Tabletop Interfaces for Remote Document Review Meetings

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ABSTRACT
We consider the problem of remote review meetings, in which geographically-separated colleagues review text documents. We propose remote tabletop interfaces as an approach to addressing this problem and show that the necessary underlying technology has now progressed sufficiently to allow exploration of this new research area. We present a novel remote tabletop interface that we have created to investigate this area, and discuss our design in the context of prior work.

1. INTRODUCTION
Many knowledge workers spend a significant proportion of their time discussing and revising draft documents with their colleagues. These document review meetings have been well-studied in the literature, and are predominantly carried out while sat at meeting tables and using paper documents [8]. As an example, consider two co-authors of an academic paper, discussing each other's draft contributions.

Starting with Freeman and Wellner's DoubleDigitalDesk [15, 16, 17], researchers have turned their attention to the problem of *remote document review meetings*, i.e. document review meetings in which the participants are geographically-separated. These research projects seat each participant at his or her own table and then use video cameras to show each participant an image of their remote partner's table. Thus both participants can see each other's paper documents, gestures and actions during the discussion.

However, these systems can be problematic because a given paper document is only ever tangible for one of the collaborators. Their partner sees merely a remote image of it, cannot rearrange it on the table, turn pages or make annotations and, depending on the system, may not be able to read small text.

Recently, several researchers in the tabletop community have investigated the possibility of linking two large interactive horizontal displays together to support remote collaboration [1, 2, 5, 10, 13]. As shown in Figure 1, this creates a shared workspace containing "virtual objects" that are not tangible to either collaborator. These remote tabletop interfaces are largely unexplored.

In this short paper, we propose remote tabletop interfaces as an alternative to the DoubleDigitalDesk approach for supporting remote document review meetings. We begin by contrasting the two approaches (Section 2). We then present our recent work on high-resolution remote tabletops as a suitable technology platform from which to begin exploration, and describe prototype interfaces (Section 3). Finally, we draw on previous studies of tabletop collaboration and document review meetings to discuss design issues that arise in such systems (Section 4).

2. REMOTE TANGIBLE AND REMOTE TABLETOP INTERFACES
DoubleDigitalDesk [15, 16, 17], Tele-graffiti [9], LivePaper [6], Agora [4] and various commercial videoconference systems all address the problem of remote review meetings using what we shall call a *remote tangible* approach. A video camera mounted above each participant's table captures images of the paper documents on the table. These images are presented to the remote partner, either on a screen or projected onto the table in front of them. The participant with the tangible paper document is able to annotate it using a conventional pen, turn the pages and rearrange the document on the desk, whereas their partner sees merely an image of the document and can do none of these things. Both participants can see each other's hand gestures in the context of the document. Depending on the resolution of the camera and display, and the size of the text, the remote participant may or may not be able to see the text sufficiently legibly to read it. A similar approach has been adopted elsewhere to support remote collaboration over physical assembly tasks [3] and board games [18].

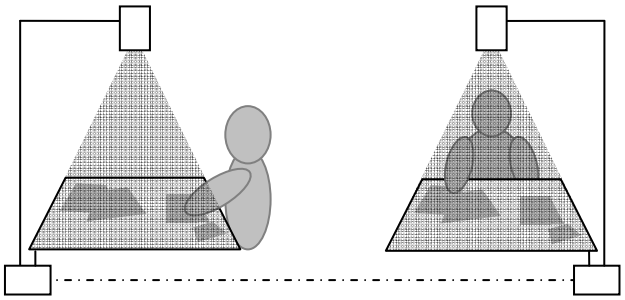

Figure 1: Remote tabletop interface.

Figure 2: Tiled multi-projector display.

By contrast, in systems using a *remote tabletop interfaces* approach [1, 2, 5, 10, 13], the objects are tangible to neither collaborator. Each collaborator sits at his or her own large interactive horizontal display. The two displays are then linked together, perhaps via the Internet, to provide a shared workspace for remote collaboration. The displays show virtual objects, such as virtual pages of text, that collaborators can move, reorient, annotate and otherwise manipulate using either their bare hands or styluses, depending on the technology. The displays also show the collaborators each other's arm gestures as shadows overlaid on the display.

