Working Together, Virtually

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Abstract

Although technologies such as media spaces have been designed to facilitate collaborative work at a distance, the existing systems have primarily focused on the use of computer managed audio and video as mechanisms to support meetings and video phone calls. Research has shown that frequent and spontaneous informal communication is crucial for project coordination and work progress. It has also found that the amount of collaboration that occurs varies directly with the proximity of co-workers. However, proximity is not always possible or desirable in today's work world. In this paper, we introduce the concept of a virtual open office, a simulated shared open office environment which creates proximity without its inherent disadvantages. We suggest that a large amount of communication among co-workers is not from actual intentional communication contact but from opportunistic contact and environmental scanning in which each individual is picking up valuable coordination information. We propose that it is this aspect of the constant contact of an open office environment which provides the closeness and cohesion necessary for effective work coordination. Based on this premise, we argue for a set of unique user requirements for the virtual open office and demonstrate an instantiation of these requirements in a working prototype, called VOODOO.

Keywords: Groupware, computer supported cooperative work, desktop videoconferencing, informal interaction, virtual spaces.

Introduction

Collaboration occurs frequently in both academic and business environments. Furthermore, it is often impossible to have all collaborators working at the same physical location. This suggests that we need a way to support effective collaboration at a distance. New computer and communication technology make it no longer necessary to assemble all collaborators at the same place, but studies have shown that physical proximity is important for informal communication[10]. It has also been found that better coordination and facilitation are supported by informal communication[5] and that fifty percent of informal work communication is opportunistic[7], e.g., triggered by the sight of another person. Research has also demonstrated the importance of being able to visually identify an opportunity for communication[9].

A large number of media space projects[2, 4, 6, 17] have focused on establishing computer managed audio and video connections to enhance collaboration at a distance. Part of their purpose is to bring back the informal communication that has been lost, but a major portion is also to emulate the rich communication environment of face-to-face contact. It has not always been stated explicitly that the audio and video connections imply a meeting, either prearranged or serendipitous, but the designs of the systems and the discussion of their usage imply that the underlying technology structure is primarily for establishing an intentional contact, what we define in this paper as a meeting. We are taking a different approach in our research. The environment we want to create with the multi-media tools is not one of supporting meetings but one of supporting constant and continuous contact among co-workers. We want to simulate a shared office where the dwellers of the shared office space are miles apart or a simple corridor away. We do not suggest that meeting support by media spaces is inappropriate, but rather, that it is insufficient for the type and amount of communication needed in complex detailed work assignments.

Even when co-workers are not conversing in a shared work environment, they are constantly transmitting details about the joint work. Proximal co-workers, for example, can overhear relevant conversations, view levels of partner progress, perceive changes in project direction, note co-worker's skill advantages and disadvantages, etc. on a real time basis. Furthermore, they can instantly corroborate the acceptableness of any path changes they might make in the joint work. Unfortunately, the large number of advantages of a shared office which promotes this information exchange have been overshadowed by the large number of disadvantages of placing employees in the same room or a weakly partitioned room. We postulate that

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if media spaces are configured correctly, we can gain back the advantages of the shared office without the incipient disadvantages, e.g., noise and interruptions. Furthermore, we propose that creating such a virtually shared office does not provide a primary benefit of travel cost reduction, but one of closeness and cohesion of co-workers engaged in joint work. Thus, media spaces are not just for enhancing communication at a distance but also for supporting communication within the same building and even on the same floor.

Several existing media space systems incorporate some aspect of supporting informal communication within their structure. Bellcore has built Cruiser[17], a prototype desktop browsing tool which enables unplanned, informal social interaction via audio and video links between co-workers. Other example media space interfaces that have some elements of the virtual office are Polyscope and Vrooms[2] at EuroPARC. Polyscope is a system which distributes digitized images of workers within a building to provide awareness of the other person's presence. It also acts as an interface to the audio and video network so that co-workers can make actual full motion audio and video connections. Vrooms is a modified Polyscope system that addresses some of the social and interface issues found in Polyscope. It employs a stronger spatial metaphor so that people can establish or terminate conversations by entering or leaving a virtual room.

