predicting when the occupant would come back.

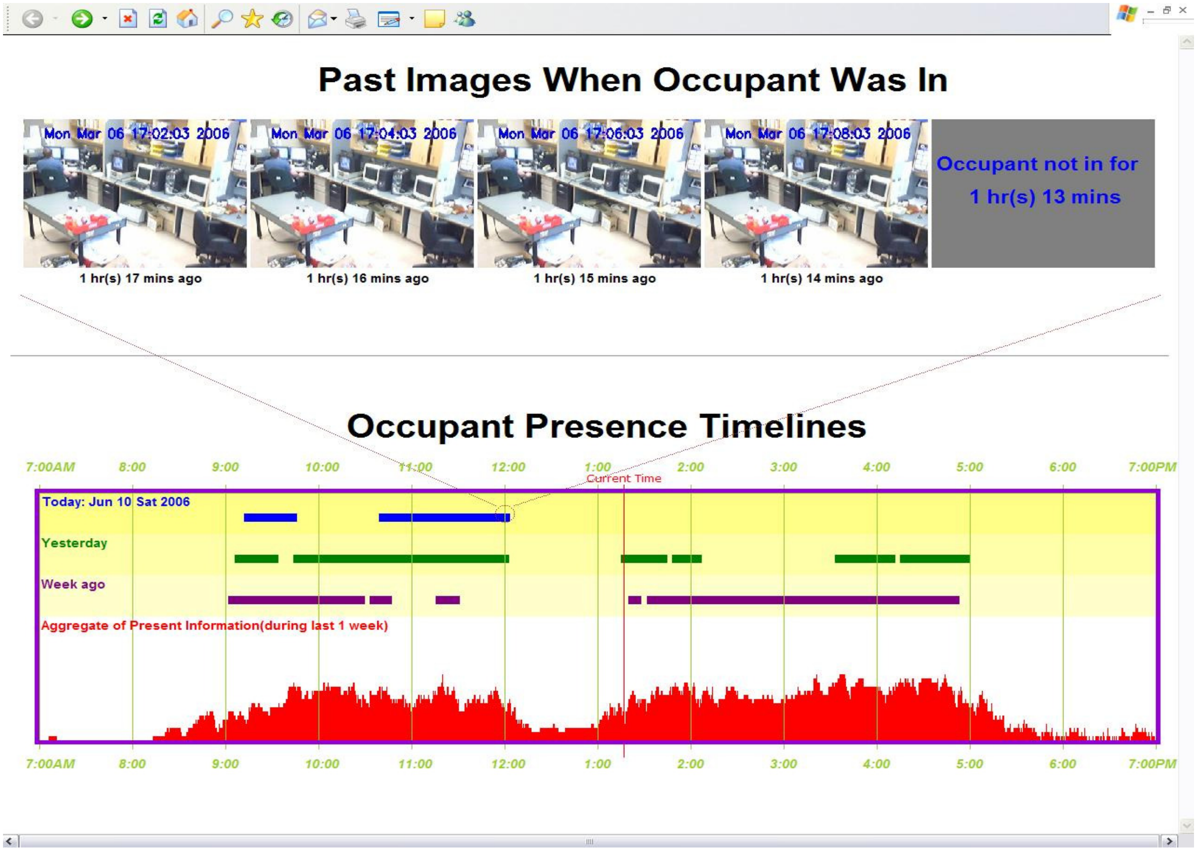



**Figure 3.18: Past Activity View- Highest Priority Viewer**

Again, different priority users get different fidelity and amount of information. So, for the images, the system blurs images, and for the time line view, it shows only some portion of time span according to the priority ().

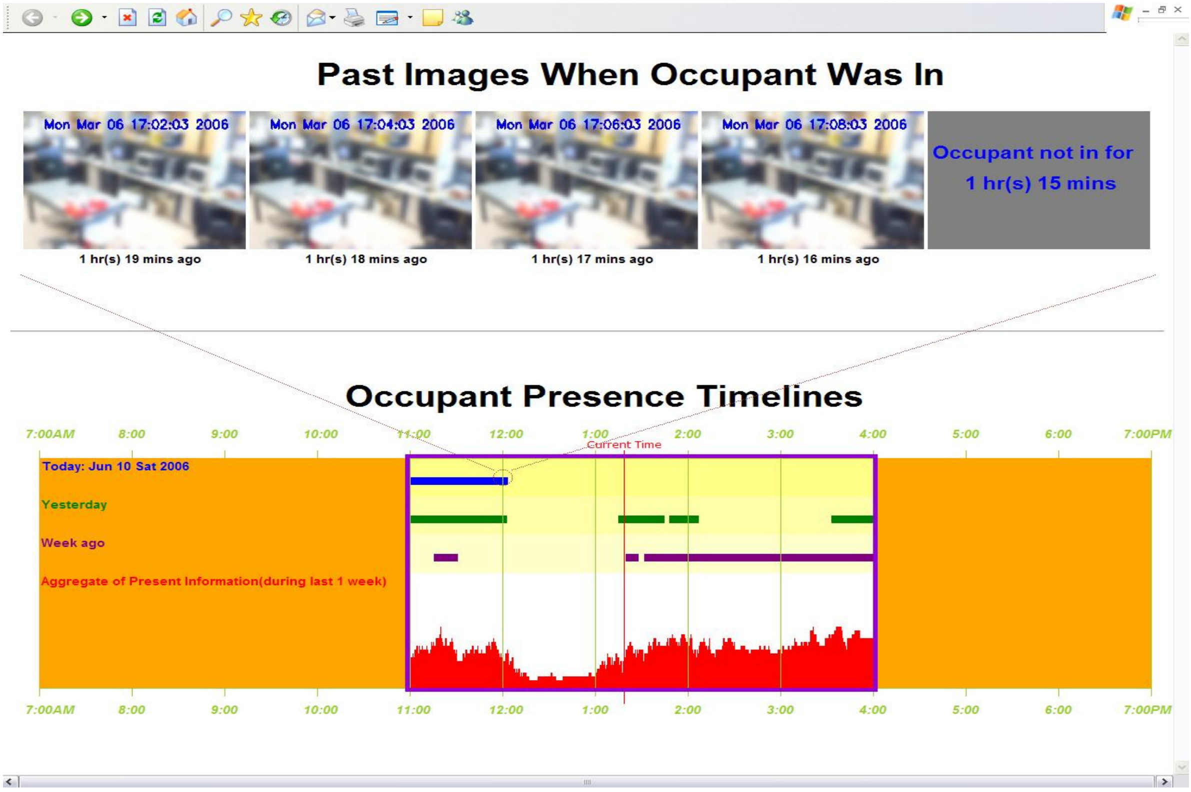



**Figure 3.19: Past Activity View for Low Priority Viewers**

### 3.3.2.3 Obtaining Awareness Easily and Decreasing Privacy Concerns

In the second version of the Magic Window, two physical displays were built to draw users' peripheral attention through ambient sound and motion to provide an easy way to gather awareness. These were added into the system to reduce the occupant's privacy concerns and the viewer's effort to obtain awareness information.

***In-Out Display*:** The In-Out display (Figure 3.20) is a very simple indicator that tells whether the occupant is currently in or out. The indicator was simply hooked up with the occupant detection feature that was already available in the first version. Viewers were able to check the basic awareness of the occupant- present or absent- from a distance without having to walk up to and log into the system.

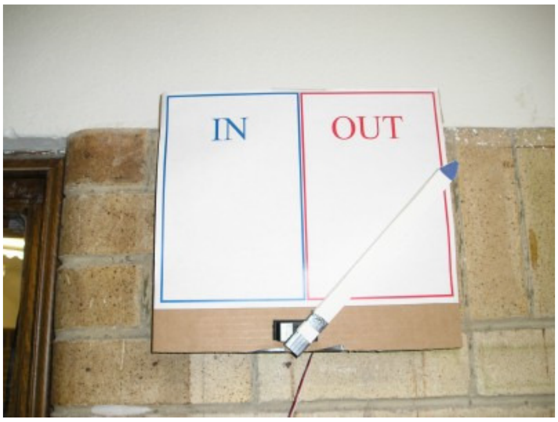



**Figure 3.20: In-Out Display**

***Time Clock Display***: After an informal interview with the occupant, it was found that the periodically captured snapshots for Past Activity view had still privacy implications, since the occupant did not know when and what kind of images were captured. To mitigate such privacy concerns, a physical display called the Time Clock display was introduced. Rather than providing the occupant with full control over capture images, a Time Clock display notifies the occupant when an image is going to be taken. The occupant can be sure when an image is taken through audible and visible feedback from Time Clock display (Figure 3.21).

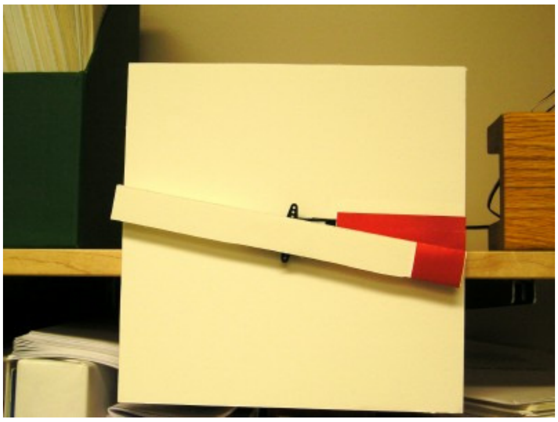


**Figure 3.21: Time Clock Display**

### 3.3.2.4 More System Feedback

Feedback on system state and user interaction was enhanced, and more feedback features were added for both the occupant and viewer. When a viewer authenticates to the system, the TextLCD display (left in Figure 3.22) displays a greeting message with the name of person, along with a log-in sound. When the log-in times out or the viewer removes the face out of the camera view angle, the greeting message disappears with a log-out sound. Also, to mitigate the problem of the processing time until the past activity view is brought up, an intermediate display saying "Processing Past Information" (right in Figure 3.22) was inserted between the moment of log-in and the moment before the Past Activity view pops up so that viewers understand the system is getting ready to display the Past Activity view.

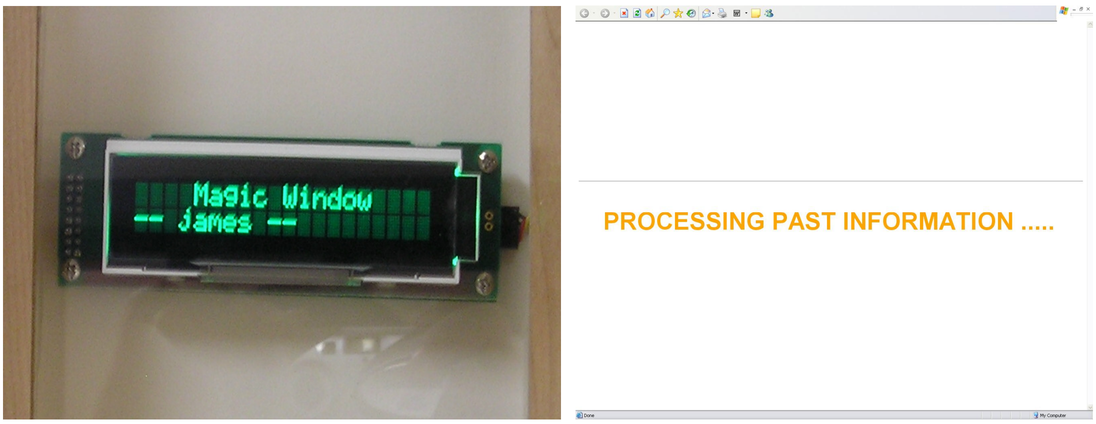



**Figure 3.22: Intermediate Message (left) and Greeting Message(right)**

Also, more feedback for the occupant was added: two displays were added on two separate displays to show what others could see from outside the office. These two views were available initially but the size of displays was small and there was latency in updating images (see Figure 3.4). These were the critical problems that caused the occupant to leave the door open (see Problem 2 in Section 5.3). Therefore, in this version, the full video of the outside view and a mirror view that is exactly identical to what viewers can see on the Magic Window became available to the occupant. These two views provide awareness and ensured the occupant knew what is being displayed (Figure 3.23).

**Figure 3.23: Mirror View (left), Full Hallway View (right)**

### 3.3.3 The Third Version of Magic Window

Two main modifications were made to the Magic Window system in the third version. The first modification was the capability for visitors to interrupt the occupant by pressing a doorbell that is integrated with the Magic Widow system. The second modification was to provide more awareness for both the occupant and the viewer. The third version of the Magic Window is presented in Figure 3.24. This section discusses such modifications of the system.


**Figure 3.24: Third Version of Magic Window Deployed in Second Office Setting (after first priority user logged into the system)**

#### 3.3.3.1 Doorbell Interaction

There were two main motivations in introducing the doorbell into the Magic Window. First, just like using relationship for confidentiality control, using relationship for solitude control would also be beneficial. Second, using doorbell and system state, the Magic Window can allow lightweight interaction between an interrupter and an occupant in a particular office setting.

***Using Relationship in Interruption*:** When a visitor presses a doorbell after logging into the system, the system does two things: first, the system notifies the occupant by playing a ringing sound. There are different intensities of ringing according to the priority of the interrupter. For a first-priority viewer, the system rings four times. For the second priority viewer, it rings three times and so on. In case that the user presses the doorbell without log-in, then the interruption effect is minimal- just one ringing.

The idea behind the implementation of different interruption intensity is that the occupant would be more willing to be interrupted by a high priority viewer and less willing to be interrupted by low priority user visitors. This idea goes hand in hand with the idea of providing different fidelity and amount of information according to the viewer's relationship with the occupant.

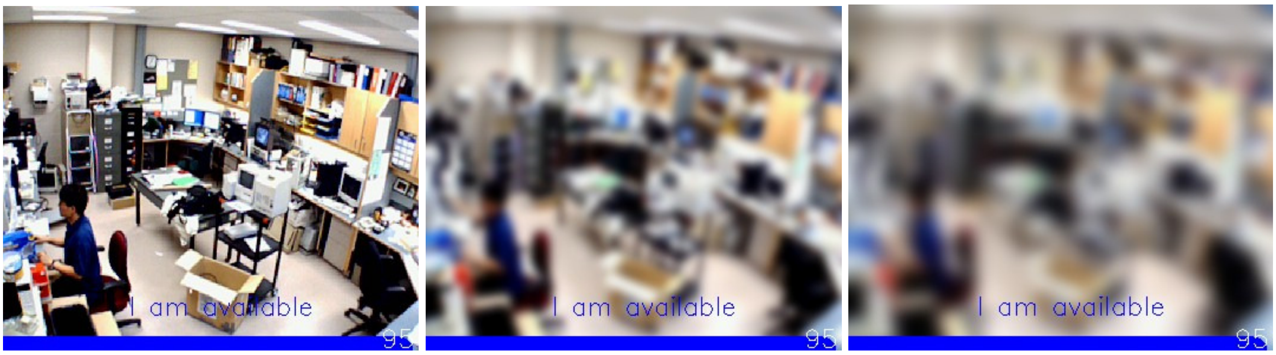
***Lightweight Interruption-Response Protocol:*** In the second office setting, the main user's desk is located in the office in a way that both the occupant and the viewer can not see each other even when the door is wide open. Until the occupant answers the door or the visitor walks in, it is difficult for the occupant to know what priority user initiated the interruption. At this stage, it is often hard to regulate the interruption since the occupant and the visitor are already engaged in an interaction. For example, it would be rude to turn down the interruption setting at that stage.

