Co-located collaborative information visualization *

Blaise ROSSIER
Department of Computer Science
CH-1700 Fribourg, Switzerland
blaise.rossier@unifr.ch

ABSTRACT

This paper provides a short state of the art of co-located collaborative information visualization. The topic is first of all defined. Possible media are cited. Possible solutions to format the data in an interactive view are explored for a co-located scenario. The limits of the proposed solutions in a Single Display Environment (SDE) are underlined. The interaction between collaborators and on the visualization is explored. Important design considerations are pointed out.

Keywords

Co-located, InfoVis, CSCW

1. INTRODUCTION

They are always more and more available data nowadays. There are sensors in our daily life that record a lot of exploitable data. The main problem is that those data are abstract and have to be analysed in order to be verbose.

However, it is often very hard to deal with raw data. Data do not make sense for a machine at least so far. But human beings can interpret data and extract information. To be understandable, those data have to be visible thus representable in a comfortable way.

Visualizations are an interesting way to show and see data but are often seen and proposed for a single user. However, visualizations must be a collaborative activity. There are several possible scenarios according to time and space. In this paper, only co-located collaborative synchronous interactions are treated; exploring the available solutions and important aspects that have to be considered. A lot of different other topics in connection with this topic could also be treated in more details but the main idea of this paper is to emphasize the essential.

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The first section of this paper explains what co-located collaborative information visualization is. Then, a second section explains possible media that can be used to interact at the same place on a shared visualization. The next section gives possible solutions to format data into an interactive visualization that can be used in a co-located scenario. The main points of interaction are presented; how people work together is an interesting question to explore. Finally, a conclusion highlights the major points of the subject.

2. CSCW AND INFOVIS

Co-located collaborative information visualization is between two main areas of research. The first one is Computer-Supported Collaborative Work (CSCW). The goal of CSCW is to understand what tools and techniques are important to build a collaborative system. The second research area is Information Visualization (InfoVis). The aim of InfoVis is to understand tools and techniques that permit to format and represent abstract data into an interactive view.

InfoVis is a multi-disciplinary task. Collaboration in a team is beneficial; it can bring motivation in addition to knowledge exchange. There are also new challenges and needs that have to be understood. Coordination and communication are very important in a shared system to avoid possible conflicts. The human aspect is crucial because conflicts can be technical but social too. Petra Isenberg [5] proposes a definition for the collaborative visualization process:

" *Collaborative visualization is the shared use of computer-supported, possibly interactive, visual representations of data by more than one person with the common goal of contribution to joint information processing activities* "

The main goal of synchronous co-located collaborative information visualization is to understand tools and techniques that allow a team to collaborate at the same time, at the same place, on the same visualization. Visualizations are often proposed for a single user and displayed on the screens of traditional computers. The interaction uses most often the well-known and robust WIMP paradigm. For a collaborative scenario, traditional solutions can be extended but new appropriate solutions exist.

3. MEDIA

A medium is a physical support for the information. A given visualization has to be shown and seen to be exploited. There are two main possible approaches that can be used in a co-located collaborative scenario; a Single Display Environment (SDE) and a Multiple Display Environment (MDE). In a MDE, displays can be different, connected or not. The displays can be physical as well as projected. It has been shown [10] that SDE permits to be more aware of what the collaborators do because the collaboration takes place on the same shared display. On the other hand, MDE can have public and private screens. Sometimes, collaborators want to be able to do some private tasks on their own display while interacting together on a shared bigger surface. The medium has to support both coordination and communication [10].

Traditional displays or projectors used in a scenario with a single user can be used also for a collaborative approach. However, the interaction is often limited to one user; there are only one mouse and one keyboard. Traditional media can be extended to support a multi-user scenario. Each collaborator has his own mouse and can directly interact with the visualization. A X-Windows system can be extended to support multi-mouse inputs; a new windows manager is created with a modified events loop that can recognize multiple mouse-cursor events. Because this approach doesn't require a new kind of hardware, a collaborative interaction can be supported with low cost. Figure 1 illustrates this scenario in a MDE.