Because it has been found that visual accessibility can be intrusive at times, designers of Cruiser and Vrooms have implemented controls on excessive visual accessibility using rudimentary techniques such as bars (what they call video blinds) crossing the video images or still shots of the co-workers taken at 15 minutes intervals. For Vrooms, Borning and Travers[2] used small video images of co-workers to limit the intrusion of a constantly open video channel. At EuroPARC, the RAVE[6] media space uses user-tailorable buttons to make a variety of audio and video connections to co-workers. One of these buttons is an "office share" button which puts two co-workers in constant continuous full motion video contact similar to the virtual office space we are proposing.

Although the above systems partially support informal interactions at a distance and awareness of co-workers, the approaches taken are ones of simply maintaining the video contact of the media space for a long period of time or of creating a general virtual meeting area where serendipitous contact can occur. This paper extends the continuous contact concept and discusses what other system operations need to be in place to effectively support continuous contact. We introduce the concept of a *virtual open office* — an open office in which physically separated co-workers are in constant contact through open communication channels. We believe that such a virtual open office, although not suitable for all forms of office work, will be useful for detailed technical collaboration, e.g., joint programming. While a media space system is an infrastructure for facilitating collaborative work, a virtual open office is a software environment that is configured within the media space system to satisfy its unique set of user requirements. In the following section, we focus on the user requirements that are appropriate for the virtual open office environment. We then describe our instantiation of these requirements in a system we call VOODOO.

User Requirements

At the University of Toronto, we have built a media space called CAVECAT (Computer Audio Video Enhanced Collaboration And Telepresence)[12]. Whereas CAVECAT is designed for making and breaking video and audio connections with one or more people, the virtual open office is set up to maintain connections with one or more people continuously throughout the workday. This means that co-workers residing in a virtual open office must be accessible for standard CAVECAT video calls just as they would be open to people walking into their shared office. It also means that such calls are made to all members of the open office not just to a single co-worker. Of course, private conversations can ensue just as they might in an open office, but all co-workers would be aware that such private conversations were taking place. Thus by creating a virtual open office in a media space, we add all nature of additional constraints on how that space is to be managed. We have combined existing research on open office communication behavior with experimental observations in our laboratory to generate a list of user requirements for the virtual open office. Although this list is not exhaustive, we have attempted to specify that set of requirements which preserves the advantages of an open office and eliminates its disadvantages. Table 1 lists the entire set of user requirements.

	User Requirements
1	Ability to implicitly establish a co-worker's level of accessibility
2	Ability to enforce reciprocity in information exchange
3	Ability to explicitly set one's level of accessibility
4	Ability to change one's position with respect to co-workers
5	Ability to trivially make verbal and visual contact
6	Ability to trivially close verbal and visual contact
7	Ability to have multi-way conversations
8	Ability to support multi-media information exchange
9	Ability to filter out unwanted noise
10	Ability to discriminate among sounds in the virtual open office
11	Ability to obtain feedback on the communication environment

Table 1: Virtual open office user requirements

Accessibility

In a normal open office environment, co-workers are in constant contact, and thus, they are always available for interaction. In an open office, it is not availability, but co-workers' *accessibility* that is important, e.g., whether the co-worker is at an interruption point in their work or conversation.

Requirement 1: Ability to implicitly establish a co-worker's level of accessibility

Kraut, Egido and Galegher[10] and Allen[1] have postulated that physical proximity is crucial for informal interaction. Our survey of users of the CAVECAT media space has found that users do not make video connections for fear of intruding on the other party[4]. Root[17] has pointed out that people use implicit interaction protocols to indicate a willingness to receive a communication contact. After noticing that someone is in their office, people use cues such as the type of work a potential contact is engaged in to ascertain the occupant's accessibility for interaction. For example, in a conventional open office, co-workers implicitly know not to interrupt a person talking on the telephone. Material placed in one's own workspace as opposed to a more common area such as a book shelf implicitly determines its viewability and thus, accessibility to others. The virtual open office environment should provide similar mechanisms for users to determine the accessibility of co-workers. Because this accessibility is established by spatial arrangements and events that are the normal course of work, this same implicitness needs to be available in the virtual system.

Requirement 2: Ability to enforce reciprocity in information exchange

When people used EuroPARC's media space, Polyscope, video symmetry was almost never requested, that is, users did not ask to see who was looking at them. Users may not be aware of the unequal information exchanges supported by the system. In an open office, viewing is reciprocal. If I can see someone I know that person can see me. In a media space, this is not necessarily true. Furthermore, although I can see someone, they might be able to see more of me and at a much finer level of detail. This unequal exchange can cause severe imbalances in relations and exchanges. It is therefore necessary to explicitly enforce reciprocity in all information sharings in a virtual open office if natural coordination relations are to be maintained.