Upon the doorbell being pressed by a visitor, the system state application window pops up and is brought to the foreground of the occupant's desktop computer. In that moment, three choices are given to the occupant in dealing with that particular interruption. The occupant can choose to invite the visitor (left image in Figure 3.25), ask the visitor to hold on for a moment (right image in Figure 3.25), or ignore the interruption. For the first two choices, the Magic Window displays messages "Come in" or "Hold on" on the display. For the last choice, the Magic Window would not display any message so the interruption will be ignored. The doorbell and occupant response can make the interaction smoother by putting an impersonal barrier between the occupant and the viewer.


**Figure 3.25: Two Messages upon Occupant's Response**

### 3.3.3.2 More Awareness for Viewer- Less Blurry Default View

From the first and second versions of Magic Window, the default view was too blurry so it was hard to tell if someone is in the office or how many people are in the office. If the default view is less blurry then it was thought that more basic awareness would be available to the viewers. So instead of using box filter, in the third version, a Gaussian filter was used to blur the video because given the same size of filter, Gaussian filter gives less blurry image than a box filter; therefore, the overall fidelity of the awareness information available on the Magic Window increased. The different effects by different size of Gaussian filter are presented in Figure 3.26.




1x1 Gaussian Filter 25x25 Gaussian Filter 41x41 Gaussian Filter

**Figure 3.26: Less Blurry Effect With Gaussian Filter**

#### 3.3.3.3 More Awareness for Occupant

***System State Application***: There is an application process running on the occupant's desktop computer, which is called the System State Process. It provides the occupant with fine-grained system state information with little effort. It tells the occupant the current confidentiality setting, current solitude message, and current state of In-Out display state.

The introduction of this process has to do with the occupant's effort to maintain awareness of the system state and the second office setting. In that office setting, the mirror view and the 2D GUI (Figure 3.2 and Figure 3.3) were running on two separate computers sitting near the occupant's desktop computer, so the occupant had to stand up and walk to those computers in order to see the state of the system. With the System State process, the occupant can monitor at his own desktop computer by double clicking or hovering over an icon in the windows system tray (Figure 3.27).

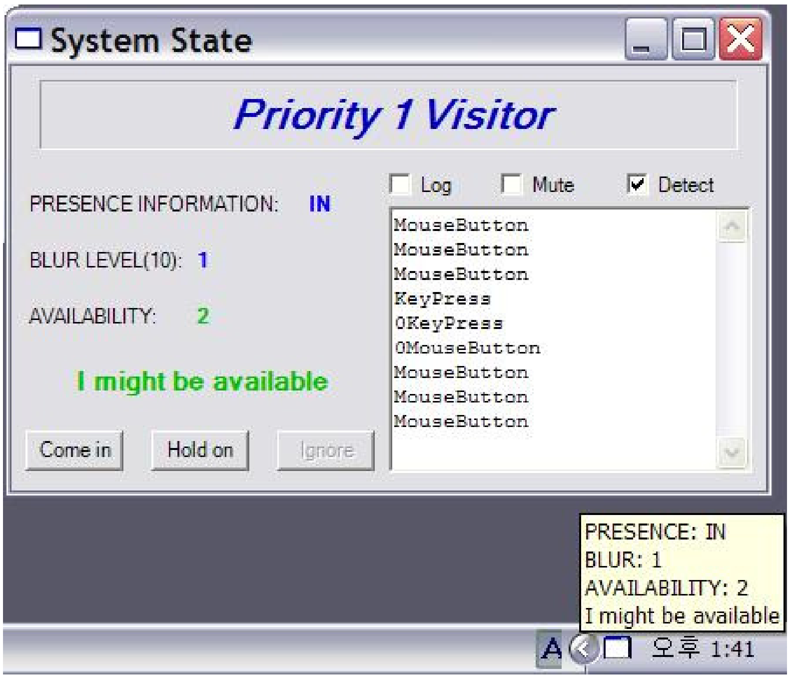



**Figure 3.27: System State Application**

***Who-Visited-When Information***: Often office occupants want to know who has visited their office while they are away. Sometimes they wonder if they missed anyone very important. To address this kind of problem, a visitor record was added into the Magic Window. Whenever a viewer logs in, the system records the name of the viewer and the time of log-in, and this information is used to generate the visitor log.

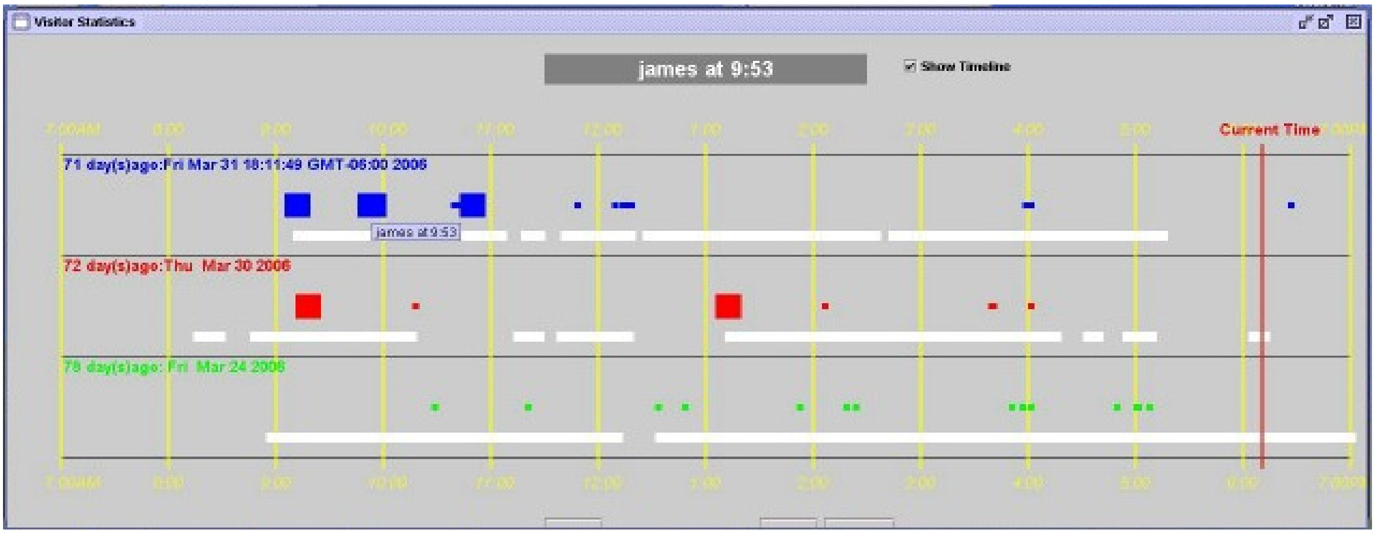



**Figure 3.28: Visualization of Visitor Records**

Visitor information visualization (Figure 3.28) takes the almost same format as the Past Activity view. Four squares that are different in size are displayed along with the time area, with each square representing each instance of visit and the size of square representing the priority of the visitor. For more information about the visit, the occupant can double click or move the mouse cursor over to each instance of square to see the name of visitor and time when the visit was made. To see if the visit was made during their absence, the occupant can choose to show presence time along with the visitor visualization; this allows easy identification of the visits that were made while the occupant was out of office.

## 3.4 Technical Design and Implementation

In this section, underlying technical details such as system architecture and techniques to alter visual awareness in the Magic Window are discussed.

### 3.4.1 The Overall System Architecture

The Magic Window system was implemented using several different programming languages:

- C++ for Video capture and image processing, and Phidgets control
- Java and C# for 2D graphical user interfaces
- JavaScript and HTML for visualization of Past Activity

Hardware used in the system includes two (three in the second office setting) Pentium 3 PCs installed with Windows XP, Phidgets analog sensors, two PC cameras, one fingerprint reader, and one motion detector. There are several independent processes that communicate with one another through TCP/IP socket connections and

RMI (Java Remote Method Invocation). The heart of the Magic Window system is a single independent process called the MagicWindow process. The application processes and communications among processes in the Magic Window system are illustrated in Figure 3.29.

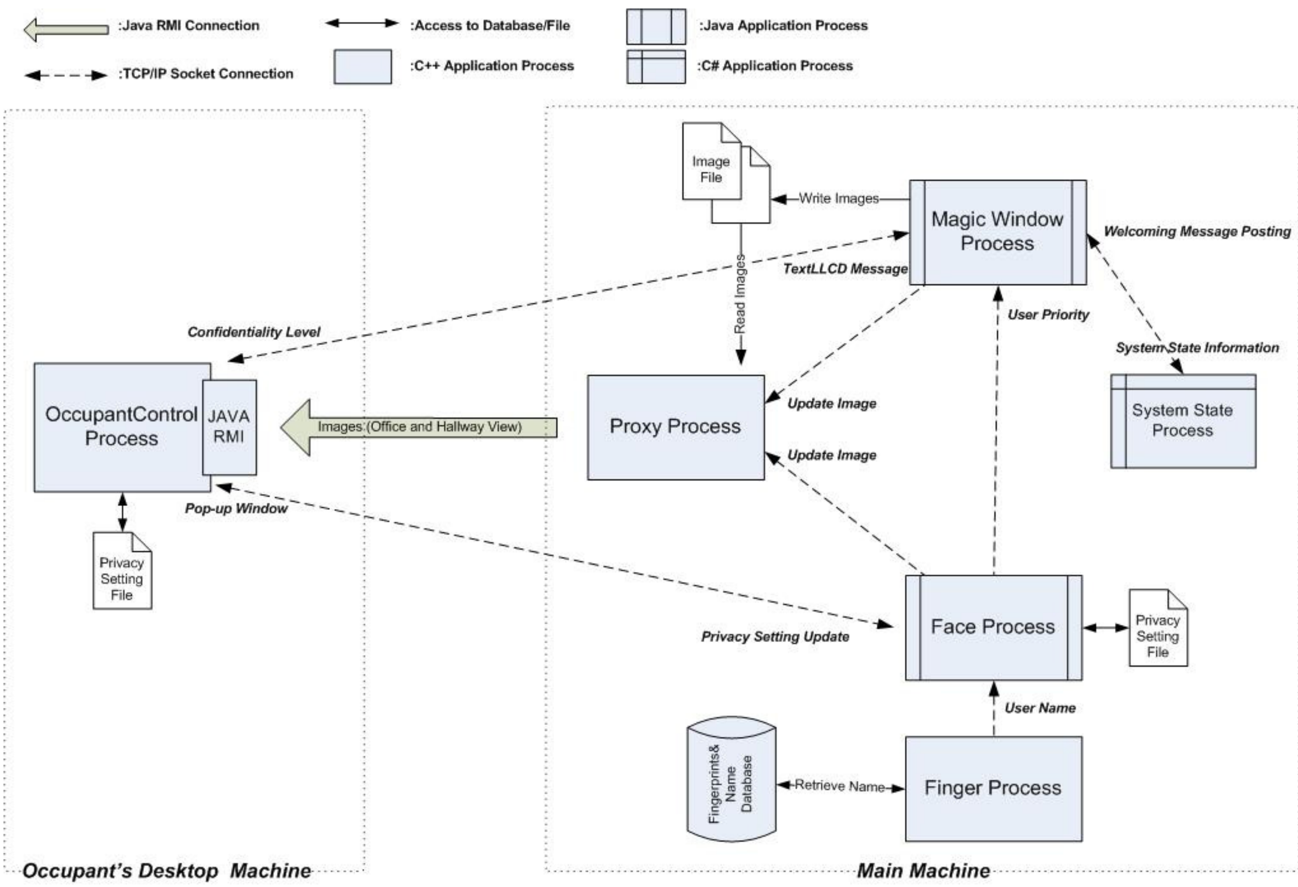



**Figure 3.29: Communication among Processes in Magic Window System**

### 3.4.1.1 Processes in the System

There are a total of six independent processes running, distributed over two (or three) machines. Each process has its unique task to perform and cooperate with other processes in the system.

***The MagicWindow Process:*** The Magic Widow Process is a main process that captures, processes, and displays the video of the occupant. This process has an infinite loop where each frame of the video of the office is captured by a camera. Several hardware components are controlled in this process and communicate with this process by sending signals. Hardware components controlled by the MagicWindow process include an office camera, a fingerprint reader, components in the physical user interface, Text LCD display, In-Out display, the Time Clock display, and motion detector.

***The Face Detection Process****:* The main functionality of the Face process is to provide the occupant with the hallway view. This process detects a face and writes the hallway view to a file on the local disk. It also keeps track of any updates in user priority setting. When notified by the Finger process, this process retrieves the user priority given a user name, and then notifies the MagicWindow Process to show an appropriate view to the viewer. The hardware controlled by the Face process is the hallway camera.

***The Finger Process:*** This process accesses a MS Office Access database file that contains the information of user names associated with viewers' fingerprint images. Finding a match between the fingerprint image captured and the fingerprint image in the database, it notifies the Face process of the viewer's name. The application was developed using a commercial version of a fingerprint development kit called GrFinger (http://www.griaule.com). The hardware controlled by this process is the fingerprint reader.

***The Proxy Process:*** This process works as a mediator between processes in the main machine and the on the occupant's desktop computer. It reads from image files (hallway view and office view images) from the local disk and transfers them to the OccupantControl process running a remote machine. The process gets notified by the MagicWindow process or the Face process when a high image transfer rate is desired (e.g., when face is detected). The image transfer rate increases to one image per three seconds.

***The OccupantControl Process:*** This process provides the occupant with a 2D GUI (Figure 3.2 and Figure 3.4) that enables the relationship based privacy control and shows the occupant what video image is being presented to the viewer, as well as the images of the current viewer. It communicates with the Proxy process through Java RMI and updates the hallway view and office view images.

***The SystemState Process:*** The SystemState process was introduced in the later version of the system in the second office setting to support lightweight interactions between the office occupant and the visitors. It communicates with the MagicWindow process to provide the current state of the system and current privacy level. In the second office setting the SystemState application was necessary since the OccupantControl process was running on a shared computer in a shared office environment.

#### 3.4.1.2 Inter-process Communication

The different computers running the processes described above were connected through a LAN using TCP/IP. Two different technologies were used to communicate among processes: socket connections were used to send string messages and a Java RMI connection was used to send image data. This section describes how inter-process communications are performed among processes on each event (see Figure 3.29).

***Upon Log-in*****:** When a user logs into the system by providing the fingerprint, the Finger process captures the fingerprint image and compares it with images in the database looking for an associated name. Upon a match, the user name is sent to the Face process and then the Face process looks for the user name and priority information in a preloaded user name-priority file. After that, the Face process sends the level of priority for that particular viewer to the MagicWindow process which uses it to show an appropriate view of the office according to the priority. At the same time the Face process sends the name of the viewer to the Occupant Control process running in another machine so that a pop-up window with the viewer's name is shown on the display to notify the occupant.

