Towards Understanding Collaborative Visual Data Analysis in Multi-Device Environments

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ABSTRACT

There is a steadily growing interest in leveraging ecosystems of digital devices that go beyond a single desktop for visual data analysis and exploration. However, multi-device ecologies pose several challenges as information and tasks are scattered among separate devices and displays. To understand the challenges associated with multi-device environments for information visualization, we performed an exploratory study designed to examine how users employ different tools to perform different kinds of activities in approaching a visual analysis task. Previous work examined three factors (users, tools, and tasks) independently. We study the synthesis of these factors. To do this, we adopted a hybrid analysis approach that focuses on three different aspects: users, tools, and tasks. We believe this analysis will help us identify associated challenges and better inform design goals in developing multi-device tools for visual data analysis.

Keywords: Collaborative visual analytics, exploratory analysis, multi-device ecology.

1 INTRODUCTION

Visual analytics "The science of analytical reasoning facilitated by interactive visual interfaces" [1] is rarely a solitary activity. Analysis of large amount of data and the inclusion of multiple users demanded solutions that go beyond a single desktop [2][3]. Multi-device environments emerged to support co-located collaboration for visual analytics by utilizing each device strengths and capabilities. Several proposed frameworks support visual analysis tasks in novel displays configurations. Chung and North [4] presented spatially aware visual links for cross display visualizations. Vistribute [5] can automatically distribute a set of visualizations and UI components across multiple devices. VisPorter [6] is a multi-device system that enables gesture-based sharing of information among different devices.

Research questions: In this research we investigate collaborative visual data analysis in multi-device environments that go beyond a single desktop. In practice, visual data analysis is an iterative process involving cycles of data transformation, visualization construction, interaction, hypothesis generation and validation. In multi-device environments, collaborators employ different tools to perform different kinds of activities in approaching a visual analysis task. The main question is what flow patterns the collaborators follow in approaching the respective task? We believe that the flow of the data analysis process is shaped by the sub questions: How users use the tools? What types of activities do they perform? And how they communicate? Each question corresponds to one aspect: tools, tasks, and users. We aim to synthesize the flow patterns of the analysis process by quantitatively and qualitatively analyzing the three aspects. We aim to understand how the analysis process unfolds and identify challenges and further requirements on how to provide tool support for collaborative use, sharing and coordination of analytics components in multi-device settings. We conduct a study to better understand the process of sense making during collaborative visual data analysis in a multi-device environment.

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2 METHODOLOGY

This study will help us derive design guidelines for multi-device environments, but we designed an initial application, the PolyVis framework [7], which meets basic design goals derived from the areas of collaborative visual analytics and visual data analysis in multi-device environments.

2.1 Apparatus

For these studies, we used a cross-device framework that we developed for collaborative visual data analysis, PolyVis [7]. In PolyVis, we integrate SAGE2 [8], a large display collaborative application, with portable devices for co-located, multi-device visual data analysis.

Portable displays can vary from the less immersive smartwatches to the fully immersive VR headsets. Due to the unique requirements of integrating devices from these categories for information visualization, we limited our scope to support the integration of portable devices that vary in between like tablets, laptops, and HoloLens AR headsets. Specifically, PolyVis integrates SAGE2 large display with laptops, tablets and the HoloLens AR headset. It provides users with an environment for visualization compositions and sharing across devices. PolyVis offers the capability to utilize each device for specific tasks to work separately or in conjunction with the large display. Some of these tasks include data filtering, visual mapping, visual representation, visualization construction and sharing. This environment allowed analysis across different devices and many visualizations with the ability to move and share visualizations.

PolyVis usage scenario: Using a laptop or a tablet, users can start by mining the data for all earthquake events during 2010, and then specify their visual representation (i.e. map) to visualize them on the large display. Any user with a tablet can capture the barcode attached to the map of earthquakes using the camera of the device to pull the map visualization to the portable device. Analysis charts like scatterplot, line or bar charts can be created for the pulled map and then they can be pushed back to the wall. Using the laptop, user can select a specific area on the map to view data points in 3D using HoloLens. PolyVis was developed based on declarative visualization design like Vega-lite [9] and the paradigm of operation transformation for seamless migration of visualizations and their interactivity between devices.

2.2 Study design

We conducted an observational, exploratory study to observe how groups approach a data analysis task using multiple devices.

Using PolyVis as a visual data analysis tool for multi-device environment, subjects were provided with two tablets, a laptop and a HoloLens to use in conjunction with the large display.

