Visualizing Interactions on Distributed Tabletops

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Abstract
We describe our experiences with a tool we created to interactively visualize the interactions of groups collaborating over a distributed tabletop system. The tool allows us to ask and explore several questions about how users are actually interacting and making use of the space. We briefly describe the tool, discussing both our experience in building and using the tool. Finally, we describe our goals for attending this workshop.

Keywords
surface, tabletop computing, visualization

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Context
We built a system that connected three interactive tabletops, allowing the users of the systems to interact with one another on a shared workspace (Tang et al., in press). As illustrated in Figure 1, this system was integrated with a video media space, allowing users to see and speak with one another while simultaneously interacting in the shared work space. Our specific interest was in manipulating the space so that users

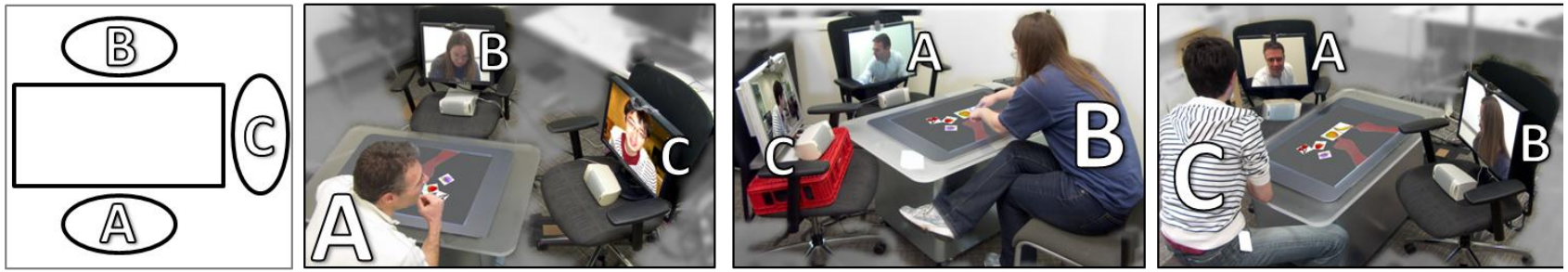

Figure 1. Three collaborators working around a shared tabletop (left: overhead schematic). In each physical space, remote participants are embodied as surrogates (with display, camera, microphone and speaker). Note that the spatial relationships are preserved in this setup. As B works in the space, her arm shadows are propagated to remote surfaces.

could sit "virtually" along different sides of the table, and to determine whether (and if so, how) these arrangements would affect the way in which users interacted with one another and in the space.

This system also captured the hands and arms of users as they worked with video, and overlayed videos of remote users onto each workspace (Figure 2). This design allowed users to gesture in the workspace to one another, as well as to maintain an awareness of one another's activities. We expected these arm shadows to mitigate interference issues, and facilitate spatial coordination of the workspace (as in Tang, 1991).

Figure 2. Arm shadows are displayed locally as feedback, as well as at remote sites. Finger contacts are transmitted to remote sites, and conveyed via trace pearls: the contact point is represented by a small disc, and the trail fades over time.

We built our system to log interactions (i.e. touches) on the table, and then constructed a tool (in parallel) that would allow us to interactively visualize this data. These visualizations were important, as they allowed us to answer several research questions. For example:

1. Are users' actions on the tabletop localized (i.e. are users territorial in their use of space)?
2. Are there conflicts, for example, where users attempt to interact with the same artifact in the workspace at the same time?
3. How do hand-offs work, where one user will pass an artifact to another?
4. Do users gesture on the workspace, altogether independently of the artefacts?

The main difficulty of answering these questions from direct observation is that interactions with the shared work surface are fleeting—they occur rapidly, and since there are three users in the workspace, relying only on

