NSF IIS-HCC Project 0705569
Physical and Digital Design for Fluid Collaboration
Georgia Tech
Year 3 Status (Sep 1, 2010 – Aug 31, 2011)

I. Participants

1. What people have worked on the project?

Faculty:

Keith Edwards (Associate Professor, Georgia Institute of Technology)—Principal Investigator. Responsible for overall project management and coordination.

Ali Mazalek (Assistant Professor, Georgia Institute of Technology)—Co-Principal Investigator. Guided research activities focused on prototyping and development of physical interaction technologies and interfaces for collaborative workspaces.

Elizabeth Mynatt (Associate Professor, Georgia Institute of Technology)—Co-Principal Investigator. Responsible for interactions with partner organizations (particularly Steelcase), and oversight over activity-centric approaches for collaboration.

Derek Reilly (Postdoctoral Researcher, Georgia Institute of Technology)—Senior Personnel. Responsible for software infrastructure for device and service communication, connectivity to virtual world services for remote collaborators. Project planning and day-to-day management of research and development activities.

Tony Tang (Postdoctoral Researcher, Georgia Institute of Technology)— Senior Personnel. Tony has recently joined the project. He is responsible for defining, prototyping and evaluating a range of techniques to promote awareness of activity and intent across local and remote collaborators. He is actively engaged with student research on the project.

Students (grad and undergrad):

Chih-Sung (Andy) Wu (Ph.D., Digital Media, Georgia Tech)—Explored tangible interaction techniques for navigating virtual environments. Development of Or de l'Acadie demo game, and demo of system at ACM Symposium on User Interface Software and Technology. Assisted with layout study, including running the study and analysis (video coding and sketch analysis).

Catherine Grevet (Ph.D., Computer Science, Georgia Tech)—Responsible for empirical data collection and analysis, interaction technique development.

Andy Echenique (MS HCI, Georgia Tech) — Assisted with layout study, including running the study, scheduling participants, video coding, and sketch analysis.

Jonathan Massey (Undergrad CS, Georgia Tech) — Development of Or de l'Acadie demo game, work on first-person shooter (FPS) study of audio channel collaboration in teams.

Hafez Rouzati (MS HCI, Georgia Tech) — Assisted with layout study, including running the study and video coding of collected data. Demonstrated Or de l'Acadie mixed reality game at ACM Symposium on User Interface Software and Technology.

Firaz Peer (MS Digital Media, Georgia Tech)—Assisted with layout study, including video coding of collected data.

Sam Mendenhall (MS Digital Media, Georgia Tech) — Assisted with the development of the Responsive Objects, Surfaces, and Spaces API.

2. What other organizations have been involved as partners?

Steelcase is involved as a partner of this research, and is lending their design expertise in creating physical artifacts as well as collaborative spaces; they have also provided in-kind support in the form of production furniture artifacts as well as custom design services. Turner Broadcasting met with project members to discuss possible follow-on collaborations based on this work, but as of the writing of this report this is still up in the air.

3. Have you had other collaborators or contacts?

N/A

II. Activities and Findings

1. What were your major research and education activities?

Research Activities:

- Layout Study.

We designed and undertook a study to determine how spatial layout of a physical space impacted the spatial mental models of both collaborators in that physical space, and of collaborators using a connected virtual environment. The goal of this work was to inform how various "mappings" between physical and virtual environments might impact collaboration: for example, whether a one-to-one correspondence of physical and virtual environments, in which the virtual environment is a replica of the physical, helps or hinders the establishment of common ground, etc.

This study was executed during this project year, and data analysis was completed. Results were written up as a paper submitted to the ACM Conference on Computer-Supported Cooperative Work (CSCW), and is currently under review.

- Or de l'Acadie mixed reality game.

This game, developed beginning in the last project year and continuing into this one, was demonstrated in the refereed demos track at the ACM Symposium on User Interface Software and Technology (UIST) last October. A paper discussing our experiences and recommendations for a framework to support rapid prototyping of mixed reality applications was written and submitted to a games conference (ICEC) but unfortunately not accepted.

- Tangible Navigation and Object Manipulation in Virtual Environments

The goal of this part of the project was to specifically investigate approaches to navigating and manipulating objects in a Collaborative Virtual Environment that make use of tangible objects and an interactive table interface. We prototyped several different types of tabletop interfaces and studied the benefits and drawbacks of each. Our proposed prototypes included different interactions of combining tangible objects with hand gestures on an interactive tabletop display. We presented this research in the ACM Fifth international Conference on Tangible, Embedded, and Embodied interaction in January 2011 (TEI 2011).