In the first task, the subjects were given a focus question that can be answered by creating one or two visualizations. The focus question is designed in a way that helps subjects learn how to use the system and be familiar with the datasets. Subjects then were asked an open question to find correlation between earthquakes events and wells' volume injection of two states, California and Oklahoma, from the years 2000 to 2010. They were asked to create as many visualizations as they need with no restrictions with regard to using devices or moving in the space. The whole room is tracked using OptiTrack Mocap system. Each subject wore a helmet with attached Mocap markers for position and orientation tracking. The position and orientation of devices were also tracked using attached markers. Systems usage logs were collected from all used devices. Each log includes the device id and type, the action type, and the timestamp. Systems logs will be used in our quantitative analysis of the devices usage. The study is video and audio is recorded using two cameras, one showing the full room from behind and one showing the subjects interaction with the large display from the front. The setup is pictured in figure 2.

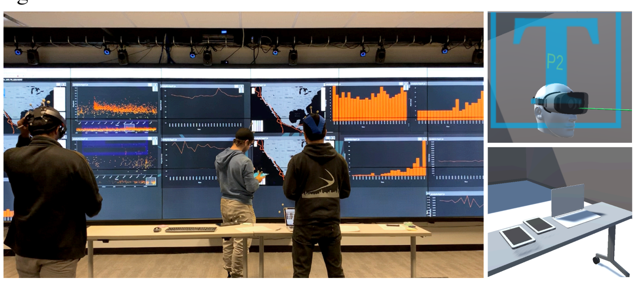

Figure 1: Subjects examining a set of created visualizations while using different devices. Position and orientation of subjects and devices are streamed from OptiTrack mocam system to a Unity application depicting a 3D model of the physical space.

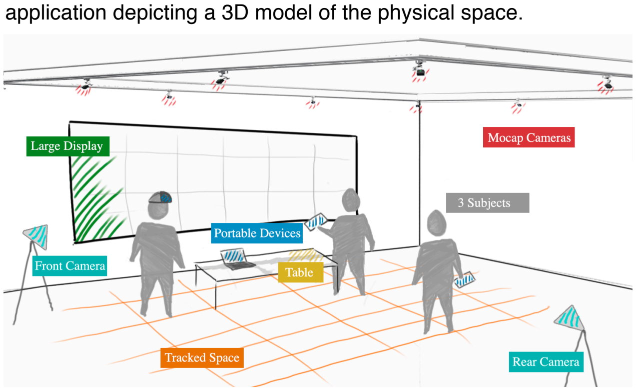

Figure 2: Illustration of the study setup.

2.3 Participants

18 subjects, 6 groups of 3, 13 male and 5 female, between ages 18 and 34 participated in the study for between 45min-1.5hrs. Participants had varied backgrounds in visual data analysis, ranging from moderate to advanced. We recruited participants from a pool of university students at the undergraduate and graduate level who were taking visualization class.

2.4 Data Analysis

Earlier studies of collaborative visual data analysis around interactive surfaces focused on either collaboration styles, use of the tools, or analytical task activities. We believe that all these aspects shape the experience of a group in multi-user multi-device settings. To better understand the complex picture of a groups' experience in multi-user multi-device settings, we focused on the three different aspects together: users, tools and tasks. We aim to synthesize the analysis of the three aspects together, in effect addressing the question 'How users used the tools to perform what kinds of activities to approach their analytical task?' We will use quantitative and qualitative data in this analysis.

3 Initial Finding and Future Work

For each aspect (users, tools, and tasks), we are performing a hybrid method of quantitative and qualitative analysis. Here, we provide very initial findings of quantitative analysis of the usage of the tools from 3 sessions. We collected the system usage logs where each log represents the device id, the process, and the timestamp. The initial results showed that groups 1 and 2 used tablets for visualization creation and exploration for 23% and 36% of their time, respectively. They spent 16% and 18% of the time on visualization exploration on the large display. Group 3 spent 36% of the time on general usage of the large display, like apps moving and arrangement, and 24% of the time on visualization exploration on the large display. They used tablets for 10% of the time for visualization creation and exploration. All groups used the laptop between 6-10% of the time for data foraging and between 2-6% of the time exploring the dataset on HoloLens for 3D viewing.

This is a work in progress, so we are currently performing an in-depth quantitative analysis of the system and space usage as well as qualitative analysis of video recordings and follow-up surveys to reveal the relationship between users, tools and the analysis activities. We are interested in focusing on the flow of analytical process, in relation to users, tools and tasks. We aim, after multiple passes of coding, to identify design implications and development directions of information visualization tools around interactive surfaces. By presenting this work to the visualization community, we aim to get feedback and discuss promising developments.

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