Requirement 3: Ability to explicitly set one's level of accessibility

Chatting with co-workers is often a hindrance (albeit enjoyable) to work in an open office. So is maintaining document privacy. Therefore, control over conversational and workspace accessibility is an essential need for the virtual open office.

Requirement 4: Ability to change one's position with respect to co-workers

Marmolin, Ahlstrom and Ropa[14] have found that people use a large video image for discussion, but when they are working intensely on their own tasks, they use a small video image for checking the communication status of their co-workers. Our own laboratory studies of two individuals working on a joint programming task over the media space showed that people did not use the visual image of their partner when they were focussing on the task. They only glanced at the video occasionally and sat away from the video screen. When they were negotiating a detail about the task, they moved their chairs directly in front of the video image and engaged in a more direct face-to-screen contact. In an open office, people often learn a large amount about their co-workers by glancing around their co-workers' office or looking at what's on their co-workers' desk or book shelf. By walking over to the other's desk, people are able to get a closer look. A virtual open office environment should be capable of handling the close contact as well as the environmental scanning which people use in their daily work to gain information about their colleagues.

Communication Cost

There are financial and behavioral costs associated with establishing communication. The behavioral cost aspect is more important for informal interaction at a distance. Different communication media have been shown to affect the collaboration process. The more limited the communication medium is, the less effective the collaboration process. If the behavioral cost is high, such as remembering and pushing several digits on a telephone, waiting for an answer and establishing a communication, a mental cost/benefit tradeoff will be calculated and communication below a particular threshold will not take place — even if the communication would have transmitted important information. Allen[1] has shown exponential drop-offs in the frequency of communication between co-workers as the physical distance increases. In their study of communication, Kraut et al.[11] found that 52% of the conversations involved people located off the same corridor and 87% of the conversations took place among people who shared the same floor of a building. We believe that it is the cost of making informal contacts when distance increases that causes their significant fall off.

Requirement 5: Ability to trivially make verbal and visual contact

In the absence of close proximity, we need to make the initiation cost of communication very low to encourage frequent and spontaneous communication. In the joint programming studies we conducted in our simulated virtual open office environment, we found that conversations opened and closed without any formal protocols just as they might in regular exchanges. We noted that no conversation commencement and termination protocols occurred even when there existed gaps of five to ten minutes between verbalizations. We assume a state of communication that no longer needs formal contact protocols, much like that of a continuous conversation with pauses. Contact should be as easy as starting to talk or raising one's head to gain other's attention.

Requirement 6: Ability to trivially close verbal and visual contact

It is equally important to have a low behavioral cost for terminating communication. Co-workers should not need to follow a formal closing protocol. After all, the conversation is assumed to be continuous in this state, only punctuated by pauses. Our studies of joint programming in our simulated virtual open office support this behavior as well.

Requirement 7: Ability to have multi-way conversations

It should be easy to have a third party join or leave a conversation. People should be able to make entrances

into a virtual open office conversation similar to the way they normally would in a physical open office. However, entrants into a physical open office often walk up to one person's desk and engage in a private conversation. Such activities should also be supported in the virtual open office including the one in which the two conversants leave the open office for an even more private exchange. As in a regular open office, concurrent conversations of several subgroups of co-workers should be permitted to occur with listening support for other co-workers. However, such listening support should not permit others to overhear private verbal exchanges.

Information Sharing

Information sharing adds semantic content to a conversation and provides an underlying context for the discussion[11]. Tang[19] has demonstrated that shared drawing space is not only useful for storing information and conveying ideas, but also for developing ideas and mediating interactions. Ishii[8] has shown the problems of work integration in shared computer environments and presented a video solution for seamless shared workspaces. Lauwers and Lantz[13] have suggested a set of user requirements for shared window systems to support sharing using existing collaboration transparent applications. Although document sharing is important, so is document privacy. Oldham and Rotchford[15] have shown that in an open office, co-workers preserve their ownership of a workspace by placing personal spatial markers around that space. There is the need for both defining and preserving the ownership of people's workspace when that space becomes virtual. Thus there is a need for both workspace sharing in a virtual open office but also one of allowing a user to establish limits on this sharing.