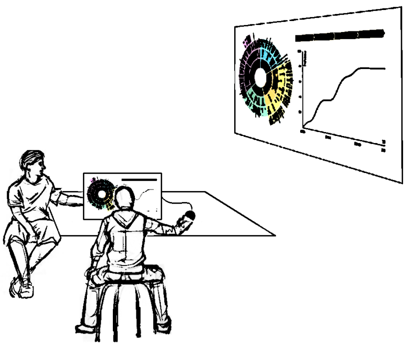

Figure 1: Multi-mouse in MDE [1]

More suitable but also more expensive devices exist and permit a better interaction in a team. An **interactive tabletop** - Microsoft PixelSense for example - is a horizontal multi-touch screen. An **interactive wall** is meanwhile a vertical system. Horizontal and vertical system have different properties. Vertical visualizations are good when there are a lot of collaborators; all of them can view the visualization comfortably. However, they can not interact fairly in most cases. Figure 2 illustrates a horizontal and a vertical system in a SDE. With the horizontal system, the orientation of the visualization must be taken into account. The section that explores the interaction will investigate this problematic.

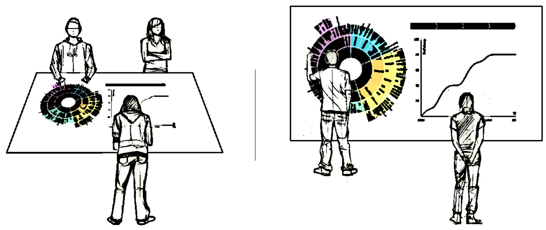

Figure 2: Interactive tabletop | wall in a SDE

In a MDE, those devices can be combined together. A retained solution [9] uses an interactive shared tabletop and a smartphone per worker. The smartphone is a private screen. An interactive screen has a significant cost; an original interaction that uses small **handheld projectors** [2] can be a less expensive solution. Each collaborator has his own projector. They share a common physical display (that can be just a wall) and the same interaction space but they can display different information with their own projector. Each collaborator may be comfortably seated, this is not the case with an interactive wall.

4. VISUALIZATION

A visualization has three distinct roles [1]; descriptive - analytical and exploratory role. A visualization is descriptive if the subject is known; the aim of the visualization is to show the subject in an interactive and understandable way. A visualization is analytical when collaborators look for something that is known. Finally, an exploratory visualization is when collaborators seek something that is unknown. The visualization has to be synthetic and ideally propose visual patterns that can be meaningful and help to find something new.

The medium is the technical support for the visualization; the visualization has to be encoded to be supported by the medium. Many solutions exist and are interesting to create a rich visualization. In a co-located synchronous scenario, SDE has for the time being limited number of easily exploitable solutions. Indeed, new kind of hardware is often needed. An interactive tabletop has the multi-touch propriety; several touch event can be caught at the same time. This is very important if two collaborators want to work together exactly at the same time. Microsoft Surface 2.0 SDK offers APIs to implement applications that can be run on a interactive tabletop. The graphical elements, thus the visualization, are made with Windows Presentation Foundation (WPF). Cambiera [5], an implemented tool for co-located collaborative information foraging, uses this approach. All the visualization part has to be implemented from scratch using the WPF; this is a non-trivial task. This solution is platform dependant.

There are other available graphical libraries for other languages and other platforms. Traditional events, as the mouse inputs, are also natively supported most of the time. The

[1] Illustrations use sketch characters from:
`http://goo.gl/cPl3cb`
`http://goo.gl/saHkfZ`
`http://goo.gl/WX2jc5`

problem is that new hardware like an interactive tabletop uses the touch modality. This new modality is often emulated as a mouse event and multi-touch is not supported with the traditional graphical library. In a MDE, this is different because not all events occur on the same device. In this case, if each collaborator can interact with his own display, many interesting solutions can also be used to build a visualization.

