Supporting Telepresence by Visual and Physical Cues in Distributed 3D Collaborative Design Environments

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Abstract
We present new interaction techniques for supporting telepresence in distributed 3D collaborative design environments. Synchronized turntables enhance physicality in manipulation of virtual 3D objects and provide physical cues for awareness of others. Virtual shadows, visualization of hand movements of remote partners, imply not only location and activities of others but also indicate pointing and gestures toward 3D objects. Aspects of Augmented Reality are employed to maximize spatiality in the 3D workspace. Preliminary studies show that users found the system useful with regard to intuitive manipulation and heightening telepresence by visual and physical cues conveyed via the turntables and shadows. This led to rapid and efficient remote collaboration.

Keywords
Telepresence, Remote collaboration, Tangible interface

ACM Classification Keywords
H5.3 Information interfaces and presentation: Group and Organization Interfaces

Introduction

With rapid advances in computer and network technologies, there has been growing interest in distributed/collaborative 3D CAD systems. In the design domain, remote collaboration for manipulating 3D models has also become increasingly important due to competitive and complex product development processes.

A number of studies have been conducted in this area, mainly focusing on technical issues such as effective data transmission [1], data base systems, [10] and visualization [12]. However, while considered essential for supporting remote collaboration in the HCI community [3, 4, 6, 12], telepresence has not been fully explored. Also, most studies to date have been limited to 2D desktop environments, and thus fail to reflect the three-dimensional characteristics of 3D models.

In the present study we investigate new interaction techniques in distributed 3D collaborative design environments with the goal of facilitating efficient communication and collaboration for manipulating 3D models among remote participants.

Requirements of Distributed 3D Collaborative Design Environments

Supporting verbal and nonverbal communication is considered an important issue for facilitating remote collaboration. Several studies not only support interpersonal spaces for those communications but also emphasize seamless integration of interpersonal spaces and shared workspace to enhance telepresence [4, 6]. Spatial approaches have been motivated in cooperative work (see [2]), enabling users to exploit spatial properties. We believe spatiality becomes more significant in manipulating 3D models than with 2D objects. Upon this background, sharing contexts and awareness of others have been raised as important issues for remote collaboration. In this regard, it should be noted that some studies stress the importance of physicality for interpersonal communication and for natural manipulation of virtual information [3].

In addition to related works, we conducted observation studies of 3D collaborative design [9] to shed light on the requirements of the system. Findings particularly related to distributed 3D collaborative design environments are as follows:

- It was found that among various nonverbal channels individuals consider pointing and gestures very essential for collaboration while rarely relying on facial expressions. Incorporation of this aspect would be a unique feature not utilized in general remote collaboration supported with video streaming.
- During collaboration, individuals used various software programs for handling necessary information. This results in a workspace that is too complex in terms of recognizing where and how others are working. Thus, an adequate workspace where users can obtain critical information such as knowledge of the activities of other users' activities and/or shared objects is required.
- When finalizing a design, individuals attempted to determine the actual size and volume of the common model, but failed due to the limitation that 3D models were merely visualized on desktop screens.

Based on the above findings, a distributed 3D collaborative design environment should meet the following requirements:

- Spatiality
- Non verbal communication directly related to common objects
- Awareness of other users
- Seamless integration of interpersonal space and shared workspace
- Physical manipulation for virtual objects

New interaction techniques for distributed 3D collaborative design environments

We propose a new concept for a distributed 3D collaboration design environment which allows remote users to review and manipulate 3D models together in real time. The proposed workspace consists of new interaction techniques for supporting telepresence - Synchronized turntables and Virtual shadows. Aspects of Augmented Reality are employed to facilitate intuitive manipulation of 3D virtual information, providing maximized spatiality in the workspace.

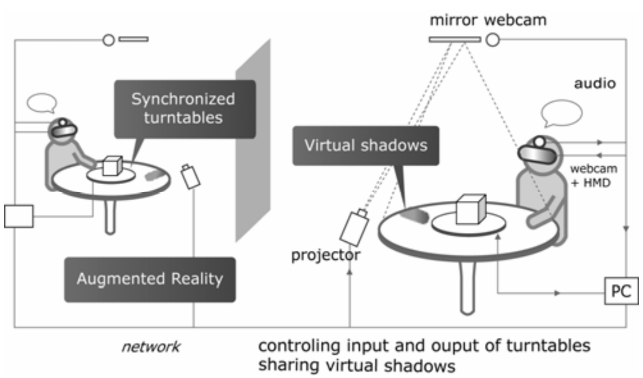

figure 1: Remote users can collaborate on manipulating 3D models in this AR based workspace through physical turntables and virtual shadows.

