Visualization Techniques for Circular Tabletop Interfaces

Frederic Vernier, Neal Lesh, Chia Shen

TR2002-01   March 2002

Abstract

This paper presents visualization and layout schemes for a multi-person conversational setting.

Advanced Visual Interfaces, May 2002. Trento, Italy.

Visualization Techniques for Circular Tabletop Interfaces

Frederic Vernier
Neal Lesh
Chia Shen

TR2002-01   March 2002

Abstract

This paper presents visualization and layout schemes developed for a novel circular user interface designed for a round, tabletop display. Since all the displayed items are in a polar coordinate system, many interface and visualization schemes must be revisited to account for this new layout of UI elements. We first discuss the direct implications of such a circular interface on document orientation. Then we describe two types of fisheye deformation of the circular layout and explain how to use them in a multi-person collaborative interface. These two schemes provide a general layout framework for circular interfaces. We have also designed a new visualization technique derived from the particularities of the circular layout we have highlighted. In this technique the user control the layout of the elements of a hierarchical tree. Our approach is not to automatically compute the most effective position of the nodes and leaves of a tree but to provide the user rich interaction possibilities to easily and quickly produce a layout comparable to the hyperbolic view developed at Xerox PARC. Finally, we discuss future work and possible visualization techniques based on different information structures. The visualization work presented in this paper is part of our ongoing Personal Digital Historian (PDH) research project. The overall goal of PDH is to investigate ways to effectively and intuitively organize, navigate, browse, present and visualize digital data in an interactive multi-person conversational setting.

Visualization techniques for circular tabletop interfaces

Frédéric Vernier
Vernier@merl.com
+1 (617) 621-7582

Neal Lesh
Lesh@merl.com
+1 (617) 621-7583

Chia Shen
Shen@merl.com
+1 (617) 621-7528

Mitsubishi Electric Research Labs (MERL)
Cambridge Research Lab
201 Broadway, Cambridge, MA, 02139, USA

ABSTRACT

This paper presents visualization and layout schemes developed for a novel circular user interface designed for a round, tabletop display. Since all the displayed items are in a polar coordinate system, many interface and visualization schemes must be revisited to account for this new layout of UI elements. We discuss the direct implications of such a circular interface on document orientation. We describe two types of fisheye deformation of the circular layout and explain how to use them in a multi-person collaborative interface. These two schemes provide a general layout framework for circular interfaces. We have also designed a new visualization technique derived from the particularities of the circular layout we have highlighted. In this technique the user controls the layout of the elements of a hierarchical tree. Our approach is to provide the user rich interaction possibilities to easily and quickly produce a layout comparable to the hyperbolic view developed at Xerox PARC. The visualization work presented in this paper is part of our ongoing Personal Digital Historian (PDH) research project. The overall goal of PDH is to investigate ways to effectively and intuitively organize, navigate, browse, present and visualize digital data in an interactive multi-person conversational setting.

General Terms

Design, Human Factors

Categories and Subject Descriptors

H.5.2 [**Information interfaces and presentation**]: User Interfaces
- *Graphical user interfaces, Interaction styles, Screen design, Windowing systems*
H.5.3 [**Information interfaces and presentation**]: Group and Organization Interfaces *Synchronous interaction*

Keywords

Circular interface, tabletop, Fisheye view, collaborative interface, tree visualization.

1. INTRODUCTION

There are many advantages of tabletop displays over traditional desktops or handheld devices for collaborative tasks in which multiple people need to both work with each other and access computational resources. People can sit around a table and thus easily face each other, rather than try to crowd around a desktop or a small handheld device. A tabletop provides shared space and also each person to have their own personal, if not entirely private, space to work in. Finally, whether it is an electronic display or not, a tabletop affords a convenient layout space within which users can spread out and organize their documents.