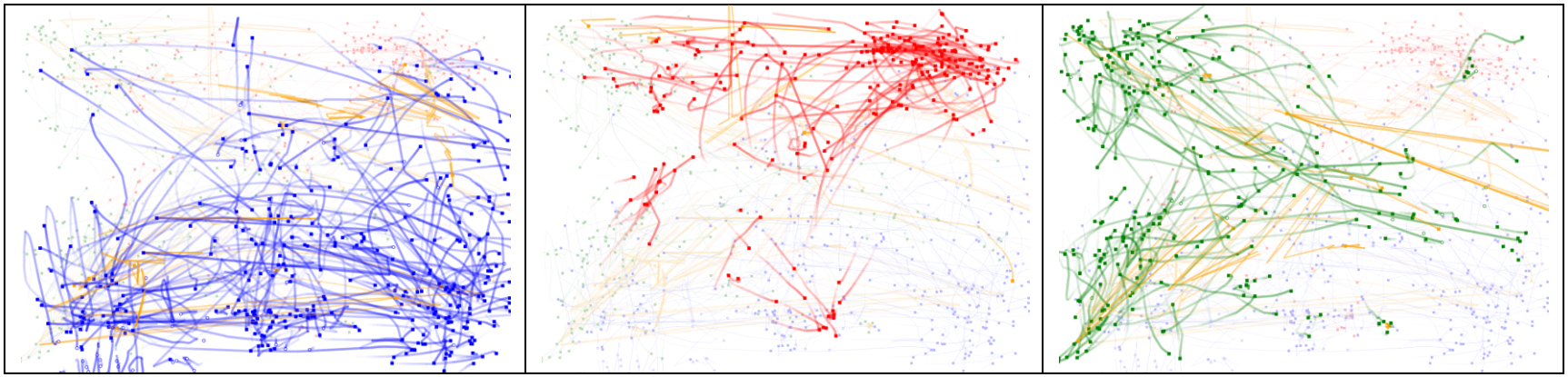

Figure 3. Given a setup where users are seated at different sides of the table, we see that each user's interactions with the tabletop is suggestive of territorial behaviour. Each frame here represents the traces generated by each of the three users in the same collaborative session.

direct observation means that we are likely to miss many events.

Types of Questions

We designed our tool to address several types of questions. In general, we classify these questions into a 2x3x2 space of different question types that were relevant for our research space:

Axis 1: Aggregate vs. Local. This partitioning allows for two different ways of considering the data that has been collected: are we interested in understanding specific episodes, occurrences and exceptions, or are we interested in aggregate "overviews" of these interactions. An example of a "local" question would be: how did users interact with this particular puzzle piece as they went to complete the puzzle? An example of an aggregate question: where did users interact (overall) in the workspace—were their interactions localized, or was there no evidence of territoriality?

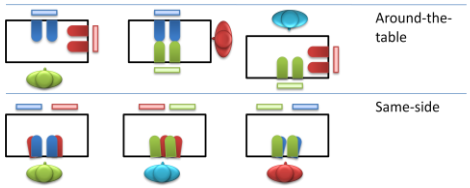

Figure 4. Our technology allowed us to generate two virtual "seating arrangements" around the tabletop.

Axis 2: Artefact vs. User vs. Multi-User. We also found that our research questions could be classified as being focused on a specific artifact, a specific user or interactions that involved several users. For example: how many times is this artifact interacted with? For this user, which artefacts does s/he interact with? How many hand-offs occurred between users?

Axis 3: Process vs. Incident. Finally, a third partitioning we found useful was the difference between addressing questions of process (i.e. understanding the general ways in which users did things) as compared to finding evidence of unusual incidents, and deeply understand when and why those things occurred.

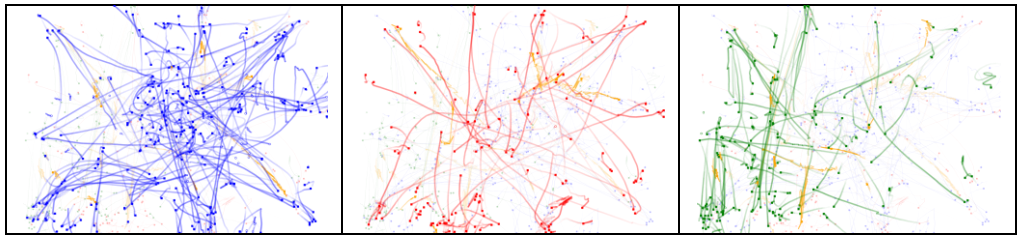

Figure 5. When users are virtually placed at the same side of the table, we see that their behaviours are not as spatially territorial.

Utility of Visualizations by Example

To illustrate how the visualizations helped us to understand how the collaborative activity was influenced by the different experimental conditions, we provide two examples drawn from the data in our study.

Example 1: Do users localize their interactions with the table? Prior work investigating users' actions around traditional tabletops had suggested that users were likely to partition their activities (i.e. interactions) with the tabletop (e.g. Scott et al., 2004; Tang, 1991). A study with this base case, where users are seated at different sides of the shared tabletop is suggestive of this territoriality (Figure 3). Our particular technology arrangement allowed us to explore two variations on this (Figure 4): (1) would this partitioning occur if users were virtually "sitting at the same location" on the tabletop (Figure 5); (2) would still partitioning occur if there was no feedback of other users' bodies in the workspace (Figure 6)? These are compelling questions to ask, as they allow us to tease apart the effect of physical proximity to areas on the table vs. task semantics vs. embodiment in causing the partitioning behavior that we see. From our framework, we would call this a question that asks about an aggregate process across multiple users.

