Shared Space at a Distance : A Model of Integrated Shared Space for Supporting Informal Interaction at a Distance

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Abstract. Informal interaction among team members is an important factor in collaborative work. This paper discusses the issue of how the notion of shared space is used to support informal interaction at a distance. We reviewed existing shared space examples, examined how they support informal interaction and identified critical issues that emerged from the characteristics of shared space technologies which do not fully support the nature of informal interaction. We then propose a model of integrated shared space (ISS) whose main objective is to address these issues and support collaborative work at a distance through a shared space for natural informal interaction.

1. Introduction

With the advent of internet network and communication technologies, team members who are geographically distributed are able to collaboratively work over physical distance in a variety ways such as using instant messages, telephone, email and video conferencing. These tools are useful in conducting and facilitating conversations, however, as reported by Kraut et al. [1] and Mackay [2], communication supported by these tools is less frequent, sometimes delayed in sending and receiving messages and more effortful than in face-to-face conversations. More importantly, team members could not benefit from informal communication from which creative ideas spring [3]. Basically, informal interaction often occur when people are co-located or being in a shared environment in which the spatial and temporal factors provide opportunities for people to encounter each other thus foster them to come into contact and communicate. So far, researchers have developed a variety ways to enable

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informal interaction among co-workers who are separated by distance in which interaction metaphors such as hanging out, encounter in hallway and face-to-face communication are integrated in the systems in order to imitate the actual situations in real life. Therefore, people could encounter and interact with their geographically distributed co-workers in a shared virtual environment such as in a shared-virtual-window space [4], a shared virtual hallway [5] or a shared 3D multi-user space [6, 8]. Since each type of space employs different technology to convey their purpose thus different critical issues emerge from the technological characteristics.

In this paper, we seek to understand how shared space is used to support informal interaction at a distance and what the appropriate way to create a shared space which could minimize the critical issues is. Firstly, we examine the concept of shared space and the ways it is supported at a distance in order to have a grounded knowledge of shared space approach. Secondly, we review examples of shared space and their technologies to support informal interaction and their corresponding issues. From this examination, we propose a way to address these issues through the model of integrated shared space.

2. Shared space and the ways it is supported at a distance

Shared space, in Gaver's paper [9], is described as a "encompassing space" which "is rich with perceptual information about objects and events that can be explored and manipulated". With regard to the issue of being there together [10], a shared space is a space that provides "excuses to be there", "opportunities to see what's going on and to be seen in a non-intrusive way" and "easy switching between inward- and outward-oriented activities".

Practically, all collaborative activities requires co-workers to work in a shared environment whose physical proximity facilitate people to meet, discuss, exchange and share information in order to reach a common understanding and rapid decisions. With the aid of internet and communication technologies, geographically distributed co-workers are also able to work in a shared environment which is created as electronic "*distributed environments where participants can exploit spatial properties such as containment and movement in order to manage their communication*" [11]. Benford et al. [11] categorized technologies for virtual shared space into five types : media spaces, spatial video conferencing, collaborative virtual environments, telepresence systems and collaborative augmented environments.

Media spaces

A media space is combination of different kind of media such as audio, video and computing technologies that enhance the possibility of existing workspaces in order to facilitate "cross-site" communication for working and social purposes

[12, 13]. Media spaces enable physically separated people to be aware each other's presence and activities thus bring people "together" across time and space through "always on" and "always available" video channels [12, 14]. Media spaces are mostly used to create and sustain working relationships at a distance through casual communication [13], social browsing [5] and peripheral awareness [15, 16].

Spatial video-conferencing

Video conferencing is a system which integrates interactive communication technologies to support formal meetings between two or more locations through two-way audio-video connection. Differing from media spaces, video conferences are used for focused meetings rather than using for supporting peripheral awareness and maintaining working relationships.

Collaborative virtual environments (CVEs)

CVEs are computer-generated spaces which are created as distributed virtual environments in which participants are represented as graphical forms such as avatars and able to exploit the virtual environments as well as meet and interact with others using real world metaphors [17]. Differing from media space, CVEs provide an integrated environment for geographically distributed people instead of representing them in separate windows.