In this paper, we present a novel circular interface, illustrated in Figure 1, designed to support collaborative management and exploration of large collections of electronic documents. We have developed this interface in the context of our ongoing Personal Digital Historian (PDH) project [9, 10]. The goal of PDH is to help people share digital recordings, such as images, video, spreadsheets, or text documents, in social or professional gatherings. For example, friends might use PDH while catching up on what has been happening in each other's lives since they last saw each other, a group of managers might use PDH to brief each other on recent activities, or co-workers might use PDH to co-design and review their ongoing projects.

Figure 1: A circular tabletop setting with 3 chairs, 2 users and a set of documents on the table

Most of architectures, furniture and documents in our daily living and work environment are rectangular in nature. This is a very convenient system for constructing engineering and mechanical artifacts, for packing and shipping, and for point of reference in human navigation. In visualizing physical or electronic documents, rectangular linear system gives each individual user a personal directional viewing angle.

However, when multiple peoples gather around a tabletop display, there is no single orientation that is ideal for everyone. A polar-coordinate system, which is well suited to a circular display, allows people to share documents by easily rotating individual items or the entire display. Therefore, the interesting research question is: " How can we design a system that can support both the strong rect-linear directional preference of each individual user, while at the same time provide the entire group the capability to collaboratively work on, to view, and to layout the same set of objects? ".

We are in the process of constructing the initial PDH prototype. The PDH prototype user interface is being implemented using Java on Windows 2000. A tabletop display with top projection onto a standard whiteboard as shown in Figure 2 is currently used as the physical PDH table. As input we used for the first experiments a Mimio stylus [7]. Important figures presented in this paper also appear in the color plate section of this proceeding.

In the next section, we review related work in the area of tabletop computing. Then, after we give an overview of our circular tabletop features, we first present how to handle the unique issues of orientation of documents that arise for circular interfaces. Deformation techniques to control the size of documents on the tabletop display are discussed next. We describe the facilities in our interface for helping users to define, layout and navigate hierarchical organizations of their documents on the tabletop before we conclude the paper.

Figure 2: Two users around the PDH prototype projected from the ceiling and manipulated with a Mimio stylus.

2.   RELATED WORK
In the past 10 years, there has been a proliferation of beyond-the-desktop research projects, looking at how to integrate the design of computation into architectural spaces and furniture, including tabletops [1, 3, 4, 5, 13, 14, 15, 17, 18]. DigitalDesk [b, c] was a physical desk augmented with vision and projector capabilities so that the physical and electronic desktops are merged into one. DigitalDesk was designed for use by one person. While the coffee table design in the Living Memory (LiMe) project [5] employs two semi-circle tabletop displays on each coffee table, each semi-circle displays all the information in a fixed direction. The InteracTable in the i-Land project supplies a rectangular surface to be shared among multiple users. The issue of rotation and shuffling of documents is considered only very briefly in [13].

Most of these tabletop interfaces deal with only Cartesian coordinate systems. To our knowledge, no interface has previously been proposed to handle the challenges of how to orient and organize shared documents in a polar coordinate system when the interface sits between people who are all looking at it from different angles.

In a more general sense, our work complements existing systems described above. Previous work provides solutions to the problems of how to let users view, manage, annotate and interact with individual documents on a table in a Cartesian coordinate system, while our work explores the issues of orientation, visual layout, automatic scaling and relocation of individual subgroup as well as the entire tabletop viewing area in a polar coordinate system. This in part is similar to the latest work on ZoomScape [4] which is a wall display system, thus does not deal with orientation issues.

3.   TABLETOP ORIENTATION AND USER POSITION DETERMINATION
Our circular interface supports multiple people working together with documents on a tabletop surface. In order to be able to fully support both individual user viewing preferences and the group shared viewing needs, we have developed the following two general user interface functions:

First, the entire tabletop interface surface can be freely rotated in either direction. This operation is a very convenient way to pass around a global layout of the tabletop content for each individual user to review from his or her viewing angle.

Second, we allow menus to be positioned along the perimeter of the tabletop wherever a user is sitting. Two examples of this feature are shown in Figure 4 and Figure 8. In Figure 4, two users are sitting facing each other. Figure 8 shows two users sit 90° apart around the circular interface. This function provides the system the information of where is the individual user's preferred viewing angle.

