VICPAM: A Visualization Tool for Examining Interaction Data in Multiple Display Environments

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Abstract. Multiple Display Environments (MDEs) facilitate collaborative activities that involve the use of electronic task artifacts. Supporting interactions and infrastructures have matured in recent years, allowing researchers to now study how the use of MDEs impacts group work in controlled and authentic settings. This has created a need for tools to understand and make sense of the resulting interaction data. To address this need, we have designed and developed a new interactive analysis tool called VICPAM. Our tool reduces the effort necessary to analyze and make sense of users' interaction data in MDEs. VICPAM consists of several components: (i) a *time-aligned view*, which shows users' activities over time and the duration of each activity; (ii) A *spatial view*, which gives a 2D overview of all users' activities in the environment; (iii) A *time-bar*, which allows selection of a desired time period for in-depth analysis; and (iv) a *video player,* which allows the user to watch a video of the session synchronized with the selected period of time.

Keywords: Visualization, Multiple Display Environment, Interactive Analysis.

1 Introduction

Multiple Display Environments (MDEs) represent an emerging environment for conducting group problem solving activities involving electronic task artifacts. Group-based programming and collaborative design are two examples. During these activities, group members will relocate cursor input and artifacts such as IDEs, web pages, sketches, and documents between personal and shared devices. This provides the opportunity to share, manipulate, and discuss related information. In MDEs each individual typically has a personal device, and all computers are connected via a network [11]. Large shared displays may also be present to facilitate group collaboration. Colab [11], iRoom [9], and OCEAN-Lab [12] are examples of such environments. Figure 1 shows an example of a MDE configured for collaborative software development.

With many instances of MDEs available, researchers are beginning to study how their use affects collaborative problem solving. For example, Biehl et al. [3] studied the use of MDEs in the context of collaborative software development activities. In another study Streitz et al. compared multiple configurations of MDEs for group meeting tasks [12]. Also Izadi et al studied a system called “Dynamo” which enables

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users to share and exchange information in unfamiliar public places [8]. In all these studies, in order to evaluate the environment, all interactions between group members and devices were captured, e.g. which applications were shared, what devices were involved, and at what time. The researchers had to analyze the interaction data collected to answer their respective study questions. However, analyzing this type of data can be challenging because multiple interactions of interest can overlap in time (e.g., two or more users placing artifacts on a shared display) and users (e.g., one user sharing an artifact with others at different times). This data can be complex and voluminous.

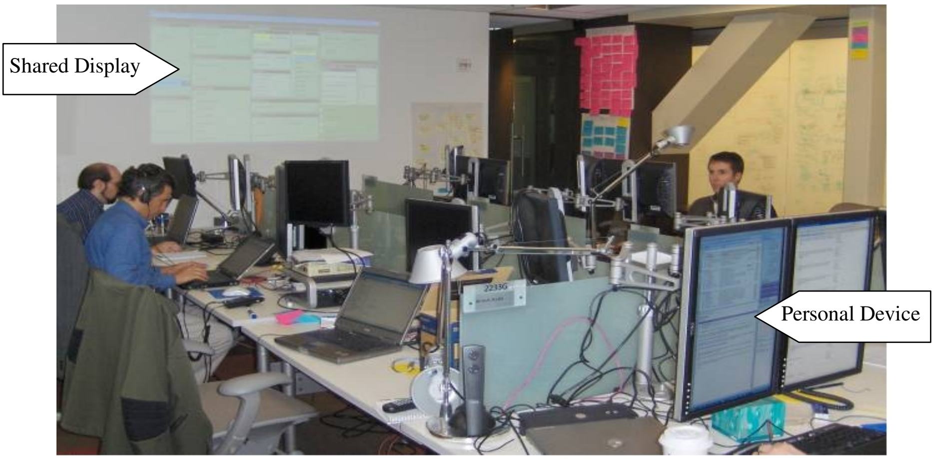

Fig. 1. A group of five developers are using a MDE for collaborative software development (from [4] with authors' permission)

A common method for analyzing interaction data from MDEs (and other) evaluations is the use of spreadsheets. Spreadsheets can be used to record and examine the data in a structured manner, but they do not allow interaction with the resulting visualizations. Visual explanations are suitable to get an overview of the data, but they do not (by themselves) support interaction for investigating patterns and clusters. Interaction techniques can allow the user to better perceive the information when visually exploring a data set [6]. Many interactive visualization tools have been developed to make sense of complex data in myriad domains, including Google Finance [1] for analyzing stocks, profilers and debuggers in software development, and Nasa's Hurricane analysis tool in the domain of earth science [2].