Telepresence systems

Telepresence systems enable people to discover a remote physical location as if they are physically present there. Telepresence systems enable users to view, navigate the remote space as well as to interact with the remote objects and remote participants. People's embodiments at the remote location are typically in the form of a moveable robot with attached camera [11]. Telepresence system differs from CVEs in that users are able to exploit a physical environment by viewing a real-time video display of the environment instead of a 3D virtual environment.

Collaborative augmented environments

Augmented Environments enable people to see an integrated physical-virtual environment in which some graphically generated objects are superimposed and dynamically registered on the real world scene [18]. People need to wear head mounted display to view the augmented reality scene. Differing from telepresence systems which provide users the live video of the real scene, in collaborative augmented environments people see real scenes superimposed with augmented information of the environments which is not apparently visible such as ruined, unbuilt or hidden parts though graphically generated objects.

3. Shared spaces for supporting informal interaction at a distance and their critical issues

3.1. Shared spaces for supporting informal interaction at a distance

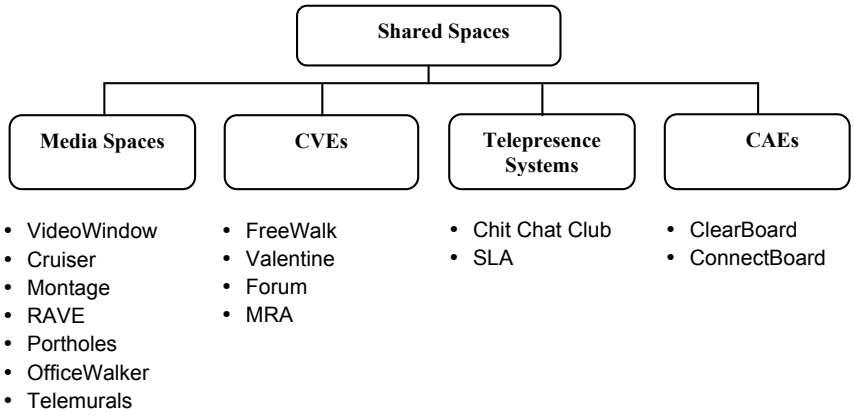

Fig. 1. Shared Spaces for Supporting Informal Interaction at a Distance.

Informal interaction refers to the "conversations take place at the time, with the participants, and about the topics at hand" [19] or the "unstructured information exchanges that tend to occur in face-to-face encounters during "off-tas" moments" [20]. Informal interaction occurs when people are co-located so that the physical proximity provides a chance for them to come into contact and communicate [1]. When people are physically separated, their interaction would be mediated by technologies. Therefore, researchers have created a variety of methods to support informal interaction at a distance with the purpose to mimic the real situation when people encounter each other thus encouraging physically separated people to engage in unplanned conversations. In order to create a shared environment for bringing geographically distributed people to come together across space and time, shared spaces technologies have been employed to implement the research purposes.

Figure 1 classifies the examples for supporting informal interaction at a distance based on the four categories of shared spaces technologies introduced by Benford et al [11]. They are media spaces, CVEs, telepresence systems and CAEs. Video conferencing systems are excluded because though they provide facilities for distance-separated people to communicate with each other, they are

often used to serve planned and formal meetings thus not appropriate for interaction by chance.

