MeetAlive: Room-Scale Omni-Directional Display System for Multi-User Content and Control Sharing

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Figure 1. MeetAlive transforms an ordinary meeting room into an omni-directional display for sharing content. (a) The walls around a meeting table serve as a canvas for desktop content. (b) Participants of a meeting can share their desktop at any time anywhere in the room. Our system keeps track of participants and content.

ABSTRACT
MeetAlive combines multiple depth cameras and projectors to create a room-scale omni-directional display surface designed to support collaborative face-to-face group meetings. With MeetAlive, all participants may simultaneously display and share content from their personal laptop wirelessly anywhere in the room. MeetAlive gives each participant complete control over displayed content in the room. This is achieved by a perspective corrected mouse cursor that transcends the boundary of the laptop screen to position, resize, and edit their own and others' shared content. MeetAlive includes features to replicate content views to ensure that all participants may see the actions of other participants even as they are seated around a conference table. We report on observing six groups of three participants who worked on a collaborative task with minimal assistance. Participants' feedback highlighted the value of MeetAlive features for multi-user engagement in meetings involving brainstorming and content creation.

Author Keywords
Meeting system; Room scale; Collaboration; Large displays; Projection Mapping

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INTRODUCTION
Face-to-face conference room meetings serve a variety of purposes [20]: meeting new people, working through issues, reaching decisions, presenting projects, lectures, generating ideas and many more. In a typical meeting room, chairs are arranged around a large conference table so that participants are facing each other (Figure 1a). This allows for effective face-to-face communication during discussions.

Such meetings nowadays normally feature digital content (e.g., presentation slides) displayed on a wall for everyone to see. Traditionally, participants physically connect their laptop to the display. In modern setups, content is transmitted wirelessly [1]. Typically, only one person at a time is in charge for displaying and controlling content. Digital content can only be displayed at one specific location (e.g., a display in the room or a projection surface) potentially making it difficult for all participants to see the display in a face-to-face arrangement. Lastly, passing control of the single display between participants remains a time-consuming process, often disrupting the flow of a meeting.

In this paper, we present the *MeetAlive* system, designed to *enable every participant in the meeting to display content from their laptop at any time on any wall surface in the room and control their own content and content of others regardless of their role in the meeting.*

MeetAlive enhances an ordinary meeting room with five projectors covering the walls and table to create a ten-megapixel omni-directional room-scale display (Figure 1b).

Every participant in a MeetAlive conference room can share the desktop from their personal laptop and control a cursor both on their screen and everywhere in the room. Each participant controls the arrangement of their content and as well as the content of others. Participants can freely move, resize and replicate content to ensure optimal visibility while maintaining a face-to-face seating arrangement. Finally, all participants can directly edit any content displayed by any participant.

The main contribution of our work is a novel system, where a combination of existing technologies is utilized specifically to enhance a meeting room scenario. To the best of our knowledge, MeetAlive is the only conference room display system that offers:

- omni-directional multi-user room-scale display;
- where every participant can easily share, position, scale, edit, replicate and snapshot content from their laptops anywhere on the room's walls;
- using a per-participant perspective-corrected mouse cursor;
- without requiring the user to worry about which projector they are controlling.

The interactive capabilities of MeetAlive are illustrated in Figure 2. We also contribute feedback from our user evaluation of MeetAlive with six groups of three participants (18 total) collaborating on a task. Participants reported that MeetAlive was easy to learn and use and indicated higher engagement, better control of content, and more awareness during the meeting compared to their typical meeting experience.

RELATED WORK

We focus our overview of related work on augmented meeting room systems, multi display environments and room-scale projection displays. We restrict our review to co-located experiences.

Augmented Meeting Room Systems

Providing more effective collaborative meeting room experiences has been an active research area for decades. Notable early examples include Tivoli [22], based on Xerox's LiveBoard touch-enabled vertical display, and electronic meeting systems by Nunamaker et al. [20] which combined large shared and small personal displays.

More recently, many custom systems explored specific co-located collaborative activities such as work meetings [14, 31], design tasks [12, 30], scientific inquiry [33], informal meetings [9, 16, 17], and software development [3, 4]. For example, WeSpace [33] was designed to support regular meetings of scientists, incorporating an interactive tabletop and a large high-resolution vertical display. Pictionnaire [12] and NiCE [9] focused on integrating physical and digital assets in a seamless fashion to aid informal group meetings. WeSearch [16] was designed for collaborative web searching on a large tabletop display, finding that increased awareness stimulates discussion among group members. inSpace [31]

The presenter displays the presentation shared from their laptop at the center wall behind them.