4.   DOCUMENT ORIENTATION
Traditional rectangular interfaces typically assume that the users will always be viewing the interface from roughly the same direction and angle. In contrast, our interest is to support face-to-face collaborations in which the interface is situated between the participants, and thus we must consider issues of rotation and re-orientation of the entire interface. This need has led us to develop novel visualization and interaction schemes in order to facilitate (a) the convenient re-orientation of any or all documents on the interface surface, and (b) the ease of passing documents around the table surface.

In our system, the users can rotate the entire interface or move individual documents within the interface. Our circular interface

maintains two independent polar coordinate systems, one table centric, for the entire circular interface surface, and the other image centric, for each individual document on the surface.

These two separate polar coordinate systems are used to calculate the values of the following three variables:

- Distance (d) from each document to the center of the table,

- Angle (α) of rotation around the center of the table, and

- Angle (β) of rotation around the center of each document.

These three variables represent the three degrees of freedom of the documents to consider in the interaction. The two angles are illustrated in Figure 3. For comparison, the first document labeled "AB" has a β greater than α and the other document labeled "CD" has a very small β and an α close to 90°.
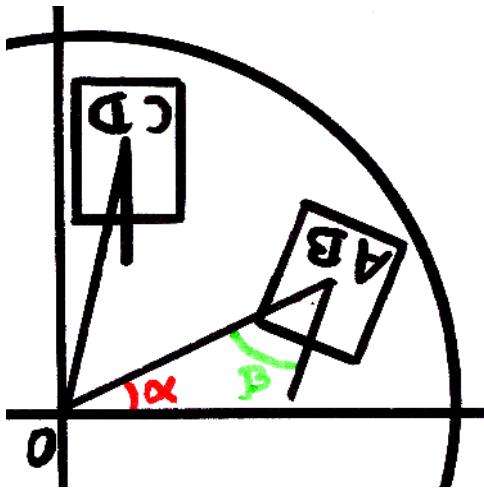
Figure 3: Scheme of two documents with the same distance to the center (d) but with two different angles α and β.

One challenge in this context is how to allow users to manipulate the documents. When sliding physical papers on a table, one can use two or more fingers to control both the location and orientation of the document. With traditional touch-screen or mouse-based pointers, a user has only one point of contact to work with. It would seem very awkward for the user to have to separate functions to control location and orientation. Thus, we allow the user to control two dimensions (d and α) of a document and our system automatically manages the third dimension (β). We have two ways of managing β:

- Centric orientation

- Magnetized orientation

In the first mode, illustrated at Figure 4, every document is oriented in the direction of the center of the table. In this mode every $\beta = 0$.

In the magnetized orientation mode, illustrated at Figure 5, all the elements are oriented to face the same direction given by the position of the user's menu, which has activated this mode. If the global angle of the menu is φ then every $\beta = -\alpha + \varphi$.

Figure 4: General[1] PDH interface with two menus for two users sitting across from each other and a set of digital pictures displayed in the centric orientation mode.

The magnet mode can also be used in synergy with the ability to rotate the entire interface. After magnetizing the interface the user can rotate the table to show the result to someone else.

Magnet icon
Highlighted

Figure 5: Same picture set as in Figure 4 in the magnetized orientation mode activated by the bottom menu ($\varphi = -90°$).

---

[1] In other figures, the full interface is cropped to provide more detail on discussed part of the interface. All pictures have been processed for better rendering in black and white. Important illustrations also appear in color plate at the end of the proceedings.

5. DOCUMENT SIZE

In the previous section, we saw how the computer can facilitate the layout and orientation of documents. We now present methods for helping the user manage the size of the images. There are several reasons for varying the size of documents, including:

- It is not possible to stretch real documents like a sheet of paper and the zoom feature is an important benefit of the augmented table.

- Image size can be used to emphasize certain pictures for discussion or better inspection.

