Synchronized Mixed Presence Data-Conferencing Using Large-Scale Shared Displays

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Abstract

Real world group-to-group collaboration often occurs between partially distributed interdisciplinary teams, with each discipline working in a unique environment suited for its needs. Groupware must be flexible so that it can be incorporated into a variety of workspaces in order to successfully facilitate this type of mixed presence collaboration. We have developed two new techniques for sharing and synchronizing multi-user applications between heterogeneous large-scale shared displays. The first new technique partitions displays into a perfectly mirrored public space and a local private space. The second new technique enables user-controlled partial synchronization, where different attributes of an application can be synchronized or controlled independently. This paper presents two main contributions of our work: 1) identifying deficiencies in current groupware for interacting with data during mixed presence collaboration, and 2) developing two multi-user data synchronization techniques to address these deficiencies and extend current collaborative infrastructure for large-scale shared displays.

Author Keywords

Mixed presence collaboration; computer-supported cooperative work; large-scale displays; multi-user interaction; data synchronization.

ACM Classification Keywords
H.5.3. Information Interfaces and Presentation: Group and Organization Interfaces: Computer-supported cooperative work, synchronous interaction.

Introduction
Commercial software, such as Google Hangouts, Skype, and WebEx [3,9,10] has made significant strides to enhance remote collaboration between single users. Other systems, such as Oblong's Mezzanine [7], have enabled mixed presence collaboration (remote collaboration between multiple collocated groups), but only when the display environment is cloned in all locations. These configurations are not always practical in the real world since collaboration is often interdisciplinary, with each discipline having a unique work environment suited for its needs.

Research endeavors have also attempted to enhance collaboration over distance. CollaBoard [5] augments video and audio with shared applications to create a data-conferencing system that imitates a life-sized face-to-face meeting. However, CollaBoard only supports one-on-one remote collaboration and requires a special setup of cameras and displays. Hugin [4] is a framework for mixed presence collaborative information visualization. Networked tabletop displays are utilized to allow multiple users located at various sites to collaboratively view and analyze visualizations. While Hugin doesn't fully restrict hardware and allows each group to choose what content is shared publicly, it represents a domain specific solution for collaborative information visualization. PolyChrome [1] synchronizes web applications between heterogeneous devices such as a large-scale display and a tablet. This allows multiple users to interact in a shared application simultaneously. However, PolyChrome only handles one web application at a time and enforces full synchronization between devices.

Since many other existing systems enforced hardware or content limitations and large-scale displays have been shown to foster collaboration [2], we identified SAGE2™, the Scalable Amplified Group Environment [6,8], as the most suitable collaborative infrastructure for researching mixed presence data-conferencing using shared displays. SAGE2 provides a windowing environment that allows simultaneous multi-user interaction with documents and applications on large high-resolution shared displays of any size. Prior to the work presented in this paper, SAGE2 enabled limited forms of mixed presence collaboration: *data-pushing*, and *perfect-mirror*. *Data-pushing* allows collaborators at one SAGE2 site to share any application or document that is currently on the display with another SAGE2 site. A copy of the application is sent to the remote site, and each group can interact independently without affecting the remote instance. In *perfect-mirror* mode, collaborators at a remote location can view an exact copy of an entire SAGE2 display. In this scenario, users at both locations interact with and manipulate the same instances of applications and data. Additionally, SAGE2 has already been adopted at more than 200 sites worldwide, and builds upon more than 10 years of research surrounding large-scale shared display collaboration.

Since SAGE2 already had a basic mixed presence collaboration infrastructure in place and had an active user community, we decided to leverage its framework and extend its capabilities. However, the techniques described in the rest of this paper can broadly apply to mixed presence groupware in general.

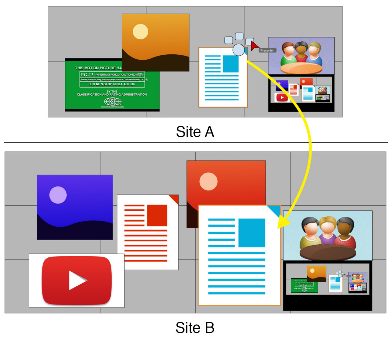


Figure 1. Illustration of *data-pushing*. Two sites are using heterogeneous shared displays and viewing separate content, private to the local group. Site A has shared the blue document causing a copy to appear at Site B. Further interaction with this document will not be synchronized.