COPROT was the first interactive analysis tool designed for exploring data gathered from studies in MDEs [12]. This tool helps researchers to record and track cooperation modes and the time spent in each mode by watching the video of an evaluation session. Unlike their tool, our work aims to support researchers in determining the cooperation modes and the *collaboration patterns* by both visually representing the interaction data and showing the video of the evaluation session. WorkspaceNavigator [7] enables capture, recall, and reuse of the digital information, decisions, and rationale generated by a group collaborating within an interactive workspace. Our work is original in that it targets exploring data in order to investigate the collaboration and communication patterns between group members.

To address the need to make sense of the interaction data from MDEs, we have designed and developed a new interactive analysis tool called VICPAM (Visualizing Interaction and Communication PAtterns in MDE's). VICPAM consists of (i) a time-aligned view, which shows users' activities and the duration of each activity; (ii) a spatial view, which gives a 2D overview of all users' activities; (iii) a time-bar, which can be used to adjust the period of time under analysis; and (iv) a video of the session synchronized with the timeline. The tool reads an XML file as input.

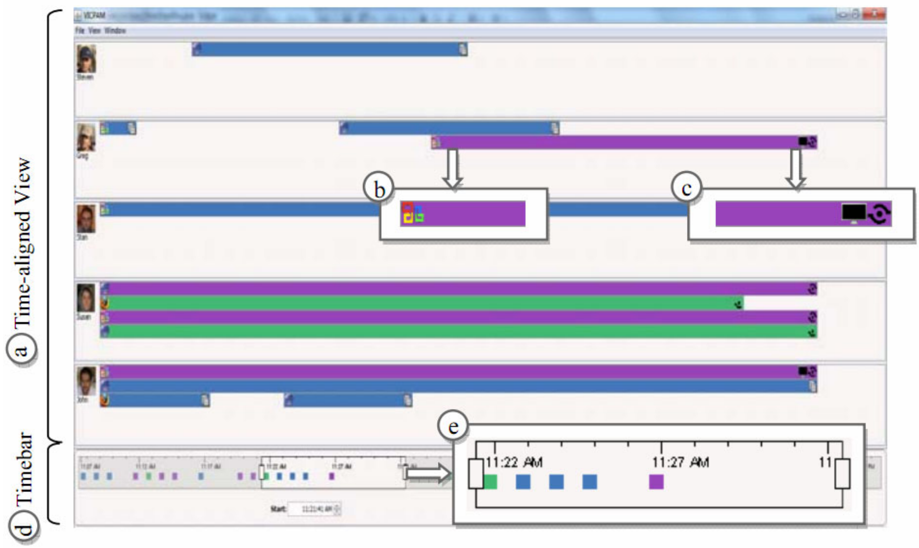

Fig. 2. The main screen consists of the time-aligned view and an interactive visual time-bar. (a) The time-aligned view shows users' activities and the duration of each activity. User's activities are shown by rectangles. (b) The application icon is located to the right of a rectangle while (c) the activity icon is located on the left. When the activity has been performed via a shared display, a device icon is also shown on the left indicating the use of the shared display. (d) The time-bar can be used to select a desired time period for analysis. (e) The square-shaped visual indicators displayed on the time-bar mark the start of a new activity.

The contribution of our tool is that it demonstrates a new interactive visualization technique for facilitating analysis of complex data collected from studies of group problem solving in MDEs.

2 VICPAM

VICPAM is an interactive visualization tool which helps researchers to analyze the interaction data captured during their studies in MDEs. Our system was developed through an iterative design process, starting with examining different configurations of MDEs and several studies conducted in each configuration. We designed two different prototypes that addressed the requirements identified in our analysis. To evaluate them, two MDE researchers and three HCI researchers were recruited, asked to perform similar tasks (e.g., identify the duration of a specific activity) with each prototype, and asked to explain their relative strengths and weaknesses. From the results, we implemented our prototype of VICPAM.

VICPAM reads the interaction data from an XML file. The file begins with meta-data information including the number of users and their information, their relative position in the room, types of activities users can perform in the environment, and a link to the icon of each activity type to be displayed in the visualization. The actual data should consist of a <total duration> tag which indicates the duration of the entire session as well as a number of <entry> blocks which represent an activity a user has performed on a specific application for a particular period of time. In each <entry> block there should be a <user> tag indicating the user's name, an <application> tag indicating the application's name, an <activity> tag indicating the type of activity the user has performed, an optional <device> tag indicating the device used for performing the activity (personal device or shared display), and a <time> tag which contains <start> and <end> tags specifying the duration of the activity.