- Responsive Objects, Surfaces, and Spaces API

Based on our observations of the challenges involved in programming applications for mixed reality collaborative environments that combine a variety of different physical input devices and platforms, from mobile devices to interactive tabletops or whiteboards, we are developing a tangible toolkit that allows designers and developers to more easily build applications for heterogeneous network devices. We call this toolkit the Responsive Objects, Surfaces, and Spaces (ROSS) API. One of the most significant differences of ROSS from other APIs is its nested structure that allows application developers to specify the relationships between the various devices and platforms in their target application context. The nested structure of ROSS is a hierarchical tree structure that allows one node to have access other nodes. We designed the specification of the ROSS based on the requirements of projects in the lab and have found that ROSS can support creativity by allowing application designers and developers to think outside the confines of typical platform configurations. Results so far have been written up and submitted to the Conference on Tangible, Embedded, and Embodied interaction (TEI 2012).

Education Activities:

In addition to its use in our research on mixed reality and collaborative virtual environments, we have incorporated the ROSS API into our teaching activities in the Digital Media and HCI programs at Georgia Tech. Specifically, the ROSS API has been made available to students in a Digital Media project studio course taught by Prof. Mazalek for two semesters to date. A number of projects have leveraged this resource in order to prototype cross-platform interactions for their own applications. Examples include a paint program that lets users collaborate on a shared drawing from many different devices (smartphones, laptops, interactive walls) and artistic explorations that link mobile and tabletop imagery in novel interactive ways. Incorporating the ROSS API into educational activities has also allowed students outside of the project to contribute to the ROSS codebase by incorporating their own favorite platforms (e.g. Kinect) in order to broaden the toolkit's usefulness.

A number of graduate and undergraduate students have also been directly involved in the day-to-day research of this project; for many of them, this represents their first exposure to research.

2. What are your major research findings?

- Layout study findings

Our study of how spatial layouts impact collaboration in connected physical and digital environments yielded a number of findings. Primarily, layout of the physical room had an impact on the spatial mental model held by collaborators of the connected virtual environment. Secondarily, a number of other factors played a role in influencing participants' spatial mental models; as examples, audio (volume as an indicator of proximity), the affordances of various controls and input devices (e.g., rotating a control dial to traverse content suggested that the content was laid out in an arc or circle), and even attributes of the content elements themselves (e.g., if documents are logically organized along two dimensions this suggests that the documents are laid out in a corresponding way).

Participants could identify the role these other factors played in mental model formation but they did not identify the layout of the physical space. So, physical layout is a factor that might need to be considered up front in the design of cross-reality collaborative spaces.

Unsurprisingly it was most important to have a sense of what the remote collaborators were doing and how to engage with them. This did not always require an accurate spatial mental model—particularly for tasks that allowed content traversal based on content attributes rather than spatial location.

- Game framework findings (from experiences building Or de l'Acadie and other prototypes):

The TwinSpace framework permitted rapid prototyping of physical controls for multiplayer gaming, in particular through supporting heterogeneous game interfaces (different interfaces for different players), and supporting iterative prototyping by multiple developers on different parts of a game system simultaneously.

While this framework provided a number of important capabilities, several gaps were identified through our prototyping experiences. Specifically, these included better control over the timing of communication between components, support for more sophisticated spatial translations of sensor data into virtual world movement, and centralized naming of real/virtual devices and objects. These are generally capabilities TwinSpace could provide as designed, but weren't apparent to us until we'd undertaken our prototyping work with Or de l'Acadie and other systems built using the framework.

We also identified issues related to using tangibles for virtual object manipulation and navigation (virtual objects and physical representations getting out of sync, granularity issues with physical object relative to tabletop display size and tracking capability, different "constraints" in physical and virtual spaces -- e.g. dimensions, interactive regions, gravity), and identified some solutions.

- Tangible Navigation and Object Manipulation in Virtual Environments

Our prototyping efforts involving object manipulation and avatar navigation in collaborative virtual worlds using tangible and tabletop interfaces have yielded a number of findings. In particular, we have identified two new types of CVE navigation methods: one combines a tangible with finger gestures and the other builds on the action of relocating an object on a table. We have also articulated three design issues that are common to using tangibles for object manipulation and navigation in CVEs and have proposed solutions to these problems within the context of CVEs. The three main challenges faced by all CVEs are:

1) Physical/Virtual Object Inconsistency: In the virtual world, inconsistency happens when two or more people try to change the property of one object.

