

VICPAM: AN INTERACTIVE ANALYSIS TOOL FOR VISUALIZING  
INTERACTION AND COMMUNICATION PATTERNS IN MULTIPLE  
DISPLAY ENVIRONMENTS

BY

ROSHANAK ZILOUCHIAN MOGHADDAM

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Adviser:

Associate Professor Brian P. Bailey

# 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 consists of several components: (i) A spatial map view, which gives a 2D overview of all users' activities; (ii) a time-aligned view, which shows users' activities and the duration of each activity; (iii) the time slider, which can be used to adjust the period of time under study; and (iv) a video of the session synchronized with the timeline. The tool can reduce the effort necessary to analyze and make sense of users' interaction data in MDEs.

*To Father and Mother.*

# Acknowledgments

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# List of Abbreviations

MDE            Multiple Display Environment.



# Chapter 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 devices, and all computers are connected via a network [19]. Colab [19], iRoom [12], and OCEAN-Lab [21] are examples of such environments.

With many instances of MDEs available, researchers are beginning to study how their use affects collaborative problem solving. For example, Biehl et al. [1] recently studied the use of MDEs in the context of group programming. In order to evaluate the environment, all interactions between group members and devices are typically captured, e.g. which applications were shared, what devices were involved, and at what time. 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.

A common method for analyzing interaction data from MDEs (and other) evaluations is the use of spreadsheets. Spreadsheets can be use to record and examine the data in a structured manner, but they do not allow interaction with the resulting visualizations. Interactive analysis is important for making sense of large and complex data sets [4]. Many interactive visualization tools have been developed to make sense of complex data in myriad domains. Examples include ManyEyes [22], DEVise [13], and sense.us [6]. However, these and other interactive analysis tools have not been targeted to meet the unique analysis needs of MDEs. More specifically, these tools are not useful for investigating patterns and clusters, although they are suitable to get an overview of the data.

In this work we describe the design and use of VICPAM (Visualizing Interaction and Communication Patterns in MDE's), an interactive analysis tool for analyzing interaction data gathered from studies

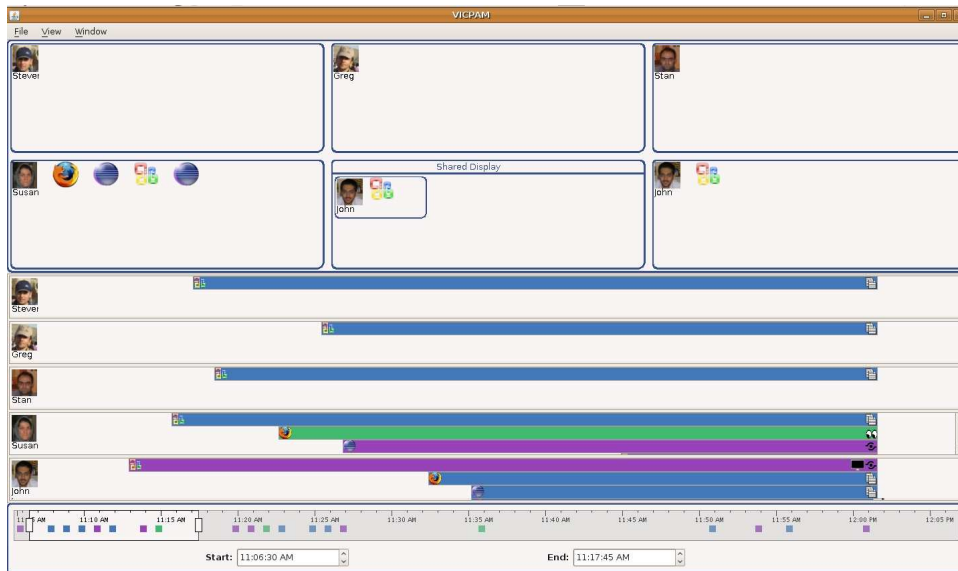


Figure 1.1: This shows the main interface screen of VICPAM. The map view is on the top and the time aligned view is at the bottom.

within MDEs (Figure 1.1). Though it was designed with MDEs in mind, the tool can 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 multi-user surfaces [17]. Analysis of multi-user surfaces can be achieved by modeling personal areas as personal devices in our tool and modeling the shared working area as a shared display. Several studies have been done in the domains of multi-user surfaces that can be visualized in VICPAM without any significant changes. For instance, Fiebrink et al. [5] evaluated the effectiveness of an approach that offers precise control for tabletops. In their environment of interest they have provided a single, shared multi touch display area and several small physical controllers for users. The data they have collected from their study can be easily imported into VICPAM by mapping the shared multi touch area to the shared display in VICPAM and mapping the small physical controllers to the personal displays.

# Chapter 2

## Related Work

### 2.1 Multiple Display Environments

A multiple display environment (MDE) is a physical workspace which contains some personal and shared devices which are connected together via a network. The goal of the workspace is to provide users with the ability to create, share, and organize electronic task artifacts among the devices in the workspace during group or individual problem solving [12].

Colab [19] is one of the first MDEs. This MDE has been set up in Xerox PARC. Colab has been designed to support collaboration and enhances problem solving in face-to-face meetings. The focus of Colab project is to increase the effectiveness of face-to-face meetings. The Colab project consists of different tools to support different meetings. “Boardnoter” is one of the tools that has been designed for informal meetings. This tool replicates the functionality of chalkboard. It also provides capabilities like copying, moving, resizing, etc. “Cognoter” is another tool that has been designed for formal meetings. This tool helps with organizing ideas for a presentation. Another tool that has been designed for formal meetings is “Argnoter”. This tool facilitates considering and evaluating various proposals.

Other examples of MDEs are iRoom [12], and OCEAN-Lab [21]. The iRoom contains three touch sensitive large displays, a custom-built 9 mega-pixel diagonal display, and a table with a  $3 \times 4$  foot display. A software infrastructure has been created for this environment called iROS (Interactive Room Operating System). The types of activities that the user can perform in the iRoom are: moving data between different applications that run in various screens and moving control of a device or an application. Also the iRoom should provide dynamic application coordination which means that activities of different tools should be coordinated. The interactive aspects of the iRoom has been designed so that the user can focus on the task itself rather than the interaction.

## 2.2 Studies in MDEs

A great number of researchers have investigated the use of MDEs for individual and group work. One aspect of research efforts in MDEs is investigating the effects of different configurations of personal and public devices. Streitz et al. [21] conducted a study to compare three different configurations: WS condition in which a networked compact workstation has been provided to each individual in the room, WS + LB condition in which a live board was also networked with the workstations in the WS condition, and LB condition in which only the liveboard was available. They have gathered different kinds of data from their study. For example, they video recorded the entire study. Also they have logged system interactions of the subjects with their system.



Figure 2.1: An example of a multiple display environment used in studies (from impromptu paper [2]).

A variety of other studies have been conducted in MDEs, each seeking answers to a definite set of questions. Biehl et al [1] compared different classes of interfaces: textual, map, and iconic in collaborative activities in MDEs. During their study, they collected different sets of data such as how users interacted with the MDE, the interfaces, and each other. They have also collected some quantitative data. They used all these data to compare textual, map, and iconic interfaces in collaborative activities. In another study, Biehl et al [2] studied the effectiveness of their tool, IMPROMPTU which is an interaction framework that was designed to foster collaboration in MDEs (Figure 2.1). In their study, they have gathered the usage data of this tool. The data included the

applications that have been shared and the duration of share, the device that applications have been shared on, how often input redirection was used, etc. The data has been gathered to investigate the effectiveness of IMPROMPTU.

Izadi et al [11, 3] proposed a system called “Dynamo” which enables users to share and exchange information in unfamiliar public places (Figure 2.2). They ran a study on Dynamo to find out how people use their tool. During the study they have logged users interactions with the system.

In all these studies, researchers have to analyze the interaction data they had collected in their studies to answer their study questions. In order to analyze the data, they have to use tools which were not specifically designed for MDEs, such as text editors, statistical analysis software like SPSS, spreadsheets, etc. Since these tools are not specific to MDEs, researchers have a hard time analyzing and making sense of the collected MDE data using these tools. Besides, these general purpose tools do not provide researchers with the ability to investigate some important aspects of the data such as collaboration and interaction patterns. Researchers could have explored the MDE data more effectively by use of an interactive analysis tool like VICPAM which targets MDEs.



Figure 2.2: A screen-shot of dynamo (from dynamo paper [11, 3]).