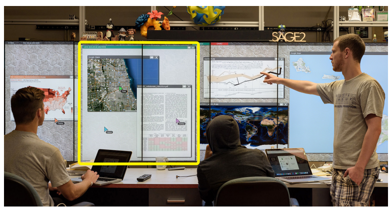
Unlike video and audio, data-conferencing with fully synchronized content may not always be ideal. Groups or individuals may be analyzing different portions of the same data, and therefore desire unsynchronized interactions in certain situations. We have supplemented one of the existing remote collaboration techniques of SAGE2 and designed two new data-conferencing techniques to allow various forms of semi-synchronized content sharing. First, we enhanced the existing *data-pushing* technique by augmenting a shared application with its current state. This enables a shared application to be initialized on the remote site as a snapshot of its original application. Further interaction within the shared application from either site would still be unsynchronized.

The first new technique developed was *data-duplication*, where one section of the shared display contains local unsynchronized versions of private data-conferencing content and a second portion of the shared display contains fully synchronized copies of public data-conferencing content. This technique partitions the shared display into two spaces – public content that would be perfectly mirrored with the remote collaborators and private content that would be viewed and controlled independently. The second new technique developed was to use *advanced data-synchronization options*, where collaborators chose which aspects of each shared application are synchronized and which are controlled independently. This technique allows for independent window management by each site and enables continuous synchronization of some or all aspects for each shared application.

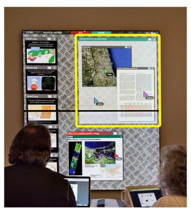
Methods

The work previously done on SAGE2 made it a powerful and flexible system to better enable collocated and remote collaboration. However, there was still a need to develop and evaluate more advanced means of supporting groups working together across distance in a mixed presence environment. In order to mirror content and have all interactions synchronized between multiple sites, SAGE2 required matching hardware configurations at all locations. For collaboration between heterogeneous shared displays where groups are working on separate but related pieces of a problem, collaborators were limited to *data-pushing*: sending unsynchronized applications between locations. Multiple sites could not simultaneously interact with a shared application in this situation; each site could only interact with their own local copy. For example, if one site pushed a PDF to another site, the same document would be shown on each shared display. However, the position and size of the document and which page of the PDF was being viewed would be completely independent between the two sites. We have supplemented this technique by initializing a shared application with its current state so that it serves as a snapshot of what the original collaborators were viewing (Figure 1). Extending the above example, when a PDF currently showing its third page is shared with a remote site, a copy of that PDF will open on the remote site showing page three. However, further changes to which page is visible will only affect the local site since interaction is still unsynchronized.

SAGE2 natively supports screen sharing from remote machines. This feature can be utilized in a mixed presence collaboration setting to share a videoconference application, such as Skype or Google



Site A



Site B

Figure 2. Mixed presence collaboration using the *data-duplication technique*. The yellow highlight in each photo shows the shared portal on each shared display with synchronized applications and pointer icons.

Hangouts, on the shared display. In order to provide remote collaborator awareness, we determined that sharing two videoconference windows, one with the camera showing the collaborators and one with the camera showing the remote shared display, would work well for mixed presence collaboration.

To improve coordination and user awareness by allowing users at different sites to collaborate on a shared application, we developed two new techniques to handle synchronizing applications across remote sites. These two techniques have been termed *data-duplication* and *advanced data-synchronization options*.

Data-Duplication

The first new technique we developed was *data-duplication*, where one section of the shared display contains local unsynchronized versions of private data-conferencing content and a second portion of the shared display acts as a shared portal that contains the fully synchronized copies of public data-conferencing content. These sections partition the overall screen space of the shared display. At any time, any user can move an application from the local space to a remote partition in order to share the application. The application will appear in the corresponding partition on the remote site's shared display. Users at both locations are able to simultaneously interact with the shared application. Both window management actions, such as window movement and resize, and interactions inside the application are fully synchronized across sites. Additionally, interaction icons for pointers and touch events in the shared partition are displayed at both locations (Figure 2). This gives the appearance of both groups working on the same application simultaneously, and is designed to improve remote collaborator awareness.

Unlike perfect-mirror sites, this technique allows for both a shared and a private space for data. Additionally, remotely located shared displays do not need to be homogenous. Any two shared displays using our *data-duplication* technique could create a shared data portal regardless of size, resolution, or aspect ratio. Additionally, the shared portal can be freely moved and resized on each shared display independently – only relative positions and sizes of applications inside the portal remain constant. This allows each group to scale the shared portal to a size that is best for their technology.

Since applications are executing separately at each site, the application's state, which defines all properties necessary to fully reproduce the application, is observed at all sites. Any time an aspect of the state is modified, its value is streamed to the linked remote application. This ensures that the state of shared applications at both sites remain the same. Since each site has its own instance of the application, other aspects of the application can vary between sites, such as frame rate. This gives users the appearance that the groups are interacting with the same application, while optimizing performance for each site's local hardware.