- The maximum resolution a video-projector can project on a table is a poor XGA (1024 x 768), which is far less than the human eye resolution. In our application, if we display 5"x7" pictures the system loses most of the content of each picture.

We have implemented two focus+context visualization techniques based on fisheye views in our circular tabletop interface in order to improve the user's interaction experience. These techniques are based on our observation that the focus and context of the conversation is quite different in following two different uses of our system:

- Each user is working separately but shares documents with the other users.

- One user is showing her documents to the other users.

For each of these cases we designed a different fisheye technique:

- The central focus

- The central black hole

Both visualizations modify the size of the document according to the distance to the middle of the table. As shown in Figure 6, the central focus provides a unique focus in the middle of the table for all the users to share and personal areas for individual users along the border of the table (where the documents are small).

Figure 6: Central focus effect with a zoomed in image in the center, few normal-size picture around and zoomed out image in the periphery.

The central black hole illustrated at Figure 7 is exactly the opposite: the border of the table handles normal size documents and the documents become smaller when they are closer to the center of the table. The central focus is well suited for the situation in which one user wants to show documents to other users. Externally it looks like a traditional fisheye technique but the context is smoothly divided into different areas facing each user around the table.

In the second technique, each user uses the periphery of the table that is close to him in order to manage his own documents. When he pushes a document toward the middle of the table the document becomes smaller and uses less space. As can be seen in the figures, the central black hole approach (Figure 7) has much less overlapping among documents than the "normal" approach (Figure 4).

Figure 7: Central black hole effect with the same density of pictures than the previous figures.

Two users can exchange a document by using the central focus or central black hole as a transaction zone. One user gives a picture by pushing it into the center of the interface, and the other takes it by pulling it to his own area. The central focus allows potentially interested users to visualize the picture in detail before deciding to take it or not. In contrast, the central black hole allows one user to push many pictures in the middle without filling the space. It can be described as a graphical compressed buffer for picture exchange! The system can also support the methods of exchanging pictures that people use for physical photographs on a tabletop.

The work on fisheye deformation [2] shows it is easier to understand and use a deformed space if it comes with a perspective effect. We first decided to add a spider web grid in the background to reflect the distortion. However, the improvement did not seem as significant as was he improvement from the corresponding perspective effect in previous fisheye deformation systems, e.g., VITESSE [8]. Our explanation is that the position of the fisheye center is obvious to users of our circular interface, because all the documents point on the center. In more traditional interfaces, the understanding of the fisheye deformation is difficult because the choice of the deformation center is an arbitrary point in a uniform space. The central point of a polar space seams a stronger cue than the position of the mouse or the center of the screen typically used as center of deformation.

6. HIERARCHY VISUALIZATION

6.1. Hierarchy Presentation

While the fisheye deformations described above allow the users to manage more documents on the screen at once, the visualizations described so far become more cluttered and eventually unusable as the number of documents becomes very large. To scale up our system to handle large numbers of documents, we provide support for hierarchical representation of data. In particular, we allow the users to form "groups" of data, which can contain individual documents or other groups created by the users. This representation is similar, for example, to the standard file and folder system widely used in Operating Systems graphical interfaces. Because many people will be using the system at the same time, we need an approach where folders can be opened at the same time. Figure 8 shows an example of hierarchical layout. It is a part of the PDH system in which people can browse through portraits of all the people that appear in their database.
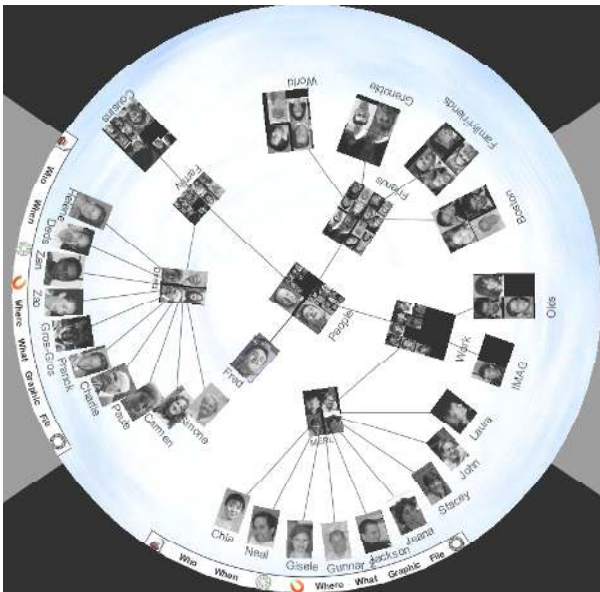
Figure 8: The hierarchy organization of people's portraits on the PDH tabletop display with two menus for two users sitting 90° apart around the table.