## 2.3 Single Display Groupware

Besides MDEs, there are Single Display Groupware (SDG) systems that support group collaboration. Examples of such systems are tabletops and interactive spheres. Tabletops provide a single display that allows several users to collaborate by sharing control over the display. A broad range of

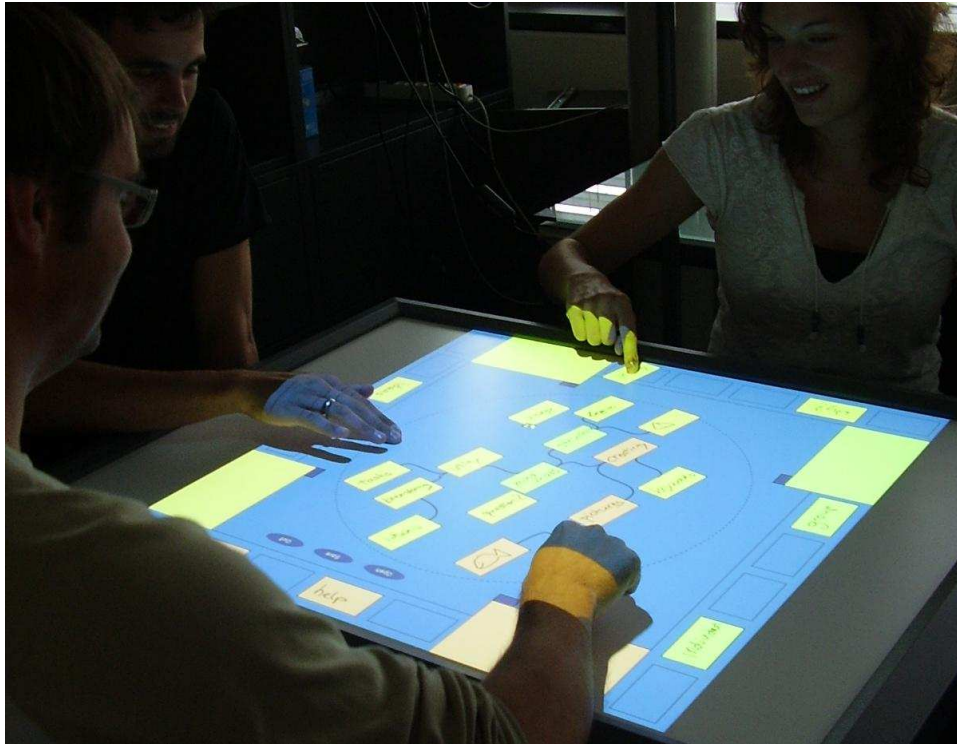


Figure 2.3: Users are collaborating on a tabletop(from Hinrichs et. al. paper [7]).

collaborative activities are supported by tabletops from Photo sharing [18] and document sharing [20] to planning and organizing [16]. Figure 2.3 shows a tabletop system which is used by three users simultaneously.

Similar to MDEs, collaboration and interaction patterns are one of the important aspects that researchers are interested to investigate in their studies on tabletops. Due to the resemblance of goals and tasks in MDEs and tabletops, mapping the data gathered from one system to the other is straightforward. The shared area on the tabletop can be mapped to the shared display in the MDE, and the personal working areas on the tabletop can be mapped to personal displays in the MDE. The similarities of these two systems and the great number of studies that have been conducted in both systems suggest developing an interactive analysis tool which support both MDEs and tabletops and any future system that has some commonalities with these systems.

Several studies have been conducted on tabletops, for instance Piper et al [15] designed and evaluated a tool called SIDES which helps adolescents with Aspergers Syndrome practice group work skills. They have done a study on their tool to find out whether their tool facilitates social skill development for their specific audience. During the study, they logged all the interactions

of users and the system, and they video taped the whole study. Hinrichs et al [7] evaluated the concept of Interface Currents in tabletops and explored users' interaction with Interface Currents. An Interface Current is an interface component that has a directed flow. During their study, they logged the participants' interactions with the digital tabletop to a data file. They also video taped the entire session. The interaction data gathered from these studies can be further explored by use of an interactive analysis tool like VICPAM. VICPAM enables the researchers to analyze and interact with the interaction data that they have logged in their studies. Besides, the video player component of this tool lets the researchers to refer to their recorded video when necessary.

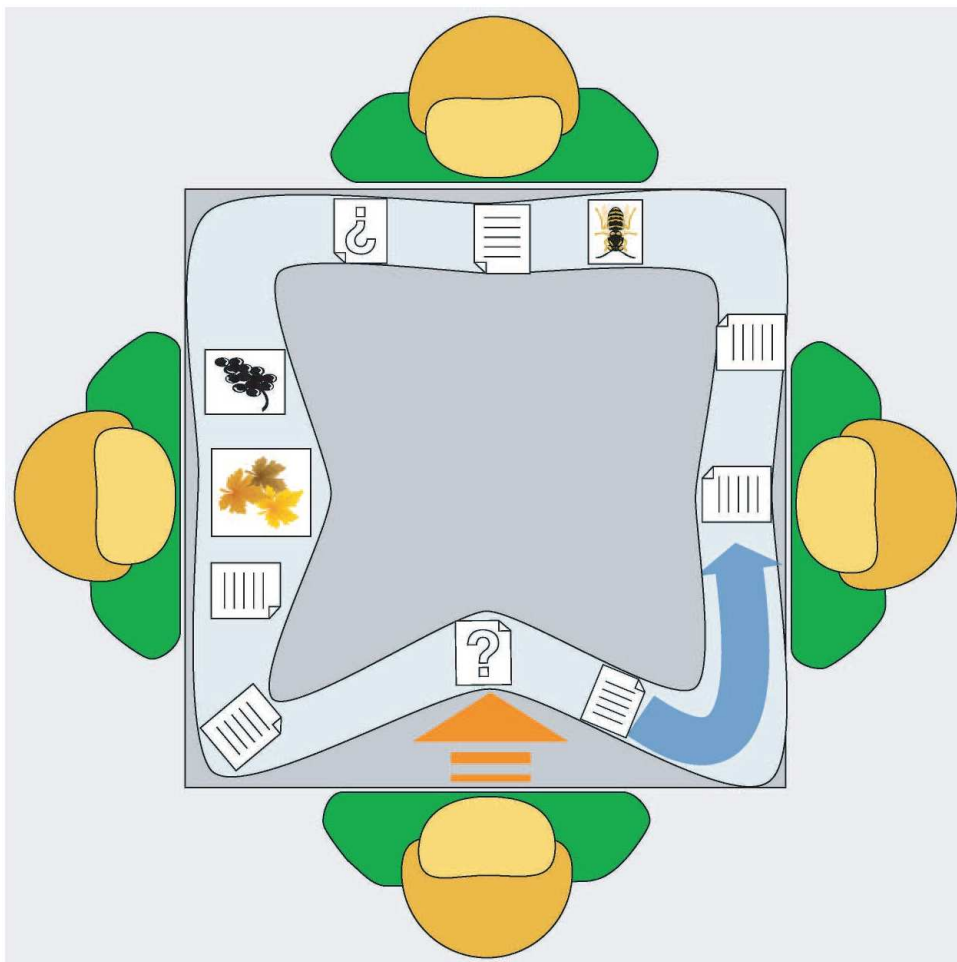


Figure 2.4: An example of Interface Current component (from Hinrichs et. al. paper [7]).

## 2.4 Interactive Analysis Tools

Interactive analysis tools have been created in several domains. Google [8] and Yahoo [9] Finance in stock and marketing, profilers and debuggers in software development and engineering, and Nasa's Hurricane analysis tool [14] in earth science and geoinformation are all examples of such tools. The value and need for such tools in different domains is clear. Interactive analysis tools enhance data analysis by providing the researcher with ability to interact with the data set. The way of interaction they support may vary depending on the nature of data under study. For instance, these tools may provide different views of the data to let the researcher view the data from different aspects. Or they may provide some filtering options which let the researcher to focus on a desired part of the data.

An interactive analysis tool in the domains of MDEs and tabletops will not only help the future studies in these domains, but will also provide the researchers with the opportunity to go over their past studies and find interesting results that they may have missed. COPROT [21] was the first interactive analysis tool designed for exploring data gathered from studies in MDEs. This tool helped researchers to find different cooperation modes and the time spent in each mode during a group meeting in an MDE. Depending on the number of group members, the number of cooperation modes may vary. For instance, with a group of 4 people, 15 different cooperation modes can be distinguished. The interface of COPROT includes one icon for each cooperation mode (Figure 2.5). The researchers had to watch the video and specify different cooperation modes used during the meeting by pressing the associated icon. While COPROT has been mainly designed for recording different cooperation modes only by watching the video, VICPAM has been designed to help the researcher find the cooperation modes or collaboration patterns based on the interaction data and the video of the session.

Another set of analysis tools in this domain is WorkspaceNavigator [10]. These tools have been designed to capture, recall, and reuse the digital information that has been generated by a group of people in an interactive workspace. The focus of these tools is on capturing the information to recall the rationals of decisions and the discussions in a group in future. However, VICPAM targets exploring data in order to investigate the collaboration and communication patterns between group members.