A participant in the back row has a hard time seeing the bullet points at the bottom, so they replicate the window and display it in front of them.

The presenter reaches a slide with an important diagram, so they create a snapshot and position it for later reference.

A participant in the audience has a question in the middle of the presentation. To clarify what they are asking, they quickly place an image from their laptop on the wall and refer to it (blue border).

Another participant has a question, but does not want to interrupt, so they make a snapshot of the current slide and place it under the diagram for later reference (green).

Having concluded the presentation, the meeting transitions to a more general discussion. The speaker joins the table and no longer controls the meeting. Participants discuss various topics while continuing to share their desktops.

Figure 2. Possible meeting scenarios supported by MeetAlive.

and iRoom [14] focused on the custom design of meeting spaces to foster collaboration. Office Social [7] provides shared slide view and control mechanisms for the audience members in a presentation scenario. Oblong Technologies' Mezzanine [21] incorporates a variety of personal and shared devices and displays into a unified meeting system.

Most previous room meeting systems feature a large, dedicated shared display, requiring participants to orient themselves for best view. Such configurations can limit the face-to-face interaction with other participants. In contrast, the large shared display in MeetAlive envelops the participants in an omni-directional (potentially even immersive) manner. This allows for more flexible arrangement of content, higher overall resolution, as well as the sharing, control and joint editing of content from any meeting participant on any available surface in the room.

Multi Display Environments

Many research projects have explored combining multiple heterogeneous displays to support meeting scenarios. Streitz et al. presented i-LAND [29], a collection of collaborative workspaces investigating creativity support in group work. The Emmie system [6] used multiple displays with a variety of form factors (including head-mounted displays) to create a consistent collaborative environment where users can connect their personal devices and view both 2D and 3D spatialized data. In addition to meeting scenarios, Multi-display environments have been explored in the context of collaborative programming [3], lunch table conversations [17], and scientific visualizations on high-resolution tiled displays [1].

Nacenta et al.'s E-conic system [19] investigated the concept of perspective-corrected multi-display environments. We build on Nacenta et al.'s Perspective Cursor [18] which allows for seamless movement between displays by taking the user's perspective into account.

Allowing multiple users to simultaneously control content in a multi-user multi-display environment has been explored in a variety of projects (e.g., [11, 12, 17, 21, 32, 33]). However, most systems restrict the joint control and editing to the content residing on the shared display and not on personal devices. Inspiration for MeetAlive's simultaneous editing features came from Wallace et al. [32] who demonstrated multiple users sharing parts of their desktop while allowing for remote input in a many-to-many fashion.

Room-Scale Projection Displays

MeetAlive's room-scale display is based on spatial augmented reality technology [23], primarily based on *projection mapping*. While we share much of the core functionalities and ideas with other room-scale projection mapping systems (e.g., Office of the Future [24], Urp [30], CAVE [8], LightSpace [34], Ubi Displays [10], and RoomAlive [15]), we use projection mapping purely as an enabling technology for a seamless display on every surface in the room, and focus our efforts on supporting sharing and editing of content among multiple participants in the room.

Conceptually, MeetAlive is closest to Rekimoto and Saitoh's Augmented Surfaces [25] where two projectors transform the table and wall surfaces into a continuous display supporting the exchange of documents between laptops. In contrast, we focus on meeting scenarios and treat the shared display as a room-scale display that supports joint editing and control for increased awareness of actions and collaborative work.

Guidelines and Surveys

Finally, we draw inspiration from Huang et al.'s "Secrets to Success and Fatal Flaws" [13] which aggregates knowledge and guidelines from a comparison across multiple systems exploring collaboration on large displays. We further draw our guidelines from other observational research [5, 26, 27] that examines issues of awareness, social aspects, and productivity in collaboration on large displays.