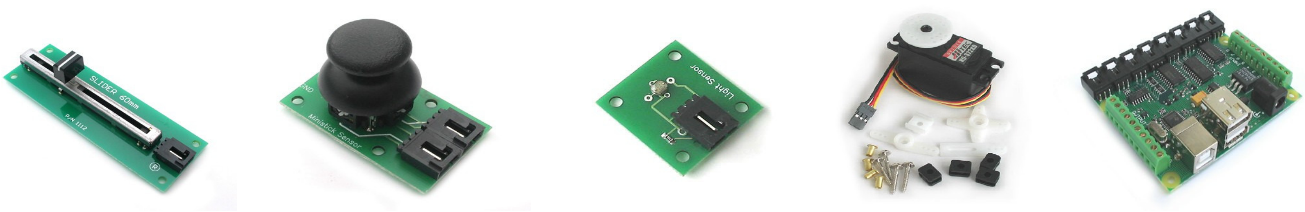
***Upon Detection of Face/Change of Setting by Phidgets*****:** Whenever any components of physical user interface are manipulated (e.g., adjusting solitude slider), the image of the office is periodically (e.g., every two seconds) written in local disk (the main machine in Figure 3.29) by the MagicWindow process. When a viewer's face is detected, the image of the office is also periodically written in local disk by the MagicWindow process. Then the Proxy process reads these two images and transfers them to another machine where the Occupant Control process is running for display.

***Upon Doorbell Event.*** When the doorbell is pressed by a visitor, the MagicWindow process notifies the SystemState process running on a remote machine and waits for a response. When the occupant chooses one of three options to deal with the interruption, the SystemState process sends a message back to the MagicWindow process. The MagicWindow process displays either “Come In” or “Hold On” text message on the display.

### 3.4.1.3 Hardware

In efforts to solve specific problems, a variety of hardware was integrated into the Magic Window system. This section introduces such hardware used to build the system.

***Phidgets:*** Phidgets are devices that provide a physical user interface as opposed to software widgets. Phidgets were used in the Magic Window to provide a physical interface where its users can manipulate and control the system in a lightweight way. For example, a Phidget slider can replace 2D GUI widget slider, yet do the same job. Whereas one should open an application to manipulate the widget slider, the user can simply adjust the slider by hand. Pictures of Phidget components used in the system are presented in Figure 3.30. The first four components are connected to the interface kit that provides an interface between analog and digital inputs. The MagicWindow process receives analog signals through the interface kit from various sensors, such as phidget sliders, light sensors, and servo motors.



slider mini joystick light sensor Servo Motor Interface Kit

**Figure 3.30: Phidget Components used in the Magic Window**

The usage of phidget components are as follows:

- Two sliders: to set and adjust solitude and confidentiality levels
- Mini joystick: to pan and tilt the office camera
- Light sendor: to detect the telephone hook-up and hang-up
- Servo motors: used in In-Out display, Time Clock display, camera position
- On/off switch (not shown in Figure 3.30): to turn on or off the system
- Three-way switch (not shown in Figure 3.30) : to change views
- LEDs (not shown in Figure 3.30): to indicate current confidentiality level, camera position, and solitude level

***Fingerprint Reader and Doorbell:*** To enable the viewers to authenticate themselves with their fingerprints, a commercial Microsoft fingerprint reader was used in the system. It captures a visitor's fingerprint image in real time and the system verifies the captured fingerprint image against fingerprint images in the database. A real doorbell was also used in the system to facilitate the lightweight mechanism of interruption and response between the office visitor and the occupant. The doorbell works exactly same as a normally open switch. When the door bell is pressed, the phidget interface kit receives digital input signal and the system notifies the occupant in several different ways. Pictures of the finger print reader and the doorbell are presented in Figure 3.31.

**Figure 3.31: Fingerprint Reader and Doorbell**

***Motion Detector:*** A motion detector (Figure 3.32) was introduced in the second office setting, because the office camera was not robust enough to detect the occupant movement due to the physical layout of the office and other environmental factors. We mounted a motion detector on the office wall to make the detection more robust. With coverage angle of over 90 degrees, the motion detector along with the office camera made the occupant detection much more robust and accurate.

**Figure 3.32: Motion Detector**

***Other Hardware:*** Other hardware used in the system includes two off-the-shelf PC cameras and LCD panels and desktop PCs. Most hardware is connected to the main PC thorough USB connections. Due to the limited number of USB ports in the PC, it was essential to use a USB hub, but this caused some problems such as lack of power and signal loss in components.

### 3.4.2 Image Processing and Computer Vision Techniques

Image processing and computer vision techniques were used to detect the presence of the occupant, detect the viewer's face, and display different views of the office occupant. This section discusses how theses techniques were used for the Magic Window system.

#### 3.4.2.1 Detection Techniques

***Occupant Detection***: Detecting the presence of occupant is done using a PC camera. The assumption is that if the occupant is in the office, he would move over time. If three images captured by the camera periodically (e.g., every 30 seconds) seem identical, the system assumes that there is no occupant in the office. Otherwise, the system assumes that occupant is in. There are two difficult cases to be handled properly to achieve robust occupant detection result. When noise captured by the camera is significant, the system assumes that there is an occupant inside. Also when the occupant's movement is minimal, it is hard to distinguish differences in two images caused by the movement from the differences in two images caused by noise.

However, satisfactory results were achieved through the following image processing methods. First, three images were periodically (every 30 seconds) captured by the camera and stored in memory. Every 90 seconds, the images were processed by a median filter to reduce noise in the color image. The noise-reduced image was then converted to a black and while image (e.g., image1, image2, and image3). To determine if there is any moving foreground over the period of 90 seconds, these processed images are subtracted from one another (e.g., image1 minus image2, image2 minus image3, and image3 minus image1). The three difference images are further applied by the canny edge detection (Canny, 1986) filter to generate edge images that represents the differences between two images (e.g., image1-2, image2-3, and image3-1). This process was required to further minimize the noise effect captured by the camera. To determine if the difference is significant or not, the sums of image1-2, image2-3, and image3-1 are calculated, and if any of these three values are greater than a certain threshold value, the assumption was that there is an occupant. The threshold value was based on heuristics since the lighting condition and office layout can vary depending on the system deployment context. In the first deployment setting, the detection was very robust, but there were a few times when it did not work (e.g., when the sun comes out suddenly) In the second deployment setting the false positive rate was higher, because the camera tended to pick up more noise and there were many other factors that can affect the images captured (for example, a separate security monitor changed its view automatically and was captured by the office camera)

***Face Detection:*** The face detection was implemented using the Open Computer Vision (OpenCV) library (Intel Corporation 2005) and face detection sample code that is available in the OpenCV newsgroup. The OpenCV library provides a number of object detection functions. One function, *cvHaarDetectObject* does all the face detection tasks. First, a dataset contained in an XML file called *haarcascade_frontalface_alt2.xml* containing information about human face profiles is loaded and when *cvHaarDetectObject* function is called, it finds rectangular regions that are most likely faces in each image frame captured by a camera in real time, and the function returns those regions as a sequence of rectangles. The function considers overlapping regions in the image frame, and also applies some heuristics to reduce the number of analyzed regions. After it has collected the candidate rectangles, it groups them and returns a sequence of average rectangles for each large enough group. The size of rectangle that represents faces is measured, and the largest rectangle is assumed to be the user's face.

#### 3.4.2.2 Different Views

***Amount of Activity View***: A simple algorithm was used to calculate the sum of pixel differences between two consecutive image frames captured at a rate of one frame per three seconds. The magnitude of easy difference sum corresponds to the height of a spike in the visualization. The visualization is presented in Figure 3.11. One can notice that the occupant's action was significant (e.g., leaving office) when the visualization was generated.

***Ghost View & Shadow View:*** For the moving ghost effect, the background reference image without the occupant is captured at the start of the application. This image is always kept in system memory. At each frame, the current frame is subtracted from the previous frame and the difference image is displayed on the top of the reference image. The Shadow View uses the same algorithm introduced by Hudson (Hudson and Smith 1996). There is a subtle difference that Hudson's method alters the reference image but the Magic Window alters the difference image between two consecutive frames without altering the reference background image.

# CHAPTER 4

# SYSTEM DEPLOYMENT AND EVALUATION

The previous chapter has discussed the principles and design considerations of the Magic Widow system. The evaluation described in this chapter is based these principles and considerations. System deployment and evaluation took place for a period of eight months in two different office settings.

## 4.1 Design Process

The system went through an iterative design process for system evaluation. The design process focused on improving usability problems and identifying issues over the course of system's usage. The process includes a system deployment stage, an analysis stage, and a re-design stage (Figure 4.1). At each iteration, a new and improved version of the system was designed and deployed for the next iteration. Through this design process, we identified a number of issues and possible solutions that will aid in the design of future co-present media space systems.

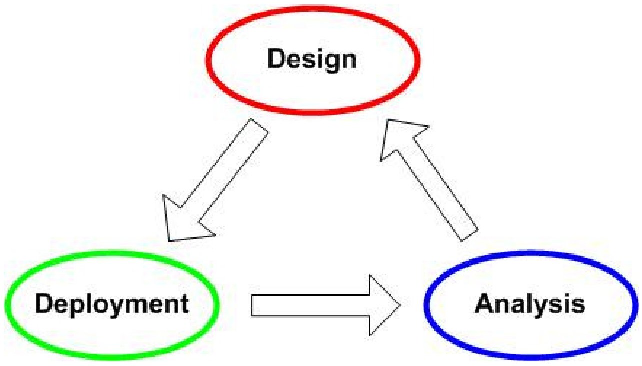



**Figure 4.1: Design Process**

***System Deployment:*** While the system was deployed, its usage was observed and logged, and users including the office occupants and visitors were asked questions by interview or questionnaires to assess its usability. For the viewer, we asked whether enough awareness was provided to determine availability, and for the occupant, we asked whether it was felt that privacy was safeguarded.

***Analysis of Issues:*** Any usability issues raised during deployment and found from user experience were analyzed at this stage. Information included what was observed by the observer (evaluator), and what was mentioned by the users (the occupant and the viewers).

***System (Re)Design:*** At this stage, possible solutions to issues analyzed in the previous step were considered. The system was re-designed based on the proposed solutions. After redesign of the system, the process went back to the deployment stage, and the process was repeated three times.

## 4.2 Deployment Phases and Settings

Three versions of the Magic Window system were deployed in two different office settings over approximately eight months. The two different office settings included an academic research lab and an ordinary office shared by two occupants; hereafter these settings will be referred as the first office and the second office. In the first office setting, the occupant was a faculty member, and viewers were graduate students and another faculty member working in that lab. In the second office setting, there were two occupants sharing the same office whose jobs were to maintain and take care of the department's undergraduate lab machines. The viewers were other technical staff members (co-workers), faculty members, graduate and undergraduate students.

The whole deployment process consisted of three phases according to the versions of the system. The first phase happened only in the first office setting. The second phase occurred in both the first and second office settings. The last phase occurred in the second office setting only. To gather the users' feedback for evaluation, the system usage was observed frequently and users, including the occupants and the viewers, were interviewed five times over the whole deployment.

Five arrows with two different patterns in Figure 4.2 indicate approximately when users were asked for evaluation. Different patterns of arrows mean that users were interviewed with different sets of questions. The two horizontal timelines represent two different office settings and they are divided into three regions that represent the first, second and third deployment phases. The Magic Window system is still deployed in the second office setting.

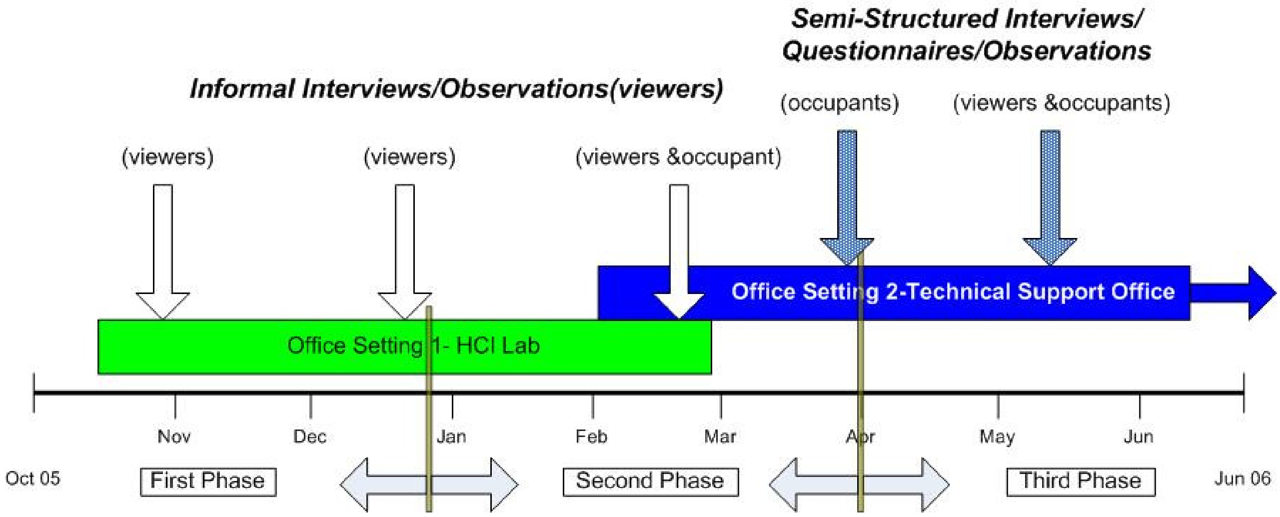



Figure 4.2: Timelines of Deployment and Evaluation

### 4.2.1 First Phase of Deployment (First Version of System)

**Where (HCI Lab)**

The initial system was deployed at a professor's office in the HCI lab, at the University of Saskatchewan. The main user (occupant) was a supervisor of a number of Ph.D. and M.Sc. students whose desks were located in the HCI lab. The floor plan of HCI lab and the location of the system are presented in Figure 4.3. It also presents the physical layout of the first office setting and locations of various components of the system. Note that the Magic Window display was located on the outside wall of the occupant's office within the HCI lab. In such a deployment setting, for viewers to check whether or not the occupant's door was open, they only needed to take a few steps towards the office past the main entrance to see the door state. Lab members whose desks were located in the HCI lab became informally aware of the occupant's presence much more easily than others whose desks were not in the HCI lab.