Requirement 8: Ability to support multi-media information exchange

In our shared programming study, we emulated a virtual open office by setting up two offices back-to-back and passing cables for exchanging computer screen images and camera images to monitors on the other side of the wall. We used Y-cables to split each computer's video output and send it to a second screen on the other side of the wall. Thus, each programmer had a view of what activities and code the other programmer was working on as well as video and audio connections to their co-worker. We found that an extensive amount of time was spent looking at the other person's code and hand copying it from one terminal to another. Each person also pointed to elements in the other person's code but this action was not visible by the second person in our rudimentary setup. From these exploratory studies we ascertained that the virtual open office environment should have all shared work information available to all parties in the office. Co-workers should be able to easily share objects such as drawings and text[3]. Telepointing facilities should be provided for people to easily refer to objects in the shared workspace. The system should be able to handle off-line as well as on-line material and to allow synchronous annotation of screen objects. Co-workers should be able to easily demonstrate processes. For example, a person may show the execution of a program which contains bugs and ask the other person how to correct the program. Co-workers should also be able to easily copy relevant screen objects from their co-workers' machine.

Environmental Improvement

Use of open audio and video channels leads to concerns about preserving an individual's privacy[2]. An open office is not private[16, 18], but workers are always aware of this lack of privacy. A virtual open office is problematic because the cues to indicate a privacy problem may no longer be available. Privacy issues in a virtual open office are very different from that in a media space system. A virtual open office does not provide co-workers with total privacy, thus it is not a suitable environment for people who want to work privately. Co-workers in a virtual open office face the problem of distractions such as noise. Noise has been a common complaint of workers in open offices[18]. Ambient noise in the office and noise generated from co-workers' chatting and typing forces people to make an extra effort to concentrate on their work. One of the problems with an open office is that there is so much noise that it is very difficult to discriminate between the sounds we want to hear and those we want to shut out. The inability for participants of a media space to localize sound makes it more problematic because the location cues used for sound filtering are lost. During CAVECAT sessions, on many occasions several people would answer their phone when the phone rang in another office. Users of our CAVECAT system have expressed the desire for system generated cues to help them spatially separate sound sources[4].

Requirement 9: Ability to filter out unwanted noise

Limited options exist when a co-worker is very noisy in a physical open office but the virtual open office makes it simple to quiet a noisy inhabitant just by lowering a volume control. Thus, one should be able to muffle out the noise generated by a co-worker. This silencing capability needs to be reciprocal, i.e., users should be able to prevent a conversation from reaching others as well as inhibiting conversations from disturbing them.

Requirement 10: Ability to discriminate among sounds in the virtual open office

Through the use of technology, e.g., a three dimensional sound system or different phone rings for different people, the system should provide implicit cues to people for spatial separation of sound sources and identification of salient signals.

System Status

Awareness of both the physical and social environment is required for maintaining informal activities in a virtual open office. Information and feedback should be provided so that collaborators have a constant overall picture of the work environment.

Requirement 11: Ability to provide feedback on the environment

People may have set up their phone to be accessible so that they can receive phone calls, but the receiver may have been misplaced in its handset so that it is still off the hook. The system needs to give clear feedback on the settings of each worker's personal accessibility settings at

all times. The environment should be able to signal users of inconsistencies in their desired and actual settings and of temporary (non default) settings they have selected that are still in place. In an open office, one has complete awareness of the office environment and can always tell who is talking to whom in the office. A virtual open office should provide appropriate feedback to its dwellers so that they are fully aware of co-workers' communication and accessibility status.

Figure 1: Three co-workers use VOODOO to work in a virtual open office

The Design of VOODOO

We have built an instantiation of the virtual open office at the University of Toronto. We call it VOODOO. It works as follows: Teams of co-workers are assigned to one virtual open office that is their permanent office, i.e., the equivalent to their physical office in the real world. Whenever co-workers log into the media space system, they are, by default, put into their permanent virtual open office. They may be the only occupant, in which case, they have a virtual private office. On the worker's computer screen are small, faraway shots of the co-workers who are in the office. The worker is visually aware of co-workers' activities yet is not disturbed by their typing because the typing sound has been filtered out. The worker knows that viewing of others is reciprocal and that preventing someone from viewing oneself is done only by relinquishing the privilege of seeing the other person. Different views of co-workers can be obtained, one faraway and one closeup. The default view is faraway. One can change the view to engage in a more intimate interaction with co-workers.