Tabletop interfaces are a promising area of investigation. They support some of the affordances important for co-located document review meetings, such as a large horizontal workspace on which documents can be compared side-by-side [8]. For design tasks they have also been shown to support some of the coordination mechanisms observed in collaboration around conventional physical tables, such as fluid transitioning between coupling styles [11]. Escritoire [1] and the very recent C-Slate work [2] are both remote tabletop systems for document review tasks. However, these projects focus on the supporting technology, and both remote tabletop interfaces and remote document review meetings on them are still relatively under-explored.

3. OUR SYSTEM

The reasons for this gap in the research are two-fold. Firstly, it is necessary to display the documents at a sufficiently small size that they can be passed around the table between collaborators, grouped into piles and compared side by side. This requires the ability to display small text legibly on a tabletop display but, until recently, the resolution of tabletop displays used in research labs was too low to support this. Secondly, it is technically quite challenging to create remote display systems that support tabletop interaction techniques and a high display resolution while remaining responsive, because the combination of requirements was, until recently not addressed by research tools.

We have recently addressed these issues by creating the T3 toolkit [14], a software library that allows researchers to easily create high-resolution tabletop interfaces by tiling multiple projectors together, and to create remote high-resolution tabletop interfaces, and to rapidly create prototype interfaces for such systems. We have created two high-resolution tabletop displays, each using between 4 and 6 projectors in a tiled array to create a display of area 0.5m^2 and resolution 60dpi, capable of displaying legible text at font size 12pt (Figure 2). Such displays are, of course, too costly and complex for wide-scale deployment, but allow us to prototype ideas that may eventually be available to the mass market using the cheap, thin, flexible "e-paper" displays currently under development.