In designing VICPAM, we extended existing visualization techniques to create a tool which enables researchers to visualize and interact with the data they have collected from their studies in MDEs. Moreover, due to the ease of mapping MDEs and tabletops, VICPAM can be also used to



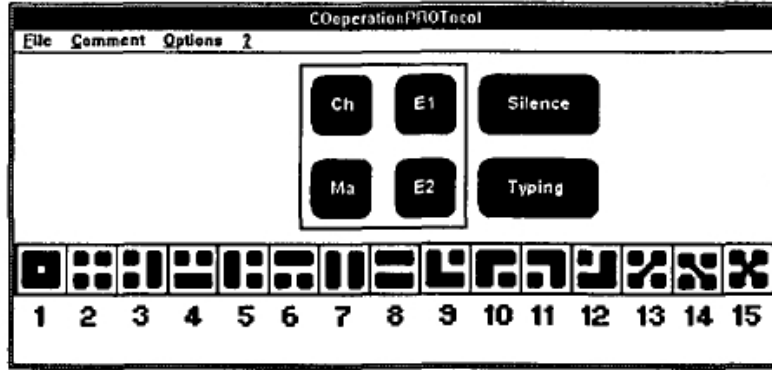


Figure 2.5: The interface of COPROT with buttons for recording cooperation modes (1 to 15)(from Streit et al. paper [21]).

visualize data came from the studies on tabletops.

# Chapter 3

## VICPAM

VICPAM is an interactive visualization tool which helps researchers evaluate their systems and analyze the results of their studies in MDEs. This tool has four main components: (i) *The map view*, which shows all users' activities in the environment during a selected period of time (for example the programs that they have shared with each other or shared via the large display)(Figure 3.1); (ii) *The time aligned view*, which shows users' activities and the exact duration of each activity(Figure 3.2); (iii) *The time slider*, which can be used to adjust the period of time under study(Figure 3.3); (iv) *The synchronized video player* which plays the video of the session under study(Figure 3.4).

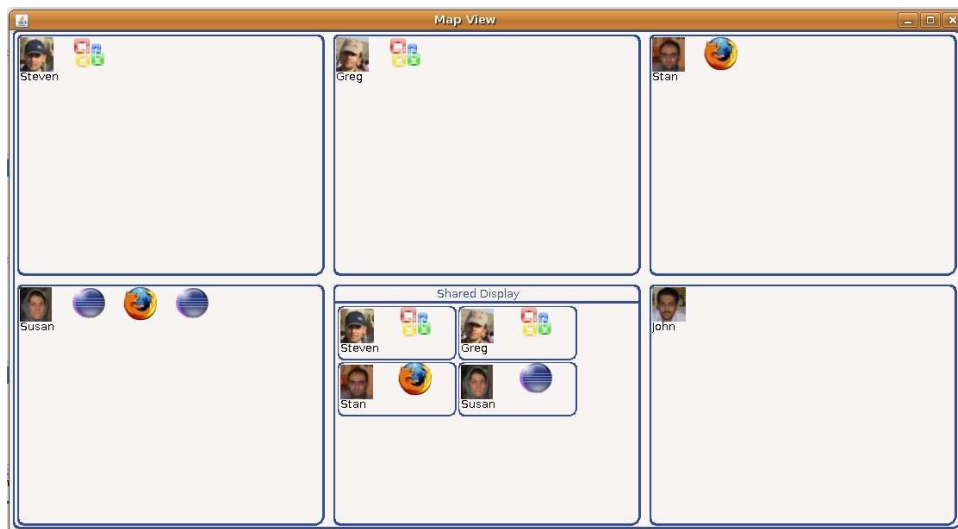


Figure 3.1: From the map view, the user can get an impression of people's position in the room. The user can also get an overview of the type of applications that people are sharing.

### 3.1 Data Background

We analyzed various studies and evaluations in MDEs in order to determine the requirements of an analysis tool. We built VICPAM to address those requirements. So, VICPAM can be used to

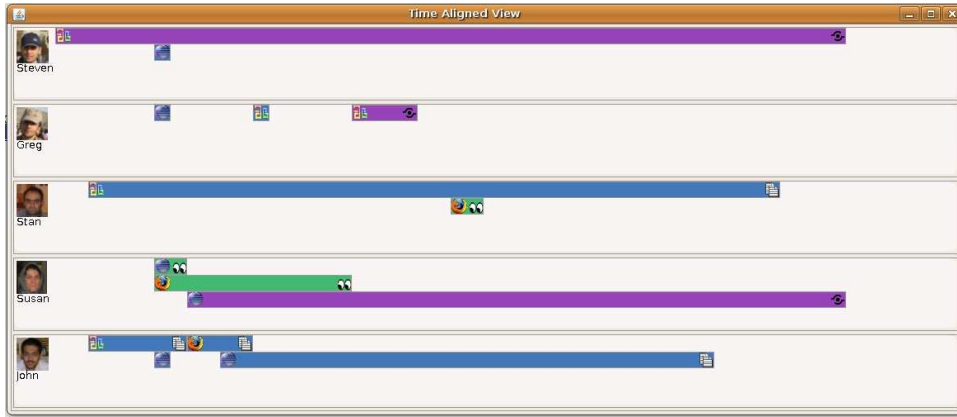


Figure 3.2: From the time aligned view, the user can find the exact time that a particular team member shared an application and the duration of the share.

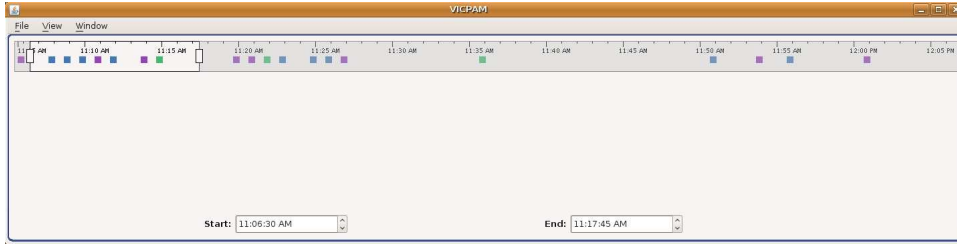


Figure 3.3: The user can adjust the duration of time under study by use of the time slider.

analyze data came from any configurations of MDEs. In this chapter, we will describe VICPAM in the context of a particular set of data. The data was collected in studying IMPROMPTU which is an interaction framework that facilitates group work [2]. The group under study were software developers who used IMPROMPTU in their meetings. IMPROMPTU logged the usage data during their meeting. This data includes the which applications had been shared or shown and for how long, etc. Besides the usage data, a video of the meeting has been captured by a camera. The data that we have chosen to explore are the log file and the video. For simplification purposes we made a smaller set of data based on the original data set and we used the simplified data set to evaluate our tool.

The data contains three different user activities for any application: (i) Show, which means the application window is available to the group in the view-only mode. So, group members can view contents of the window if they replicate the window; (ii) Share, which means the application window is available to group members and everyone can interact with its content if they replicate it on their own machines; (iii) Replication which means one of the group members copied an instance of a



Figure 3.4: The user can watch the video of the session under study by use of the video player.

shared or shown application on his personal machine. Group members can also share applications on the shared display.

In the following, we describe how the interactions logged in IMPROPMTU can be converted to the VICPAM input format. VICPAM accepts an XML file as an input. The key tags in the XML file are `<entry>`, `<user>`, `<application>`, `<activity>`, `<device>`, and `<time>`. Each entry in the IMPROPMTU's log file can be mapped to an `<entry>` block. User and application names go under the `<user>` and `<application>` tags, respectively. User activities i.e. share, show, and replication should be placed under the `<activity>` tag and the `<device>` tag will indicate whether the application has been shared on the shared display or a personal machine. Finally, the duration of the activity goes under the `<time>` tag.

## 3.2 Visualization

Figure 1.1 shows the map view and the time aligned view of VICPAM. The map view is a general view of the activities people have performed in the environment. In the map view shows a box for each person in the MDE. Each box includes the picture of the person and the applications that he

has shared or shown with others. Further, there is a box for the shared display. This particular box includes the applications that has been shared in the shared display along with the picture of their owners.



Figure 3.5: The first bar shows that an instance of Microsoft Word has been shared in the shared display. The second bar shows that some one has replicated an instance of Microsoft Word. And the third bar shows that someone has shown an instance of Firefox in his personal display.

The time aligned view is a more detailed view. This view includes both the activities and the duration of each activity. The time aligned view also shows the applications that a particular person has been replicated from another person. In the time aligned view, there is a rectangular space in front of each person. This space includes all the activities that the person has performed. The activities have been shown by bars. These bars represent the following information about each activity: i) type of the activity (e.g. show, share, and replication), ii) information about the application, iii) information about the device that application has been shared or shown on. The type of the activity has been represented by the color of each bar and an icon on the right side of the bar: green represents share, purple represents show, and blue represents replication. The application icon has been placed on the left side of the bar. If the application has been shared on the shared display another icon will be shown on the bar next to the activity type icon. Figure 3.5 shows some sample bars.