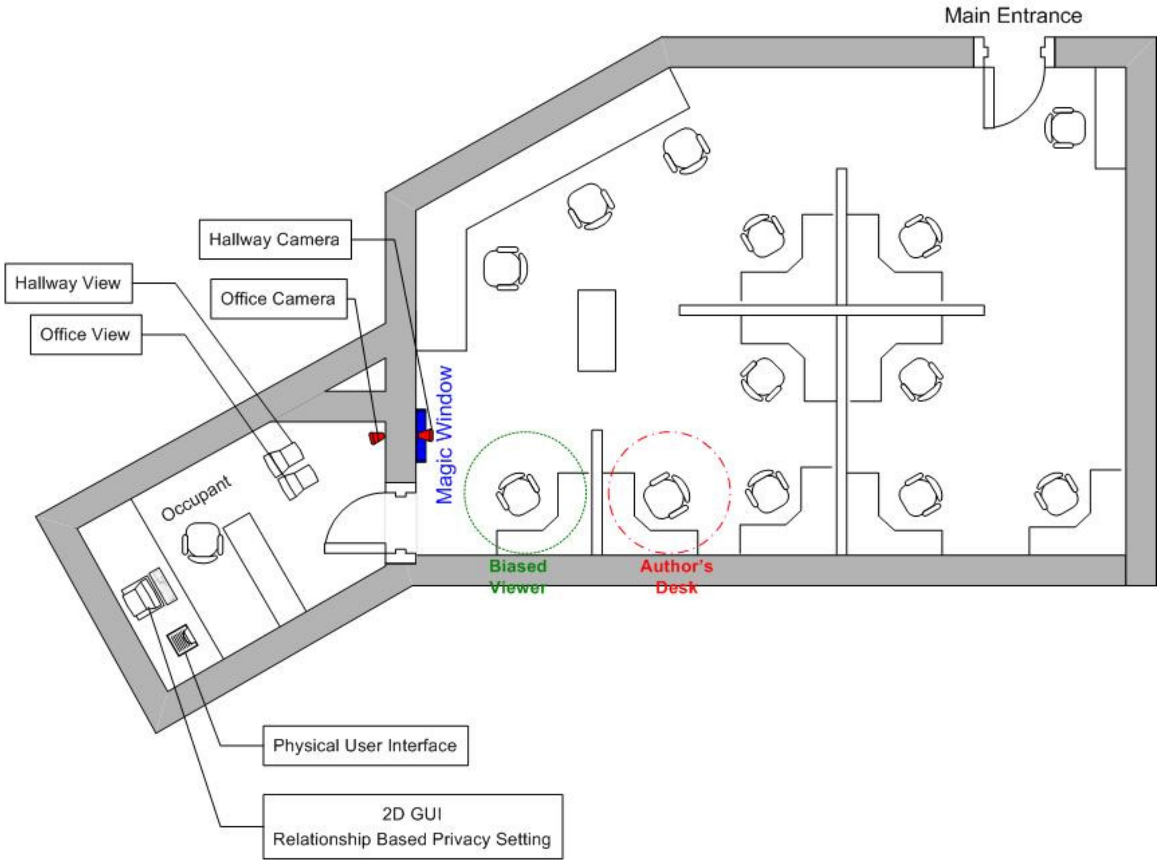



**Figure 4.3: HCI Layout and Deployment of Magic Window**

**When (Middle of Oct - Dec 2006)**

The first version of the Magic Window system (Figure 3.7) was deployed in the first phase of the study. The initial system was deployed over the period of three months from Oct. 2006 to Dec. 2006. It was during a typical academic semester.

**Who (Occupant: faculty member, Viewers: grad students)**

There was one main occupant who is the head of the HCI lab and about ten registered viewers who interacted with the occupant on a daily or weekly basis. Registered users are users whose fingerprints were scanned and stored in the system so that they can be prioritized by the occupant. The occupant's main role as a supervisor in the office was to offer discussion and hold scheduled or casual meetings with the graduate students. Students who needed help with their project or who needed to talk about project ideas casually came into the office and had discussions with the office occupant. Graduate students and faculty members from outside of the HCI lab also visited the occupant for discussion.

The questionnaire showed that there was high traffic of interactions going on between the office occupant and other team members. More than 15 visitors visited the occupant's office on an average day, and more than 30% of them were by regular visitors. Also the occupant was interrupted more than 10 times per day by other means, such as telephone or cell phone. The frequency of leaving his office during work hours was high. The occupant momentarily left his office more than 10 times a day during work hours for periods of one to ten minutes.

**How (Observation and Informal Interviews)**

Over the course of the first deployment period, observation and informal interviews with viewers took place in the HCI lab. Since the author's (observer) desk was located near where the system was deployed (see Figure 4.3) system usage was observed frequently and naturally on a regular basis by the observer. Two rounds of informal interviews were performed shortly after the beginning of the first phase and at the end of the first phase. In the first round of interview, three participants (viewers) interviewed with questions mainly about the Past Activity view (Figure 3.11). Based on the user feedback from the interview, the Past Activity view was redesigned in a way that the visualization became more informative. Four viewers participated in the second round of the interview with a focus on system usage, effort, system feedback, quality of information, and understanding of the system. The occupant's activity with the system also was observed and frequent feedback was collected, but no interview was performed with the occupant in this phase.

**Findings**

The following sections describe what was found after the evaluation during the first phase of the study.

***System Usage (Viewers):*** Viewers used the system twice a week on average. Other times, they used other sources of awareness information, such as open door, to maintain their awareness of the occupant. It seemed that users used the system as a additional information source to existing information sources. They tended to use the system when they were not sure if the occupant was in, such as when the door was closed, or when the door was partially open but it was hard to assess the availability of the occupant. Also when the occupant was not obviously available (e.g., when engaged with meeting), some users used the system to see who else was in the office for curiosity.

***Effort (Viewers):*** Viewer's effort to obtain awareness and to understand what is being displayed on the Magic Window seemed to substantially affect the system usage. Given how people obtain awareness in an office-hallway setting, lightweight ways of obtaining awareness had to be taken in account. For example, users, in many cases, just wanted to know if the occupant was in or not. However, the cost for obtaining such basic awareness seemed high through the Magic Window system. A main problem of the viewer's effort was the time that it took until the Magic Window brought up the Past Activity view. In synchronous mode, it took about one second for the first priority viewer to see the live video of the occupant after the time a viewer's fingerprint is scanned. Even more, in asynchronous mode, it took four to five seconds to generate 10 image snapshots and one big “Amount of Activity” view image from memory, and another 1 to 2 seconds to open a web browser to display them. Another effort problem with the system was that viewers had to maintain their face in a certain position to the hallway camera to remain logged into the system. People had different height but the hallway camera was fixed at a certain height. It became a big problem for some users who are much taller or smaller than average people.

***System Feedback (Viewers):*** Another problem on the viewer’s side was a lack of understanding of how system works and, it caused the viewers to get confused. For example, there was no visual and audio feedback on log-in, and some participants commented that they were not able to tell if they were authenticated correctly by the system while waiting for the system to bring up the information.

***Understanding of Information Presented by System (Viewers):*** Viewers found it difficult to interpret the Past Activity view. It was hard to relate the sequences of images with the Amount of Activity view. Also, viewers used it mainly to see whether or not the occupant has been in today or how long the occupant has been gone. It certainly suggested that there was room for improvement for the Past Activity view.

***Quality of Awareness (Viewers):*** In synchronous mode, the default video provided little awareness since it was blurred somewhat severely by a 41x41 box filter. It also was difficult to tell how much the occupant was available by looking at the availability bar and the color of the video, which was explicitly set by the occupant. To address the problem, the default view was blurred by a 41x41 Gaussian filter, and the availability level was displayed with explicit messages in the next version of the system.

***Quality of Awareness (Occupant):*** The occupant wanted to stay aware of what is going on outside the office, but the system was deficient in providing awareness from outside of the office. So, the occupant preferred to keep the office door open most of working hours. This broke the aim that different priority users should get different fidelity and amount of information since everyone in the lab was able to see and hear the same amount and quality of information through the open door.

***Privacy (Occupant):*** There were privacy concerns about images periodically captured and stored in a local hard disk to be used for the Past Activity view. Since there was no means for the occupant to pre-screen, select, or delete images, the occupant could not tell at which moment an image of themselves was captured for the display.

### 4.2.2 Second Phase of Deployment (Second Version of System)

**Where (Two Places-HCI Lab and Department Technical Staff Office)**

The second version of the Magic Window system continued to be deployed at the professor's office in the HCI lab. Shortly after the second deployment phase started in the first office setting, the exact duplicate of the Magic Window system started being deployed at another place, an office for department technical staff in a separate building. The physical office layout and the deployment of the system are presented in Figure 4.4.

There were two main differences between two office settings from the social perspective. First, the second office environment was shared by two technical staff members. Therefore, it was necessary to run the OccupantControl application, which provided a 2D GUI for relationship based privacy setting, on a shared machine. Second, the Magic Widow LCD panel was deployed at the entirely public space (the hallway) whereas it was deployed in the semi-public space (the HCI lab) in the first office setting. These two differences influenced the way users used the Magic Window system. In addition, it was necessary to use a wider view angle camera since the second office was much larger.

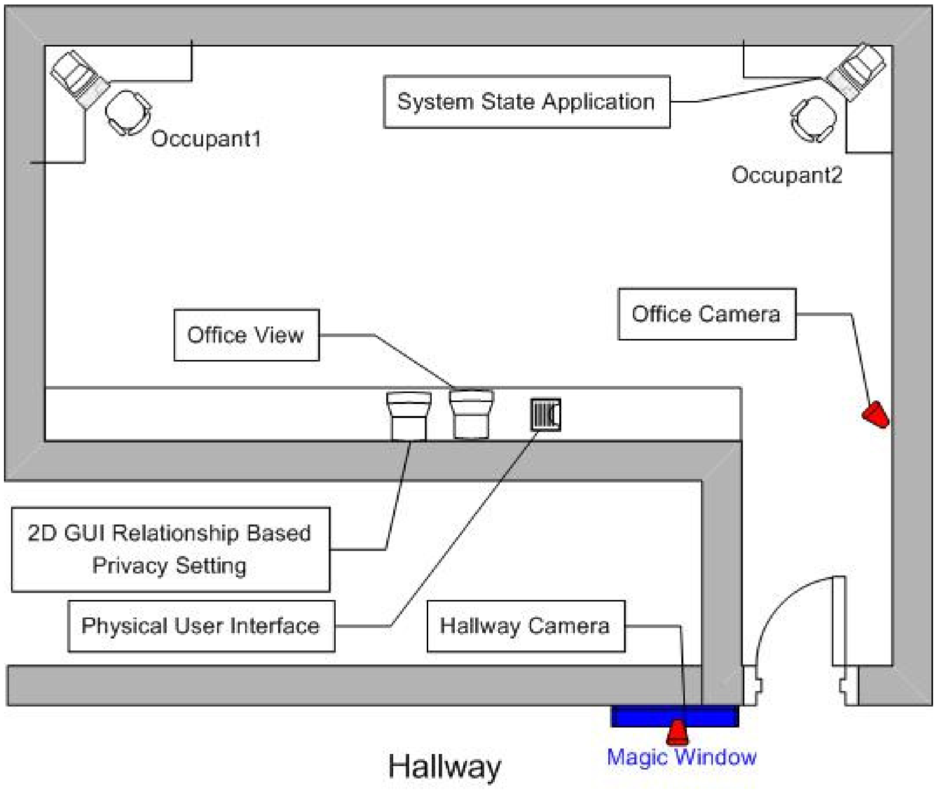



**Figure 4.4: Second Office Setting Layout and Deployment of Magic Window**

**When (Jan - Mar 2006 and Feb –Mar 2006)**

The second version of the system (see Chapter 3) was deployed over a period of three months, from Jan 2005 to Mar 2006 in the first office setting and from Feb 2005 to

Mar 2006 in the second office setting. It was also during a typical academic semester. For a one and a half month period, two Magic Window systems were running in two different office settings at the same time.

**Who (Occupants: faculty member, Viewers: grad students; Occupants: technical staffs, Viewers: other technical staff, faculty members and students)**

The users in the first office setting were the same as first deployment phase. In the second office setting, the two occupants' main duty was to support and take care of the department lab machines and department servers. The occupant had, on average, at least eight to ten visitors on a daily basis and only 10 to 20% of them were regular visitors. These occupants had casual visitors such as undergraduate students. Due to their job, it was often necessary to leave their office to help students who often had difficulties logging in to a lab machine, on average, five to ten times a day. For one occupant, the trip took on average less than ten minutes but for the other occupant it was between 10 and 20 minutes. The number of interruptions by other means such as telephone or cell phone also varied. Since the first occupant tended to take a short time out of his office, he was interrupted more by other means than the other occupant. For most time of the third deployment phase, the second occupant stayed in another office rather than the office where the Magic Window was deployed. There were eight registered users in total and seven of them were the occupants' co-workers and one user was an undergraduate student. Un-registered users consisted of most undergraduate students and faculty members who needed to collaborate with the office occupants for various reasons.

**How (Observation and Informal Interviews)**

Two sets of evaluation were carried out during the second phase of deployment. In the first office setting, both the occupant and viewers were observed and interviewed; in the second office setting, only the two occupants were interviewed for the system usage. After interviews in the first office setting, the system deployment in the HCI lab discontinued but the system in the second office setting continued for further evaluation. More specific interview questions were asked for the viewers after the first deployment phase. These focused on how viewers used the system when there was another information path. The questions for viewers included:

- how they used the system (blurred video, Past Activity view, In-Out display, availability messages)
- whether they succeeded in finding the information they wanted
- whether there was a confusion interpreting information provided by the system
- what the major usability problems were
- what required the most effort
- how people used the door state

Also, the interview questions for the occupants included questions regarding:

- usability
- privacy
- alternatives for privacy control
- effort for privacy control with the system

- feedback from the system
- user trust in the system

**Findings**

Observation and informal interviews with both the viewers (first office setting) and the occupants (first and second office setting) revealed the detailed system usage of individual components of the system and feedback on improvement from the first version. The following sections describe findings from the second deployment phase.

***System Usage (Viewers)***: The new features added to the first version of the system seemed very useful. The In-Out display enabled viewers to check the presence of the occupant from a distance. It seemed to require very little effort and viewers mentioned that this feature was very useful. The explicit availability message was used and respected by most viewers too. They assumed that the message reflected the current level of the occupant's availability level, although the interview with the occupant revealed that the occupant sometimes forgot to update the message. Compared to the continuous abstract solitude level display, explicit messages seemed much more effective by making the level of the occupant's availability clear and easy to understand. In particular, the "I am talking on the phone" message was the most effective availability information. Viewers succeeded in that they did not interrupt the occupant when the occupant was on the phone.

***System Feedback (Viewers):*** The Text LCD display that was introduced in the second version of the system helped the viewers understand when they logged on and logged out of the system. Although sound effects were introduced to synchronize with the welcome message on the Text LCD display, they seemed intrusive to lab members whose desks were near the system, so the sound effects were dropped soon after their introduction.

***Quality of Information (Viewers):*** For default blurry live video, people did not seem to use it only to obtain crucial awareness information even though the blur level was reduced using a 41x41 Gaussian filter. However the information from other components of the system such as the In-Out display made the awareness information richer. Viewers used the upgraded Past Activity view (Figure 3.18) for high level of past awareness information. They primarily used it to check if the occupant had been in on that day and how long the occupant had gone for. For example, more detailed information such as the "last week" and "yesterday's timeline" views were not used much. For some users, it was still difficult to understand the visualization of the Past Activity. Especially for low priority users, blurry effects on images and occluded areas in the timeline made it difficult to understand (see Figure 3.19).

***Usability and Satisfaction (Viewers):*** Users seemed to succeed with what they tried to achieve with the Magic Window system. After improvement of the system, there seemed to be less confusion in using the system and interpreting awareness provided by the system. However there were some problems with accuracy of the awareness information. The In-Out display was slow to update the occupant's current presence. Although its detection rate was very high, the indicator provided momentarily false information about the occupant's presence due to the slow update speed. For example, it indicated that the occupant was in for about a minute after the occupant went out of the office. It eventually switched to the "out" position, but it provided false positive information temporarily.

***System Usage (Occupants):*** The control of privacy through the physical interface seemed very easy and satisfactory to regulate privacy. There was a clear distinction among usage of privacy control features. The On-off switch, Ghost/Shadow view, camera tilt-pan, and confidentiality control were not used very frequently. However the availability message feature was used frequently in regulating privacy. The occupant seldom changed the relation-based privacy settings. After setting these for the first time, the occupant had no need to change them.

As mentioned before, the explicit availability message was very effective when it was used correctly. One day, the occupant set the availability level to unavailable all day long and had almost no interruptions by office visitors. The occupant also thought that the availability messages were respected and this is also consistent with what the viewers said about the availability messages.