Media spaces

Most of the examples employed media spaces for creating virtual shared space. VideoWindow [4] created a shared virtual lounge between two distance-separated public lounges through a high bandwidth video channels and full-duplex four channel audio. By projecting the image on a three-foot high by eight-foot wide screen, it allows nearly the whole lounge area to be seen together with people appearing about the same size. Informal interaction initiates when a person walks into the room, glances at the window and sees another at the other end. RAVE [21] was developed as shared virtual workspace with which people are able to maintain awareness of remote locations through viewing the selected location "background" and "sweep"-ing the locations (find out who is around and what are they doing) and able to find out the availability of remote people through "glance" function. Portholes [15] approached the notion of virtual shared office by enabling people to keep a peripheral awareness in a variety of places through a matrix of slowly scanned continuous video images. By seeing these images one is able to know who are available thus establishes an audio-video connection with this partner. The last type of shared space that has been used in many systems is the notion of shared virtual hallway. Typical applications are OfficeWalker [16], Cruiser [5] and Montage [22] in which the mechanism of shared virtual hallway enables people to walk through and "peek" into each other's offices in order to see who are there. The "hallway" is actually a path which contains a set of locations (offices, common areas) which the user might visit. By peeking into other's office, both parties are able to see each other and may involve in the conversation if one is available. Telemurals [23] introduced a sociable shared space for encouraging social interaction between two remote physical spaces. The shared space is created by rendering captured video of people in each space into silhouette shapes, blending them together and projecting blended images onto the wall of respective space. People are able to interact through audio channel and subtle cues of expression such as hand movement and other postures.

Collaborative virtual environments (CVEs)

Since virtual worlds have been shown to support social interaction through users' navigation and social positioning (the degree to which one related to the space they inhabit or others who shared it through movement and positioning [24]) thus they could provide a structure for encouraging unintended interaction [25]. According to Phillip and Andrew [25], the primary ways to support informal interaction focus on using media spaces instead of using CVEs. However, CVEs is expected to provide greater degree of social interaction than media spaces. Typical CVEs for supporting informal interaction include Forum [25], FreeWalk [6], Mixed Reality Architecture (MRA) [26] and Valentine [7]. Interactions

among users in Forum happen in a shared information landscape where each user is represented in terms of an avatar. By placing the users' avatar close to each other based on what the users are working on, Forum provides opportunities for opportunistic informal interaction that fit current activities of users. In FreeWalk, a 3D space is developed just like a virtual hallway or lobby for encouraging accidental encounters in a more relaxed atmosphere with maximum freedom to the participants' activity. A participant is represented as a pyramid on which his/her video is mapped on the rectangular plane. Participants can find others on the radar screen while wandering in the 3D environment thus can encounter other accidentally. Similar to FreeWalk, MRA links multiple diverse physical spaces in a shared virtual environment in which a Mixed Reality Architecture Cell displays the live video of a physical space and transmits the live audio captured from the physical space. Valentine [7] was developed as a 3D virtual office environment for enabling home workers to come to work together. Participants are represented as avatars whose bodies are 3D polygons and heads are still photos of specific user. Valentine facilitates more natural communication among participants through the possibility to recognize the other people and the possibility to feel presence of others.

Telepresence systems

A representative of telepresence systems for casual interaction is Chit Chat Club [27]. It is a mixed physical and virtual environment for casual communication among distributed group of people. Remote participants could interact and communicate with local participants by logging into a physical telepresence sculpture which is created in an anthropomorphic form and placed at the table where local participants hang out. Differing from the concept of telepresence systems whose remote embodiments are able to navigate, the sculpture is installed as a fixed object and faces a fixed direction. Therefore, remote participant who logs into the telepresence sculpture is unable to explore the physical environment and his/her field of view is constrained by the fixed direction as well as the field of view of the attached camera on the sculpture. Recently, more realistic robotic avatars named Shared Lamps Avatars (SLA) [28] could support more natural conversations through dynamic motion (gesture and talking) and appearance of a real people.

Collaborative augmented environments

ClearBoard and ConnectBoard [29] are developed as a seamless integration of interpersonal space and shared workspace with which co-workers in two remote locations are able to talk through and draw on one transparent glass window [30]. The collaborative work represented as shared drawing image is overlaid on the RGB video of the partner. Since ClearBoard was designed as drafting table producing unnatural view of the remote user, ConnectBoard support more natural interaction through upright screen.

3.2. Critical issues

From reviewing the above examples, a few critical issues were identified.