MEETALIVE DESIGN GOALS

MeetAlive is designed to support the different phases of a meeting and transitions between these (Figure 2). Many of our design goals are tackling common problems in meetings as also pointed out by related work. For instance, some meetings suffer from an inequality of participation and contribution of participants during discussions. Other problems include the loss of eye-contact between participants when looking at the digital content and potential inconvenient postures when having to rotate the head towards the display. While MeetAlive can facilitate the existing one-person-in-charge dynamic typical of today's conference rooms, it can further support more egalitarian scenarios, where multiple people can share their desktop, edit each-others' content, and contribute equally to the conversation in the room. Furthermore, we envision MeetAlive to be used for collaborative tasks like programming. Based on our vision described earlier and drawing from guidelines from related work, we describe the main design goals of our system:

Equal control among participants: To maximize participation and contribution of all participants, the system should give equal control to everyone in the meeting. Every participant is always in full control, even during presentations with one speaker. Because participants are co-located, and the system is designed so that all actions are visible to all participants, we rely on the participants themselves to negotiate potential conflicts that can arise with shared editing and control.

Simple and quick reconfiguration of environment: Instead of optimizing for a specific meeting workflow, we acknowledge and emphasize the dynamic nature of meetings; i.e., situations, roles and communication patterns can change within a meeting. The system should provide a fast and simple mechanism for participants to quickly configure the environment according to the needs of the meeting.

Minimizing context switching: The participants should be able to easily switch between working on their own laptop and interacting with the content in the room.

Simple and familiar user interface: The interface should be familiar, easy to learn and use for a wide variety of people to avoid embarrassment from learning the system in a public situation [5]. The interface and its use should not distract from the meeting itself.

Facilitate face-to-face arrangement: The system should make it possible for the participants to maintain a face-to-face arrangement while comfortably viewing and editing projected content.

MEETALIVE INTERACTIVE CAPABILITIES

In this section, we describe the core features of MeetAlive.

Color coding users: To identify ownership of content and cursors, each participant and their laptop is assigned a unique color when they connect to the MeetAlive system. A diffuse colored area is displayed around each laptop on the conference room table in our room (Figure 3).

Desktop sharing: MeetAlive participants can share their desktop by pressing *Ctrl+D*. A live copy of their desktop is then displayed on the wall directly in front of them.

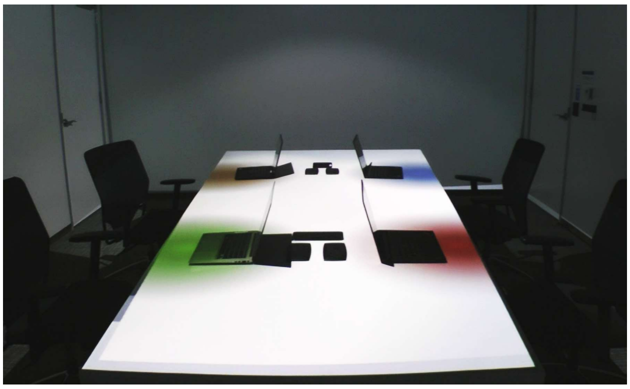


Figure 3. Example setup with four laptops. Each laptop is assigned a unique color.

Content window title bar: Every shared desktop is displayed as a rectangular content area with a title bar (Figure 4). The title bar contains a caption to indicate the type or state of the content, and is colored to match the assigned color of the desktop's owner. Participants can freely position content by dragging its title bar. They can also resize each content window by dragging the resize button. Lastly, they can close any content window by pressing on a close button. Depending on the type of content, the title bar also contains buttons for replication and creating snapshots (discussed below).

Desktop Cursor: Each participant controls one cursor identified by the assigned color. The cursor is controlled using the participant's laptop touchpad or mouse, and has two interactive states. The first state, which we call *Desktop Cursor*, is the ordinary cursor when working within the participant's laptop display; i.e., the default behavior of the operating system cursor. The Desktop Cursor is rendered on the participant's laptop as well as on the shared content in the room, where it appears as a flat cursor (cursor 1 in Figure 4).

Room Cursor: The second state, which we call *Room Cursor*, is activated when the participant's Desktop Cursor reaches the edge of the laptop display (or, equivalently, when the cursor reaches the edge of the projected window). The cursor is rendered with a shadow to appear slightly above the surface, indicating that it is now operating outside of the participant's shared desktop (cursors 2 and 3 in Figure 4).