The Time Clock display seemed to be effective in that the occupant could stay aware of the moments that the image was taken. The occupant used the audio feedback rather than visual feedback without bothering looking at the display. The occupant mentioned that the ticking sound was not so intrusive but helpful psychologically in safeguarding privacy.

***Privacy (Occupants)*:** The occupant's confidentiality seemed well protected through the system. Especially, the blurry live video provided as the default view well balanced the privacy and basic awareness level such as "the occupant is in." The occupant in the first deployment was willing to provide more awareness about himself through the default video view to help viewers make better decisions. However, occupants in both office settings were a little concerned about the Past Activity views. They showed their concerns about privacy since the presence timeline and aggregate views might be used by their bosses who would expect the occupants to be in the office. They wanted to be able to control their presence information or have control over the way the information was visualized.

***Alternatives (Occupants):*** The occupant in the first office setting often used the office door to regulate privacy whereas the occupant in the second office seldom used other means than the Magic Window system. It seemed that the outside of the first office setting was less public than the outside of the second office setting, so keeping the door open was not a big concern at the first office setting. Also the number of interactions in the first office setting was higher than the second office setting. Therefore, the large amount of interaction traffic prompted the occupant to use other means for privacy regulation which can accommodate high volume of interaction traffic in a quick and adequate way.

***Effort (Occupants):*** The effort to control privacy through the system seemed minimal. Both occupants from both office settings mentioned that they were able to change or regulate their privacy settings easily. In particular, the physical user interface enabled lightweight control over privacy. However, there was a problem of forgetting to set the privacy level at each situation. Even though there was an easy way to control privacy, forgetting to use the system was problematic since the current availability message was out of date, but the viewers still thought that it was reflecting the occupant's current availability level.

***User Trust and Feedback (Occupants):*** The feedback from the system seemed appropriate and adequate. The occupants were made confident about what is being controlled and displayed by the system feedback. Feedback was not too intrusive either, so the occupants felt comfortable with the system as a tool for privacy control. However, at the beginning of the system deployment, the user trust was degraded by the low speed of system response. The image update rate of viewers and feedback from occupant's privacy setting change was somewhat slow because there was a one second delay in updating the images. However, the occupants regained almost full trust in the system over time as they saw the system work correctly. After a certain period of time, the occupants began to ignore the system feedback. The speed problem with the feedback did not erode their trust in the system any longer from that time on.

### 4.2.3 Third Phase of Deployment (Third Version of System)

**Where (Department Technical Staffs' Office)**

The third version of system was deployed at technical staff's office only. For more detail on the setting, see section 4.2.2.

**When (Apr –Middle of May, 2006)**

The third version of system was deployed over the period of one and half months from April 2005 to the middle of May 2006. The first half of the phase was also during a typical academic semester of the university (final exam period) the last half of the third phase was during a summer break.

**Who (Occupants: technical staffs, Viewers: other technical staffs, faculty members and undergraduate students)**

The users in the third deployment phase were the same as during the previous deployment phase. For more detail, see section 4.2.2.

**How**

At the end of the one and a half month deployment period, participants, both registered viewers and occupants were interviewed. Participants included 4 registered viewers, 1 unregistered viewer, and 2 occupants. The interviews were carried out in the form of semi-structured interviews where participants were given questionnaires to fill out and then asked a set of questions. All interview content was recorded and transcribed. The categories of questions asked during the third phase were similar to those in the second phase but the questions followed participant views and answers. The categories of questions include:

For the viewers

- Alternatives and Existing Social Norms
- Viewer's Privacy
- Viewer's Trust
- Gathering Awareness
- Feedback
- Unnoticed Glancing
- Doorbell Interaction
- Design Ideas

For occupants:

- Usability
- Shared Office Environment
- Reciprocity
- Safeguarding Privacy
- Alternatives
- Effort
- Awareness from Hallway
- Feedback
- User Trust

**Findings**

***Doorbell Interaction:*** After a real doorbell was placed beside the system, the occupant mentioned that office visitors used it about 80 to 90% of the time. Sometimes, the occupants got odd knocks. When the doorbell rang, the occupant was immediately notified of the priority of the interrupter by hearing the number of rings, and could identify the interrupter by looking at the hallway view in the 2D GUI user interface. Multiple rings were found somewhat intrusive according to the occupant; it was suggested that providing different sounds would be beneficial (providing a voice message such as “First priority user logged in”).

When interrupted by a visitor, the System State application seemed very useful, yet not too intrusive. The occupant mentioned that he felt he did not have to get to the door before the visitor left, but he had the option to invite the visitor right away or hold the visitor if he was in the middle of something. It also could be done very easily requiring minimal effort.

There was still room for improvement in doorbell interaction. The doorbell should not ring if the occupant is obviously unavailable. For example, if the occupant is on the phone or the solitude message is set to "I am not available," the doorbell should not make any sound so as not to interrupt the occupant. Also, if a visitor presses the doorbell without log-in, the interrupting should be a minimal or have not effect, since without the visitor identification information, the system is unable to provide the visitor's priority information to the occupant. This is also necessary to maintain the idea of reciprocity.

**Findings from Questionnaires**

There were a total number of eight participants (five viewers and three occupants) who participated in the questionnaires. Participants were asked Likert-scale questions (9 levels). The following sections discuss findings from questionnaires only. Due to the small sample size, we do not perform statistical analysis on the findings.

***User Satisfaction (Viewer):*** Most viewers stated that the system was ease to use, easy to learn and useful. For the low priority user (not counted in calculating average), the system seemed less useful and hard to learn. Figure 4.5 shows the average values of four registered viewers. Low quality of awareness seemed the cause of low satisfaction for the low priority user. For example, the interviewed low priority user was able to access only limited awareness (e.g., middle image in Figure 3.26 and the Past Activity view in Figure 3.19) whereas high priority users were able to obtain high quality awareness (e.g., left image in Figure 3.26 and Past Activity view in Figure 3.18). However, the system seemed easy to use for high and low priority users.

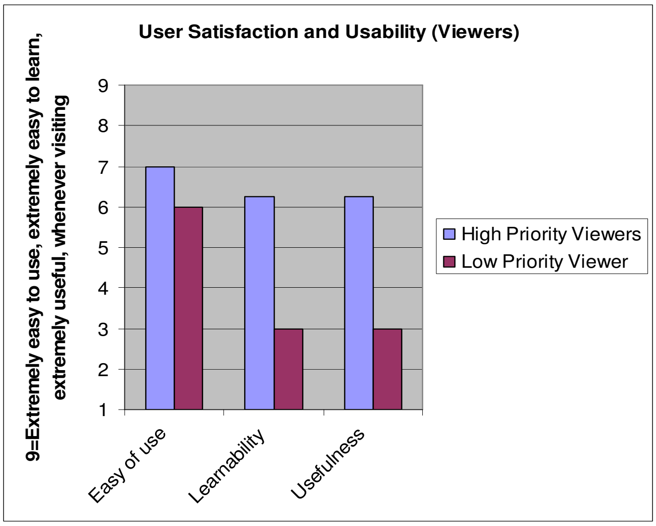



**Figure 4.5: User Satisfaction and Usability Results (viewers)**

***Effort Compared with Alternative (Viewers):*** Viewers were asked to compare the Magic Window with regard to effort in using the system such as through a physical office window. The majority of viewers stated that the effort to gather awareness through the Magic Window system was more than through an open office window but less than a translucent office window. Figure 4.6 shows that the low priority viewer had to make more effort than high priority users in obtaining awareness through the system.

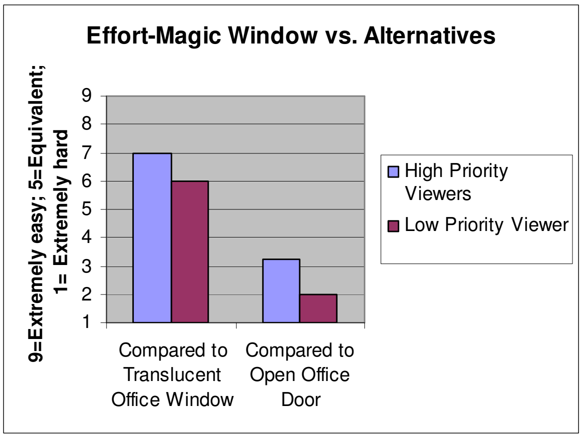



**Figure 4.6: Effort – Magic Window vs. Alternatives (viewers)**

***Awareness- Compared with Alternatives (Viewers):*** Responses about usefulness of awareness also showed a similar pattern to those about amount of effort. The awareness information provided by the Magic Window was more useful than a translucent office window but less useful than an open door in determining the occupant's availability.

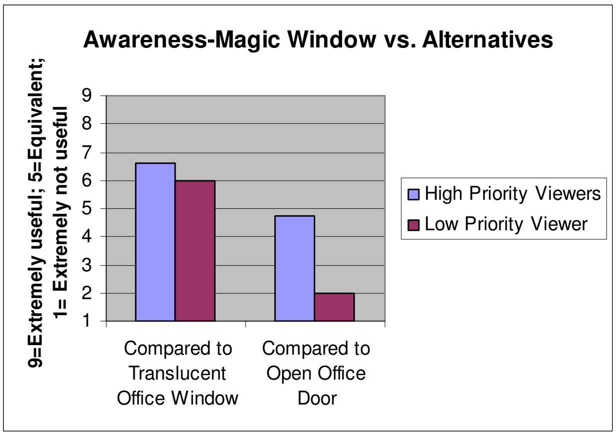



**Figure 4.7: Awareness- Magic Window vs. Alternatives (viewers)**

***Others (Viewers):*** Other factors such as viewers' privacy, trust and frequency of use are presented in Figure 4.8, the value 5 being equal to the alternative system (e.g., open door) and 9 being highest trust, privacy or frequency of use. The viewer's trust varied from viewer to viewer. Some viewers who were aware of the accuracy problem with the In-Out display showed low trust in the system but others showed high trust in the system. Most viewers did not worry too much about their privacy as office visitors, and in more than half visits to the office, they partially or fully used the system to assess the occupant's availability.

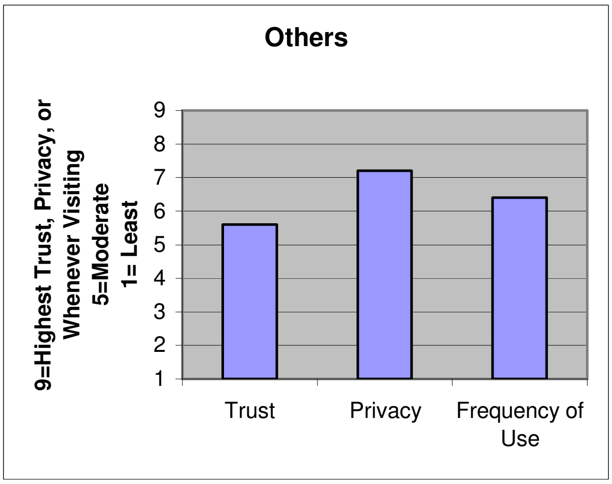



**Figure 4.8: User Trust, Privacy and Frequency of Use (viewers)**

***User Satisfaction (occupants):*** Overall user satisfaction was high. All three occupants stated that they were in favour of Magic Window system. Moreover, they all mentioned that they would like to replace their office window with the Magic Window system permanently. Two out of three occupants thought the system was very easy to use. All the occupants mentioned the system was very easy to learn and useful in balancing privacy and awareness. However, one occupant at the second office setting indicated that the system was a bit hard to use. He mentioned that it was difficult to register new viewers at the beginning of the system use. These results are presented in Figure 4.9.

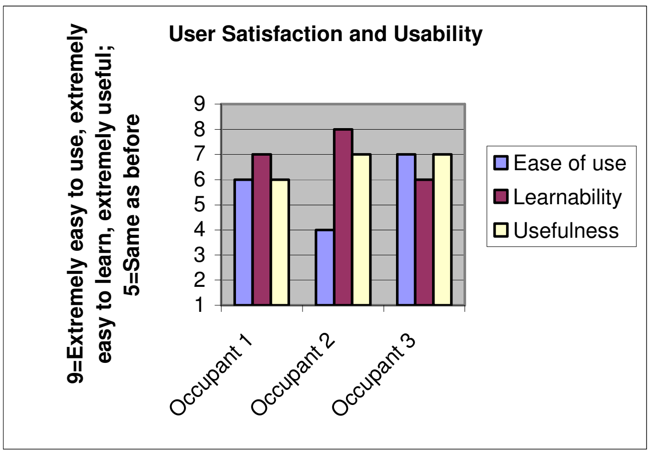



**Figure 4.9: User Satisfaction and Usability Results (occupants)**

***Privacy and Awareness (Occupant):*** The occupants were asked whether their privacy level was affected with the system deployment. The confidentiality level in the first office setting felt the same as before the system deployment but in the second office setting, two occupants showed different opinions regarding confidentiality. For all occupants, the solitude level also was felt to increase. They mentioned that they had fewer inappropriate interruptions than before. So, the overall privacy level seemed to increase with the system deployment. Occupant 3 thought his privacy level decreased since his presence information seemed always available to office visitors through the system. Before system deployment at the second office setting, presence information was controlled easily by turning the light off and closing the office door. Results are presented in Figure 4.10.

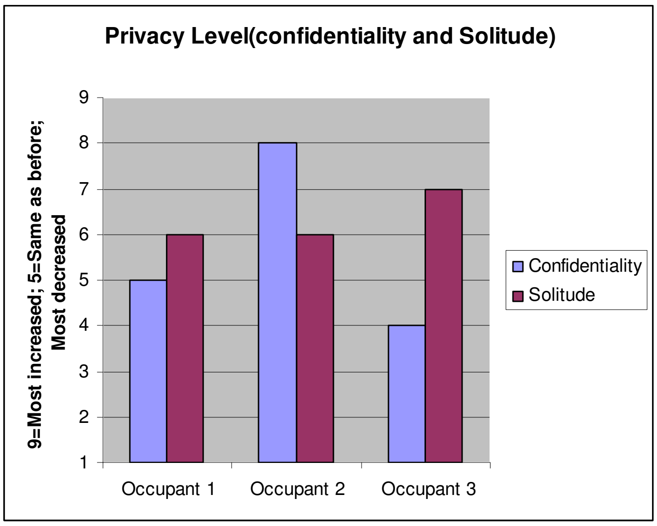



**Figure 4.10: Privacy Level (occupants)**

***User Trust and Preference:*** User trust in the system was very high (Figure 4.11). The occupants were asked whether they would like to keep the system. All three occupants mentioned that they wanted to keep the system for good in their offices. These results are also consistent with the user satisfaction results. In particular, the way the occupants were able to keep the door closed was preferred most by the occupants in the second office setting. Some occupants said they wanted to keep the system with minor improvements (such as easy start-up, easy user registration, and more reliable presence information).