As described in Figure 1, remote participants work together while seated at round tables provided with turntables and virtual shadows. This seating configuration is inspired by the ordinary situation of workers gathering around a table for a meeting, and as such the aim is to provide a similar experience to that of such co-located spaces.

Synchronized Turntable

We utilize a physical turntable as the main interface for manipulating and sharing 3D models. A rotating feature of the turntable enables intuitive manipulation and makes it easier to review 3D models in every direction. Also, it provides physicality in manipulating virtual 3D objects, specified as one of the requirements above, enhancing the sense of reality despite that virtual objects are not touchable. A distinctive feature is that turntables shared by all participants are connected by a network so as to rotate simultaneously. At this time, users wearing HMDs can see 3D models placed on the turntables rotating together. This simultaneousness allows the users to visualize how the others manipulate common objects, thus satisfying the requirement of awareness of other users. Moreover, it provides physical cues for awareness of manipulation of objects by the other users, enhancing the sense of presence of remote colleagues.

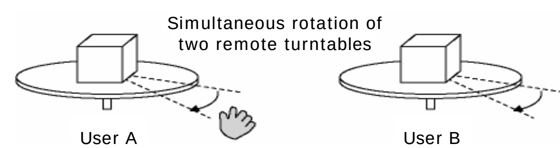

figure 2: Once user A rotates his/her turntable by 30 degrees, user B's turntable rotates by the same amount simultaneously from its location.

Virtual Shadows

Traces of users, mainly hands and arms, are visualized on tables as virtual shadows. Hand gestures are used to communicate various intentions and even emotions during discussions between people. In addition, when there is a table before them, people tend to lean on it or place their hands on it. Thus, the new concept of virtual shadows could provide rather natural interaction to users. Users can recognize the location of other users within the collaborative environment through virtual shadows. Also, they can approximately point and make gestures regarding common objects on the table. As users also express ideas with gestures unconsciously, virtual shadows serve to enhance communication between users.

figure 3: Virtual shadows are displayed on the surface of table.

Hence, virtual shadows support awareness of other users and nonverbal channel related 3D objects; these aspects have also been identified as requirements for an effective collaborative environment. Although the two-dimensional characteristics of virtual shadows have some limits, we believe that they can provide continuous and peripheral awareness of other users, while not disturbing the main tasks of 3D manipulation. This fulfills the requirement of seamless integration of interpersonal spaces and shared workspace.

Prototype Implementation

Control of turntables

Stepping motors with encoders are utilized and attached to turntables for both input and output of accurate rotation. Because the motors used here were too large to be placed on the tables, the tables were modified. A hole was made at the center pf the table to lower the turntables.

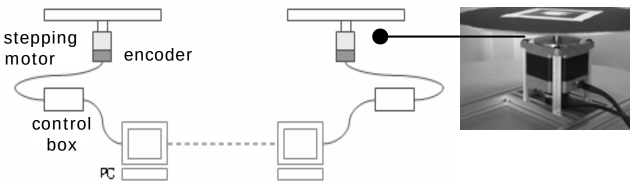

figure 4: Prototype architecture of the turntables

Visualization of Virtual shadows

A webcam above the table captures images around the turntable and separates hand movements from the background. The processed image is sent to the other workspace by a network and projected onto the surface of the table. Half-mirrors are used to reduce the scale of the system.

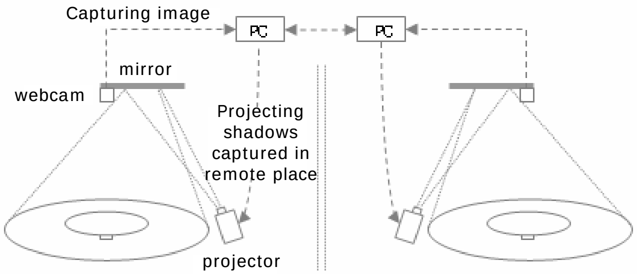

figure 5: Prototype architecture for virtual shadows

AR based workspaces were built utilizing DART [5], a software toolkit that supports quick design and implementation of AR application in the Macromedia Director.