The time bar will enables the user to select the time period that she wants to focus on, the time period can be as small as a second or as large as the entire session. By changing the selected period of time in the time bar, both the map view and the time aligned view will be updated. These views will only includes the activities that has been performed in the selected period of time.

All of the bars in the time aligned view are interactive. By hovering the mouse over one of the bars in time aligned view, the person who has shared or shown that application will be highlighted. Also all of the replications of that application in the time aligned view will be highlighted (Figure 3.6). If that bar represents a replication itself, the bar which represents the source application will be highlighted. Also the owner and the associated application in the map view will be highlighted (Figure 3.7). By hovering the mouse over the picture of a person in the map view all the applications

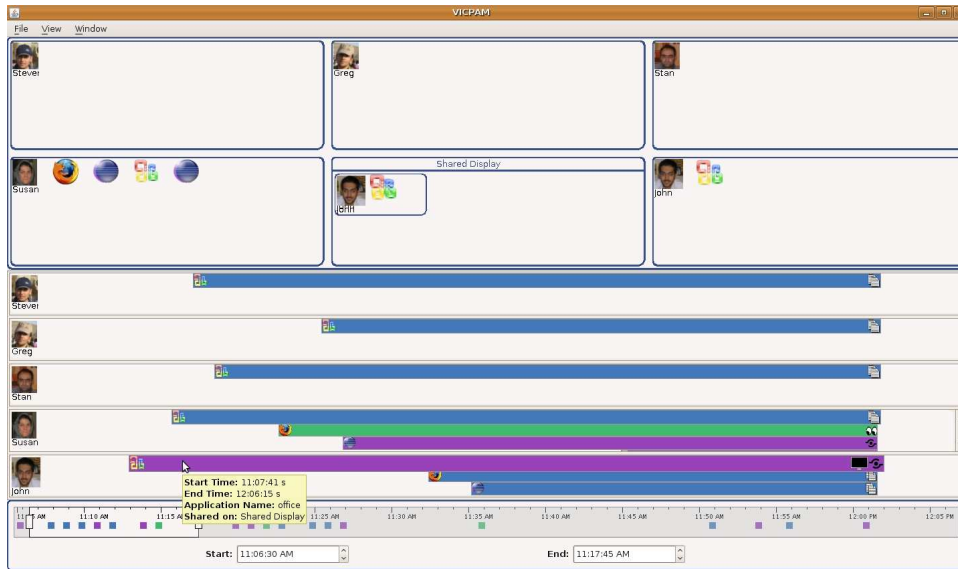


Figure 3.6: When the user hovers the mouse over one of the bars in time aligned view, the picture of the person who has shared or shown that application will be highlighted. Also all of the replications of that application in the time aligned view will be highlighted.

that she owns in both views will be highlighted (Figure 3.8).

These views are adjustable to match user's needs and overcome the challenges of representing large data sets. For instance the user can right click on the map view or the time aligned view and open these views in a new window (Figure 3.9). This will not only facilitate exploration of large data sets in each of these views, but also will allow the user to focus on one view at a time. Moreover, the size and place of the artifacts inside the time aligned view and the size and place of both view windows can be adjusted.

### 3.3 Video of Interaction

The video captured from the session can be imported and played in a separate window. The video is aligned to the same time-line as the map view and time aligned view.

### 3.4 Filtering

A separate filtering window shown in figure 3.10 is available for researchers to filter the data based on the applications, the users, and the activities that users can perform in the MDE under study, e.g. share, show and replication. The filtering window has three separate tabs. The first tab includes

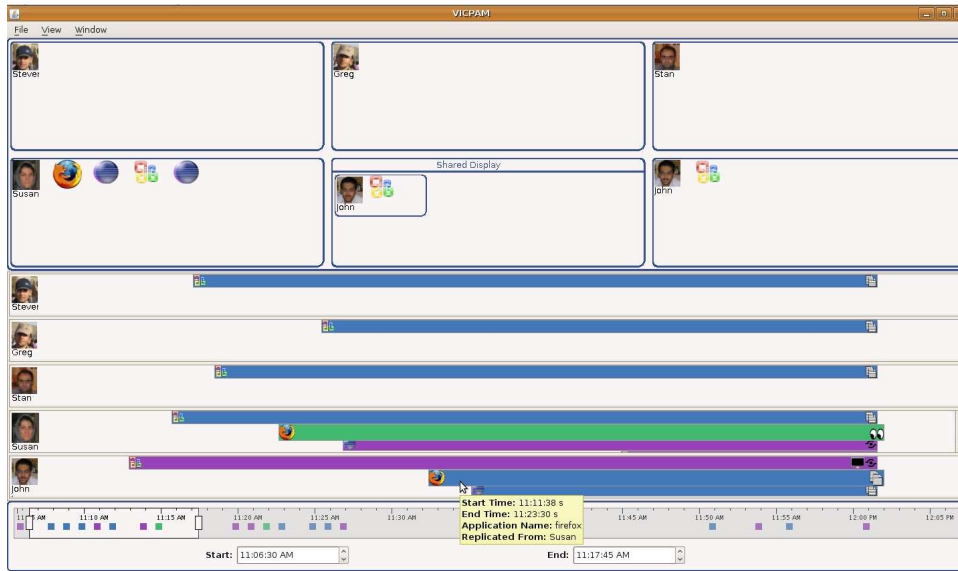


Figure 3.7: When the user hovers the mouse over a bar that represents a replication, the bar which represents the source application will be highlighted. Also the owner and the associated application in the map view will be highlighted.

the list of team members in the MDE, they can be selected by clicking on the check-box next to them. The next tab includes the list of applications that has been shared or shown during the entire session. And the last tab includes the activities users can perform in the MDE. In each tab, “select all” and “select none” buttons are available for convenience.

By filtering out data, researchers can focus on their desired part of the data and avoid possible confusion which can arise from facing a lot of information at once. According to the feedback that we have got from our preliminary evaluations, filtering options help researchers to answer focused questions, e.g whether two particular team members have any interactions during the session. Figure 3.11 shows the map view and the time aligned view when the user filtered out all team members except John and Stan.

### 3.5 Putting it Altogether

We used the data described in the “Data Background” section to illustrate features of our tool. Upon starting the tool, the user needs to load a desired session. By loading a session, the time aligned view of the session is shown. The video of the session is loaded and the filtering window is filled with filtering options related to the session. Figure 3.12 shows the basic visualization. In order to see the map view the user should click on “Show Map View”. Figure 1.1 shows the visualization

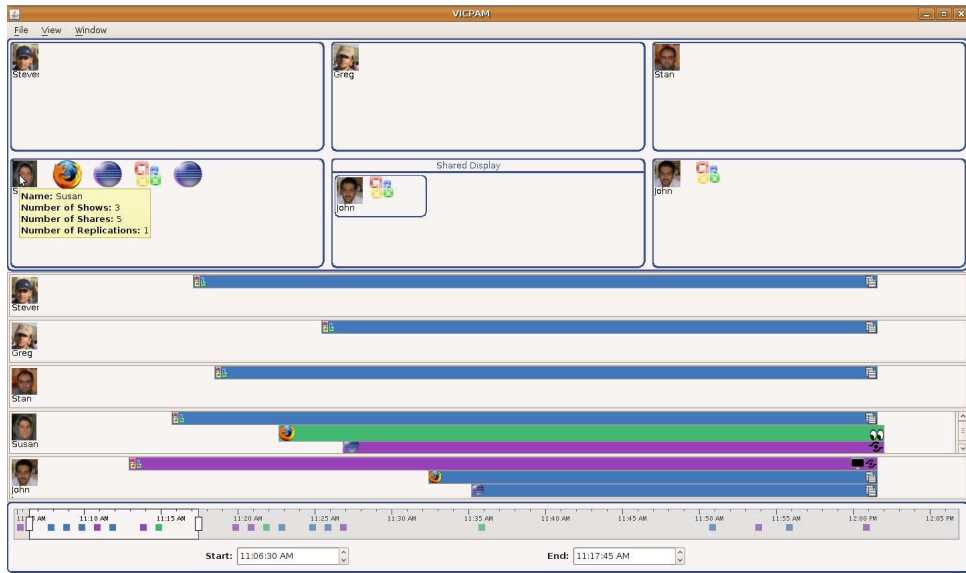


Figure 3.8: When the user hovers the mouse over the picture of a person in the map view all the applications that she owns in both views will be highlighted.

with both views open.