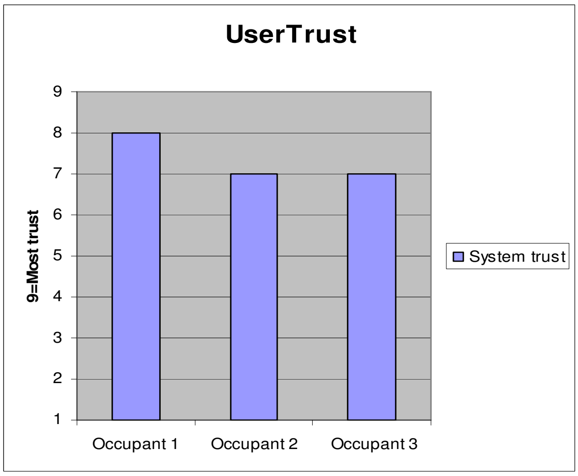



**Figure 4.11: User Trust (occupants)**

# CHAPTER 5

# ISSUES AND DISCUSSION

During the evaluation period described in the previous chapter, we identified six major important co-present media space usability issues. This chapter discusses these fundamental issues identified and analysed based on the findings from the deployment phases.

## 5.1 Issue 1: Multiple information Paths

***The existence of multiple information paths in office setting where the Magic Window was deployed substantially affected the usage of the Magic Window.***

Multiple information paths in obtaining informal awareness for casual interaction are created when the same information becomes available in several different ways or channels. For example, an office worker in a shared office environment might be able to become aware of another co-worker's presence in many ways, such as by approaching someone's desk, by hearing the person talking with others, or by being notified by instant messenger log-in. Depending on the environmental settings and different situations, information paths appear or disappear over time. When multiple information paths are created, people often tend to choose a certain or combined information paths. People's such tendencies have something to do with amount of effort required to obtain awareness, amount of time that it takes until the information becomes available, and the fidelity of information used to interpret someone's availability. There are two specific examples of multiple information paths problem with the Magic Window deployment.

**Problem 1:** *The layout of the first office setting where the Magic Window was deployed made people aware of the occupant with less effort than when using the system.*

The first example of the multiple information paths issue with the Magic Window is that people were able to see and stay aware of when the office occupant came in and went out of his office without using the system. This happened due to the layout of HCI lab, where the occupant's office is located inside the lab. In order for the occupant to get into his office, he had to enter the main door of the lab and then walk through the lab all the way to his office door. As a result, people in the lab easily became aware of the occupant's coming-in and going-out. Consequently, people did not have to check whether or not the occupant was present by walking up and logging into the Magic Window to check the occupant's presence, and further his availability.

However, we observed that people from another office or from other labs more often used the Magic Window to see if the occupant was in, had been in, or was available, since they could not automatically maintain awareness of the occupant's presence. For example, an assistant professor who is also a faculty member in the lab but whose office is located outside of the lab often checked Magic Window to see if the occupant had been in that day, whereas one student whose desk was located right in front of the occupant's office (see Figure 4.3) did not need to use the system often to check for that same reason since he could see the occupant coming and going. In this case, that student more easily (effort) obtained clearer (fidelity) information from a source other than the Magic Window. Therefore, that user's usage of the Magic Window was reduced through other means. As a result of being able to keep track of the occupant's walking in and out of the office, the need to check availability with the Magic Window diminished for some users.

**Problem 2:** *The office door in the first office setting was often kept open*; *as a result*, *the same information became available both through the Magic Window and through the open door.*

The second example of the multiple information paths issue has to do with an open office door. Most times, the office door in the research lab was kept open with the Magic Window running. Whenever the door was open, people usually looked through the open office door, by-passing the Magic Window. In other words, the open door led people to use conventional mechanisms to obtain awareness (e.g., sticking their head into the office to check availability).

There are two main reasons why the office door was kept open occasionally. First, the lack of awareness for the occupant made the occupant open the door. Before the system deployment, the number of interactions going on between the occupant and office visitors was large. The number of interruptions by regular visitors (mostly students in the lab) was very high. Maintaining a good awareness of the outside office was essential for the occupant in coordinating these interactions. However, the Magic Window provided less awareness information to the occupant than an open door, because the design did not carefully consider the occupant as an information requester but as an information provider; as a result, the occupant kept the door open to better stay aware of others outside his office (see also Section 5.3). Second, keeping the office door open all the time was not a threat to the occupant's privacy. Outside of his office was not a completely public place but the lab, a less privacy-sensitive environment from the occupant's perspective. The occupant did not feel his privacy was harmed by keeping the office door open. As a result, an additional information path was created.

When the door was open with the Magic Window running, most users chose to obtain awareness through the open door because they were able to get higher quality of awareness information; one can get clear audio as well as visual awareness information through an open door, whereas the Magic Window provided possibly blurry video with a narrow angle and at a low frame rate. In addition, peeking through an open door, which can be done even from distance, seemed much easier than logging in, waiting, and getting information which must be done right in front of the system (see also section 5.2). So, the usage of the Magic Window was significantly affected in situations where the door was open.

**Discussion**

For existing media space systems, multiple information path issues are not very significant since the users are usually remotely distributed, and there is no need for a visitor to be co-located at the other party's office to use the system. However, when designing co-present media space systems, one must consider that possible multiple information paths can substantially influence the system usage. In situations where two information sources compete, information requestors have to choose either the system (e.g., the Magic Window) or an alternative (e.g., an open door) in obtaining awareness information. This issue must be taken into account and be addressed in system design. Solutions to this issue can be considered in two ways.

First, we can minimize or eliminate the chances of the existence of multiple information paths by carefully selecting the office setting where the system is deployed. The Magic Window may be more useful in situations where there are no or few alternate information paths, for instance, situations where the office door is always kept closed and people do not work closely with one another or where people have their own offices located in close proximity. The story of the assistant professor who checked the Magic Window more often than other users can be a good example supporting the potential usefulness of the system in other situations. Users of the later version of the Magic Window also commented that the system would be more useful at a specific person's office where privacy is more of a concern and work relationships are stricter. It suggests that co-present media space systems may be more useful in situations where there are higher expectations for privacy and the work relationship is more formal.

Second, in situations where multiple information paths are obvious, the system design should take into account the possible multiple information sources (e.g., door state) as context. In other words, the system works normally when there are no alternatives to obtain awareness information, but when there is an alternative, it works to supplement otherwise unavailable information in a way that requires minimal user effort. So the system should be designed as a support for existing information paths but not as a substitute for it. For example, we can add one more mode to the Magic Widow, "open door mode," in addition to the synchronous and the asynchronous mode. In open door mode, the users are provided with otherwise unavailable information such as today's agenda and customized message posting even when the door is open.

## 5.2 Issue 2: Effort

***The amount of effort required to gather awareness affected the usage of the Magic Window.***

Maintaining and gathering awareness requires a certain amount of effort. However, the amount of effort and the ways to obtain awareness may vary depending on situations. For example, in a shared office environment, one may be able to gather awareness of others by looking around the office. In separate office setting, a visitor may glance into the office through an open office door or an office window with the door closed. Glancing from a distance may be possible with a clear window, but the visitor may have to be close to the office window with a translucent window. The viewers' willingness to spend the amount of effort may also vary depending on their situations. People who are in a hurry to interrupt the occupant would not be willing to spend a lot of effort to check the occupant's availability. On the other hand, people who do not want to face an embarrassing moment caused by a bad interruption may be willing to make enough effort to assess availability correctly.

Initially, the Magic Window was designed to minimize the viewers' effort. However, the system still required a certain amount of effort in gathering awareness. To use the system, the viewer needed to place a finger on the fingerprint reader to log in and wait a few seconds until the system processed and displayed the video on the display. In order to remain logged in after initial log-in, the user had to keep their face in a certain position in front of the hallway camera. If the camera missed detecting the face at any moment, the viewer automatically got logged out. Also, the position of the hallway camera was not right for every viewer. Those who are too short or too tall, had difficulties in keeping their face in view to the camera to remain logged on. Having to stand on one's toes or bend one's knees to use the system certainly seemed a lot of effort for some users.

**Problem:** *The threshold of user effort in using the Magic Window was higher than the level of effort that the viewers who did not explicitly need to maintain awareness of the occupant were willing to spend.*

We observed that people did not bother to be aware of the occupant although they could have chosen to maintain awareness of the occupant. It seemed that the threshold of effort was not low enough to make people get motivated to remain aware of the occupant. One particular viewer, in the first deployment setting, whose desk was far away from the occupant's office door mentioned that he often used to check the occupant's presence by standing and looking over a partition to see whether or not the light in the office was on, but was not willing to make the effort to walk up to the office to check if he is in at that moment. As mentioned earlier, it seemed that having to log into the system, keep one's a face in a certain position and wait for a few seconds until the information became available was too much for the particular user in that situation. So the viewer did not bother to maintain awareness through the system because his need for gathering information and the amount of effort required by the system were unbalanced. In other words, the user's level of need was low (just checking presence); thus level of willingness to make effort (just standing and looking) became also low, but the amount of effort required by the system was higher than a threshold set by the level of need. As long as viewers had no pressing need to gather awareness information regarding the occupant, they were not willing enough to use the system for maintaining awareness. This kind of behaviour did not change substantially even after the speed problem had improved with the installation of commercial fingerprint recognition application; many of them were still reluctant to make efforts to log into the system to maintain awareness, so the Magic Window was not used as much as it was intended in obtaining awareness information.

**Discussion**

To address the user effort problem, two approaches can be considered. The first approach is to make a system that requires the minimal user effort in gathering awareness. The system should be designed to take as little user effort as possible. However, this approach is somewhat ambiguous in that no one knows the exact threshold of effort that is acceptable. All we know is that any awareness systems require at least some amount of user effort, and for co-present media space systems, this can be problematic. Even a small amount of user effort required by the system can be a very sensitive problem since there are always possibilities of multiple information paths existence. As mentioned in the previous section, multiple information paths and a certain amount of effort together can substantially affect the system usage. In addition, designing systems that require less effort than alternatives would be extremely difficult (e.g., peeking through open door vs. logging into a system). Therefore, this approach would not be as effective as expected.

The second approach is to design a system that can balance the viewer's need for awareness and the amount of effort required. The system should be able to support the proportional relationship between need for gathering information, the amount of effort, and the quality of the information provided by the system. We can adopt the price discrimination principle (Shapiro and Varian 1999) into the design of co-present media space systems to achieve a balance between user need for gathering awareness and user effort in gathering awareness through co-present media space systems.

The principle of price discrimination states that sell your product at different prices to different consumers according to how much they are willing to pay for it. In other words, by discriminating the prices, the seller can maximize the profit and the buyers' satisfaction since they can choose the right price that they are willing to pay according to their budget. By the same token, we can maximize the usefulness of awareness provided by the system as well as users' satisfaction by differentiating the quality of awareness according to levels of effort to make and by letting the viewers choose the level of engagement with the system according to their need for interactions with the occupant. Such awareness provision mechanisms will allow co-present media space systems to satisfy both the office visitors who just want to obtain very basic awareness with little user effort and the viewers who want to obtain rich awareness by making enough effort to be able to assess the availability. An example of such awareness provision mechanism for different levels of engagement with the system is presented in Table 5.1.

| **Effort** | | **Awareness** | | | **Events to Occupant** |
|---|---|---|---|---|---|
| **Level** | **Steps to Make** | **Level** | **Kind** | **Method** | |
| Low | Step 1: looking at physical display | Basic | In-Out information | Physical display | Nothing |
| Medium | Step 1 plus Step 2: walking close to system and show Face | Medium | Clearer live video for a short moment | Unnoticed glance | Nothing |
| High | Step 1, step 2, plus Step 3: placing a Finger and wait | Detailed | Clearer live video for a long time | Log-in | Notified by system |

**Table 5.1: Different Amount, Richness and Levels of Awareness and Engagement**

As the viewer wants richer and more awareness (the second column in Table 5.1), the amount of effort to make for awareness increases (the first column in Table 5.1). The Method column describes how information can be presented. The Events to Occupant column describes what events may happen at each step. For a viewer who just wants to know if the occupant is in the office, the system may provide such information through an always-on-the-wall display. So the viewer gets presence information by simply looking at the display from a distance without having to log in. If the user wants to further check what the occupant is doing, the person may glance at the Magic Window, and a short-period (e.g., one second) clearer video image may become available on the display. When the viewer really needs to assess the occupant's availability more carefully, the person may normally log into the system to see a full video of the occupant in order to assess their availability.

Based on the principles mentioned here, we introduced an In-Out display in the later versions of the Magic Window. Most of viewers found that this feature was useful and liked being able to check basic presence information from a distance. Some users only checked presence, but some users fully used the system by logging into the system and checked the occupant's availability by logging in, but the In-Out display was always the first thing to check whether they logged in or not afterwards.

## 5.3 Issue 3: Quality of Information

***Low quality of awareness information affected the ways the system was used by both the viewers and the occupant.***

Quality of awareness information may be defined in terms of three dimensions. These are fidelity, granularity and richness of information (Figure 5.1). *Fidelity* of awareness represents how closely the information resembles the original information source. In an office setting, one may get higher fidelity of information about the occupant through a clear window than through a semi-transparent window. In terms of video, blurry video is lower in fidelity than non-blurry video. G*ranularity* of information refers to how detailed the information is. In video-based media spaces, the video resolution and frame rate determine the granularity of information. *Richness* of information refers to the number information sources that are available to the information requestor. Visual plus audio information from an office together can make the awareness of the occupant richer than when only visual awareness is available.

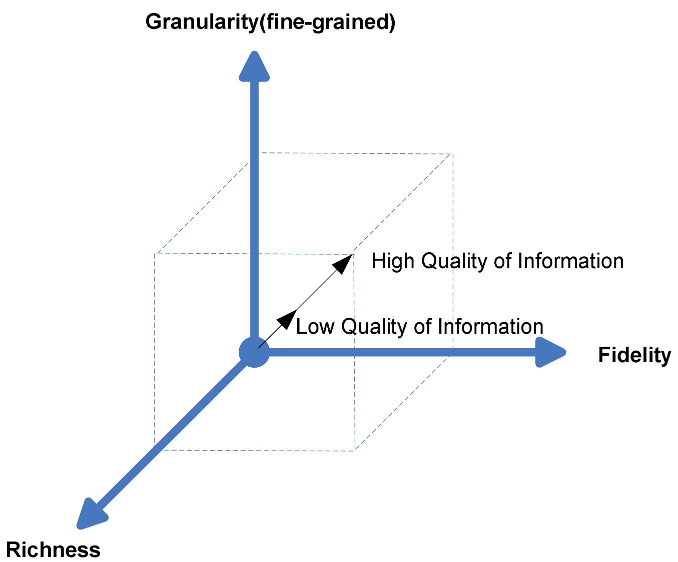



**Figure 5.1: Dimensions in Information Quality**

Quality of awareness information plays an important role in determining one's availability; high quality of information generally makes it easier to determine availability. Information quality also affects privacy. As higher quality of information is provided, the information provider's confidentiality decreases. By making sure that only low quality of information is provided, the person's confidentiality can be safeguarded. Therefore, there is trade-off between quality of information and confidentiality, and between quality information and the level of difficulties in determining availability using such information.

The study showed that there are two instances of quality of information problems with the Magic Window- both for the occupant and the viewers.