The visualization technique is a compromise between the need to show the tree structure of the documents and our desire to have the user control the location of the documents on the table. In the example of Figure 8, the user on the left is browsing the content of the node [People→Family→Direct] (i.e., the group named "People" contains a group named "Family" which contains a group named "Direct" which contains many pictures). The user on the bottom is browsing another branch of the hierarchy [People→Work→MERL].

In the hierarchy layout of Figure 8, each leaf of the hierarchy is an image of a person's portrait and a text string below it showing the name of that person. The non-leaf nodes of the hierarchy, such as the root titled "People" in the center of Figure 8, are represented by a mosaic of 2 or 4 of the images of that node's children and a string title. Such nodes can be open (e.g., "People" or "Direct" in

Figure 8) or closed (e.g., "World" or "Grenoble" in Figure 8). The mosaic indicates whether the nodes children are individual documents, represented by a single image, or are themselves groups, represented by a mosaic which itself can contain other mosaics.

The default position of the root is the center of the table, but it can be re-located by the users. Putting the node in the focus in the middle and opening the children in the direction of the table border produces a layout comparable to the hyperbolic browser [6]. When used in conjunction with the central black hole view, the layouts even more closely resemble the hyperbolic browser. However, the hyperbolic browser automatically lays out the nodes while our approach allows the user more control of where groups and leaves are positioned. We also allow users to bookmark and restore (i.e., save and load) alternative hierarchical layouts. We believe that users will prefer, as well as better remember and be able to make more effective use of, layouts they help design.

Before describing the interactions which make it possible to quickly produce the user layout presented above, we list four other actions used in the manipulation of the hierarchy:

- A click on a leaf or non-leaf node selects it.

- A free stroke lasso selection in a different mode select multiple leaves and node at the same time.

- A drag&drop of a leave or non-leaf node onto other node move the dragged element into the hierarchy.

- A contextual menu proposes to create a new node or destroy an existing one.

6.2. Interaction And Animation

To manage the hierarchy we provide features to create, destroy move, open and close a group or a leaf. The key problem is where to display the children which appear when the user opens a node. Our system provides two features to control the layout of their hierarchical data:

- The flower animation

- The fan drag&drop

The flower animation illustrated in Figure 9 is played while the user continuously maintains the input device button pressed over a node (long click). When opening a node, the system displays the node's children uniformly around the node being opened ("MERL" at Figure 10), and moves them farther and farther from the node. The animation stops when either the user ends the long click or the children are far enough apart that they are separated by a pre-set gap. Figure 9 shows examples of our system in use. For viewing portraits, the middle layout in Figure 9 is sufficient, but for reading text, the third step on the right is preferable. We chose to decrease the size of the node being opened as the children move further to give direct feedback on the manipulated object. If the user performs the same long click action on an opened node, the system closes the node by playing the animation in the reverse order. (Figure 10 from right to left).
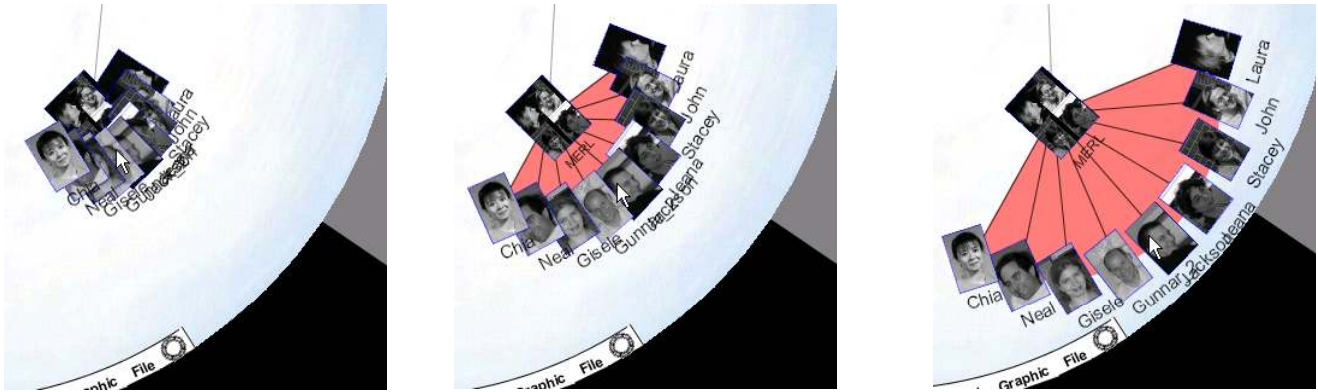
Figure 9: The fan drag&drop distributing the 9 children of a node in the bottom-right direction

While this mechanism opens and closes nodes elegantly, they do not help avoid overlap among different branches of the hierarchy. The second mechanism essentially allows the user to control the direction of the flower animation. During the long click used to open a node, the user drags the mouse cursor in some direction. The distance between all the children and the opening node equals the distance of the drag&drop. The angle used depends on this distance and the number of nodes (to avoid overlapping). The children of the node are equally distributed on each side of the mouse cursor and a red background highlights the used angle. This last feedback artifact clearly shows the metaphor of a fan which inspired the name of this interaction.

The Figure 9 illustrates a fan drag&drop while opening the node "MERL" in the "bottom right" direction. With this mechanism the user chooses an empty area or an area where the overlapping is acceptable.

The goal of this interaction technique is to produce a layout comparable to the hyperbolic browser but static and more configurable by the user. Face-to-face collaboration requires the ability to have more than one focus and the possibility to support many collaborative manipulations (exchange, repartition, etc) on the data.

7. CONCLUSION AND FUTURE WORK

We have described several new HCI mechanisms to support collaborative interaction on a circular interface. Our approaches are designed around three principles. The first is to give users the full capability to relocate, re-orient, scale and layout the documents in the circular interface. The second is to provide automatic methods when (1) a user requires the layout in a Cartesian system, or (2) a user needs to minimize overlapping/crowding of documents. The third is to support users' focus within their group meeting context for group collaboration around the table.

We have developed a new layout mechanism, based on a polar coordinate system. We presented two fisheye view deformations, each of which supports a different type of user activity. Finally we presented an interaction technique to support user-driven construction and layout of hierarchy in our interface.

As future work, we plan to explore using the α component of the polar coordinate system as a dimension to control deformation. For example, the default size of the images in front of each user might be larger than the ones between them. Such a technique would be independent of the black hole or central focus. Experimentation will be carried out to determine if two deformations can be performed on the 2 dimensions of a polar coordinate system (d and α) without overloading the cognitive effort of the user.

Figure 10: The flower animation homogenously distributing 9 children of a node

We also plan to integrate novel input devices into our circular interface. While the techniques we have described so far require only a mouse-like input device (including a single-point touch screen), we believe much more could be done with the full range of inputs that are possible on a tabletop display.

Finally, we are interested in developing new visualization techniques that are appropriate for, and/or take advantage of, circular context. Some work (e.g., [12]) seems to already provide a solution for Treemaps[11]. A more interesting perspective would be, for example, to study how to build a DragMag technique [16] in a circular interface.