2.1 Data Background

We will describe VICPAM in context of the interaction data collected in studying IMPROMPTU, an interaction framework for MDES, for collaborative software development [4]. The data contains three different user activities: (i) *Show* which means an application window is provided to the group in view-only mode. (ii) *Share* which means an application window is provided to the group members and anyone can edit its content if they replicate it on their own machine; (iii) *Replication* which means an instance of a shared or shown application has been copied on a personal machine. IMPROMPTU logs the usage data including the type of the activity (i.e. share, show, and replication) and the duration of the activity. All of the figures illustrating the use of our system are based on this data set.

2.2 Visualization

VICPAM's main screen consists of the time-aligned view and an interactive visual time-bar (Figure 2). The time-aligned view shows the exact duration of each activity a person has performed (Figure 2a). Each person is displayed inside a rectangular frame. This frame includes the person's information, and a set of rectangles representing the activities he performed on different applications. The width of each rectangle corresponds to the duration of the activity and the color corresponds to the type of activity. For this particular data set, green represents show, purple represents share, and blue represents replication. There are also a number of icons shown on each rectangle including the application icon on the right side (Figure 2b) and the activity icon on the left (Figure 2c). If the activity has been performed via the shared display, a device icon will also be shown on the left side indicating the use of the shared display. Note that the color and icons used for each activity type are specified at the beginning of the input XML file to make the tool usable for different data sets.

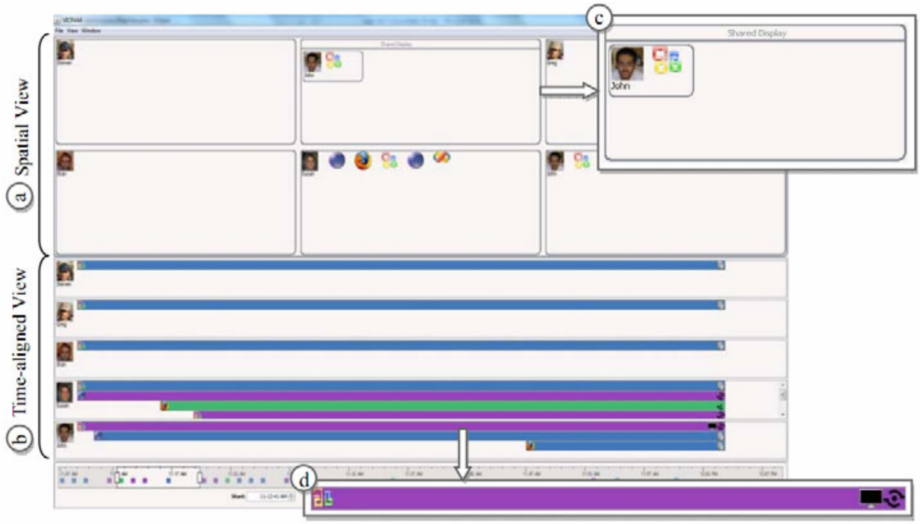

Fig. 3. When the user selects "Show Spatial View", the spatial view will be displayed on the top of the time-aligned view. (a) The spatial view shows a spatial 2D view of the users and their activities. (b) The time aligned view shows the exact duration of activities. (c) As it's shown in the shared display section of the spatial view, John has shared an instance of visual studio in the shared display. (d) John's activity is also shown in the time-aligned view.

The user can use the slider in the time-bar to select a desired period, the time period can be as small as a second or as large as the entire session (Figure 2d). Upon her selection all the views in the visualization will be updated illustrating only the activities happened during the selected period. To support the user in detecting and exploring interesting periods, the time-bar includes visual indicators which mark the start of a new activity (Figure 2e).

By selecting "Show spatial view" from the "View" menu on the menu-bar, a spatial view is added to the visualization (Figure 3). The spatial view shows a 2D overview of the activities people have performed in the environment. Each person is displayed in a rectangular frame, which includes a picture of the person, her name, and the applications that she has shared or shown during a specific period of time. Unlike the time-aligned view, the spatial view doesn't show the duration of the activities, instead it orders the people based on their actual position in the room. For example, this can be used to determine whether a person's position affects his or her collaboration patterns. Also, the spatial view is more useful in answering certain questions, such as what is the most frequently used application in the entire session. Both the spatial view and the time-aligned view are adjustable, these views can be opened in new windows, and the size and place of the artifacts inside these views can be configured.