Privacy invasion and intrusiveness concerns the possibility to control the boundaries of interaction so that the visual and auditory information is only accessible by those to whom they involve. One primary and necessary factor in the systems for supporting informal interaction at a distance is to support mutual awareness with which people are able to be aware of others' presence and activities, thus, facilitate them to come into casual conversation. However, the more information is revealed, the more potential for intended or unintended privacy invasion to occur [14]. Therefore, there is a dual trade-off between level of awareness and potential for privacy invasion [31]. This issue is quite prevalent in media spaces which use audio-video connection to support awareness between two remote locations. Experiment data of Cruiser system has shown that the method for initiating communication was abrupt and intrusive. The "glancing to other office" feature for being aware of other's availability caused a sudden image of the caller on the recipient's screen thus it might violate recipient's privacy and interrupt his/her current activities [16]. Moreover, the caller's image placed the recipient in the zone for conversation (50cm-150cm) [32] that urged the recipient to respond even when it was not welcome. Intended and unintended privacy intrusion was also reported in CVE when an avatar tried to approach a group while they were talking to each other. Since communication in VideoWindow [4] and Chit Chat Club [27] occurs in public environment where drop-in conversation often occur thus it is difficult for people to control their communication boundary for a more private conversation.

Spatial incongruity concerns the level of spatial continuity, seamless connection and homogeneous integration of the shared space structure that facilitates people to explore the space in order to have a peripheral awareness of the space's surroundings. In media spaces, video connection acts as a window placed between the two spaces in order to enable people in one space to see the scene of the remote space. According to Gaver [9], the restrict field of view of the window limits people peripheral vision and constrain their perceptual exploration. There are two reasons for this limitation. First, "*video conveys a limited amount of information about three-dimensional structure of remote scenes, and thus limits exploration, inspection, and peripheral awareness*" [9]. Second, "*camera and microphones are stationary or only moved remotely, preventing the perceptual of exploration*" [9]. Fixed camera also caused spatial incongruity in Chit Chat Club in which people only see the remote space from the view of a stationary sculpture. It disables the possibility to move freely in the space even though the sculpture is the user's embodiment in the remote space. In some media spaces, although multiple screens are used to enhance peripheral awareness [15], they pose difficulties for users to switch their focus among multiple screens thus distracting users' attention. Multiple video screens also cause spatial discontinuity and

spatial arbitrariness because of separated windows [9, 33]. Although SLA supports natural gesture and talking, spatial incongruity is also a problem in SLA as well as in Chit Chat Club since the models are stationary thus limits the possibility to have a peripheral awareness of the remote space's surrounding.

Lack of engagement concerns the extent to which informal interaction may occur through the use of the system. Evaluation on the use of media spaces reports that spontaneous interactions did occur across these video connections, however, they occurred less frequently than in actual situation where people spontaneously encounter each other in a physical environment. The probability that an encounter will lead to communication is therefore reduced [34]. Similarly, spontaneous encounter also occurred in CVEs environment while participants were moving or wandering in the 3D environment. However, occurrence of conversation in 3D space was scarce since participants enjoyed moving in 3D virtual space more [6]. It is explained that the 3D virtual space activated the motivation of participants' moves. When people enter the 3D environment, they leave their physical world behind and interact inside a virtual world with virtual counterparts and artifacts. In this case, people are isolated in the virtual worlds and disconnected with their real world counterparts thus only able to interact with their virtual parties [11, 35]. According to Obata and Sasaki [16], interaction in virtual environments is meaningful only if virtual parties are around and getting involved in the activities of the virtual worlds. Since virtual parties are not logged into the virtual world all the time, thus, to some extent, the likelihood for informal interaction to occur in CVEs is not as high as in real life where their co-workers are around and can easily engage in a conversation when they encounter each other.

4. Model of integrated shared space for supporting informal interaction at a distance

As discussed previously, CVEs provide spatial structure conducive for geographically distributed people to populate and socialize, and media spaces enable people to be aware of others' presence, their activities and support the likelihood to encounter real world parties. This paper attempts to make use of these advantageous features and combine them together into an integrated shared space (ISS) in which firstly, CVE is augmented with real life scene providing opportunities for CVE users to encounter and informally interact with their real-world counterparts. Secondly, the physical space is extended with a 3D perceptual space providing opportunities for local users to interact with geographically distributed parties in a natural manner. ISS's broad aim is to create a share space with a globally integrated frame in which the physical space and the 3D collaborative virtual environment are seamlessly combined and continuously

integrated in order to provide a sense of shared space for distance-separated people. Therefore, real and virtual participants have the impression that they are populating one environment thus can freely interact with each other. We employ the concept of shared space with mixed reality boundaries by Benford et al. [11] and the concept of virtual team user environments by Kauff and Schreer [36] to develop our approach.