From the map view, the user can get an impression of people's position in the room and see if their positions affect their communication and interaction patterns. The user can also get an overview of the type of applications that people are sharing. From the time aligned view, the user can find the exact time that a particular team member shared an application and the duration of the share.

The user should interact with the tool in order to find out 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? In the particular set of data that we used to evaluate our tool two kinds of collaboration patterns can be detected: group collaboration and peer-to-peer collaboration.

In order to see the group collaboration the user needs to set the timebar at the start of the session. She can see in the time aligned view that John, one of the developers, had shared a Microsoft Office application onto the shared display and all team members have replicated a copy of that on their personal machines(Figure 3.13). To explore this further, user may play the video related to this part of the session and she will be able to see that they have taken turns to add features they thought had to be added to the next iteration of their work.

Besides the group collaboration explained above, there is also peer-to-peer collaboration. If the



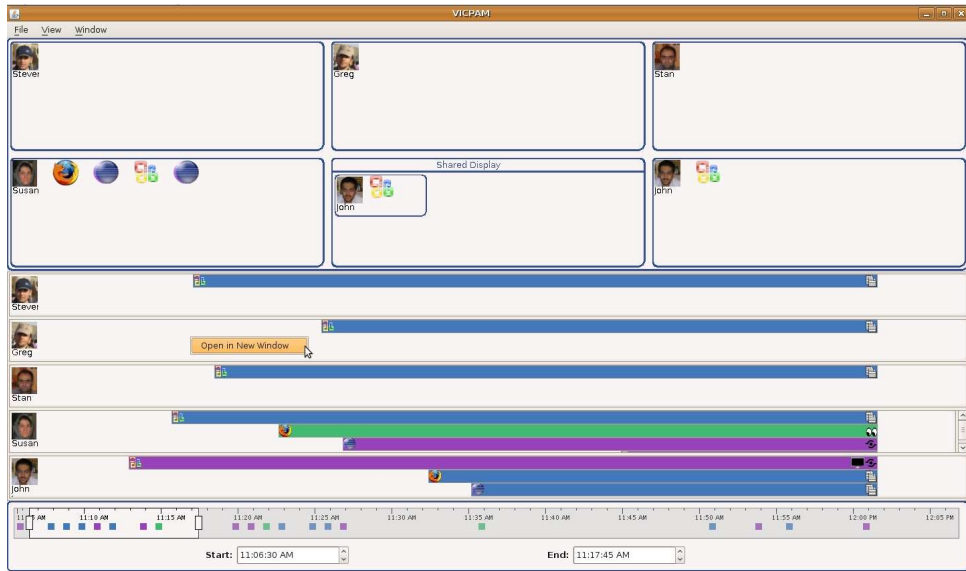


Figure 3.9: The user can open the map view or the time aligned view in a new window by right-clicking on them.

user positions the timebar at the end of the session, she can see that 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 user can see that they are reviewing Steven's code(Figure 3.14).

At the same time we can see in the time aligned view that John has shared an instance of Visual Studio and Stan has replicated the application. In the video we can see that John had a compile error and Stan was trying to help him in finding the issue(Figure 3.14).



Figure 3.10: This filtering window has three tabs for filtering out users, applications, and activities.

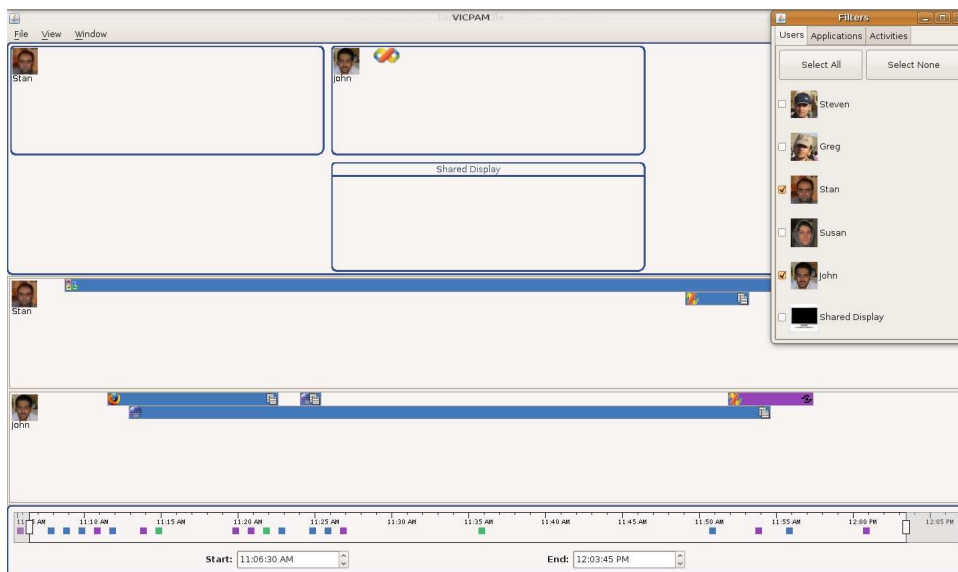


Figure 3.11: The user filtered out all team members except for John and Stan.



Figure 3.12: The time aligned view which is the default view of VICPAM.

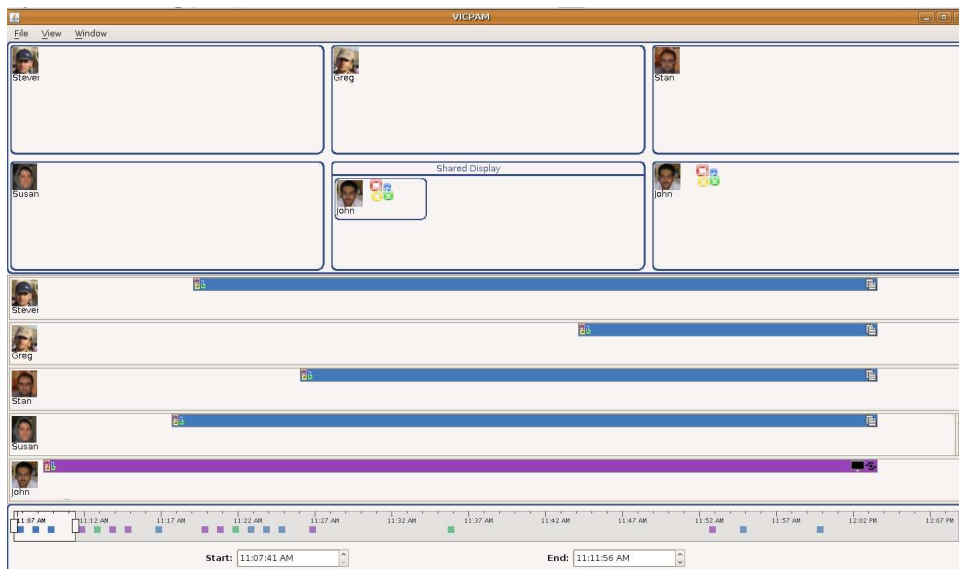


Figure 3.13: John has shared a Microsoft office application onto shared display and all other team members have replicated a copy of that.

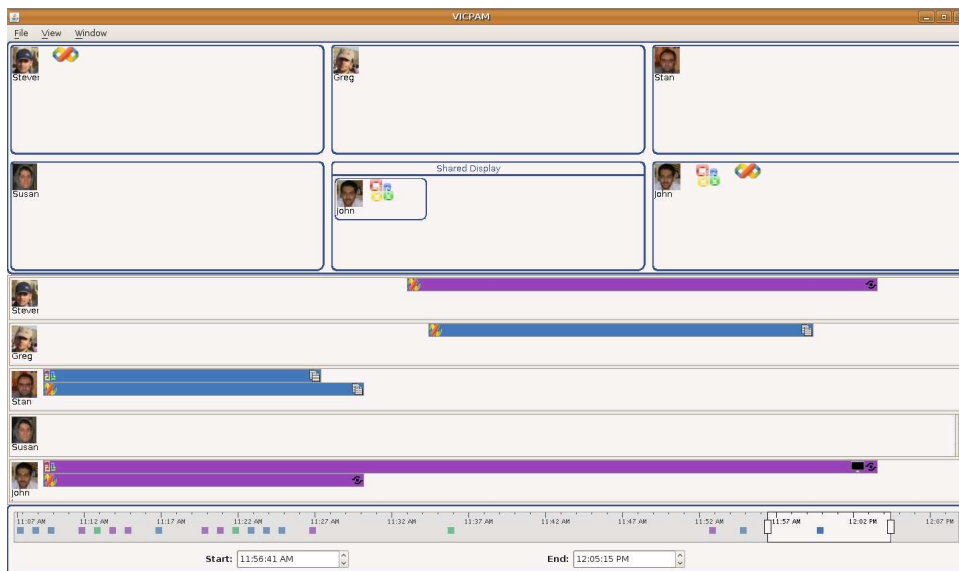


Figure 3.14: Steven has shared an instance of Visual Studio application and Greg has replicated a copy of that. At the same time John has shared an instance of Visual Studio and Stan has replicated that. In this view all other team members and applications have been filtered out.