To help the researcher with data analysis, several interaction mechanisms have been implemented in the interface:

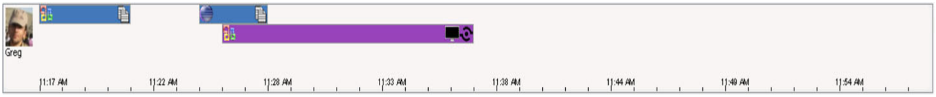

Fig. 4. Selecting "Show rulers" from the "View" menu in the menu-bar displays a time ruler under each person's frame

Interaction with users and activities: Hovering over each user's picture shows detailed information about that user, including the number of activities she has performed. Hovering over each activity shows information about that activity including the exact start and end time, the application name, and the user's name.

Display time rulers: Selecting "Show rulers" from the "View" menu in the menu-bar displays a time ruler under each person's frame in the time-aligned view (Figure 4). Using these time rulers the researcher can easily compare the start and end time of activities without having to draw an imaginary vertical line down to the time-bar.

Link between the spatial view and the time-aligned view: To support the researchers in using both spatial view and time-aligned view simultaneously for analysis, a virtual link has been created between the users and activities in these views. When both views are open, hovering over a user's picture in the time-aligned view will highlight that user and his activities in the spatial view. Conversely, hovering over a user's picture in the spatial view will highlight that user and his activities in the time-aligned view. Hovering over an activity on the time-aligned view will highlight the corresponding activity in the spatial view and vice versa.

2.3 Video of Interaction

A MDE's evaluation session is usually captured by a video camera. This video can be imported to VICPAM and played in a separate window. The video is synchronized with the time-bar. When the user presses the play button the part of the video corresponding to the selected time period in the time-bar begins to play.

2.4 Filtering

A separate filtering window is available to filter the data based on applications, users, and activities (Figure 5). For instance, if the researcher selects one application and filters the rest, only the activities related to the selected application will be shown in the interface. The filtering options allow researchers to focus on their desired part of the data. This feature is especially helpful when the amount of data shown in the interface is overwhelming. During our preliminary evaluations, the participants found the filtering options to be helpful for answering focused questions (e.g. how many applications have been shared by a particular user).

2.5 Putting It Altogether

In this section, we illustrate the value of our tool through a user scenario. The scenario is grounded in the same data set described earlier in Data Background.

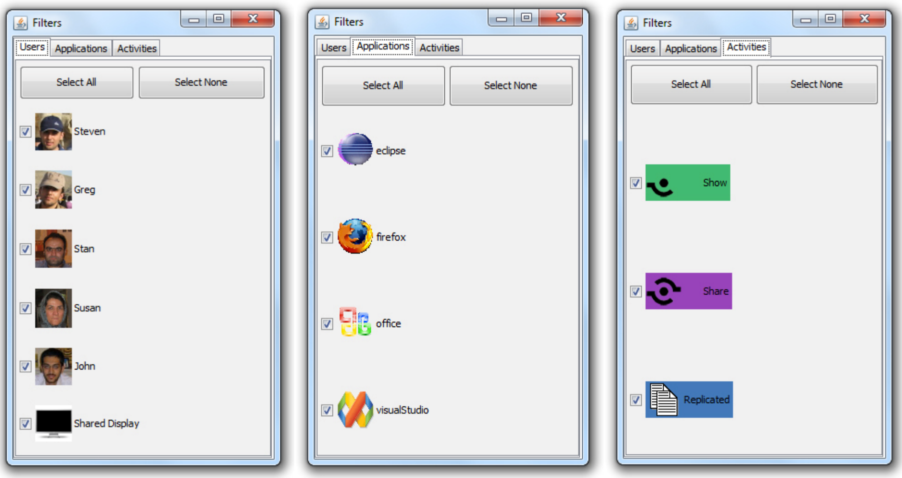

Fig. 5. The filtering window has three tabs for filtering out users, applications, and activities

Bob is a researcher interested in understanding how the use of an MDE affects collaborative software development. Of the many interaction frameworks available, Bob installs IMPROMPTU [4] to enable his study of MDEs. In his study, five developers utilize the MDE for four hours each day for two weeks. The MDE consists of five personal devices and a large shared display positioned such that all the developers can see it. During each evaluation session, he logs all of their activities and captures a video of each session. Now he wants to analyze the data collected to examine the use of the MDE. He writes an adaptor to convert each session's collected data to the XML format readable by VICPAM, He opens VICPAM and loads the first evaluation session by clicking on "File" and then "Load Session" on the menu-bar.