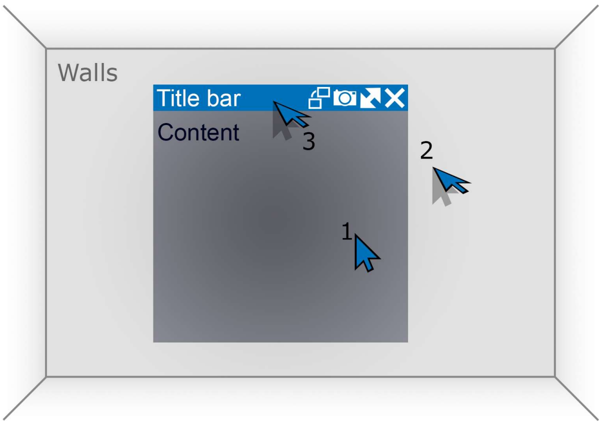


Figure 4. Cursors in MeetAlive. (1) Desktop Cursor is a virtual copy of the standard OS cursor and it shows that the participant is working within their own desktop. The cursor is flat. (2) Room Cursor is activated when the participant moves the cursor out of their own desktop. It is rendered lifted. (3) The participant can access room-related functionalities and arrange content in the room with the room cursor and the title bar icons.

Each participant can control the shared elements in the room via their Room Cursor. To accommodate varying arrangement of people in the room, we use the relative movement of each person's positioning input device (e.g., a mouse) together with 3D model of the environment and the person's point of view to determine the movement of the RoomCursor in their perspective field of view. This behavior closely resembles the Perspective Cursor technique [18] whereas we dynamically slow down cursor movement on surfaces with narrow grazing angles to the user.

Remote input: By clicking the content window of another participant, remote desktop control is activated. Mouse clicks and key input are then redirected to the laptop which is sharing the respective content. Using this functionality, participants can jointly edit content on each other's computers. Furthermore, participants can send the content of their clipboard to the other machine and paste it by pressing *Alt+V*.

Replication: In MeetAlive, it is easy to create multiple instances of some shared content. The title bar of a content

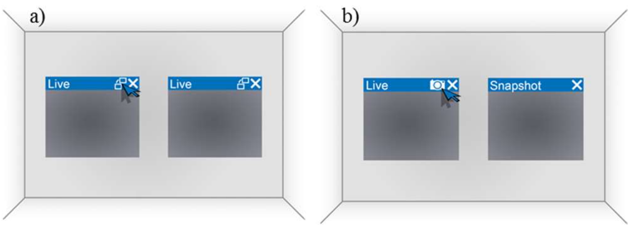


Figure 5. Replication and Snapshot functionality: (a) The participant clicked the replicate button. The replicated content window is updating the same way as the original. (b) The participant clicked the snapshot button, which takes an image of the current state of the content window.

window contains buttons for creating replications (Figure 5a). When the replication button is pressed, a new content window is created with the same title bar. This content window is updated in real time in the same way as the original. The window can be positioned and resized without affecting the original. Replication can be used to ensure that every participant can comfortably view the replicated content, especially when they are sitting opposite to each other. Cursors hovering over replicated content are rendered semi-transparently in every replication.

Snapshot: When pressing the snapshot button, a new content window including title bar is generated and can be positioned and resized freely (Figure 5b). The content shows a snapshot of the shared desktop from the moment the button was pressed. This window is not updated in real time and no cursors are replicated. The Snapshot function enables quick capture of content (e.g., during presentation) to enable further discussion or serve as a reminder for later.

MEETALIVE IMPLEMENTATION

We now describe the key infrastructure details enabling MeetAlive features and discuss the system's performance.

Hardware Setup

The MeetAlive room display employs five Optoma EH415ST projectors. The resolution of each is 1920x1080 pixels for a combined total of about ten megapixels. Projectors are arranged such that there is one projecting onto each of the four walls of our meeting room and one projecting on to the meeting room table (Figure 6).

Eight Kinect v2 cameras are installed in the ceiling. Each is connected to an Intel NUC mini-PC computer (Intel Core i5, 8GM RAM) processing the camera streams, tracking each participant's body position in the room and transmitting all data via Ethernet. The *RoomAlive Toolkit Ensemble Calibration*[1] is used offline to calibrate the projectors and cameras, finding the pose of each.

