Distributed Tabletops: Territoriality and Orientation in Distributed Collaboration

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CHI 2007, April 28–May 3, 2007, San Jose, California, USA
ACM 978-1-59593-642-4/07/0004.

Abstract
Previous research has shown that orientation and territory serve key roles during tabletop collaboration. However, no one has yet investigated whether they can play similar roles in distributed collaboration. In this paper, we design and implement *distributed tabletops* to address this problem and hence improve distributed collaboration. We show that distributed tabletops allow geographically-separated collaborators to use orientation and territory to mediate their interactions as they would in co-located collaboration. We also suggest that distributed tabletops offer further benefits such as an increased sense of presence.

Keywords
Remote collaboration, large interfaces

ACM Classification Keywords
H.5.3 [Information Interfaces and Presentation]: Group and Organization Interfaces – Computer-supported cooperative work.

1. Introduction
It is well known that co-located collaborators around a tabletop will reposition and reorient task artifacts to mediate their interactions. Consider, for example, two co-located collaborators completing a jigsaw puzzle. They will naturally, and without any explicit discussion about space, position the puzzle pieces to establish

personal territories on the tabletop. They can then use these personal territories to store pieces that they have reserved for their own use, and to explore ideas before presenting them to their collaborators [8]. Similarly, they will orientate the pieces to indicate ownership, to construct personal territory and to establish an audience for their actions, among other things [5].

These studies have shown that orientation and territory serve key roles in collaboration. Recent developments in tabletop interfaces allow co-located collaborators to position and reorient digital task artefacts (such as digital photos) in a similar way, with excellent results [6]. However, to our knowledge, no one has yet investigated whether territoriality and orientation could bring similar benefits to distributed collaborators.

In this paper, we present *distributed tabletops* that allow distributed collaborators to use territory and orientation to mediate their interactions, as though

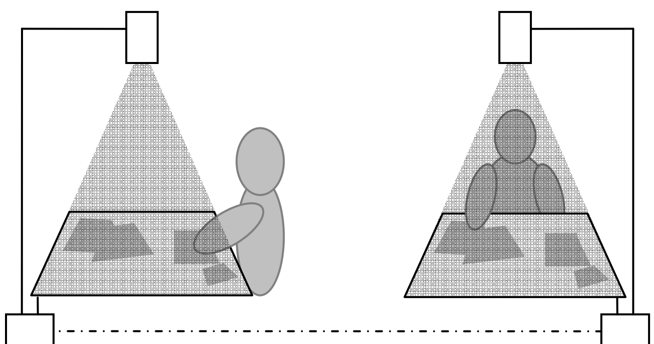

Figure 1: Distributed tabletops. Each distributed collaborator sits at their own tabletop. Tabletops are linked to create a shared workspace that supports territory and orientation.

they were co-located around a tabletop (Section 2). We discuss further benefits of distributed tabletops, such as providing collaborators with a greater sense of presence and also allowing them to transition more easily between personal and group working (Section 3). We present a flexible implementation that we can use to investigate different tasks (Section 4) and conclude by proposing future work (Section 5).

2. Distributed Tabletops

Conventional tabletop interfaces successfully allow co-located collaborators to use territory and orientation to mediate their interactions over digital artifacts. We therefore use these tabletops as a starting point when designing *distributed tabletops* that will support these notions for distributed collaborators.

As shown in Figure 1, each distributed collaborator sits alone at their own tabletop interface. Digital artifacts are displayed on the table, and the collaborators can position, reorient and interact with the artifacts simultaneously as they would with a conventional tabletop interface.

The distributed tabletops are linked in such a way that they all display exactly the same image at all times, creating a shared workspace in which each collaborator sees the same artifacts positioned and oriented in the same way relative to each other. Furthermore, each participant also sees the effects of their collaborators' interactions with the artifacts so that, for example, when one participant repositions and reorients an artifact, their distributed collaborators will see the artifact moving and rotating. Embodiments such as arm shadows could be projected onto the displays to allow participants to gesture to each other and to support consequential communication [10]. An audio channel also connects the collaborators.

So far, we have described a fairly conventional design for distributed groupware, albeit using a large horizontal surface. However, the most important aspect of our system is that collaborators do not see exactly the same perspective of the workspace; instead, each sees the entire shared workspace rotated, as though the collaborators were seated at different positions around the workspace (Figure 1).