4.1. ISS paradigm

Figure 2 depicts the conceptual paradigm of ISS. It consists of two kinds of spaces : physical space and CVE. People from different remote locations (rL) could login to the CVE and interact with their real-world counterparts at a specific physical space. Differing from the collaborative augmented environments presented in section 2 whose virtual space and physical space are superimposed on each other, the two spaces in ISS are placed adjacent to one another and are connected together by creating "transparent walls" between them. Therefore, the two spaces could become one shared space in which the "transparent walls" allow bidirectional awareness about people's presence and activities without any obstruction. The "transparent wall", on the physical side, is a screen to display a graphical projection of CVE and, on the virtual side, is a polygon for mapping the texture video of the physical space. Through the "transparent wall", users are able to see an extended perception space seamlessly connected with their current environment.

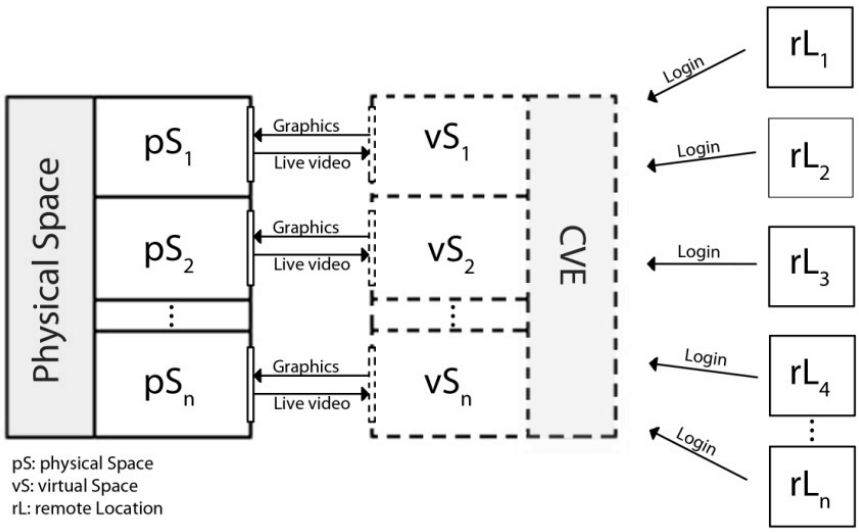

Fig. 1. ISS paradigm.

4.2. ISS's features for minimizing the critical issues

Enhancing spatial congruity. The sense of spatial continuity is created by identifying the spatial setting of physical space with the spatial setting of virtual space in terms of size, perspective, coordinate system and interior design. The continuity between physical space and virtual space at the "transparent wall" is created by registering the physical elements and the virtual elements at the wall together by creating a seamless transition of geometry and texture of the elements (Figures 3 and 4). For example, the physical and virtual bar counter in Fig. 3 are seamlessly connected together to become one bar counter of the shared space.

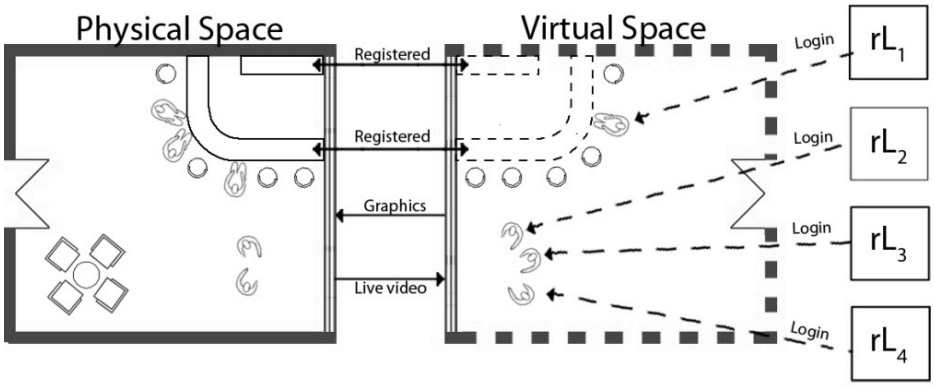

Fig.2. A single connection between a physical space and a CVE.