Web technologies are an interesting solution to build a visualization as example. They offer a lot of possibilities to format the data in a interactive way. The content and the form can be easily separated. The form is the most important part because the purpose of visualization is to format data. Web technologies offer more possibilities than traditional graphical libraries. A Web engine can render Web pages and is present on all the Web browsers. Standards are most of the time supported and enough; no plugins are needed[2]. A Web page is accessible with different devices because there are Web browsers for different devices. This is the main advantage of the web technologies. Different languages can be used on the server side to treat the data. The Web is distributed by default using the client/server approach. The Web (2.0) is also collaborative; thanks to its architecture, a collaborative system is not difficult to set up. A 3-tier architecture (client - server - database) can support a visualization in a very suitable way.

There exist powerful JavaScript libraries that can be use to format data into a visual way. For example, *d3.js* is a graphical library that permits to build visualizations. JavaScript is executed on the client side but thanks to *node.js*, it is also possible to work on the server side. A communication between two clients is thus possible. There exist also libraries to help the collaboration; for example *together.js*. Those solutions are interesting in a MDE since it is not necessary to handle multi-user events on the same device at the same time. Currently, there is no out-of-the-box solution for a collaborative collocated web-based scenario in a SDE. It could be possible to imagine and implement such a solution but the task is difficult. On an interactive tabletop, two collaborators have to be able to interact together exactly at the same time. The system has to support the touch modality and the multithreading. There exist libraries to support the touch modality; as example *hammer.js*. There are also libraries that support multithreading in a browser; *multithread.js* is an example. In a SDE scenario, there is still much to improve; the topic is still young.

5. INTERACTION

Understand how people work and interact together is important to consider. Petra Isenberg [5] observes three levels of engagement on a shared visualization; viewing - interacting/exploring and sharing/creating. A given collaborator has to be able to see the visualization, to explore it and to modify it. The system has thus to support those operations. Two collaborators can work independently or in concert in the same place at the same time. **Three collaboration styles** can be identified: complete task division - independent, parallel work and joint work. With a complete task division, each team member works on his own task. Collaborators can work on the same task but on their own copy of the task; this is independent parallel work. Finally, a team can work together on the same task. Collaboration styles are very important and not exclusive. During a same collaborating session, several different styles can occur. The system has to be flexible and offer several collaboration styles.

Information visualizations could be displayed in very different places; a museum for example. Traditional modalities like the mouse and the keyboard work but dedicated media as interactive tabletops prefer a multi-touch screen. Around a traditional tabletop, people interact naturally using physical objects or communicate with their social behaviour. Those behaviours have to be understood and artificially translated in the virtual tabletop because nothing is natural. The interaction can be direct (pen-based) on the visualization or indirect (mouse). On a touch surface, several types of interaction exist. The surface can be large; there are solutions to avoid excessive movements. A possible solution called *radar view* uses a miniature of the entire workspace. The user interacts on the miniature instead of interacting on the large surface. But different types of interaction provide different levels of conflicts.

The medium stands in the **physical space**; a space that collaborators have to share. The distance between collaborators but also between a collaborator and the visualization can change and has an impact on the interaction [4]. When the collaborators are close together, they are more efficient and enjoy more the task. With direct inputs, the team members are also close to the visualization. They communicate well if they have to share a display. Multi-touch tabletops have been compared [3] with multi-mouse single-display. Mouse inputs are more efficient but collaborators that use the touch modality communicate more together; they are also more close to the visualization. People prefer to work together even if they are far away from the display. But ideally, they prefer to be close from the display. Having a display for direct inputs and a common display for the main visualization can however limit the communication and the interaction in the team.