# Chapter 4

## Iterative Design

### 4.1 Iterative Design Process

The tool was created through an iterative design process. More specifically, three major iterations of paper prototyping and three major iterations of implementation have been performed. Each iteration has been followed by an informal evaluation to confirm the effectiveness of the tool and understand how to improve it. According to the outcome of each evaluation, the interface has been changed according. These changes resulted in a less complex visualization and more intuitive interaction. Figures 4.1 and 4.2 show the time aligned view and the map view in the last version of the paper prototype.

### 4.2 Evaluating the Prototype

After several iterations on the paper prototype, but before starting the implementation, we performed an informal study on the prototype. The study had five participants who were computer science graduate students at the University of Illinois at Urbana-Champaign. At the beginning of the study, we provide them with basic background information about MDEs and a short introduction to the goals of the tool and its features and functionalities. Then we gave them some tasks to perform on the paper prototype. There were two categories of tasks: easy tasks and complex tasks. The easy tasks were relatively straightforward to perform, “*Suppose you want to investigate the programs that have been shared on the shared display, how would you do that?*” is an example of an easy task. On the other hand, the complex tasks needed more attention and took longer to perform, “*Find a user who had the most shared and shown applications.*” is an example of a complex task. Both easy and complex tasks helped us in discovering several issues that we resolved before starting the implementation.

One of the issues in our initial prototype was that the interface was cluttered. Because we had

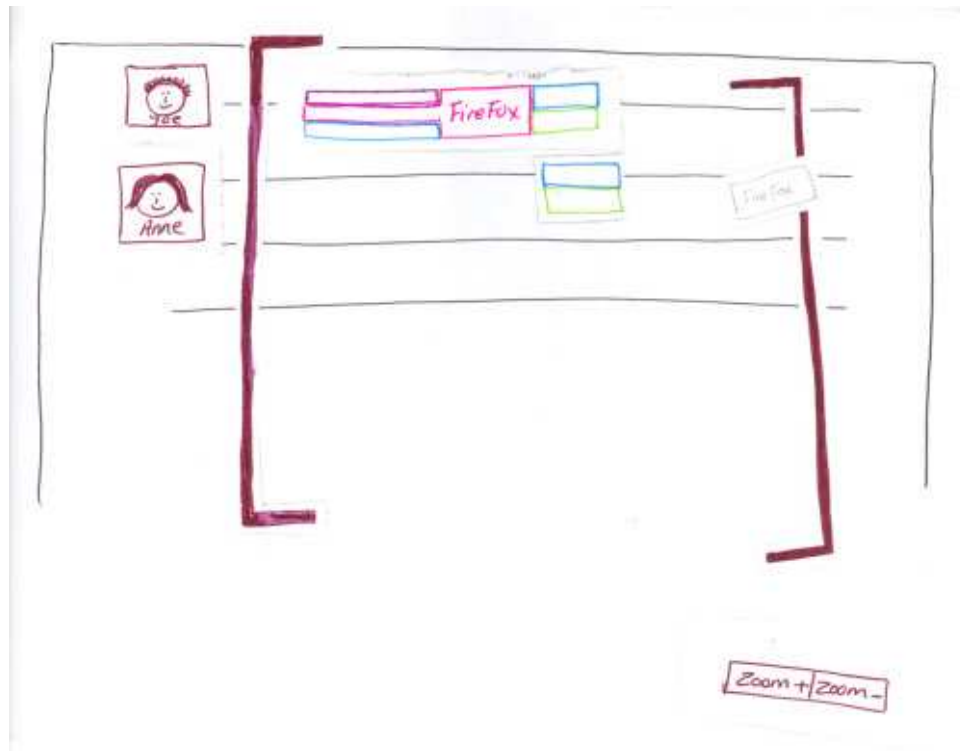


Figure 4.1: The time aligned view in the paper prototype.

drawn some lines to show participants' interaction with applications shared by others. When there were a lot of interactions in the data the visualization became cluttered, since we had to draw a lot of lines to show all the interactions. In order to solve this problem instead of connecting participants and applications by lines, we highlight the applications that a particular participant has interacted with when the VICPAM user hovers the mouse over the participant's icon. This way, we avoid cluttered visualization by gradually revealing information. Figures 4.3 and 4.4 show how artifacts will be highlighted in VICPAM.

We also discovered during the evaluations that users prefer the time aligned view, but our focus at that time was on the map view. The preference of the time aligned view over the map view may be because of the important role that timing will play in the analysis tools like VICPAM. Time is an important aspect in exploring and analyzing data. So, we made the time aligned view to be the default view and we let users add the map view through the menu.

Another issue that we resolved through our preliminary evaluations was distinguishing different types of activities that people can perform in an MDE e.g. share, show, replication. We differentiate these activities by color and icon.

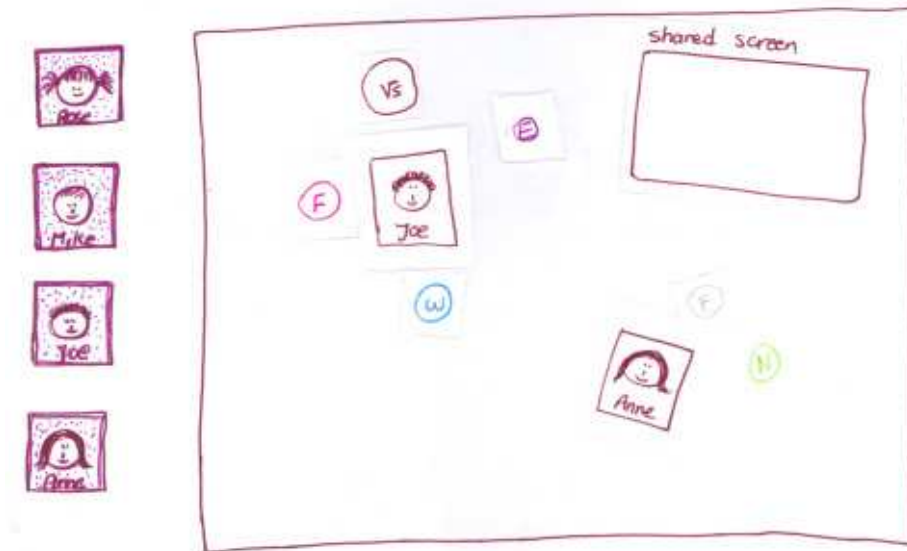


Figure 4.2: The map view in the paper prototype.

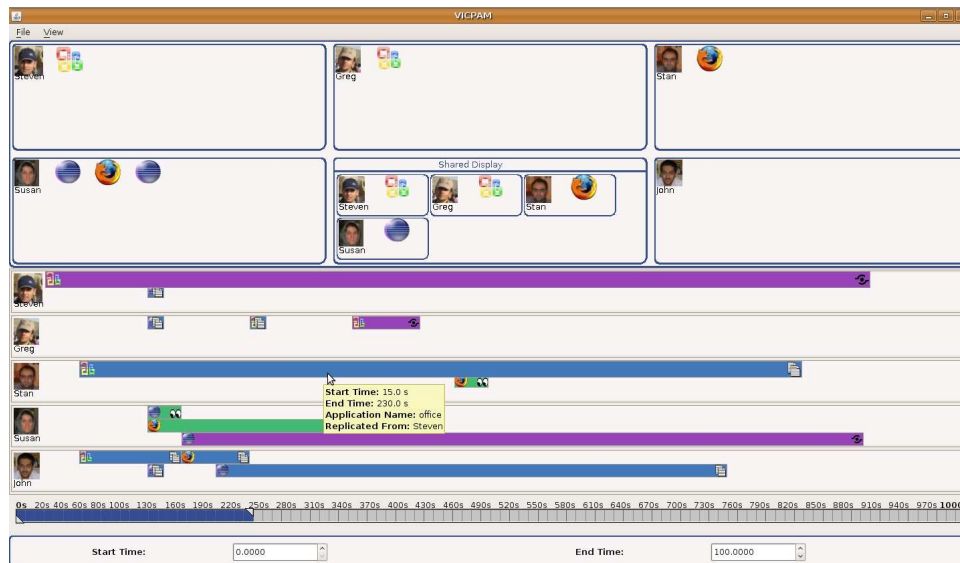


Figure 4.3: When the user hover over a replicated application, the source application and the owner of the source application will be highlighted. In this case, Steven has shared a microsoft office application and Stan has replicated the application.

