

# Public and Private Workspaces on Tabletop Displays

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## Abstract

As co-operative work environments are becoming more popular, new tools and techniques have been emerging that allow users to perform collaborative tasks more efficiently. We have been exploring new interaction techniques made possible by using a multi-view display as a tabletop surface. This paper presents the concept of public and private working areas for multi-view display environments, and presents a taxonomy that allows us to better understand how they can be applied in computer supported collaborative work environments. We have formally defined and categorized various multi-view characteristics, along with possible uses and applications. We also created a display mask that allows an LCD monitor to be used as a multi-view display from four viewing directions. Furthermore, our initial implementation of a window manager utilizing the taxonomy has been discussed to demonstrate some of the interaction techniques that are possible using a multi-view tabletop display.

*Keywords:* Multi-view display, public/private workspaces.

## 1 Introduction

With the development of large display technologies such as plasma, rear/front projection and Liquid Crystal Displays (LCDs), horizontal tabletop surfaces such as The Pond (Ståhl et al. 2002) and DiamondTouch (Dietz and Leigh 2001) have been developed. With these horizontal displays, users can observe data from all sides of the tabletop, and various techniques have been developed to allow users to collaboratively work together on common data objects. However, there has been little research looking into privacy and security of data between users whilst using collaborative tabletop work environments.

Using a custom designed display mask in conjunction with a standard LCD monitor, we have developed a technology that allows multiple users to have independent views whilst looking at one common digital display. With the ability to separate each user's view on the same display, we have developed techniques that allow users to have both public and private data displayed together. In

this paper, we present a taxonomy we have developed to help understand the various combinations of public and private workspaces that are possible. This taxonomy is useful as it helps to show all the possibilities and understand their uses when designing multi-view tabletop applications.

The different operating modes described here allow us to perform a number of new collaborative techniques. Firstly, we have achieved data hiding where only one user has access to a piece of data. Consider the scenario of an employer and employee meeting at the tabletop. Using the private work area the employer is able to view the employee's history file, assess the data, and then has the option of sharing all or some of the data with the employee. Data can alternatively be presented in an altered form, where one user has access to the private detailed data while the public data has been reduced to conceal particular parts. This allows users to point to the data on the table and others are able to understand what is being pointing at. We have developed a window manager to demonstrate how multiple users can individually control public/private attributes, visibility, position, and orientation of data using a cooperative tabletop display and our taxonomy.

## 2 Related Work

Since early systems such as the Digital Desk (Wellner 1991), we have seen the incorporation of computers and collaborative tabletop working environments. The Digital Desk used low resolution ceiling-mounted projectors that suffered from problems like shadowing when users lean over the table while making gestures. More recently, high-resolution horizontally-mounted LCD, plasma and rear projection screens have been used to improve the quality of tabletop systems overcoming some of these initial limitations.

The Pond (Ståhl et al. 2002) developed by Ståhl et al. introduced the shoulder-to-shoulder collaboration concept, where a plasma display was placed horizontally on a tabletop to better support collaboration between people gathered around a table. As the need to support collaborative work environments has increased, we have seen new technologies support features like multiple-touch-based input such as Diamond Touch (Dietz and Leigh 2001), allowing multiple users to interact with co-operative tabletop environments more naturally.

To provide a unique perspective for all users collaborating around a tabletop system, a limited number of multi-view display applications have been developed. The Lumisight Table (Matsushita, Iida and Ohguro 2004)

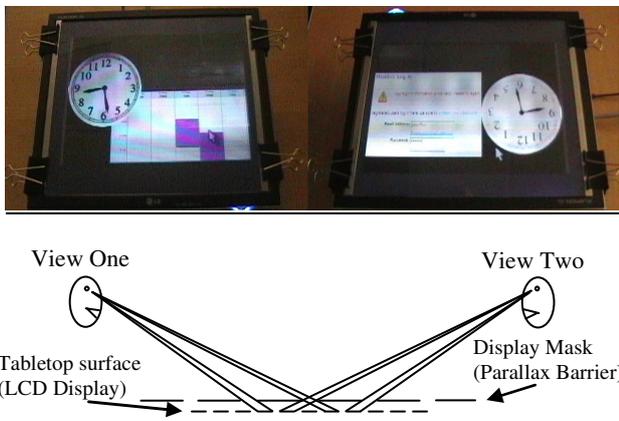
uses sheets of lumisty and rear mounted projectors to achieve four independent viewing directions. They describe how orientations and locations can be mapped between different users simultaneously to support a variety of collaborative tasks. They also presented a case scenario where four professionals from different disciplines contributed to the design considerations of a wind power plant. Each user can press any of the four buttons available to overlay data with alternate orientations and positions. Matsuda et al. (Matsushita, Iida and Ohguro 2004) evaluated a disjunctive-cooperative task (Group performance is that of the best member) using a maze application where each user's view of the maze is restricted. The current use of the Lumisight Table has shown some specific case scenarios that take advantage of the multi-directional display table, however the discussions and experiments relating to the use of public and private data are limited.

The Illusion Hole (Kitamura et al. 2001) demonstrates another multi-view display. With users having to view the display through a hole in the centre of the table, each user looks at a separate portion of the display surface. This considerably limits the usable display area for each user.