2) Physical/Virtual Constraints: Most physical controllers do not map to the movement of the corresponding virtual objects. That makes controlling virtual objects difficult.

3) Managing Granularity of Control: It is difficult to decide the amount of movement from a physical controller. Since the controlled virtual object can be in any scale of the virtual environment.

One possible extension to this work is to apply the 3D map navigation concept inside 3D games so that the zoom level of the radar map reflects the avatar's vertical position. It is also possible to apply our research results to smartphones with cameras. A user can navigate a virtual environment by moving a smartphone in the space.

- Responsive Objects, Surfaces, and Spaces API

The ROSS API has not as yet been publicly released as an open source toolkit, and our current findings are based on our own use of the API for tangible and mixed reality application development. An important lesson learned from our work on the ROSS API so far is that changing the toolset enables designers and developers to think differently about their applications. We have observed that the unified set of tools for heterogeneous networks, the hierarchical structure of objects, surfaces, and spaces, and the technical abstractions provided by the ROSS API have enabled our developers to move beyond thinking in terms of tabletop, or wall, or smartphone, but rather to think about how to design for any or all of these at once depending on physical setting and goals of the particular application. We have also learned that hand sketching and use of tangibles are important aspects of the design of physical/digital systems that make use of heterogeneous networked devices. These methods promote dialogue between developers and also help developers think about their designs in a way that leverages the creative potential of the ROSS API.

3. What research and teaching skills and experience has the project helped provide to those who worked on the project?

All of the students involved in the project have developed research skills as a consequence of participating in this work.

Andy Wu

Catherine Grevet

Andy Echenique

Jonathan Massey

Hafez Rouzati

Firaz Peer

Sam Mendenhall

4. What outreach activities have you undertaken to increase public understanding of, and participation in, science and technology?

We did a number of demonstrations of this technology over the course of the year, including “open house” demo days for the GVU Center (attended by several hundred people), a group from Taiwan, and Atlanta area teachers.

III. Publications and Products

1. What work have you published as a result of this work?

Wu, A., Reilly, D., Tang, A., and Mazalek, A. Tangible Navigation and Object Manipulation in Virtual Environments. Fifth International Conference on Tangible, Embedded and Embodied Interaction (TEI '11), Funchal, Portugal, January 2011.

Reilly, D., Tang A., Wu, A., Echenique, A., Massey, J., Mathiasen, N., Mazalek, A., and Edwards, W.K. Organic UIs in Cross-Reality Spaces. Second International Workshop on Organic User Interfaces, TEI 2011.

Two submissions to the ACM Conference on Computer-Supported Cooperative Work (CSCW) are currently under review.

One submission to the ACM Tangible, Embodied and Embedded Interaction (TEI) is currently under review.

2. What Web site or other Internet sites reflect this project?

http://ross.gatech.edu

The following website contains information about the tangible tracking table:

http://synlab.gatech.edu/project.php?id=51 http://www.cc.gatech.edu/pixi

3. What other specific products (databases, physical collections, educational aids, software, instruments, or the like) have you developed.

The ROSS software, and other prototypes listed above, have been developed as part of this work.

IV. Contributions

1. Contributions within discipline

Our major contributions are two-fold. First, we have produced a wide ranging series of interactive hardware devices that demonstrate novel support for cross-reality collaborative practices. These devices have been deployed and evaluated in our lab, and provide insight into new forms of support for both distributed and co-present collaboration.

Second, after 3 years of experience with these systems, we have codified a range of abstractions necessary for supporting cross-reality collaboration into our TwinSpace architecture. This infrastructure provides a number of novel facilities to support such collaboration.

2. Contributions to other disciplines

None.

3. Contributions to education and development of human resources

Our graduate research team has created an environment that fuels and encourages active participation, and inclusion of new members into the team. We have successfully brought in and integrated a number of new students at both the graduate and undergraduate levels throughout the course of the project.

4. Contributions to physical, institutional, and information resources for science and technology

N/A

5. Contributions to the public welfare beyond science and engineering

N/A

V. Special Requirements

1. A brief summary of the work to be performed during the next year of support if changed from the original proposal.

N/A

2. Do special terms and conditions of your award require you to report any specific information that you have not yet reported?

No.

3. Do you anticipate that more than twenty percent of the funds under your NSF award will remain unobligated at the end of the period for which NSF currently is providing support?

No.

4. Has there been any significant change in animal care and use, biohazards, or use of human subjects from what was originally approved (or approved later)?

No.