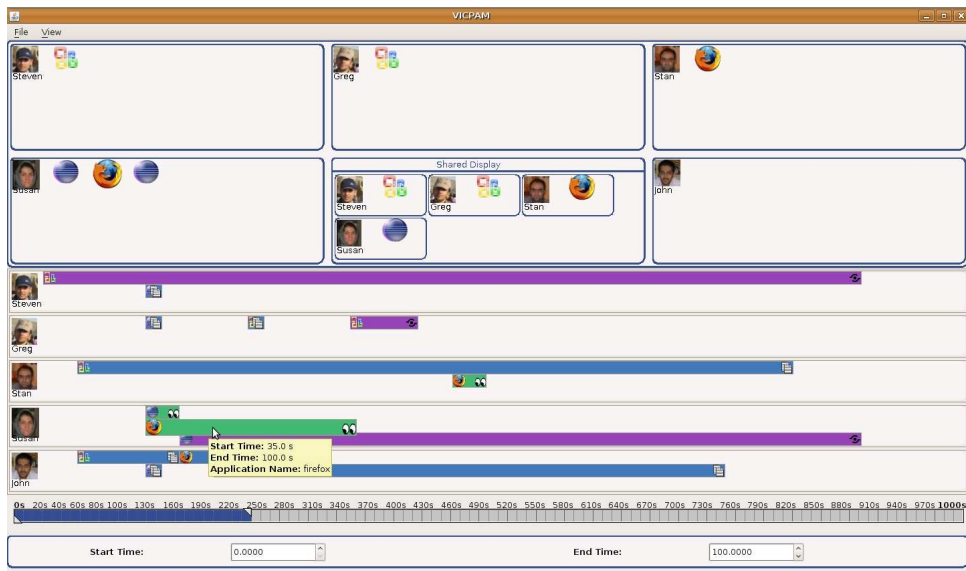


Figure 4.4: When the user hover over a shared or shown application in time aligned view, the corresponding application in map view and the owner of the application will be highlighted. In this figure, Susan has shown a web browser.



## Chapter 5

# Implementation

VICPAM was written in Java and consists of about 2,500 LOC. Swing API has been used for developing the user interface components and JMF has been used for playing the video. Although Swing didn't let us implement all the design ideas that we had in our paper prototype, it helped us implementing most of our ideas in a clean and structured way.

In order to make the code modifiable and extensible, the tool has been implemented as a layered architecture which consists of three layers of data, domain, and user interface(or presentation). The layered architecture will enable users to add new features and extend the tool to handle their desired set of data. Further, similar portions of the user interface have been factored out in to reusable components. For instance, the time aligned view keeps similar information for each user. All these similar information has been placed in one reusable component called "TimeAlignedViewComponent". Then for each user an instance of this component has been created and filled with that user's information. These reusable components made the code more organized. Besides, each visual component has been implemented in a separate Java class. This separation has made the code more readable and reusable. In general, by implementing VICPAM we found out that creating reusable components and separation of concepts are two important rules to respect in implementing such tools.

VICPAM reads the data from an XML file and makes a visualization out of the data. The file should consist of *<entry>* blocks and one *<total duration>* tag which indicates the duration of entire session. In each *<entry>* block there is a *<user>* tag which includes the user name, an *<application>* tag which includes the application name, an *<activity>* tag which includes the type of activity the user has performed, a *<device>* tag which includes the device that user performed the activity on (personal device or shared display), and a *<time>* tag which contains *<start>* and *<end>* tags and specifies the duration of the activity. Figure 5.1 shows five sample entries. The code can be easily extended to include different user activities depending on the configuration of the MDE under study.

```

<entries>
<totalduration>250</totalduration>
<entry>
  <entryID>1</entryID>
  <user>Susan</user>
  <application>res/eclipse.gif</application>
  <activity>show</activity>
  <device>shared display</device>
  <time>
    <start>30</start>
    <end>40</end>
  </time>
</entry>
<entry>
  <entryID>2</entryID>
  <user>Steven</user>
  <application>res/eclipse.gif</application>
  <activity>replication</activity>
  <fromentryID>1</fromentryID>
  <device>personal</device>
  <time>
    <start>35</start>
    <end>40</end>
  </time>
</entry>
<entry>
  <entryID>3</entryID>
  <user>John</user>
  <application>res/eclipse.gif</application>
  <activity>replication</activity>
  <fromentryID>1</fromentryID>
  <device>personal</device>
  <time>
    <start>35</start>
    <end>40</end>
  </time>
</entry>
<entry>
  <entryID>4</entryID>
  <user>Greg</user>
  <application>res/eclipse.gif</application>
  <activity>replication</activity>
  <fromentryID>1</fromentryID>
  <device>personal</device>
  <time>
    <start>32</start>
    <end>38</end>
  </time>
</entry>
<entry>
  <entryID>5</entryID>
  <user>Susan</user>
  <application>res/firefox.gif</application>
  <activity>show</activity>
  <device>personal</device>
  <time>
    <start>35</start>
    <end>100</end>
  </time>
</entry>
</entries>

```

Figure 5.1: This figure shows five sample entries and their contents.

# Chapter 6

## Evaluation

To evaluate the final product, we performed an informal usability test. In our test, first we gave the participants an overview of the tool, then we asked them to perform 7 tasks.

### 6.1 Participants

The study had three participants, one male and two female, from 23 to 27 years in age. All participants were graduate students in Computer Science. Each subject was introduced to VICPAM interaction methods and functionalities, then they were asked to perform 7 tasks. The study ended by filling out a post-study questionnaire.

### 6.2 Tasks

The tasks have been designed based on a sample data set. The data set is a simplified version of a set of data gathered from a previous study in Multiple Display Environments [2]. This simplified version of the data has been tuned to cover different features of the tool and to fit the tasks' description. The data set includes interaction data of a single session. During the session, five developers are interacting with each other in a multiple display environment for about an hour. At first one of the developers shares a Microsoft word document in the shared display. The document is the agenda of the meeting, so everyone else in the room copies the document in to his own machine. Based on this document, a group collaboration starts and developers share different files in the shared display and with each other. Toward the end of the session, some peer to peer collaborations starts. In one of these collaborations, two of the developers started to work on a bug in eclipse, they share an instance eclipse to work on the bug and an instance of firefox to browse the web. In another peer to peer collaboration, two other developers share instances of visual studio and firefox. The session ends when the sharing of the first Microsoft word document ends.

In order to complete the tasks, the user have to make sense of the visualization and interact with

different parts of the tool. Task one involves interacting with filtering options and the video. This task asks users to check whether two particular group members had any interactions through out the session. Task 2 involves interacting with filtering options and the time bar. It asks users to find all applications that a particular group member has shared. Tasks 3 and 4 involve interacting with the time bar and the map view. Task 3 also requires the users to interact with the shared display, it asks users to find at least two group members who shared an application on the shared display at the same time. But task 4 asks the users to find a group member who had the greatest number of shared applications. Task 5 is designed to evaluate information representation in the time aligned view. In this view, each user activity is represented by a box and the length of the box corresponds to the duration of the activity. When two or more activities happen at the same time, they will be stacked on top of each other and if necessary a scrollbar will be added to the right side of the panel to scroll over all the boxes in the stack. In task 5 we ask the users to set the time bar to a specific duration that a lot of activities supposed to happen at the same time. Then we ask them to find the exact duration of an application that has been shared in the shared display. Finally, tasks 6 and 7 are designed to evaluate the effectiveness of the tool in helping the users to find collaboration patterns. Task 6 asks the users to set the timebar to a specific duration of the session and describe what they can observe. In that duration a group collaboration was happening. Similarly, Task 7 asks the users to set the timebar to a specific duration of the session and describe their observations. In that duration a peer to peer collaboration was happening.

### 6.3 Results

Participants completed all tasks in 20 to 30 minutes. This confirms the effectiveness of our visualization. Besides keeping track of the time, we also looked at the components of the system that users interacted with to perform the task. For example, users should have interacted with filtering options and the video in order to perform the first task. The users interacted with the components that we expect during most of the tasks. However, in task 3 and 4 we expect them to use the map view to perform the tasks but they preferred the time aligned view over the map view.

According to the post-study questionnaires users were moderately happy with the system. They were interested in most features of VICPAM and they think VICPAM is useful for analyzing the data in MDEs. They gave comments like: “I like the colors and icons” and “I like the ability to change what time period you look at and filter what you view”. The only feature that they didn’t

like was the time bar which showed the time in seconds and they said needs to use different metrics. They also suggested to have some indicators in the time bar for the activities that have happened. This will give the user an overview of the activities in entire session.

Other than some problems that encountered because of programming bugs, we found some small design issues. One of the participants suggested that the filter window should not be open by default and there should be a “Select All” option among the filtering options. All participants wanted to see that all copies of an application highlighted by hovering over the application and they asked for more association between map view and time aligned view in general. We resolved all these issues in our final version.