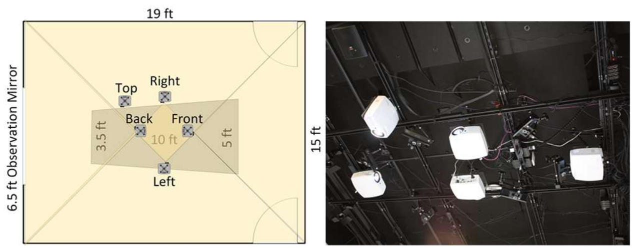


Figure 6. Floorplan of the MeetAlive room showing approximate positions of five projectors in the ceiling (one per wall and one projecting down on the conference table). Right image shows the installation of the five projectors in the ceiling.

The MeetAlive server runs on a custom PC capable of driving up to eight simultaneous displays (Intel Core i7, 32 GB RAM, two Nvidia GeForce GTX 980 graphics cards). All five projectors are directly connected to our server. MeetAlive client software runs on a variety of standard laptops without the need for a dedicated graphics card. Our MeetAlive room is equipped with a Wireless 802.11ac access point as well as several wired network ports in the table for easy network connectivity for each client.

System Architecture

The MeetAlive Server handles connections, event processing and room rendering. Each participant can use their own PC and the MeetAlive client software to connect to the MeetAlive Server.

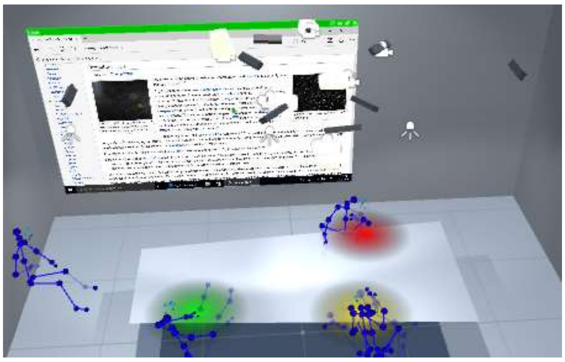


Figure 7. A Unity Editor view of the MeetAlive Server running a live meeting in the room. Each participant is represented as a tracked skeleton and color-coded position at the table. The shared desktop from the green participant can be seen on the wall. Projectors and Kinect cameras are shown near the ceiling.

Both MeetAlive client and server software are implemented in Unity 3D game engine[2] (Figure 7). Furthermore, the open source *RoomAlive Toolkit for Unity* plugin is used to combine projector displays and Kinect skeletal tracking streams to create a unified 3D spatial display similar to the room-scale display in the RoomAlive project [15]. Once calibrated, all projectable areas are treated as a single display, enabling the sharing of content without worrying about which projector ultimately displays the content.

Each MeetAlive client captures the desktop contents of their local display as well as mouse and keyboard events. This information is streamed to the server as two separate streams (desktop and input). A native Unity plugin captures the desktop on the MeetAlive Client using on the real-time DirectX (DXGI) Desktop Duplication API. Desktop captures are compressed with JPEG compression (quality set to 35%) in order to reduce the network bandwidth requirement.

The MeetAlive server receives the two streams from each client and updates the overall state of the room display. The server distributes the input events to other clients to enable collaborative editing across machines (similar to [32]).

System Performance

The performance of our system depends on a variety of conditions such as network bandwidth, client display resolution, image compression choice. We conducted a

[1] https://github.com/Kinect/RoomAliveToolkit

[2] http://www.unity.com

series of tests to characterize the performance of our current prototype system (five projectors and eight cameras).

We stress tested the streaming performance with up to six clients simultaneously streaming their desktops (full HD resolution 1920x1080). MeetAlive was able to maintain the steady streaming framerate of ~10Hz for each client. With smaller number of clients, the framerate can be higher, but we chose to keep 10Hz as the default streaming framerate as it provided a good tradeoff between the overall system responsiveness and reasonable network bandwidth utilization. Therefore, each MeetAlive client streaming full HD desktop content at 10Hz using JPEG compression with a 35% quality setting requires approximately 16Mbps of network bandwidth. When bandwidth is further limited, MeetAlive clients automatically throttle the desktop image transmission framerate, without throttling transmission of the comparatively tiny input event stream (mouse & keyboard events). With our network setup and chosen framerate, we experienced very few dropped frames during operation (e.g., in our experiment, with four clients streaming via wireless network for 15 minutes, our system dropped ~0.5% of incoming frames due to longer than expected transmission delay).

Furthermore, we measured the latency of the content projected on the room display compared to the local screen. When clients are connected via wired Ethernet connections, we observed the following system latencies: one client ~200ms, two clients ~230ms, three clients ~290ms, and four clients ~340ms. Using the wireless network instead of the wired connection added additional 10-20ms to the measured latency.