A conversation is started by moving the mouse cursor to the picture of the co-worker and clicking on the mouse button. Eye contact or verbal hailing catches the co-worker's attention. A conversation is closed by a mouse click to toggle to an audio off state. A person can join an on-going conversation by moving the mouse cursor to the picture of one of the participants and clicking the mouse button. Several subgroup discussions can happen at the same time in the virtual open office without interference.

Screens of current work can be shared between the conversing parties and users can mutually point to a topic of interest on these shared screens. An occupant can temporarily leave the virtual open office, e.g., go to lunch, or can permanently leave, e.g., move to another office space or simply leave the project. Users can freely walk into any existing virtual open office to which public entrance has been permitted, but are restricted to be in one

virtual open office at a time. Figure 1 illustrates what the screen of a user might look like when the user is in a virtual open office called *cave* with two co-workers. Each of the windows represents a person that is present in the office. At the base of each window are a button labelled *s* for adjusting communication states between each person, e.g., changing the view of that person's office, and a panel for displaying the current communication state. A discussion is going on between Mantei and JinLi. The other office member Buxton is working at his desk and not part of the conversation. When an audio connection is made between Mantei and JinLi, unless explicitly set to be different, video images of both users will fade into close-up views during their discussion. The white border around the image indicates the audio is on, while the black border indicates audio is off. After the conversation, their images will again fade into their original state, most likely a faraway shot. In this example, JinLi is the owner of this screen, that is, the picture of this screen is viewed from JinLi's workspace.

	User Requirement	Design Solution
1	Ability to implicitly establish a co-worker's level of accessibility	Constant open video communication channel
2	Ability to enforce reciprocity in information exchange	Enforced audio, video and computer screen symmetry
3	Ability to explicitly set one's level of accessibility	Explicit software settings available
4	Ability to change one's position with respect to co-workers	Close-up and fly on the wall cameras
5	Ability to trivially make verbal and visual contact	Open video channel and mouse click on image
6	Ability to trivially make verbal and visual contact	Open video channel and mouse click on image
7	Ability to have multi-way and concurrent conversations	Software to explicitly select participants for a conversation
8	Ability to support high quality information exchange	Shared computer screens, telepointing, workspace viewing and (not implemented)document tray metaphor
9	Ability to filter out unwanted noise	Muffler metaphor(partially implemented)
10	Ability to discriminate among sounds in the virtual open office	3D sound system with MIDI(not implemented)
11	Ability to provide feedback on the environment	Diagrams of connections(not implemented)

Table 2: Design solutions to the user requirements

VOODOO is implemented on a Macintosh computer using a client-server architecture. The server resides on a SPARCStation and keeps an updated database of resources, connections and activities in the virtual open office. Table 2 illustrates the proposed solutions to the user requirements. We discuss the features of VOODOO in the following sections.

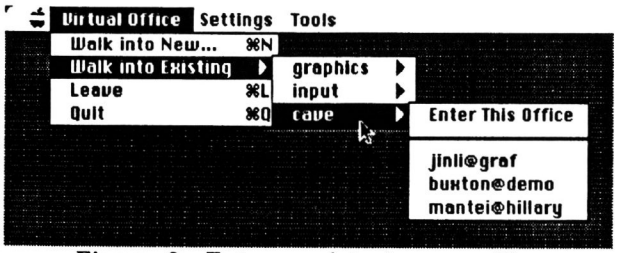

Figure 2: Enter a virtual open office

Figure 2 shows how a user enters a virtual open office by selecting the appropriate office from the virtual offices menu displayed at the top of the Macintosh screen. The menu dynamically displays all the existing virtual offices that are accessible to users and shows who are currently working and where they are physically located in the respective virtual offices. Once a user has entered a virtual office, all video images of co-workers in the office appear as small windows on the user's screen. Via the open video channel, the user can easily tell who is currently working in the office and implicitly establish co-workers' accessibility. This satisfies user Requirement 1. VOODOO uses full motion but low spatial resolution video for the faraway shot. Full motion video provides users with real time visual awareness of events, while low quality video preserves co-workers' privacy and prevents excessive visual intrusion. When co-workers are engaged in a conversation to negotiate details about a task, full motion closeup video is used to enhance information exchanges. Since co-workers can see each other when they are visually accessible, this meets the reciprocity constraint of Requirement 2. Associated with each individual image on the screen is a set of communication and workspace attributes that specify a person's accessibility. They can be explicitly set. For example, a user can turn off the audio coming from a colleague who is unusually noisy. This capability satisfies Requirement 3.