3. Discussion

This rotated perspective of distributed tabletops is crucial in supporting orientation and territory among the distributed collaborators. Consider two distributed collaborators using our system and seated "at opposite ends of the workspace". The artifacts that appear close to participant A will appear far away to participant B. Since social norms dictate that people conduct their personal work in the area immediately in front of them [8], this naturally leads our collaborators to construct their personal territories at either end of the shared workspace, leaving the area in the centre of the workspace for group work. The system uses direct interaction so that, in order for B to interact with artifacts in A's personal territory, B must first reach across the workspace towards A's personal territory, and A will therefore see the arm embodiment approaching from B's personal territory. Furthermore, since participants naturally orient artifacts in their own personal territory towards themselves [8], B will see the artifacts in A's personal territory oriented away from B, and vice versa, and so both collaborators will be mutually aware of each others' personal territories. Since the collaborators can see each others' personal territories and actions, they can monitor each others' activities and anticipate when artifacts are likely to be available to use, just as they would do when working on conventional tabletops [8].

It is therefore reasonable to expect that distributed tabletops will give distributed collaborators the notions of orientation and territory, just as conventional tabletops do for co-located collaborators. This is particularly beneficial because orientation and territory allow collaborators to reserve resources and to transition between personal and group working, which are both well known problems in conventional distributed groupware applications [3]. Alternative ways of achieving both personal and group working usually involve either a separate display for personal work or a visualization such as an overview+context view, neither of which would provide as much awareness as our system. Orientation also offers a further benefit for distributed collaboration: it helps to establish an audience for verbal communication, which can be a problem for distributed groups in the absence of other visual cues.

We also expect distributed tabletops to provide the participants with an increased sense of spatial presence. Presence is the subjective experience of collaborators being in the same place as each other, even though they are physically distributed, and is desirable because it helps participants to overcome the "distortion effect" [4] which creates problems in distributed collaboration. Scott [8] observed that personal territory is used to reserve artifacts for personal use and suggested that collaborators think of personal territory on a tabletop as an extension of a person's personal space. Using our distributed tabletops, participants are aware of their collaborators' personal territory, and would be reluctant to retrieve artifacts from it, suggesting that they have a greater sense of presence than in conventional distributed groupware. This is comparable to the effect reported in HyperMirror [7], a system in which participants saw a life-sized live video of themselves superimposed on a live video of their distributed collaborator: the participants were always careful to make sure that they did not obscure each others' images by "standing in front of each other", even though they were not physically in the same place.

Conventional groupware applications present distributed participants with identical perspectives of a shared workspace and therefore inhibit the notions of territory and orientation. Even recent research using large horizontal displays for distributed collaboration [1, 4] similarly provided all distributed participants with identical perspectives. Distributed tabletops offer a radical alternative to address this problem.

To our knowledge, no research has been conducted into the notions of territory and orientation for digital artifacts in distributed collaboration. The idea is in some ways similar to Tang's MPGSketch [10], a shared horizontal whiteboard for both distributed and co-located collaboration, but the effect is very different because on a whiteboard there is no opportunity to reposition or reorient the artifacts.

If distributed tabletops give participants a sense of sitting around the same tabletop then what might we say about conventional distributed groupware applications? Such applications provide all participants with the same view of a shared workspace so presumably, with a sufficient sense of presence, the collaborators would have a sense of sitting on each others' knees. This would obviously lead to some social discomfort on the part of the participants and, since the effect has not been reported, we might infer that those systems do not provide participants with a great sense of presence. Either way this exercise suggests that, if we seek collaborative tools that provide greater presence, then we must ensure that we adhere to the social norms of personal space.

We must also consider that using orientation on distributed tabletops in this way could present problems because some of the artifacts will be viewed "upside-down" by one of the participants. However, studies have shown that this is actually an asset, rather than a problem [5], since it is central to the role of orientation in communication.

Distributed tabletops can be extended readily to support any number of distributed collaborators, simply by increasing the number of tables and the size of the shared workspace so that there is sufficient space to give each participant a personal territory at the edge of the workspace. With larger tables and groups we would expect the character of the collaboration to change, just as it would if the group were co-located. In particular, it will become difficult to pass artifacts across a large workspace and, in the absence of being able to walk around the table to retrieve digital artifacts that are far away, participants may need to use collaborative reaching and passing gestures of the kind that are designed for very large displays.

Finally, we note that distributed tabletops support collaboration between two distributed subgroups where the members of each sub-group are co-located around a single tabletop (in what Tang calls a "mixed-presence group" [10]). Prior work suggests that participants will feel a greater affinity towards collaborators that are physically co-present than towards remote collaborators [2].