MeetAlive currently uses JPEG compression for desktop image transmission. However, JPEG compression and decompression is a fairly CPU intensive and long operation (~40ms combined). One future improvement to the MeetAlive system latency and network bandwidth utilization would be to use hardware accelerated compression (e.g., H.264 MPEG4) or compression methods that are specifically designed for remote desktop protocol (RDP).

USER EVALUATION

To explore the usability of MeetAlive and collect feedback on the features and interactions it affords during meetings, we conducted a user evaluation with 18 participants recruited from our organization (six female, ages 25 to 52). Participants were divided into six meeting sessions (groups of three in each session). Each session lasted approximately one hour. Participants received a $10 gift card for their time.

The main part of the user study was a collaborative brainstorming task in which participants researched a given topic to gather information. We used a collaborative search task similar to that of WeSearch [16], with an added goal to jointly create a presentation.

All participants were very familiar with typical business meetings in similarly-sized conference rooms in our organization. They confirmed that they have both been active presenters and listeners/participants at similar meetings before.

Apparatus

For the study, we pre-arranged four laptops in our MeetAlive conference room as seen in Figure 3. The experimenter used one laptop while the participants used the remaining three laptops. The room consists of four walls: one wall in the center, two walls to the side including doors and one wall with a large one-way mirror. While the mirror and the room behind it are designed for observing the meetings without interfering, the mirror prevented projection on much of the rear wall. During the study, this wall could not be used for content placement.

Procedure

Each participant was greeted and asked to take a seat in front of one of the provided laptops. The study was initiated with an experimenter giving a 10-minute how-to tutorial on the main capabilities of the MeetAlive system. In the beginning, tutorial presentation slides were displayed on a single window on the center wall. However, as the presentation progressed, the experimenter directly demonstrated each feature of MeetAlive in the room. During the presentation, participants were also asked to try each feature immediately after it was introduced. This includes sharing their own desktop, moving the window, resizing it, creating replicated windows and creating snapshots. At the end of this tutorial, all participants were familiar with the core features of MeetAlive.

Following this tutorial, participants were given 30 minutes to create a short presentation (approximately five slides) on a specific topic: *"What is the difference between cloud, fog and mist?"*. Participants could choose any workflow or strategy they wanted, could access the Internet, and were free to arrange the content around the room however they wanted, i.e., they could choose anything from a conventional setup with one connected laptop to arrangements that fill the walls with shared content from every laptop. The experimenter was present in the room during this task to answer technical questions, but did not otherwise participate in the task. After completing the task, each participant completed a survey consisting of ratings and qualitative feedback. All ratings were based on a 7-point Likert scale.

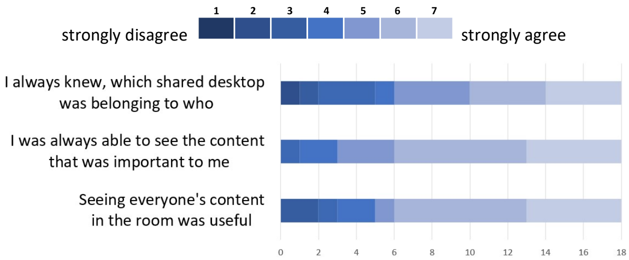
Results

While each group had a slightly different assignment of roles and workflow they all successfully created a simple presentation.

The survey specifically asked participants about their awareness of projected content in the room, how easy it was for them to control and arrange content, and their thoughts about the overall workflow. This section provides and discusses some survey findings.

Awareness

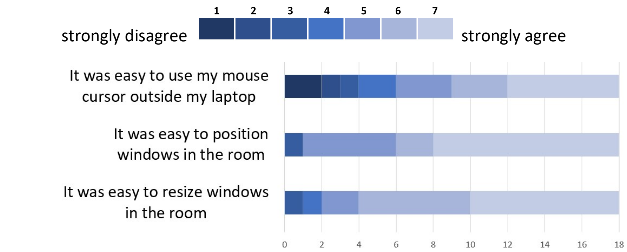
We asked participants about how they perceived the content surrounding them:



Participants quickly understood the arrangement of content. They did not report any confusion about replicated content at the walls in front of them or behind them. Figure 8 shows a typical arrangement as well as different situations.