Since SAGE2 is a multi-user collaborative platform, multiple pointers can be used for simultaneous interaction. All pointers from the remote shared display are also added to the local shared display (and vice-versa) so that collaborators at both sites can view local and remote pointers within the portal. Whenever a remote pointer enters the portal, a message is sent from the remote site instructing the local display to make that pointer visible, and whenever a remote pointer exits the portal, another message is sent from the remote site instructing the local display to make that pointer invisible. Therefore remote pointers only appear within the shared area and do not

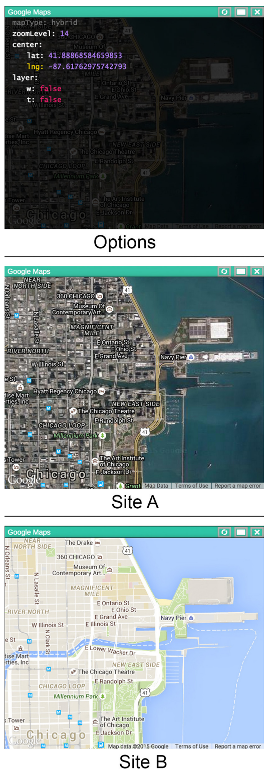


Figure 3. Mixed presence collaboration using the *advanced data-synchronization options* technique. Top – application state and selected options (all properties except for 'mapType' are synchronized). Middle – the shared application at Site A with 'mapType' showing satellite imagery. Bottom– the shared application at Site B with 'mapType' showing roadmap imagery. Other properties, such as the map's center (latitude, longitude) and zoom are synchronized between the sites.

interfere with the private content on the rest of the shared display.

Advanced Data-Synchronization Options

The second new technique we developed uses *advanced data-synchronization options*, where collaborators can choose which aspects of each shared application will be synchronized and which will be controlled independently. Users are given access to independent variables within an application's state and are able to choose whether or not to synchronize each individual property when sharing with a remote site (Figure 3). This technique was designed to allow teams at each location to coordinate their efforts based on individual needs versus whole group needs. For example, when watching a video across multiple sites it may be beneficial to synchronize the location of the play head and whether the video is playing or paused. However, different sites may wish to have independent control on the volume level.

In order to keep users from manually selecting whether to synchronize each individual property, the state is ordered hierarchically. For example, the camera position in a 3D model viewing application can be the parent of x, y, and z positions. Therefore, to synchronize or desynchronize the camera position, a user would simply need to make one selection rather than three.

Similar to the *data-duplication* technique, applications will be executing separately at each site. Any time a synchronized aspect of the state is modified, its value will be streamed to each remote application. Since each site has its own instance of the application, unsynchronized aspects of the state never get streamed to the remote instances. This gives users the appearance that they are interacting with a shared application that allows the freedom to control certain properties locally.

We designed a graphical user interface that overlays a shared application depicting its state. Aspects of the application state are organized hierarchically. Properties that are not synchronized are visually grayed out, whereas synchronized properties are visualized in full color. Users can display or hide this interface and select or unselect any property at any time. Whenever a user at either site synchronizes or desynchronizes a property, this option is streamed to the other site so that changes to this property are handled accordingly.

Conclusion

Physical distance between collaborators has created a barrier that has fueled the research and development of technology that can enable groups of people to connect and share data. While existing commercial software has begun to address the issues surrounding mixed presence collaboration, many of the solutions are limited to a particular task or a particular set of hardware.

Our research has sought to create a more flexible solution that provides a platform for researchers to share arbitrary data and collaborate in real-time with other remotely located teams. The two new techniques we developed, *data-duplication* and *advanced data-synchronization options*, enable users to engage in mixed presence collaboration in manner previously not supported in any groupware system. Using *data-duplication*, distributed teams can see exact replicas of shared data at both sites while still maintaining private workspace. Using *advanced data-synchronization options*, distributed teams can partially desynchronize and resynchronize various aspects of a shared application at any point during the collaborative session to enhance coordination and work on tasks in parallel.

Future Work

Our research and development does have certain limitations. All data sharing techniques are one-to-one, enabling two shared displays to share data with each other. In order to communicate between three or more sites, multiple one-to-one sharing connections would be required. Moving forward, the *data-duplication* and *advanced data-synchronization options* techniques could be expanded to allow for any application to be shared with any number of other shared displays. This way three or more groups involved in a mixed presence collaboration could all see and work on synchronized copies of the same applications.

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