The first application area that we have used to gain insights into the design issues and visual feedback for the work presented in this paper is the interactive viewing and navigation of personal digital photograph databases among groups of friends. This has provided us with valuable experience. Our next step is to apply our techniques to other application domains such as business and organizational meeting with other types electronic documents besides digital photos.

8. ACKNOWLEDGMENTS

9. REFERENCES

[1] Bérard F., MagicTable. *Video published at: http://iihm.imag.fr/demos/magicboard/movies/*.

[2] Carpendale M., Cowperthwaite D. and Fracchia F. Making Distortions Comprehensible Space. *Proceedings of IEEE Visual Languages'97* (Capri, Italy, 1997), pp. 36-45.

[3] Fjeld, M., Voorhorst, F., Bichsel, M., Krueger, H. and Rauterberg, M. Navigation Methods for an Augmented Reality System. *In Extended Abstracts of CHI 2000*. (The Hague, The Netherlands, April 2000). pp 8-9.

[4] Guimbretiere, F., Stone, M., Winograd, T., Fluid Interaction with High-resolution Wall-size Displays, *Proceedings of the 14th Annual ACM Symposium on User Interface Software and Technology (UIST'01).* Orlando, Florida, USA. November 11-14, 2001.

[5] Kyffin S., The LiME Project, Philips brochure published at: http://www.design.philips.com/lime/ download/brochure.pdf

[6] Lamping, J., Rao R., and Pirolli P. A focus+context technique based on hyperbolic geometry for visualizing large hierarchies. *Proceedings of CHI '95* (Denver, Colorado, USA, 1995) ACM. pp. 401-408.

[7] Mimio, capture bar using ultrasonic position capture http://www.mimio.com/

[8] Nigay L. and Vernier F., Design method of interaction techniques for large information spaces, *Proceedings of AVI'98* (L'Aquilla, Italy, 1998), pp. 37-46.

[9] Shen C., Lesh N., Moghaddam B., Beardsley P. and Bardsley R.S. Personal Digital Historian: User Interface Design. *Proceedings Extended Abstract of CHI'2001* (Seattle, WA, April 2001), ACM Press, pp. 29-30.

[10] Shen C., Vernier F. and Lesh N. A Visual Interface for Multi-person Exploration of Personal Database. *To appear in proceedings of AVI'2002* (Trento, Italy, 2002).

[11] Shneiderman B., Tree visualization with treemaps: a 2-d space-filling approach. *In Transactions on Graphics 11(1), January 1992*, pp. 92-99.

[12] Stasko J. and Zhang E. Focus+Context Display and Navigation Techniques for Enhancing Radial, Space-Filling Hierarchy Visualizations. *Proceedings of InfoVis'2000* (Salt Lake City, USA, 2000), pp. 57-65.

[13] Streitz, N. et al., i-LAND: An interactive Landscape for Creativitiy and Innovation. *Proceedings of CHI '99* (Pittsburgh, PA, May 1999), ACM Press, pp. 120-127.

[14] Tandler, P., Prante, T., Muller-Tomfelde, C., Streitz, N., Steinmetz, R., ConnecTables: Dynamic Coupling of Displays for the Flexible Creation of Shared Workspace. *Proceedings of the 14th Annual ACM Symposium on User Interface Software and Technology (UIST'01).* Orlando, Florida, USA. November 11-14, 2001.

[15] Ullmer, B., Ishii, H., The metaDESK: Models and Prototypes for Tangible User Interfaces. *Proceedings of UIST'97* (1997), ACM Press, pp. 223-232.

[16] Ware C. and Lewis M., The DragMag Image Magnifier. *Proceedings of CHI'95* (Denver, USA, 1995), pp. 407-408.

[17] Wellner P., The DigitalDesk Calculator: Tangible Manipulation on a Desk Top Display. *Proceedings of UIST '91* (Hilton Head SC, November 1991), ACM Press, pp. 27-33.

[18] Wellner P., Interacting with Paper on the DigitalDesk. Comm. ACM Vol. 36, 7, 1993. pp. 86-96.