Control

One part of our questionnaire investigated the ease of use in terms of moving cursors, positioning content, etc. Survey results suggest that participants had little trouble controlling the system and arranging content:



Participants were responsible for arranging all content when solving the task. This also includes resolving occlusion by other participants while positioning the window, which was generally not considered demanding. Locating the Room Cursor outside the desktop on the other hand was sometimes challenging, which is reflected in the participants' scores.

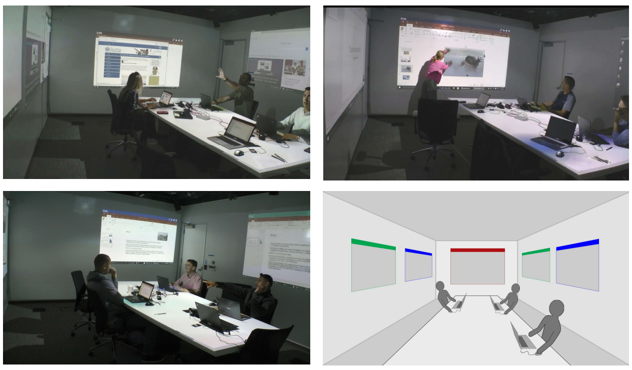
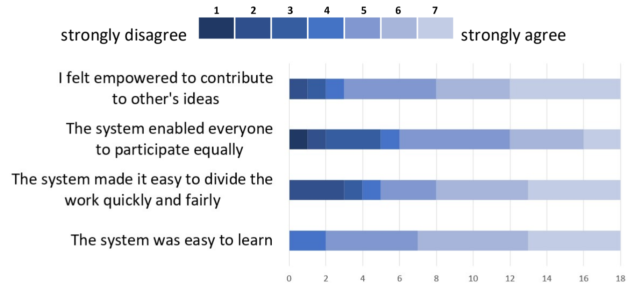


Figure 8. Arrangements of content by participants during the user study and the most frequently used arrangement (lower-right). Groups tended to place the desktop with the working version of the presentation on the center wall and the other desktops and replications, which were mainly used for web search, at the side walls.

Being able to position a cursor and content over any wall area in the room was well appreciated, but it also required that the participant remembers where they left the cursor upon last action. Luckily, due to the perspective nature of the Room Cursor, by moving the cursor via mouse or touchpad, the participant was able to quickly notice where the cursor is in the room.

Workflow

We asked participants questions about the system's impact on workflow and group dynamics:



In the observed meetings, all participants got used to the system quite easily. Even after only a short training period, participants made use of most of the system's features unprompted to optimize their workflow. We have observed them arranging and replicating content to work effectively on the task with very few interruptions. We also observed the participants helping each other with features that someone forgot, or frequently reminding each other to use a particular functionality to make better use of the system.

In addition, we observed that the meetings typically had two distinct phases. In the first phase, the participants discussed the task, assigned roles amongst themselves and spent time configuring the content and the windows around the room. During this phase, the room arrangement changed a lot and there was a lot of discussion on what should go where. The second phase consisted of the search for content and joint editing of the presentation and during this time the arrangement of the room was mostly stable with only sporadic movement of the content for better visibility. This suggests that it is likely that most meetings in MeetAlive would converge on an agreeable arrangement and only modify it when a different task is presented to the participants. An interesting extension of our system would be to consider offering a few preset layouts for content around the room as an easy way to arrange a room for a meeting.

Overall Impressions

We asked the participants about their impressions of using the MeetAlive system in contrast to their existing meeting room experiences. Participants were overwhelmingly positive in their feedback and expressed interest to use MeetAlive in their everyday meetings. Interestingly, few participants commented that using the MeetAlive system made them feel a lot more invested and more engaged in the meeting. For example, one participant stated the following about working with the system:

> *Overall, once you get used to all the cursors and the experience of owning your own window, it's really fun to collaborate this way. I found myself being much more engaged socially than I normally would.*

Participants also voiced some negatives about the system; namely that there is a learning curve required to effectively use all the functionality of the system and that keeping track of multiple simultaneous cursors can be a bit overwhelming.