# Chapter 7

## Discussion

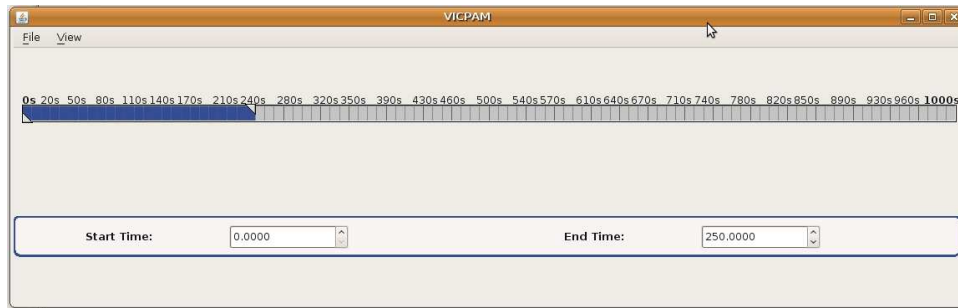


Figure 7.1: The old time bar.



Figure 7.2: The new time bar which includes some square-shaped indicators to show at what time the activities are happening.

One of the important components in our tool was the time bar. The metrics of the time bar were not appropriate according to the results of our evaluations. Further, we found out that the time bar should include some indicators to show at what time the activities are happening. These indicators will provide the user with an overview of the entire session. Our follow-up studies showed that adding the indicators makes the time bar more usable. Figure 7.1 shows the old time bar and figure 7.2 shows the new time bar. In the new time bar the squares indicate an activity has been started at a time and the color of each square is the same as the color of the activity in the time aligned view.

One possible criticism may be that our tool was studied with only one set of data from a particular study in a MDE. The data set has been chosen based on availability. The availability of different sets of data from various studies has been always an issue in studying tools. Since no other data sets were available, we analyzed the results from other studies in the domain to find out the characteristics of

their data. Those characteristics led us to build a tool which can analyze different sets of data from any configuratuos of MDEs or tabletops.

Although we studied our tool with a set of data came from one domain, results from our study did reveal opportunities for improving the design of this type of interactive analysis tools in general. One improvement would be to add some statistical data and information either in form of graphs or spreadsheets. Another improvement would be to add some data mappers. These data mappers can handle mapping of the data gathered from various kind of studies to the form of data that our tool can accept. Moreover, by using speech recognition and natural language processing techniques quotes of different group members about their activities can be extracted from the video of the session. Then the quotes can be associated with their activity in the visualization. Finally, if the data set also includes an screenshots of the actual documents that group members are sharing, each activity in the visualization can provide a link to the actual document that has been shared.

## Chapter 8

# Conclusions

To foster analysis and exploration of data gathered from studies in MDEs and tabletops, we have designed and developed an interactive analysis tool called VICPAM. VICPAM allows researchers to investigate different aspects of data by providing two different views of the same data: the map view and the time aligned view. The map view focuses on people's positions in the room to see if their positions affect their communication and interaction patterns. This view also provides an overview of the activities that have been performed in the environment. On the other hand, the time aligned view gives a more detailed view of people's activities. This view shows the start time and the exact duration of each activity.

Besides these views, a separate filtering window enables the researchers to filter out unnecessary information and focus on their desired part of the data. As MDEs, large electronic displays, and recently tabletops started to become available in study and home environments, researchers are beginning to study how their use affects collaborative problem solving. VICPAM will not only help with these future studies, but will also provide the researchers with the opportunity to go over their past studies and find interesting results that they may have missed.



# References

- [1] BIEHL, J. T., AND BAILEY, B. P. Improving interfaces for managing applications in multiple-device environments. In *Advanced visual interfaces* (New York, NY, USA, 2006), ACM, pp. 35–42.
- [2] BIEHL, J. T., BAKER, W. T., BAILEY, B. P., TAN, D. S., INKPEN, K. M., AND CZERWINSKI, M. Impromptu: a new interaction framework for supporting collaboration in multiple display environments and its field evaluation for co-located software development. In *CHI* (New York, NY, USA, 2008), ACM, pp. 939–948.
- [3] BRIGNULL, H., IZADI, S., FITZPATRICK, G., ROGERS, Y., AND RODDEN, T. The introduction of a shared interactive surface into a communal space. In *CSCW* (New York, NY, USA, 2004), ACM, pp. 49–58.
- [4] CARD, S. K., MACKINLAY, J. D., AND SHNEIDERMAN, B., Eds. *Readings in information visualization: using vision to think*. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 1999.
- [5] FIEBRINK, R., MORRIS, D., AND MORRIS, M. R. Dynamic mapping of physical controls for tabletop groupware. In *CHI* (2009).
- [6] HEER, J., VIÉGAS, F. B., AND WATTENBERG, M. Voyagers and voyeurs: supporting asynchronous collaborative information visualization. In *CHI* (New York, NY, USA, 2007), ACM, pp. 1029–1038.
- [7] HINRICHS, U., CARPENDALE, S., AND SCOTT, S. D. Evaluating the effects of fluid interface components on tabletop collaboration. In *AVI '06: Proceedings of the working conference on Advanced visual interfaces* (2006), ACM, pp. 27–34.
- [8] INC., G. Google finance: information about stocks and public and private companies. <http://finance.google.com>.
- [9] INC., Y. Yahoo finance: stock quotes and international market data. <http://finance.yahoo.com>.
- [10] IONESCU, A., STONE, M., AND WINOGRAD, T. Workspace navigator: Tools for capture, recall and reuse using spatial cues in an interactive workspace. Tech. rep., Stanford, 2002.
- [11] IZADI, S., BRIGNULL, H., RODDEN, T., ROGERS, Y., AND UNDERWOOD, M. Dynamo: a public interactive surface supporting the cooperative sharing and exchange of media. In *UIST* (New York, NY, USA, 2003), ACM, pp. 159–168.
- [12] JOHANSON, B., FOX, A., AND WINOGRAD, T. The interactive workspaces project: Experiences with ubiquitous computing rooms. *IEEE Pervasive Computing* 1, 2 (2002), 67–74.
- [13] LIVNY, M., RAMAKRISHNAN, R., BEYER, K., CHEN, G., DONJERKOVIC, D., LAWANDE, S., MYLLYMAKI, J., AND WENGER, K. Devise: integrated querying and visual exploration of large datasets. In *SIGMOD* (New York, NY, USA, 1997), ACM, pp. 301–312.

- [14] NASA. Hurricane data analysis tool: overlay various data products relevant in the study of hurricanes. <http://disc.gsfc.nasa.gov/hurricane>.
- [15] PIPER, A. M., O'BRIEN, E., MORRIS, M. R., AND WINOGRAD, T. Sides: a cooperative tabletop computer game for social skills development. In *CSCW '06: Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work* (2006), ACM Press, pp. 1–10.
- [16] ROGERS, Y., AND LINDLEY, S. Collaborating around large interactive displays: Which way is best to meet? In *Interacting with Computers* (2004), pp. 1133–1152.
- [17] SHEN, C., EVERITT, K., AND RYALL, K. Ubitable: Impromptu face-to-face collaboration on horizontal interactive surfaces. In *UbiComp '03: ACM International Conference on Ubiquitous Computing* (2003), ACM.
- [18] SHEN, C., LESH, N., MOGHADDAM, B., BEARDSLEY, P., AND BARDSLEY, R. S. Personal digital historian: user interface design. In *CHI '01: CHI '01 extended abstracts on Human factors in computing systems* (New York, NY, USA, 2001), ACM, pp. 29–30.
- [19] STEFIK, M., FOSTER, G., BOBROW, D. G., KAHN, K., LANNING, S., AND SUCHMAN, L. Beyond the chalkboard: computer support for collaboration and problem solving in meetings. *Commun. ACM* 30, 1 (1987), 32–47.
- [20] STREITZ, N. A., GEISSLER, J., HOLMER, T., KONOMI, S., MÜLLER-TOMFELDE, C., REISCHL, W., REXROTH, P., SEITZ, P., AND STEINMETZ, R. i-land: an interactive landscape for creativity and innovation. In *CHI '99: Proceedings of the SIGCHI conference on Human factors in computing systems* (New York, NY, USA, 1999), ACM, pp. 120–127.
- [21] STREITZ, N. A., REXROTH, P., AND HOLMER, T. Does roomware matter?: investigating the role of personal and public information devices and their combination in meeting room collaboration. In *ECSCW'97: Proceedings of the fifth conference on European Conference on Computer-Supported Cooperative Work* (Norwell, MA, USA, 1997), Kluwer Academic Publishers, pp. 297–312.
- [22] VIEGAS, F. B., WATTENBERG, M., VAN HAM, F., KRISS, J., AND MCKEON, M. Manyeyes: a site for visualization at internet scale. *Transactions on Visualization and Computer Graphics* 13, 6 (2007), 1121–1128.