VOODOO uses several video cameras to provide users with different views of their co-workers so that the complete office scene of a co-worker can be viewed and a richer information exchange can occur. The closeup camera is placed on top of the computer screen and captures a head and shoulders image of a co-worker. The "fly on the wall" camera is mounted on the office wall and captures the interior of the office. Figure 3 shows how a user can move closer to another co-worker for an intimate interaction or further away to get a broader view of the office by holding down the mouse button on a video image to get a popup list. This setup fulfills Requirement 4.

Figure 3: Control communication states

To initiate verbal contact, users need to use the mouse to click on the video image of the co-worker they wish to communicate with. Although the action must be done explicitly, it has the explicitness and ease of use that are intrinsic to the social protocol of calling out a co-worker's name in a face-to-face contact. Another approach that is being considered is the usage of sensors to detect head movement. As a user raises his or her head and starts talking, the head direction selects the contact person and a voice activated audio connection is made. Closing a conversation is also done by a mouse click. These interface features meet the requirements of low behavioral cost for making and breaking communication (Requirements 5 and 6). The current VOODOO system does not have the voice activated audio feature, but we are working to set up the appropriate hardware and software to incorporate it in the next version.

Users can selectively decide who is not supposed to overhear the current conversation with menu selections. Alternatively, a user just needs to mouse click on the picture of one of the participants of a conversation to smoothly join the meeting. This interface design meets Requirement 7.

We propose a document tray metaphor for users to share documents while preserving ownership of workspace. When a user places a document in a co-worker's document tray, that co-worker immediately gains viewing access to the document. However, should the user decide that the co-worker no longer has access to the document, the user can remove the document from the co-worker's tray. Even if the co-worker is reading the document, when the user takes the document, the co-worker loses access to the document. A telepointer is available in a unique color for each user. This allows each co-worker sharing a document to point to important information they are discussing. Their telepointers can be seen on all other screens displaying the document. Documents can be all possible documents generated by Macintosh applications. We have provided users with an application tools chest (Figure 4). Users can run other collaborative or single-user Macintosh applications within the VOODOO system to perform different tasks with their co-workers. Through the use of the document tray metaphor, telepointers and shared computer screens, a high bandwidth of information can be easily exchanged and thus, Requirement 8 is fulfilled. The document tray metaphor has not been incorporated into our initial version of VOODOO.

The muffler metaphor is used to circumvent the noise problem in an office. Users have the option to muffle the audio signals at several different levels. They can muffle noise such as a co-worker's typing sound but permit normal human voice to be transmitted across the audio connection. The level of muffling is controlled by a slider interface. A user sets the level by adjusting the slider bar. When a user is disturbed by the typing sound of the co-workers, after adjusting the muffling level, the typing sound will fade to the background and be filtered out completely. This feature, which satisfies Requirement 9, has not been implemented in the current system prototype.

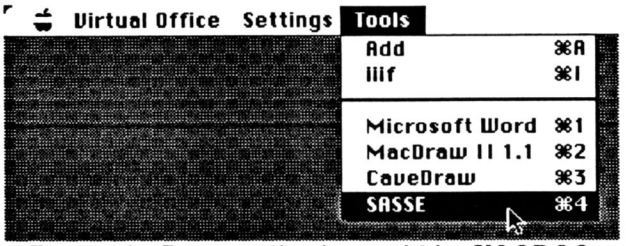

Figure 4: Run applications within VOODOO

One of the problems with current media space is the lack of proper audio feedback for users to spatially separate their co-workers. Three dimensional sound hardware and software systems can reproduce audio while preserving its spatial properties. This permits a user to recognize where the sound is coming from. If such a system were implemented in our interface, Requirement 10 could be met.

A diagram of current communication connections is provided to co-workers to give feedback on who is talking to whom in the virtual open office so that co-workers are constantly aware of communication activity in their environment. For example, when a full audio connection is established between two co-workers, the diagram could show cables connecting one co-worker's microphone connected to the other's speaker. This would then meet Requirement 11.

Conclusion

A unique set of user requirements for the virtual open office concept has been presented. VOODOO, a working prototype of the virtual open office concept, provides an environment for collaborators so that easy and seamless informal interactions can be achieved and so that co-workers are constantly aware of their colleagues' activities without problematic interruptions and noisy environments. Further detailed user testing and field study are required to evaluate the usefulness of the virtual open office.

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