4. Implementation

Having described and discussed distributed tabletops and their benefits, we now present our implementation.

As shown in Figures 2-4, our system connects two geographically-separated tabletop displays to create a distributed tabletop. Each participant has a digital stylus which they use to reposition, reorient and interact with the digital artifacts on the display. Repositioning and reorienting is accomplished in a single gesture using the Rotate 'N Translate technique [6]. The system is designed so that both participants can interact simultaneously.

Rather than focusing on a particular collaborative task, we have created a reusable system that can be tailored to create any type of digital artifact. We currently use a magnetic poetry application (Figure 2) and a collaborative web-browsing application (Figure 3), and we are working to create others.

The architecture is carefully designed to allow simultaneous interaction from both participants while minimizing pixel transfers between the two tabletops, in order to create a responsive interface with a reasonable frame rate. This is particularly difficult because we use a high resolution display (4.7 Megapixels over $0.5m^2$) to support tasks such as collaborative web-browsing, and so the potential for large time-consuming pixel transfers is high. Furthermore, windowing protocols and remote display protocols are generally unsuitable since they assume that only a single user interacts at any one time, and also that areas of pixels will move but not rotate (the Diamondspin toolkit [9] allows artifacts to rotate but cannot be linked to a second display). Our implementation uses the T3 tabletop toolkit [11] (Figure 4) to overcome these problems. Our

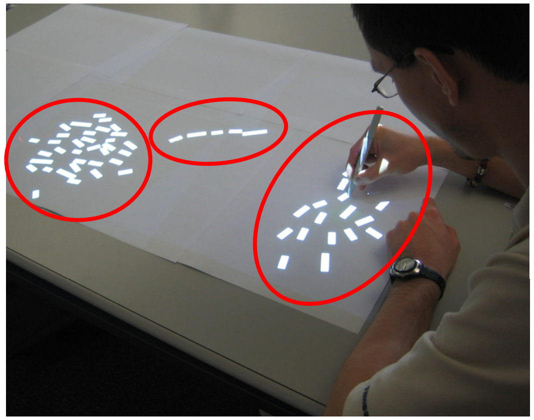

Figure 2: Magnetic poetry application on our distributed tabletop, with the participant's territory (right), the remote collaborator's territory at the edge of the table (left) and the group territory (middle).

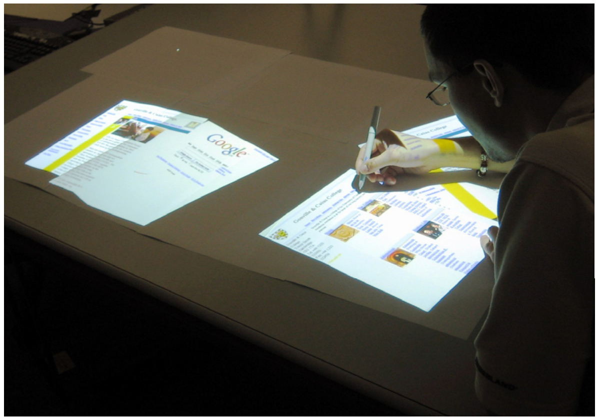

Figure 3: Collaborative web browsing using our distributed tabletop. The remote collaborator's artifacts are visible on the left at the edge of the table.

Figure 4: The T3 projected tabletop display.

collaborative web-browsing and magnetic poetry applications achieve frame rates of 30fps with no noticeable delay when repositioning and reorienting artifacts on the display.

In order to convey gesture, the system uses bright telepointer traces which follow each stylus nib; we are currently working on an arm-shadow-style implementation.

5. Conclusions and Further Work

We have presented and implemented *distributed tabletops* that allow distributed collaborators to use territory and orientation to mediate their interactions, as though they were co-located around a tabletop. In our discussion, we suggested that they also bring further benefits such as increased presence and easier transitions between personal and group working.

The design principles and benefits that we have discussed readily generalise to any collaboration involving digital artifacts. Our implementation can be easily tailored to investigate different tasks, and we are currently working to implement systems that allow collaboration over photos and text documents. Further work will investigate the extent to which the implementation realises our design goals, using an observational study and a variety of tasks to compare distributed and co-located participants.

Acknowledgements

I thank my supervisor, Peter Robinson, for his guidance and support. I gratefully acknowledge the support of Thales Research and Technology (UK) and the EPSRC, who are funding this work.

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