Preliminary User Studies

Six groups respectively comprised of two students from the design department evaluated the prototype system. Two users, participating in an experiment task, were asked to review a 3D model together and to discuss specific features to be improved. After this task, we explored and resolved hidden problems on the basis of in-depth interviews with the participants.

figure 6: For user studies, two prototype systems were set up in a co-located place simulating remote situations.

Participants, who were familiar with desktop CAD tools, reported on the usefulness of direct manipulation toward virtual models. Physical cues from the turntables and virtual shadows increased the degree of telepresence. Users could track their partners with virtual shadows and share visions approximately via the rotation of turntables. Furthermore, virtual shadows were very helpful for pointing to a part of a 3D model directly without any additional explanation. This led to rapid and smooth communication.

The prototype was also useful in terms of convenient and intuitive usage. According to the participants, direct manipulation through turntables was easier to learn and use than manipulation through mouse wheels or buttons. Moreover, users that had experience with a combination of modeling tools and chatting programs for remote collaboration found the manipulation in our prototype more intuitive.

Users attempted to use their virtual shadows when indicating a specific part of the 3D models. However, the shadows were not adequate in this regard, because they could not locate vertical positions. Thus, additional interface elements were required to solve this problem. We also identified several problems with turntables such as conflict of attribution (occurring when two users attempt to handle their turntables at the same time) and insufficiency of model rotation (caused by the turntable having only one axis).

One of the most notable behaviors observed during the experiment was that users tried to maintain the same viewpoint with each other, as though they were located at the same position. Figure 7 shows the positioning synchronization process, which allows two users to observe and handle a shared model from the same direction. Given that it is impossible in the real world for many people to stand in the same location and view a shared object from an identical viewpoint, this process will be more effective when more than two people join the system.

figure 7: Users tend to share viewpoints as if they are seated at the same location.

Conclusion and Future Work

We have presented new interaction techniques – synchronized turntables and virtual shadows - for supporting telepresence in distributed 3D collaborative design environments. Users found that the proposed system facilitates intuitive manipulation and efficient collaboration through visual and physical cues.

For future work, it is necessary to supplement an additional pointing interface. Methods of sharing viewpoints will be also proposed. Because our user studies were preliminary in a co-located place simulating remote situations, we plan to conduct experiments under realistic conditions with potential technical problems such as network delay or calibration. Experiment tasks for quantitative evaluation of the system are necessary, for example, according to different environmental conditions or task complexity.

This study has significance by deriving 3D model collaboration into real space that was previously limited to two-dimensional screens. The interaction techniques proposed in this study show promise in terms of enhancing telepresence in further remote applications.

References

[1] Azernikov, Fischer, Efficient surface reconstruction method for distributed CAD, *Computer-Aided Design, Volume 36, Issue 9*, pp. 799-808, 2004

[2] Benford, Greenhalgh, Reynard, Brown, Koleva, Understanding and Constructing Shared Spaces with Mixed-Reality Boundaries, *ACM Transactions on Computer-Human Interaction, Vol. 5, No. 3*, 1998

[3] Brave, Ishii, Dahley, Tangible Interfaces for Remote Collaboration and Communication, *Proc. CSCW 1998*

[4] Buxton, Telepresence: Integrating Shared Task and Person Spaces. *Proc. Graphics Interface 1992*

[5] DART: The Designers' Augmented Reality Toolkit http://www.gvu.gatech.edu/dart/download.htm

[6] Ishii, Kobayashi, Integration of Interpersonal Space and Shared Workspace: ClearBoard Design and Experiments, *ACM Transactions on Information Systems, Vol. 11, No 4*, pp.349-375, 1998

[7] Nam, Wright, Syco3D: A Real-time Collaborative 3D CAD system, *Design Studies 22*, 2001

[8] Regenbrecht, Wagner, Interaction in a Collaborative Augmented Reality Environment, *Ext. Abstracts CHI 2002*

[9] Sakong, Nam, "A study of collaborative behaviors in design review meetings for developing 3D remote collaborative design environments" (in Korean), Proc. Korean Society of Design Science, 2005

[10] Szykman, Racz, Bochenek, Sriram, A web-based system for design artifact modeling, *Design Studies 21*, 2000

[11] Tang, Neustaedter, Greenberg, VideoArms: Supporting Remote Embodiment in Groupware, *Video Proc. CSCW*, 2004

[12] Qiu, Wong, Fuh, Chen, Zhou, Li, Lu, Geometric model simplification for distributed CAD, *Computer-Aided Design, Volume 36, Issue 9*, pp. 809-819, 2004