**Problem 1:** *The average quality of awareness information was not rich enough for high priority users.*

For the Magic Window to allow the occupant to control information through the system, the information had to be intercepted, processed and displayed. Throughout this process, the average quality of information decreased. There are several reasons why the quality of information through the Magic Window was low. First, the video displayed on the system was narrow in a view angle, and low in a frame rate. The camera that we used had 45 degrees of view angle that is much narrower than what a human eye can see. The frame rate was set at 15 FPS or less and the resolution was set to 240 by 320 to reduce CPU load. Those problems seemed somewhat inevitable since there was a trade-off between CPU utilization and quality of information. Second, fidelity of awareness information was low to protect confidentiality. Most viewers were set to see blurred video upon log-in, so the information fidelity was low overall for viewers. Third, the awareness information was not as rich as the real world. Since we wanted to keep the metaphor of real office windows, we did not consider audible awareness but mainly focused on visual awareness, so the viewers had to totally depend on visual cues to assess availability. Often, it became difficult to determine whether or not the occupant was talking on some device (e.g., talking while wearing a headset or cell phone). Fourth, the default view of the office was very low in fidelity (blurred by 41x41 box filter). This problem was brought to attention by the occupant who wanted to provide more awareness as default information. In the later version, this problem was addressed by using a Gaussian filter that blurred the video less.

From the viewers' perspective, the low quality of information became problematic since the low quality of information frustrated high priority users and made it difficult for the medium priority viewers to determine the occupant's availability. As the occupant mentioned, the window and the office wall would have to be crystal clear for some viewers who have very close relationships with the occupant. However, the fidelity of information available to such viewers (e.g., audible and visible cues) was degraded by the system and was not as rich as information through other means.

**Problem 2:** *Average quality of awareness information for the occupant was low and limited.*

As mentioned in Section 5.1, the initial version of the system had difficulties in supporting high quality of awareness for the occupant. Although there were features supporting awareness for the occupant, they were sometimes not good enough. For instance, the hallway view and the office view were displayed on the 2D GUI (Figure 3.4). The hallway view was limited in that it updated each image at a rate of two seconds per image, and only when a face was detected. The office view also got updated every 30 seconds. The small size of the images and the slow image update rates degraded the awareness from the hallway. Also, the view angle of the images and no audio from the outside of the hallways seemed to make the occupant feel uncomfortable. The lack of awareness for the occupant left him feeling isolated in his office, making it hard to reach people outside of the office for help or interactions. The lack of quality in awareness initiated a chain reaction that eventually caused the viewers to by-pass the system in the first deployment setting. First, the occupant wanted to maintain rich awareness of the outside of office, so he kept the door open for hallway awareness (this also has to do with the main reason why the occupant is in: to become approachable to students); thus, the multiple information paths were created. As a result, along with other reasons such as an effort issue, viewers started interacting with the occupant using conventional means (e.g., look through the doorway and knock).

**Discussion**

Co-present media space systems should be able to provide high quality of information for the viewers and for an occupant who wants to maintain good awareness of others. The full video channel of the hallway view on a separate display was introduced in the later version of the system. The occupant's response was positive; however, the narrow view angle was still troublesome, and there was still a high demand for full audio information. This suggests that one must consider the richness of awareness in co- present media system. Also technical improvements such as a high video frame rate, high resolution of video, a wide view angle, high resolution, a full size of hallway view display for the occupant and full audio information for the occupant must be taken into account.

However, providing high quality of awareness information is not always feasible or desirable due to technical limitations and other trade-off issues. (e.g., trade-off between frame rate and CPU utilization). With regard to the trade-off between confidentiality and quality of information, assuming that the low quality information for the viewer is somewhat unavoidable in order to protect the occupant's privacy, we can consider three cases where different versions of the Magic Window would work differently. Depending on the situation (i.e. without the system, with system improvement, and with current system) and the occupant's demand for awareness from the hallway, different possible results on occupant's confidentiality can be expected (Table 5.2). Without the system deployed, as the occupant wants better quality of awareness, the person would open the door to see and hear from the hallway. As the door is kept open, the occupant's confidentiality decreases. Therefore, the occupant's privacy becomes compromised with the occupant's need for maintaining awareness.

| **Conditions** | **Occupant's Demand** | **Occupant's Reaction** | **Consequences** | |
|---|---|---|---|---|
| | | | **Occupant's Confidentiality** | **Quality of Awareness for Viewers** |
| Conventional way | High fidelity of awareness | Keep door open | Decreases | Increases |
| With system improvement (rich awareness for occupant) | High fidelity of awareness | Feel comfortable with keeping door closed | Increases | Decreases but balanced |
| Without system improvement | Do not need to maintain awareness from hallway | Keep door closed | Increases | Decreases but balanced |

**Table 5.2: Consequences in confidentiality depending on different conditions**

We can also consider two other situations where the occupant desires a somewhat higher degree of confidentiality and wants high quality of awareness from the hallway (the second row Table 5.2) and where the occupant desires somewhat higher degree of confidentiality but does not need to maintain awareness of the hallway (the third row in Table 5.2). If the system can provide rich awareness of the hallway to the occupant, the occupant would feel comfortable with the door closed. In this case, the confidentiality and quality of awareness for the viewers can be balanced through the system. Yet, we can obtain the same results without a significant system improvement in a different office setting where maintaining awareness from the hallway is not important. In the latter situation, the occupant would feel comfortable with keeping the door closed since maintaining awareness from hallway is not important.

During the third system deployment, we observed that the office door was kept closed by the office occupants, and the occupant's confidentiality seemed well protected through the system. The system was still able to provide balanced awareness while maintaining high level of confidentiality without substantial system improvement in increasing the quality of awareness for the occupant. Also, a balance between solitude and confidentiality would be expected because although the door is closed, there is an information path through the Magic Window that increases confidentiality, but it helps viewers determine whether to interrupt at the moment by providing information ranging from low to high fidelity.

## 5.4 Issue 4: Conflict between Social Norms and New Technology

***New technology introduced to the way people interact with the office occupant breaks social norms and brings up confusion among users.***

Social norms are appropriate values and behaviours expected and shared by a group of people. They are rules that implicitly or explicitly enforce group members to behave and interact with one another in appropriate way. For example, people are implicitly expected not to interrupt a person who is talking on the phone because it is considered rude, and it does not follow social norms. Also, a written note on an office wall such as "exam in progress" or "do not disturb" explicitly tells people not to interrupt as long as the note is displayed. When a new way of gathering awareness and interacting with co-workers is introduced, implicit enforcement of social norms can be weakened.

We found that with the system deployed, the existing implicit unwritten social rules changed and people developed new implicit rules to follow over time. After the Magic Window was deployed, office visitors had to adjust to a new set of implicit rules saying that a closed office door does not mean that the occupant is not in and not available. There are two problems related implicit social norms caused by the system deployment in the second office setting.

**Problem 1**: *A closed door with the Magic Window running made office visitors confused between existing social norms and awareness information brought up by the system.*

Unlike the first deployment setting, the office door was kept closed most times while the occupant was present in the second office setting. Before the system deployment, people assumed that a closed door at the office meant the occupant is not in. However, as the occupant became used to keeping the office door closed after the system deployment, the closed door did not always mean that the occupant was not in, but instead it meant something more to office visitors. It meant that the occupant might be or might not be in. The office visitors often had to take time to determine what to do when the door was closed with the Magic Window running. If the door was closed but the In-Out display indicated that the occupant is present, it was generally understood among office visitors that they needed to further check for more awareness of the occupants. This new implicit rule brought out some confusion to the visitors at the beginning of system deployment in the second office setting because the closed door used to always mean that the occupants were out.

**Problem2**: *The conflict between the social norms and new technology weakened the existing rules and norms among group members.*

After visitors got used to a closed office door while the occupants were present, office visitors formed their own way to interact with the occupant, which was somewhat different from what the deign intended. Although we put a clear sign of "A closed door does not mean that I'm not available. Please check the Magic Window" to ensure that there might be cases when the office door is closed but the occupant is in. The reactions to these newly formed social rules were different from person to person. Some users used the system in the way that was intended. For one particular user, the Magic Window was used as a tool to check if the occupant had been in, but whenever that person knew the occupant was in, he simply knocked on the door. Even for some visitors, they used the system as a means to notify that they want to engage in an interaction.

**Discussion**

We can consider two main reasons why people got confused in such situations where the occupant was present and the system said the occupant was in. First, at the beginning, people did not know which information source to choose between what they were used to over time (e.g., a close door means no one is inside) and what the new technology provided (e.g., In-Out display says "in"). Through the interviews with registered users in the second office setting, we found some consistent implicit rules among co-workers (registered users) in assessing the occupant's availability and interruptibility of the office occupant before the system deployment. Before the system deployment, an open door meant that the office occupants were present and fairly interruptible unless they were obviously engaged in a phone conversation or in discussion with other office visitors. On the other hand, a closed door meant that the occupants were not in the office; therefore, they could not be contacted in the office but may be contacted at different times or by different means. People did not expect occupants to be in the office when the office door was closed. However, after the system deployment, such generally accepted rules did not hold any longer. So people got confused and they did not know which information rules over the other one. Office visitors had to determine what to do in such situations. As a co-worker put it:

*"You couldn't really tell whether or not they were or not by… because the (door) was closed all the time. So it was a little harder actually to tell because I knew the routine of the door always being open … when somebody was there"*

It was not long before the users adapted a new way to interact with the occupant. Most visitors reached the same conclusion that is to go to check further for more awareness information. A co-worker who was the second priority user commented:

*When I first tried using it, it was a little confusing because I was used to the door being closed, I'm not available …. Eventually, I got used it."*

Most office visitors became used to being in a situation when the door was closed and the occupant was in. They tended to ignore the meaning of the closed door but to check the In-Out display first, and then check other means to gather awareness of the occupants.

Even after visitors got used to new implicit social rules, they were still confronted with another problem- they had to determine the availability of the occupant, which could have been done easily through the office door state before the system deployment. The closed door almost always used to mean that the occupants were not available since they were not present, but after the deployment, the information that the occupant was in provided by the indicator did not mean the same as before, because there were many situations where the door was kept closed but the indicator said the occupant was in. Office visitors began to develop their own way to gather and start to interact with the occupants. These reactions have something to do with the fact that some visitors were also office occupants in their offices. Since they are used to their experience as occupant when they were in the positions of viewers, they had different concepts about interruption and availability. When the existing implicit rules to interrupt the occupants were strong before the system deployment, their ways to interrupt the occupant followed the existing rules. But after the existing rules were weakened by a system deployment, the ways for office visitors to gather awareness and interrupting the occupants became different, influenced by their own experience as occupants.

It would be better to design a system that follows the existing social norms as much as possible. If unavoidable, to minimize confusion caused by the breakdown of existing social norms, fully informing potential users how to use the system must be done before the system deployment. It was found that posting a note to inform the users is not sufficient, but informal or formal user training will be very useful to for the potential users to understand the system fully and to minimize confusion.

### 5.5 Issue 5: Privacy (Viewer's Privacy Concern)

***Co-present media space systems have potential to violate viewers' privacy at a random place.***

Whereas live video and still images provided by video based media space systems are good sources of awareness information, the common problems with such systems are privacy concerns about the images of users captured and stored by the system. The Magic Window system also had privacy implications because it captured and stored the viewers' facial images and the registered users' fingerprint images which might be even more sensitive than facial images.

The main difference between existing video based media space systems and co-present media space systems is that the visitors' images are captured in a public space (hallway), whereas most non-co-present video based media space systems capture images in private places (offices), so it was expected that the viewer's privacy concerns regarding captured facial images shown to the occupant would be minimal. However, it was found that there still were privacy concerns regarding the fingerprints and images captured and stored by the Magic Widow system under certain circumstances.

**Problem:** *Gathering and storing the visitors' images and fingerprints had potential to violate the viewers' privacy if the system had been deployed at a random place.*

In effort to support good feedback for the occupant, it was necessary for the system to take and transfer the viewer's facial images to the other machines when any viewers intended to interact with the system. On the other machines, the captured viewers' images were displayed inside the office. Since the system was designed mainly with a focus on safeguarding the occupant's privacy, the viewer's privacy was not taken into account carefully. Also, the system cached the registered user's fingerprint in the local disk and used them to enable a lightweight way to log into the system. Individual fingerprints are unique biometric personal information. Therefore, storing user information such as facial images and fingerprint images had potential to violating the registered users' privacy since they might be used in inappropriate ways.

**Discussion**

Throughout interviews with registered users, we found that they were not concerned about their captured images and fingerprints in the second office setting. There seemed to be three main reasons why office visitors were not much concerned about their privacy in this particular setting. First, they were reassured by the computer science department privacy policy, and fully or at least partially aware of how their fingerprint images and facial images were going to be used for the Magic Window project. A user mentioned:

*"… mainly because I've got fairly decent trust with the department ethical rules that they apply to themselves and most of students. They're enough for me."*

*"because I knew what the project was for. It was a research project. I knew who was kind of in behind it."*

Second, they were sure that the office occupant would not do anything unusual with private information captured by the system. In other words, people had enough trust in the occupants that had been co-workers for a long time as the particular participant who was a co-worker mentioned:

*"I wasn't concerned about here because again I know he (occupant) is not going to (do anything) maliciously."*

Third, the fact that their images were captured in a public place (office hallway) even further lessened the registered users' privacy concerns since the level of people's privacy expectations are low in public spaces.

However, most registered users said they would be more concerned about their privacy information (facial and fingerprint images) depending on the place where the system is deployed. In other words, capturing facial images and fingerprint images had potential to violating the information owners' privacy if the system were deployed at a place where the office visitors were not familiar with the office occupant and where they were not fully aware of the privacy policy. As participants put it:

*"But I would have more concerns if it were, you know, someone's system, who I never used before. So I go to a random building and this guy has a Magic Window. Somebody I never met or.. I wonder what sort of identity theft could go on like that."*

*"If it was just some random that you had to go to for meeting or… I might be little more concerned about privacy and stuff."*

This also suggests that for some non-registered users, for example, undergraduate students or passers-by, the Magic Window in the second office setting might have been a random place; therefore, as registered users mentioned, some unregistered users who are not well aware of department policy and who did not necessarily have enough trust in the office occupant could have privacy concerns about their images captured by the system when they attempted to use it. An informal interview with a user, who randomly used the system seemed surprised when he realized that the Magic Window was a two-way window, which means the occupant could also see the viewer as a clear video while the viewer sees a blurry video through the Magic Window.

Based on what has been found about viewers' privacy, it can be concluded that if a co-present media space system is deployed in a public space, collecting and storing, distributing images from public spaces might bring up little privacy concerns for frequent users, who have built some degree of trust in the office occupant (e.g., co-workers) and aware of the organization's privacy policies. However, there always is potential to violating random users' privacy. Random users may include visitors from outside organization or users who do not work very closely with the occupant.

In designing co-present media paces system, random users' privacy should be taken into account. The system should be able to provide feedback on how captured images or personal information is used. A privacy policy as a form of public sign might be helpful along with the deployed system as we can often find in public spaces a security camera in public places. There also must be some way to let them know that the camera is capturing images of their or privacy policy near the system deployed.

### 5.6 Issue 6: Accuracy

***The inaccuracy of awareness information provided by the system caused particular users to ignore the feature, but overall trust of the system was not significantly affected.***

Accuracy of information and system reliability are fundamental elements in awareness support systems. When a system does not meet such requirements, the usability of the system can be affected, resulting in unpredictable usability problems. There was an accuracy problem in the Magic Window system. This section describes how the accuracy problem affected the usability.