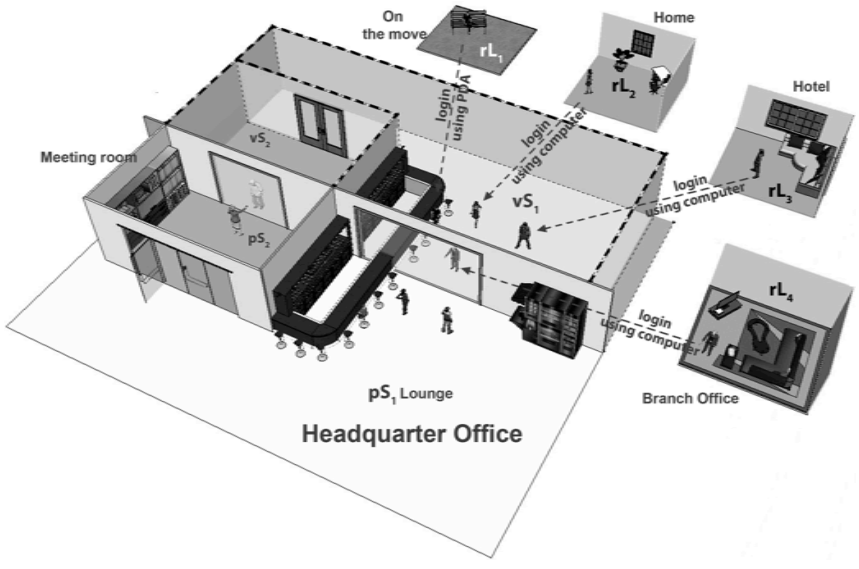

Fig. 3. Multiple connections ((pS1-vS1) and (pS2-vS2)).

Stimulating engagement. With the "transparent walls", CVE users are no longer isolated in the virtual world. They are able to encounter their real world co-workers to whom they want to discuss thus increasing the probability for a conversation to take place in ISS. Moreover, CVE users are provided with more chances to encounter their co-workers in a variety of physical places through multiple transparent walls which are used to connect physical spaces and virtual spaces.

Accommodating private communication. Informal communication ranges from public to private conversations, thus, requires different kinds of space designated for particular purposes. Therefore, the model of ISS consists of multiple pairs of physical-virtual space (pS-vS) (Figure 2) that can be used for serving the need of different conversations. For example, pS2 and vS2 are used for conversations that need more privacy. The person who occupies this space has the authority to control the accessibility to the space. Fig.2 illustrates a single connection between one virtual space and one physical space. An illustration of multiple connections is presented in Fig. 3.

5. Conclusions

Informal interaction is acknowledged as an important factor in collaborative work. This paper has contributed a way to support collaborative work at a distance through the model of integrated shared space (ISS) for informal interaction. ISS proposes a meaningful way to support informal interaction at a distance through an integrated physical-virtual environment in which geographically distributed people could make use of CVE for interacting with their real world counterparts and vice versa where people are able to interact with their distance-separated co-workers via the 3D extended perception space. ISS could be suitable to be implemented in workplace where informal interaction among local co-workers often occurs such as in hallway, lobby or public lounge. As such, ISS facilitates collaborators to keep and maintain informal interaction in a natural way even they are separated by distance. Although the model is targeted for supporting informal interaction, it could be used for any collaboration-at-a-distance purposes which require a sense of natural shared space for geographically distributed participants. In the next stage, ISS will be developed, deployed and tested for verifying how ISS could address the critical issues. The venue for deploying ISS will be a research lab at the National University of Singapore in which ISS could facilitate informal interaction among the staff, students and their geographically distributed collaborators.

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