The screen is on the physical space but has his own space; the **data space**. It is important to understand how people organize their work on a common shared medium. Because people have to be at the same time at the same place, their workspace is organized into identifiable areas. Three different territories can be distinguished [8] in a shared tabletop; personal - group and storage area. Personal space is private for a given collaborator; this space is visible for all the collaborators but only a given member of the team interacts on it. In a MDE, it is possible to have private space that only a given member of the team can see. The big shared space is the group space where all the main task is displayed; this is where the collaboration takes place. The storage space is useful to store tools for example. Those spacial divisions also exist in a vertical workspace [8]. **Territories** play a role in coordination between team members and help to avoid conflicts.

With a vertical workspace all the collaborators see the same image at the same time but with a virtual tabletop this is not the case. An image can be seen upside down. The simplest

[2] Java or Flash

solution is to have a single orientation. The tabletop can be seen as a horizontal surface where the collaborators are side-by-side. But more naturally, people can be positioned all around a tabletop, looking at the visualization under different angles. The orientation of the visualization is thus very important in that case and can offer new interesting features. Three roles of the **orientation** can be observed [6]; coordination - comprehension and communication. The orientation helps to the coordination and the communication. A collaborator can orient part of the visualization in his direction to mean that he wants to work on this part. With a face-to-face communication, people use gestures to communicate implicitly. Here, the orientation can play this role. View a visualization upside down could bring misunderstanding. The orientation can be changed manually, multiple copies can coexist together on the medium or it can be changed automatically (person-based or environment-based) [6].

Coordination helps to avoid conflicts and can be considered at two levels. The first level controls the access to the visualization and its components. The second level tries to logically structure an activity; controlling that the tasks are accomplished in the right order. This is important if an activity is split into different parallel tasks and distributed between several collaborators. With a complete task division, coordination doesn't play a major role because collaborators don't work on the same set of objects. With independent parallel work or joint work, conflicts can occur because collaborators work on the same activity. A possible solution uses different modify rights on the shared set of objects. Another solution can use a lock system to avoid that an object is modified by several collaborators at the same time. Morris and al. [7] propose different coordination policies. With concurrency, currency has to be considered; it measures how up-to-date is a given object. Automatic updates can be a problem because a collaborator can break the whole system. Rollback can be a solution to restore the system but can be too intrusive. Notifications can be another solution to account for changes on the system. Notifications are feedbacks and help to make the system as transparent as possible. A system of colours can also help to identify a given user on the visualization and also avoid a possible collision between the work of two collaborators. By the way, communication is very important and can be as natural as possible in a co-located environment.

6. CONCLUSIONS

Co-located collaborative information visualization has two types of challenges. The challenges from the CSCW and the challenges from InfoVis. A system has to support both collaboration and communication. Collaborators can come from different horizons and skills domains. The system has to be intuitive and the interaction as natural as possible. Traditional modalities like the mouse are still usable and efficient on a collaborative environment but more natural modalities like touch are often chosen. The touch modality tends to help with communication.

On a SDE scenario with the touch modality, a multi-touch device is necessary to permit real synchronous work. There is for the moment a limited number of solutions to work with a multi-touch device. A single display facilitates communication. On a MDE, javaScript libraries can be used to build a visualization because simple events are supported by default. MDE are interesting because each collaborator can dispose of his own private display. This could solve the problem of privacy in some cases.

Communication with the coordination helps to minimize conflicts between collaborators. A lot of different solutions can be used to improve the coordination within a team as a colours system, the orientation of the visualization, the position of the collaborators, territories or notifications.

Three key issues [4] related to proximity have to be taken into account: proximity between partners - proximity to the shared display and interaction at a distance. People share the physical and virtual space according to some identifiable rules. They work together by following collaboration styles.

This topic is not yet mature and still in experimental phase; the context will change (Museums, conference rooms, ...). New modalities are good to consider. In a museum, a touch interaction could be more enjoyable than a traditional interaction that uses a mouse or a keyboard. Also, other modalities like voice or tangible interface could be interesting and more interactive in the future.

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