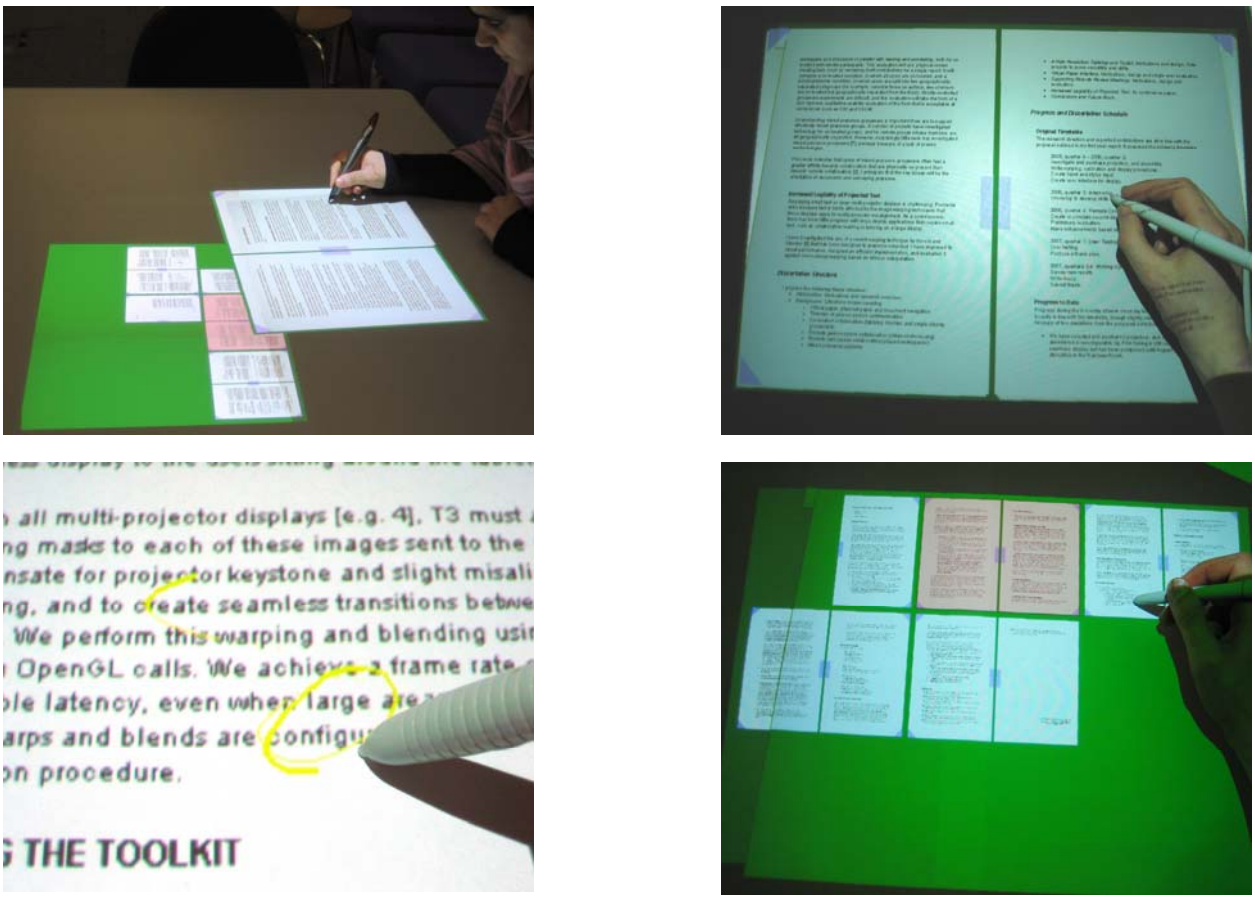

Figure 3: Documents appear as virtual pages of text on the tabletop (top left). Two pages are visible at once (top right). Text appears legible at size 12pt, and telepointers allow remote gesturing (bottom left). Thumbnails allow browsing (bottom right).

The projectors generate sufficiently little heat and noise as to not distract collaborators.

Using T3 we have created three prototype interfaces. The first interface (Figure 3) allows multi-page text documents to appear as virtual pages of text on the tabletop, showing two pages at once, rather like an open book. Text appears legible at size 12pt, and collaborators can use styluses to annotate, navigate, move and reorient multiple documents in the workspace. Using marked control points on the page, collaborators can navigate either by "turning" from one page to the next, or switching to a thumbnail view. Collaborators can gesture to each other using bright telepointer traces that follow the stylus nib, and we are currently completing an extension to allow gesture using translucent arm shadows.

Our second and third interfaces are the first steps in an investigation of tabletop collaboration over web pages (Figure 4). Although web page tasks are likely to be somewhat different from remote document review meetings, the interfaces offer an opportunity to explore interaction with multiple documents that are structured both spatially (in terms of their links to each other) and also temporally (with respect to their position in the web browser history tree or stack). The basic interface allows pages to be freely reoriented and repositioned on the tabletop by the collaborators, whereas the history tree interface determines the location and size of the page according to the time at which it appeared and the page from which it was opened.

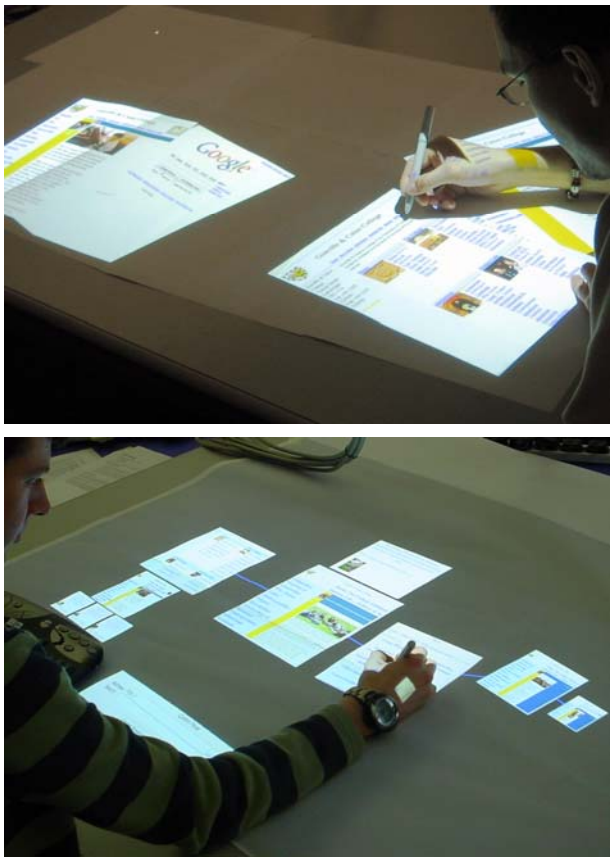

Figure 4: Basic web-browsing interface (top) and history tree (bottom).