However, many offered praise of the main idea of everyone in the meeting being able to equally contribute, control and share. For example, one participant commented:

> *The notion of leaving the traditional bounded box of a TV, monitor, or projector wall and be able to display content anywhere is awesome. I particularly enjoyed and liked some of the sharing and control responsibility semantics, such as the ability to duplicate my screen behind me and then the people who can see that duplicate version controlling it for themselves.*

DISCUSSION AND FUTURE WORK

Our final system is reduced to the core functionalities needed to enable participants to easily share and manipulate content anywhere in the room. It mixes familiar practices and interaction techniques with spatialization of content. In the following, we discuss features of MeetAlive that go beyond these core functionalities and yield potential future work.

Equal access and control of all content in the room is one of the core design goals of MeetAlive. We observed in our studies that participants heavily relied on social protocols to effectively negotiate the control of content (e.g., saying out loud “I am editing now”). We did not observe many conflicts with participants simultaneously arranging content in the room. However, concurrent editing or manipulation of the shared content was sometimes confusing for participants and should therefore be further investigated in the future.

Our vision of MeetAlive is to support the dynamics of meetings under a variety of situations. While our current evaluation was mainly focused on usability aspects, future longer-term deployment studies should give us insights on how MeetAlive impacts meetings, its versatility, and what new behaviors and communication patterns emerge among its users.

To allow MeetAlive novices to quickly become proficient at using the system, MeetAlive interfaces are deliberately designed to closely resemble those of familiar WIMP systems. This enabled a smooth transition from the laptop to the room. For example, with the same mouse movement, participants can go from their own desktop to the title bar of another participant’s shared view to manipulate it. There is no need to switch between interaction techniques. However, WIMP metaphors also impose substantial visual overhead to the content and the interactions. On-demand or context-sensitive menus or interfaces may reduce the need for continuous on-screen user interface elements.

We implemented a gestural hand pointing technique for placing and moving content around the room similar to [4]. Using that interaction, a person could position content by selecting a window on their desktop and pointing to the wall at the same time using their finger. However, this approach suffered from poor pointing accuracy due to relatively noisy skeletal tracking from the overhead cameras. Therefore, we omitted this feature from the final system. More accurate hand tracking capabilities might provide opportunities for further investigation of such interactions in meetings.

MeetAlive is implemented on top of the open source RoomAlive for Unity framework which can support many configurations of projectors and cameras. We have only experimented with our setup of five projectors; however, it would be interesting to explore how our system scales to different meeting rooms and configurations. Furthermore, we’d like to explore meetings with more than four participants. New challenges are introduced when having to negotiate physical space for projecting content due to many shared desktops. We experimented with simple grid-based automatic layout adjustments, but we removed that feature eventually, since it was not necessary for the number of participants we had. Future iterations may investigate the implications of many participants with a focus on different approaches for automatic layouts.

Lastly, MeetAlive currently uses the table only for projecting colored regions that indicate ownership of like-colored content. During development, we implemented rotating horizontal desktop views for the table surface. However, we removed this feature in the final system. The rationale for the removal is that the windowing system of many operating systems and 2D UIs are designed to be viewed on a vertical screen and not optimized for horizontal large displays. In particular, every element on a 2D UI assumes the same physical distance to the user’s viewpoint. Rectangular content gets heavily distorted or needs a lot of space when getting undistorted – especially since we assume that participants are mostly sitting during meetings. Since we cannot adapt the inner contents itself, we chose to simply keep the familiar vertical nature of desktop content by only allowing to display content on the walls. Furthermore, as opposed to walls, the table is often reserved for physical objects, sketches etc. We did not observe confusion in that regard during our user study. Future iterations, however, can build upon the research on collaborative table top interactions [16] to enable the more effective use of the tabletop in MeetAlive.

CONCLUSION

MeetAlive is an omni-directional room scale display system designed for supporting face-to-face meetings. We integrate state of the art tracking and projection technologies into one coherent system to enable participants to share content anywhere in the room at any time during a meeting. Our system is designed to work with and improve the dynamics of meetings by providing equal control to every participant. Furthermore, MeetAlive addresses the largely differing gaze directions of participants by replicating content to ensure visibility, so that participants can maintain eye contact and view content at the same time.

While this system is still a research prototype, it is already deployed in our organization. Our preliminary feedback from the user study shows that it has the potential to positively change the meeting experience. Overall, the results of our first evaluation make us confident that MeetAlive performs very well in meeting situations, is easy to learn and use, and integrates well into the existing workflow of meetings. We hope that MeetAlive can inspire a new model for conference rooms where anyone can contribute, share, manipulate and edit content displayed around the room.

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