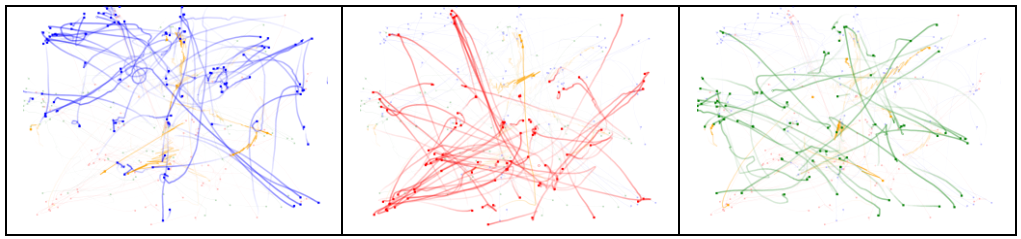

Figure 5. In this case, the arm shadows were not presented, though the participants were seated around the table. Without the arm shadows to aid the coordination of space, we see that users' behaviours are consequently considerably less spatially territorial.

Example 2: In what conditions are collisions (i.e. when two users' actions conflict with one another) most likely to occur? If the virtual shadows played a role in aiding coordination of activity, then we should see a reduction in the number of collisions. Within the context of our framework, this question addresses aggregate actions on artefacts, where we are interested in each incident.

We see then that the visualizations that we constructed allowed us to drill down and investigate specific questions we had about how users were behaving. They provide us with visual summaries of large quantities of data in readily interpretable forms, allowing us to formulate and help answer questions we have about the collaboration process itself.

Lessons Learned

As we conducted our analysis, our ability to focus and articulate our research questions helped to direct our design decisions on the tool. As a consequence, we iteratively refined our tool so as to address these interests as they arose.

In general, these requirements demanded the ability to repartition and resegment the data in novel ways, design an appropriate visualization within the context of the tool, and then provide UI support to manipulate the visualization.

More generally, our experience in this work helped to reinforce the difficulties of studying, observing and understanding collaboration. Individuals and groups exhibit idiosyncratic behavior, making it difficult and/or unfair at times to compare between groups. Achieving some level of external validity in such studies requires the use of moderately complex tasks, which results in more variability in the behaviors we are apt to see. Where technology does not fit their immediate needs, users will produce workarounds, and gravitate toward these workarounds when they encounter similar problems again. Raw data that is collected does not have immediately obvious cause/effect relationships because of these complexities, which are made even more difficult to interpret due to temporal nature of this data.

Tools that help visualize these interactions allow us to cut through the chaff of our own assumptions and preconceptions, instead allowing us to formulate and test hypotheses from a grounded perspective based on visualizations of the collaborative process.

Goals for Participation

Share *our experiences*. We learned a lot from the use of our tool, and more generally, from seeing how the use of visualizations has helped in our analyses of collaborative behavior. Others can make use of our ideas and findings to further their own work.

Understand *others' experiences*. Similarly, we believe that others' experiences with generating and using visualizations has been a useful tool in their explorations and research. It serves to understand those experiences, as they can help inform our own ongoing work, inspiring us in new directions.

Find *commonalities to share expertise*. There should be utility to discussing our individual experiences in shared forum, as it allows us to understand how our respective problems and approaches fit together within the broader context. It should allow us to learn from one another.

Bios of Authors

Anthony Tang is a PhD candidate in the Human Communication Technologies Laboratory at the University of British Columbia. Supervised by Dr Sid Fels, Tony's interests include collaboration, pervasive gaming, and information visualization. The experiences described in this paper are based on work that was conducted while Tony was interning at Microsoft Research.

Michel Pahud is passionate in researching and prototyping innovative breakthrough experiences that inspire product groups. His interests range from productivity applications, videoconferencing, to education. Michel joined Microsoft in the US in March 2000 and has worked for several groups including Microsoft Research and the Advanced Strategy Group. He is now back at Microsoft Research working directly with Bill Buxton on user experience research.

He has a Ph.D. in parallel computing from the Swiss Federal Institute of Technology. He also has been

working for 2 companies as a C.S. engineer in Switzerland prior joining Microsoft in the U.S. He won several awards including the prestigious LOGITECH prize for industrially-oriented innovative hardware/software senior project at Swiss Federal Institute of Technology and a runner-up prize from the Microsoft internal employees Tablet PC developer contest for an innovative fun Tablet PC application for kids.

Bill Buxton is Principal Scientist at Microsoft Research and the author of Sketching User Experiences: Getting the Design Right and the Right Design. Previously, he was a researcher at Xerox PARC, a professor at the University of Toronto, and Chief Scientist of Alias Research and SGI Inc.

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