4. DISCUSSION

Our investigation of remote tabletop interfaces to support remote document review meetings is still at an early stage, and future work will involve a field study. Nevertheless, even in this early work we have identified several issues that must be considered in the design of such systems.

In their investigation of paper documents, Sellen and Harper [8] emphasise the importance of the affordances of paper for reading and reviewing:

- Ease and flexibility of navigation.
- Ease and richness of annotation.
- Ability to cross-reference and compare multiple documents.
- Visibility of actions to colleagues.
- Ease of interweaving of reading and writing.
- Ability to annotate or read, and discuss in parallel.

These were most influential when designing our interface, and led us to a design based on replicating paper rather than anything more radical. Of course, because of the constraints of the system and the approach, we would not claim that our interface affords these nearly as well as paper does. However, surpassing paper was not our aim in this project; rather, we set out to create an effective interface for remote collaboration in document review meetings.

In reviewing prior work, we contrasted the approaches of remote tangible systems and remote tabletop systems. We believe that the two approaches present a tradeoff between symmetry and effectiveness in the extent to which they afford the properties identified above. A remote tangible system offers one of the participants the ability to interact with a document in a tangible, unconstrained manner, affording effective bimanual actions for navigating and arranging documents, and rich annotations, while their ability to read and write is not limited by a display resolution. However, the other participant cannot interact at all, and their ability even to read the document is likely to be severely constrained by the camera resolution and camera noise. By contrast, remote tabletop systems offer symmetric but less effective, more constrained interaction. Bimanual actions, fine-grained annotations and display resolution are likely to be limited by the capabilities of the system for both participants.

One exception to this tradeoff is that, because of the constraints of today's technology, remote tangible systems tend to offer small disjoint workspaces, and so our remote tabletop system may well better support the ability to cross-reference and compare multiple documents.

It is also interesting to speculate as to whether, even in a co-located document review meeting, each collaborator asserts a strong ownership over the documents that he or she has brought to the meeting, leading the collaborators to naturally partition their actions between the documents in such a way that the asymmetric access of remote tangible systems does not present them with a problem. We are not aware of any studies of this effect, and we shall investigate it in the field study.

In designing the interface we have adopted and adapted several design principles from the tabletop community, such as small virtual objects on a large display, lightweight mechanisms for moving and reorienting, mimicking tangible objects with projected light, and aiming to afford the styles of collaboration observed around conventional physical tables. However, these principles were derived largely from observations of design tasks [e.g. 12] rather than document review tasks, and have

been validated in studies of co-located tabletop collaboration rather than remote collaboration. The extent that they can be applied to document review tasks and to remote collaboration remains unclear and we shall investigate this in the field study.

Finally, we observe that remote tabletop interfaces allow both collaborators to sit at exactly the same location at the edge of the "virtual table", a situation which, in co-located tabletop interaction, is not physically possible unless the collaborators sit on each other's knees. Seating arrangements in co-located tabletop collaboration are governed by proxemics and the extent to which the task demands that the collaborators share a common perspective of the workspace [7]. It is unclear as to how remote collaborators will prefer to arrange themselves, and again we shall investigate this in the field study.

5. CONCLUSIONS

In this short paper, we discussed remote tabletop interfaces as an alternative to the remote tangible approach for remote document review meetings. We showed that, using the T3 library for high-resolution remote tabletops, it is now possible to begin exploration this area, and we presented three interfaces that we have created rapidly using T3. Drawing on our early experiences in designing and implementing these interfaces we discussed issues that must be considered when designing such systems.

6. ACKNOWLEDGEMENTS

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