First Bob wants to determine which application is most frequently used in this session. He selects the entire session by using the slider in the time-bar. Then, he opens the spatial view and counts the number of times each application has been displayed in this view. He discovers that visual studio was the most frequently used application during the session. Then he would like to find the most active user. Again, using the spatial view while the entire session is selected, he identifies the most active user by counting the number of application icons in front of each user's representation. He learns that Susan was the most active user in the session.

Now he would like to examine the collaboration patterns among developers, e.g. whether all team members work together on a particular problem or there are two or more smaller groups of people who work separately on different aspects of the problem. He closes the spatial view and focuses on the time-aligned view. He frequently changes the selected time period using the slider and inspects the developer's activities. He detects an interesting pattern in the middle of the session. He sees in the time-aligned view that John, one of the developers, had shared a Microsoft Office application on the shared display and all team members replicated a copy of that on their personal machines. To explore this further, Bob plays the synchronized video and sees that the developers took turns to add the features for the next iteration of their software. This activity was marked as an example of group collaboration.

He continues changing the selected time period until he reaches the end of the session. He finds another interesting pattern near the end where Steven, a developer, has shared an instance of his Visual Studio and Greg has replicated that shared application on his own machine. By playing the video of their interaction, Bob discovers that they are reviewing Steven's code. Bob notes this activity as an example of peer-to-peer collaboration.

Using the views and interaction mechanisms provided in VICPAM, Bob was able to quickly answer his questions about the most frequently used software and the most active developer. He was also able to identify two interesting collaborative patterns that he can report. This was possible because VICPAM was designed to analyze the data captured from MDE evaluations. With other analysis techniques, Bob would not have been able to answer his research questions as easily.

3 Discussion

VICPAM is fully implemented in Java and consists of about 2,500 LOC. The user interface was developed in Java Swing and the video player was implemented using Java Media Framework (JMF). In order to make the code extensible, it was written in three layers; data, domain, and user interface (or presentation). The layered architecture enables other researchers to add new features or extend the tool to handle different data sets.

Three major iterations of development and evaluation were performed on VICPAM. After each evaluation, we modified the interface according to the lessons learned. For example, during one evaluation, we learned that users prefer to initiate their analysis from the time-aligned view rather than the spatial view. We therefore implemented the time-aligned view as the default and provided an option of adding the spatial view via a menu. We also implemented the time rulers to further support this preference.

Our tool was evaluated with only one set of data from a particular framework, IMPROMPTU [4]. However, IMPROMPTU is a highly flexible framework as it allows any existing application to be utilized in an MDE and also works with any combination of personal and shared devices. Therefore this framework can be used in other studies in MDEs. Also, the data collected from other MDE frameworks can be converted to the format compatible with VICPAM. Either the framework needs to be instrumented to log the interaction data in a compatible format, or an adaptor needs to be written that converts the existing format into a compatible format. VICPAM can even be adapted for analyzing data collected from different user and hardware configurations. For example, the tool can be used to analyze data collected from studies of single display groupware such as tabletops. There have been many evaluations of interactive tabletops for collaborative work and play [5, 10]. The data collected from these studies can be imported into VICPAM by modeling personal areas as personal devices and modeling the shared working area as a shared display.

4 Conclusions and Future Work

Researchers are beginning to study how the use of multiple display environments affects collaborative problem solving. To foster analysis and exploration of data gathered from these studies, we have designed and developed an interactive analysis tool called VICPAM.

VICPAM allows researchers to investigate different aspects of the interaction data by providing two different views of the data set: the time-aligned view and the spatial view. The time-aligned view shows people's activities and the exact duration of the activity. This view helps researchers detect collaboration patterns between users. The spatial view displays the users based on their positions in the workspace. This view provides an overview of the activities performed in the selected period of time. It can also be used to determine if users' positions affect their communication and collaboration patterns. Besides these views, a separate filtering window enables the researchers to filter unnecessary information and focus on their desired part of the data.

Although we built and tested our tool with a data set generated from the use of one interaction framework in one task domain, results from our study did reveal opportunities for improving the design of this type of interactive analysis tool. One improvement would be to add another view that includes statistical data either in the form of graphs or spreadsheets. For example a graph showing the total amount of activities at any point in time can help to identify busy periods as potentially interesting periods to investigate. Another improvement would be to provide data converters that could map the data gathered from studies conducted using different interaction frameworks and device configurations to the data format that our tool accepts. By using speech recognition and natural language processing techniques, group member statements related to their activities could be extracted from the session video and associated with their activity in the visualization. Finally, if the data set also includes screenshots of the actual documents that group members are sharing, each activity in the visualization could provide a link to the actual document shared.

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