**Problem**: *One particular feature in the In-Out display was slow in updating and worked inaccurately sometimes, so temporary incorrect presence information was provided.*

The Magic Window system provided presence of occupant information primarily through the In-Out display. However there was an accuracy problem with that feature. The problem with the indicator was that it took some time (two minutes in the first office setting; three to four minutes in the second office setting depending on the situations) to switch to "out" after the occupant left the office. So the indicator had potential to show incorrect presence information temporarily. For instance, an office visitor could see the indicator show "In" and an empty office on the display temporarily. Another problem with the In-Out display was that it switched to "In" or "Out" depending on the lighting condition as well as amount of the occupant's motion. For example, while the office was empty, if the lighting condition changed abruptly (e.g., sudden appearance of sunlight) the indicator switched to "In." Also, while the occupant was present in the office, the indicator switched to "Out" if the occupant sat still for a certain amount of time (e.g., typing on the computer). Such inaccuracy problems happened infrequently but it affected the system usability.

**Discussion**

Interviews with the users showed that not all the viewers were aware of the problem but some of them knew that there were latency and inaccuracy problems in providing the presence information. The viewer who was aware of the accuracy problem with the In-Out display indicated in the questionnaire that his usage of the system was affected; however, the user still trusted the overall system except that particular feature. As one user put it:

*The part I didn't trust was In-Out display. I didn't trust that to give me accurate information. I didn't find it useful until actually log-in to tell me if he is in or out but before I log in … I wouldn't know he was in there if it said "in" as opposed to "out"*

Although that user distrusted the In-Out display, he mentioned that he did not distrust the system as a whole just because of one particular feature that malfunctioned sometimes but it became the last thing to check:

*I only distrusted that feature. Once I logged in, I was able to view the video. I was able to trust it more because the video actually told me he was there.*

This problem was also raised by occupants. The occupant in the first office setting mentioned that he saw the In-Out display show “in” when he was coming back to his office after he left the office for a short time. The occupants in the second office setting also mentioned that they were tempted to make a big motion to correct inaccurate awareness information being displayed through the indicator when they heard the In-Out display switch to “out” even though they were present in the office. It means that the occupants tried to correct the inaccuracy of the awareness themselves by making otherwise unnecessary effort. The inaccuracy problem went against the idea of providing lightweight control over privacy and awareness.

However, one interesting finding is that the overall users’ experience (both occupants and viewers) showed that the overall user trust in the system was not significantly degraded by one particular feature that provided some false positive awareness information. Users tried to seek other information sources that they replaced the inaccurate information source with, in order to assess the occupant’s availability.

The In-Out display was an important component in the system since it showed the presence of the occupant, which is an important basic piece of awareness information. For important basic information, it is always a good idea to provide through multiple redundant components so that in case that one feature fails to provide accurate awareness information, the other features of the system can make up for the deficiency. If the In-Out display was the only means to provide presence information in the Magic Window system, some users would not have trusted the system totally.

# CHAPTER 6

# CONCLUSION

The problem addressed in this thesis is that it is difficult to balance awareness and privacy for information moving through an office window in a current office setting. The main motivation for solving the problem of balancing privacy with awareness is to improve collaboration for co-workers distributed in their offices by assisting and encouraging casual interactions. Through a good balance between awareness and privacy the system, it is possible to make the occupant feel comfortable in disclosing information and assist the viewer in finding good times to initiate casual interaction, leading to more efficient collaboration.

The solution explored in this thesis was to develop a computer-mediated augmented window system, the Magic Window, which allows for fine-grained control over privacy by differentiating the amount of awareness to be disclosed according to the viewer's relationship to the occupant. To develop and build such a system, this thesis identified and explored possible issues and problems that can arise during system usage, and suggested possible solutions that will help to design better co-present media space systems. The system deployment over an eight month period helped identify a number of important issues that must be considered in designing future co-present media space systems.

## 6.1 Summary of Research

The research in this thesis consisted of the design and development of a co-present media space system called the Magic Window, deployment of the system for an eight month period, and design guidelines including issues, and identification of problems and possible solutions. Deployment consisted of three phases in two different office settings, and the design of the system evolved throughout the deployment phases. Observation, informal interviews, semi-structured interviews, pre- and post-deployment questionnaires were used to gather user experience with the system.

Several issues in designing co-present media space systems were explored, which can be used as guidelines for designers of co-present media space systems. The issues identified through three phases of deployment include multiple information paths, user effort, quality of information, conflict between social norms and new technology, privacy, and accuracy issues.

## 6.2 Contributions

Two major contributions of this research are a working system and design guidelines including identified issues, problems and suggested solutions to be considered when designing co-present media space systems. Other contributions of this thesis are:

- An initial attempt to design a video based co-present media space. The Magic Window system is a new extension of video based media spaces that have been designed for remotely distributed team members.
- A set of techniques of balancing privacy and awareness through the Magic Window. These include implicit privacy control techniques (relationship based

privacy control) and explicit privacy control techniques (control by physical user interface).

- New ways of providing and gathering computer mediated awareness as well as interrupting the office occupant and responding to such interruptions in collocated office settings.
- Evidence of the effectiveness of using relationship in privacy control through a co-present media space system. The Magic Window is the first co-present media space system that uses relationships to regulate privacy control. By using relationships, fine-grained control over privacy in a lightweight manner was achieved.

## 6.3 Future Work

This thesis represents the first steps in designing and analysing the usage of a co-present media space system that uses video. The identified issues provide guidelines that should be considered in designing co-present media space systems with the potential to improve future co-present media space research projects. Further work to be carried out includes:

- Redesign of the system based on information from the last round of interviews
- Continued evaluation over longer-term use
- Investigation of other visual effects that provide information but protect privacy
- Deploying multiple systems in different office settings
- Performing a statistical analysis on data collected from a larger group of users

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APPENDIX – EVALUATION MATERIALS

# Pre-deployment - Informed Consent Form

Research Project: Balancing Privacy and Awareness for Office Workers in Office Settings

Investigators: *Carl Gutwin*, Department of Computer Science (966-8646)

*Hyun Hoi James Kim,* Department of Computer Science (966-2327)

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

For this study you will be asked to use the Magic Window prototype and to provide the image of your fingerprints and video of your office. It will allow you to log into the system and others to see you through the prototype in a privacy safeguarded way. At a later time, you will be asked by questionnaires and interviews to explore your experience with the Magic Window prototype.

All of the information we collect from you (e.g., fingerprint images, data logged by the computer, observations made by the experimenters, and your questionnaire responses) recorded so that your name is not associated with it. Any write-ups of the data will not include any information that can be linked directly to you. The research materials will be stored with complete security throughout the entire investigation. Do you have any questions about this aspect of the study? **You are free to withdraw from the study at any time without penalty and without losing any advertised benefits.** Withdrawal from the study will not affect your academic status or your access to services at the university. If you withdraw, your data will be deleted from the study and destroyed. In addition, you are free to not answer specific items or questions on questionnaires.

Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

*Hyun Hoi James Kim,* Department of Computer Science (966-2327) hyk564@mail.usask.ca

*Carl Gutwin*, Department of Computer Science (966-8646) gutwin@cs.usask.ca

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. If you have further questions about this study or your rights as a participant, please contact:

Dr. Carl Gutwin, Associate Professor Dept. Computer Science (306) 966-8646 gutwin@cs.usask.ca

- Office of Research Services University of Saskatchewan (306) 966-4053

Participant's signature: ______________________________________________

Date: ____________________

Investigator's signature: ______________________________________________

Date: ____________________

A copy of this consent form has been given to you to keep for your records and reference. This research has the ethical approval of the Office of Research Services at the University of Saskatchewan.

Post-deployment Interview - Informed Consent Form

Research Project: Balancing Privacy and Awareness for Office Workers in Office Settings

Investigators: *Carl Gutwin*, Department of Computer Science (966-8646)

*Hyun Hoi James Kim,* Department of Computer Science (966-2327)

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

For this study you will be given questionnaires and asked a set of questions regarding your experience with the Magic Window prototype.

All of the information that we collected from you (e.g., fingerprint images, data logged by the computer, observations made by the experimenters) and that we will collect from your questionnaire responses and voice recording from this semi-structured interview will be used so that your name is not associated with it. Any write-ups of the data will not include any information that can be linked directly to you. The research materials will be stored with complete security throughout the entire investigation. Do you have any questions about this aspect of the study? **You are free to withdraw from interview at any time without penalty and without losing any advertised benefits.** Withdrawal from it will not affect your academic status or your access to services at the university. If you withdraw, your data will be deleted from the study and destroyed. In addition, you are free to not answer specific items or questions on questionnaires.

Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

*Hyun Hoi James Kim,* Department of Computer Science (966-2327) hyk564@mail.usask.ca

*Carl Gutwin*, Department of Computer Science (966-8646) gutwin@cs.usask.ca

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a participant. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. If you have further questions about this study or your rights as a participant, please contact:

Dr. Carl Gutwin, Associate Professor Dept. Computer Science (306) 966-8646 gutwin@cs.usask.ca

- Office of Research Services University of Saskatchewan (306) 966-4053

Participant's name: _________________ Participant's signature: _________________

Date: _____________________

Investigator's name: _________________ Investigator's signature: _________________

Date: _____________________

A copy of this consent form has been given to you to keep for your records and reference. This research has the ethical approval of the Office of Research Services at the University of Saskatchewan.

Post Deployment Questionnaire (Viewer)

**DEMOGRAPHICS**

1. Personal Information

Age Range: 20-25 26-30 31-35 36-40 41-45 46-50 50+
Gender: M F

2. How many times a day, on average, do you physically visit your boss' or other co-workers' offices for any reason? (e.g., for chat/ lunch/ help/ discussion/ report) ?

0 1 2 3 - 5 5- 10 10+ (Times / day)

3. When you visit an office with an office window, how do you determine the occupant's availability? Explain:

_______________________________________________________________

_______________________________________________________________

_______________________________________________________________

4. With Regard to Magic Window:

a) How many times a week, on average, do you physically visit the office where the Magic Window is being deployed?

0 1 2 3 - 5 5- 10 10+ (Times / week)

b) What is you relationship to that occupants?

Co-worker Boss Other:______(specify)

c) How much approachable is that occupant to you (where 9 means being most approachable to you)?

1 2 3 4 5 6 7 8 9

d) What is the main reason to visit that occupant (e.g., for collaboration/ to chat)?

________________________________________________________________

________________________________________________________________

________________________________________________________________

**USER SATISFACTION and USABILITY**

1. How do you rate Magic Window in terms of easy of use?

extremely easy 1 2 3 4 5 6 7 8 9 extremely hard

2. How do you rate Magic Window in terms of learnability?

extremely easy to learn 1 2 3 4 5 6 7 8 9 extremely hard to learn

3. How do you rate Magic Window in terms of usefulness?

not useful at all 1 2 3 4 5 6 7 8 9 extremely useful

4. How often did you use the system?

never used 1 2 3 4 5 6 7 8 9 whenever visiting

**ALTERNATIVES and EFFORT**

1. When determining an occupant's availability, which of following two is easier?

Magic Window 1 2 3 4 ***5*** 6 7 8 9 translucent office window
(with door closed)

If easier or harder, why? Explain:

______________________________________________________________

______________________________________________________________

2. When determining an occupant's availability, which of following two is easier?

Magic Window 1 2 3 4 ***5*** 6 7 8 9 open office door

If easier or harder, why? Explain:

______________________________________________________________

______________________________________________________________

3. When determining an occupant's availability, which of following two is easier?

translucent office window 1 2 3 4 ***5*** 6 7 8 9 open office door

If easier or harder, why? Explain:

______________________________________________________________

______________________________________________________________

**AWARENESS**

1. Compared to a translucent office window with door closed, Magic Window provides ____________ useful information about the occupant in determining availability:

extremely much less 1 2 3 4 ***5*** 6 7 8 9 extremely much more

If more or less, why? Explain:

___________________________________________________________________

___________________________________________________________________

2. Compared to an open door, Magic Window provides _________ information about the occupant in determining availability:

extremely much less 1 2 3 4 ***5*** 6 7 8 9 extremely much more

If more or less, why? Explain:

___________________________________________________________________

___________________________________________________________________

3. Compared to an open door, a translucent office window with door closed provides OO information about the occupant, which helps determine availability:

extremely much less 1 2 3 4 ***5*** 6 7 8 9 extremely much more

If more or less, why? Explain:

___________________________________________________________________

__________________________________________________________

**USER TRUST and PRIVACY**

1. How much did you trust the system?

most distrust 1 2 3 4 5 6 7 8 9 most trust

If trust or distrust, why? Explain:

__________________________________________________________

__________________________________________________________

2. I would consider replacing my office window with Magic Window:

Yes No

Why or why not?

__________________________________________________________

__________________________________________________________

3. How much were you concerned about your privacy when using the system (e.g., fingerprints/ your face image captured by system etc)?

not at all 1 2 3 4 **5** 6 7 8 9 extremely concerned

If concerned or not concerned , why? Explain:

__________________________________________________________

**COMMENTS**

1. Overall comments:

Demographics and Post-deployment Questionnaire (Occupant)

**DEMOGRAPHICS**

1. Personal Information

Age Range: 20-25 26-30 31-35 36-40 41-45 46-50 50+

Gender: M F

2. How many times a day, on average, are you interrupted by visitors during a regular term?

0-1 1-2 2-3 4-6 8-10 11- 15 15+ visitors/day

3. How many of them, on average, are regular visitors?

0-1 1-2 2-3 4+ people/day

4. How many times a day, on average, are you interrupted by other means? (e.g., office phone/ cell phone/ Instant Messenger) a day in your office?

0-2 3-5 5-10 11+ times/day

5. On an average day, during the working hours:

a) how often did you momentarily leave your office?

0-2 3-5 5-10 11+ times/day

b) For the question a), for how long?

10- 11-20 20-30 30-60 60+ minutes/leave

c) How many hours, a day, do you spend working with computers?

0-1 2-3 4-5 5-6 6-8 8+ hours/day

**USER SATISFACTION and USABILITY**

1. How do you rate Magic Window in terms of easy of use?

extremely easy 1 2 3 4 5 6 7 8 9 extremely hard

2. How do you rate Magic Window in terms of learnability?

extremely easy to learn 1 2 3 4 5 6 7 8 9 extremely hard to learn

3. How do you rate Magic Window in terms of usefulness?

not useful at all 1 2 3 4 5 6 7 8 9 extremely useful

**PRIVACY and AWARENESS**

1. After system deployment, my overall confidentiality level:
(where 5 is privacy level before deployment)

decreased 1 2 3 4 ***5*** 6 7 8 9 increased

Increased or decreased, why? Explain:

______________________________________________________________

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2. After system deployment, my average number of inappropriate interruption:
(where 5 is privacy level before deployment)

decreased 1 2 3 4 ***5*** 6 7 8 9 increased

Increased or decreased, why? Explain:

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**EFFORTS**

1. After system deployment, my overall effort for maintaining confidentiality:
(where 5 is privacy level before deployment)

decreased 1 2 3 4 ***5*** 6 7 8 9 increased

Increased or decreased, why? Explain:

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2. After system deployment, my overall effort to control interruption:
(where 5 is privacy level before deployment)

decreased 1 2 3 4 ***5*** 6 7 8 9 increased

Increased or decreased, why? Explain:

3. After system deployment, my overall effort to obtain awareness from hallway:
(where 5 is privacy level before deployment)

decreased 1 2 3 4 ***5*** 6 7 8 9 increased

Increased or decreased, why? Explain:

USER TRUST
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1. How much did you trust the system?

most distrust 1 2 3 4 5 6 7 8 9 most trust

2 I would consider replacing my office window with Magic Window for good:

Yes No

Why or why not?

**COMMENTS**

11. Overall comments: