Towards Understanding Collaboration Around Interactive Surfaces: Exploring Joint Visual Attention

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ABSTRACT
In this abstract, we present a novel method for exploring the visual behavior of multiple users engaged in a collaborative task around an interactive surface. The proposed method synchronizes input from multiple eye trackers, describes the visual behavior of individual users over time, and identifies joint attention across multiple users. We applied this method to analyze the visual behavior of four users collaborating using a large-scale multi-touch tabletop.

Author Keywords
Visual attention; collaboration; eye tracking

ACM Classification Keywords
H.5.m Information interfaces and presentation (e.g.,HCI): Miscellaneous

INTRODUCTION
The increasing availability of large-scale multi-touch displays affords new forms of co-located collaboration. Such displays enable simultaneous use by multiple users, provide high resolution, and support intertwining individual and joint work [1,2]. However, the availability of such displays is not enough to design effective collaborative environments. We also need a deep understanding of how different design characteristics of the environment will affect users' ability to collaborate. This problem motivates our exploration of visual attention among multiple users around a large-scale tabletop.

Our exploration of visual attention covers both behaviors exhibited by individual users, and behaviors exhibited by groups of users. For individuals we want to understand how design decisions will influence their ability to consume information. What are the areas of interest for users, and what are the patterns of shifting visual attention between these areas? For user groups, we need to understand how design decisions impact the joint visual attention of multiple users. What is the relationship between gaze locations for multiple users, both in time and space? And how do the visual behaviors depend on the number of users, and the characteristics of the environment?

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To answer these questions, we developed a new method for identifying patterns of shifting visual attention around a large-scale tabletop. Our method synchronizes input from multiple mobile eye trackers, to describe the visual behavior of individual users over time, and to identify joint attention across multiple users. Our method does not require the use of markers (such as barcodes), which would change the look of collaborative settings. Instead, we use landmarks from the existing visual scene.

RELATED WORK
Most research using eye tracking has explored the visual behavior of one or two participants. In contrast, we explore the visual behavior of groups, by tracking the gaze of multiple users simultaneously.

Eye tracking in collaborative tasks
Two earlier studies attempted to understand collaboration between two participants using synchronized eye tracking [1,2]. However, this work suggested that data processing remained a significant challenge. Schneider et al. [3] explored joint visual attention in pairs of participants engaged in a manual task. They computed a measure of joint attention using data from two eye trackers by carefully synchronizing the eye trackers using visual targets identified by 2D barcodes. Expanding on this work, our method synchronizes data from four eye-trackers, however it identifies joint visual attention while working on an interactive surface without using barcodes as landmarks.

ANALYZING VISUAL BEHAVIOR AROUND A SURFACE

Apparatus
We used an interactive tabletop with four MultiTaction cells (https://www.multitaction.com). We recorded gaze data using head-mounted Pupil Labs eye trackers (https://pupil-labs.com). We processed data using Matlab.

Procedure

Four female participants (average age=19.5), sat around the table while wearing eye trackers. Following a 5-minute tutorial, they were asked to collaboratively explore 135 projects and select five that should receive funding from their class funds. Participants took about 15 minutes to complete this task.

Processing method

Our participants were free to look 360 degrees around, thus we had to calculate the position of the tabletop relative to the eye tracker frame by frame for each participant. Also, the eye tracker's camera has a distorted image of the tabletop as shown in Figure 1. Finally, each participant sits in a different position, resulting in videos of the table from several perspectives.

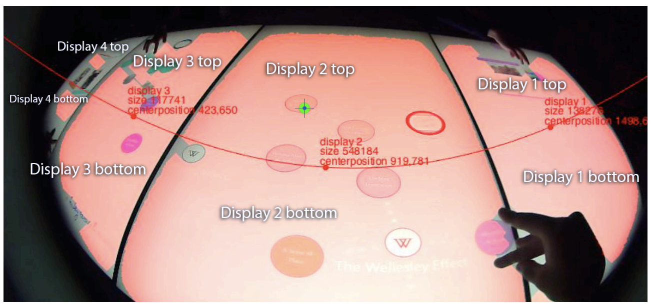

Figure 1. An analyzed frame showing the world camera view of an eye tracker with the four detected displays indicated with a red tint and a fitted curve splitting the multi-touch table into a total of 8 areas.

Since the surface emits light, we were able to isolate it from the rest of the video using a combination of filters. First we converted the image to a binary outline, covering the whole surface, using color filters, a median filter and a brightness threshold. Using morphological operations, we filtered noise on the binary image. Subsequently, we found four bright areas within this outline and identified displays based on size and position. Finally, we split each of the 4 areas into 2: top and bottom. We did this by calculating the center of mass points of the 4 displays and by fitting a curve to those points. The result is that we can mark each gaze by a participant as being aimed at one of 8 possible areas, as shown in Figure 1. In this figure, the green dot represents the gaze location of the participant. Our method would identify this gaze as being directed at the top of display 2.

Joint visual attention

Joint attention indicates that participants are focused on the same task and are monitoring each other's attention. This effect can be shown by tracking the gaze positions provided by the eye trackers and visualizing the combined visual attention of all participants.

Figure 2 shows the visual behavior of our four participants for a short segment of the 15 minute experiment. We processed data for the entire experiment and found that for 19.4% of the time at least two participants looked at the same area, indicating joint attention.

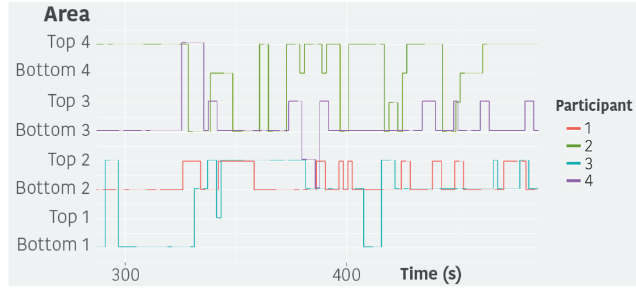

Figure 2. The visual attention on the different areas of participant displayed as a function of time. Note that this plot shows a short time segment of the entire experiment.

DISCUSSION

Our method allows assessing the visual behavior of multiple participants, and can thus allow us to gain deep understanding of collaborative behaviors in novel settings, such as large multi-touch surfaces. Our results indicate that the method is robust: in our 15-minute experiment with four participants we could calculate the location of the 8 areas about 90% of the time. And our method is not limited to four participants: in upcoming studies we plan to expand this number to 8 participants seated around the table.

A limitation of our method is that it uses the displays that make up the table as landmarks. For a display that is not segmented as shown in Figure 1, a modified method is needed. We had to dim the environmental lights in order to accurately isolate the surface and the processing time of the method is about 2 frames per second on modern hardware.

CONCLUSION AND FUTURE WORK

We seek to gain deep understanding of how different design characteristics of large-scale multi-device environments affect users' ability to collaborate. The method we propose describes the visual behavior of individual users over time, and identifies joint attention across multiple users. We will expand this method in several ways. First, we need a more precise x-y coordinates of gaze locations on the table. Also, we will adopt the method to track gaze positions on vertical surfaces (walls). Finally, we will integrate it with other modalities including touch on the horizontal and vertical surfaces, as well as on mobile devices, to further explore collaborative work around interactive surfaces with different characteristics.

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