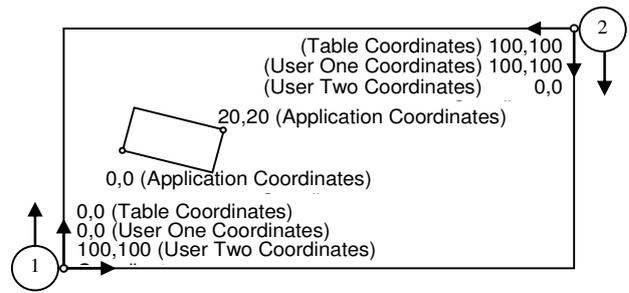
We have observed that multi-view displays can provide a range of new interaction techniques that further expand the co-operative working environment's usability. By using a multi-view display it is possible to correct orientation issues described by Kruger et al. (2003) and Hancock et al. (2006), and view private data where only nominated participants can see the full data, or a reduced subset of it. When working with our multi-view display we found that there are many different combinations that data can be viewed and shared between users. To better understand how these can be used we have classified position, orientation, public/private, and visibility combinations into a taxonomy that shows the possibilities when using a multi-view display.

### 3 Multi-view Display Details

To allow a standard LCD display to be used as a multi-view display, we have constructed a custom display mask that is placed on top of the monitor's surface. The display



**Figure 1 – Example of two view directions achieved using a display mask (parallax barrier) on a LCD Display.**



**Figure 2 - Multi-view display co-ordinate systems**

mask is similar to a lenticular lens, first known to be developed by the French painter Cois-Clair in 1692 to achieve multiple images within one painting. When such a painting is viewed from the left or the right, then different images are visible.

The display mask, depicted in Figure 1, demonstrates the parallax barrier we used to generate separate images for more than one viewing angle. Currently we have printed a display mask pattern that supports four viewing angles; we found increasing the viewing angles to more than four reduced the resolution so as we were unable to display text clearly. We experimented with a number of different patterns to determine which one provides the sharpest and highest resolution image.

### 4 Public / Private Workspaces

Collaborative workspaces, as the name suggests, are designed to provide an environment that allows users to express their ideas and opinions to a group. Horizontal tabletop displays such as (Dietz and Leigh 2001; Ståhl et al. 2002; Shen et al. 2004; Chen et al. 2006) are good examples of such tables. These systems do not allow individuals to have private data available to them whilst collaborating with others. In many business situations different professionals have access to data they do not want to reveal. We propose that a multi-view display can be used to support private data whilst using a collaborative display. Using the proposed system only users selected by the owner can view the private data.

The system we have developed allows each user to dynamically change the viewing mode of any part of the tabletop display allowing data to become either public or private. Each user has a separate view dedicated to them, using a separate frame buffer for each view, and users can choose to share their data by allowing it to be written to another user's frame buffer. Previous research performed by Matsushita, Iida and Ohguro (2004) has considered multi-view displays for displaying individual viewpoints for users seated around a table. Matsushita et al. discussed some initial techniques used to display different orientations and locations to users seated around the Lumisight table. Our system further expands on this initial research by presenting the public and private use of data on a tabletop environment.

### 5 Classification

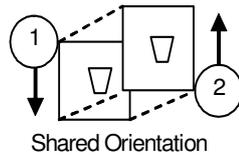
After we initially developed software for our multi-view display, we quickly found it difficult to understand all the different combinations that were available. Should data

shared by users be forced to share the same position, orientation, visibility, or some combination? We therefore started off by first defining what it means to have shared or unique orientation, position and public/private attributes. These are then used in Table 1 to provide a taxonomy of the different combinations obtainable. When describing features of the display we have used three coordinate systems, which are depicted in Figure 2. Table Coordinates use a single reference point that is relative to the physical table. All items in Table 1 use table coordinates to describe locations and orientations. User Coordinates are relative to the view direction of a specific user (one view direction per user in our example). User coordinates are only useable within some of the cells in Table 1. Application Coordinates are used on an application specific level, for example each window has its own local co-ordinate system using the user's bottom left corner as (0,0).

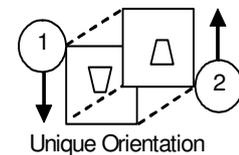
To simplify the discussion and diagrams, we have assumed that there are two individuals using the tabletop. Although the taxonomy is a scalable approach, the only limitation is imposed by the physical design of the display mask used and the number of people that can comfortably operate simultaneously around such a display.

### 5.1 Shared/Unique Orientation

Shared orientation is where each user looking at the table's surface can see the same orientation in table co-ordinates. For example, when two users sitting at opposite sides are viewing text one sees correctly-oriented text whereas the other users see the text upside down.

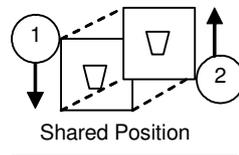


Unique orientation allows each user to view the data with an independent orientation. For example, each user is able to see text the correct way up.

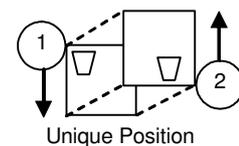


### 5.2 Shared/Unique Position

When viewing data, a shared position ensures each user perceives the location of the data to be the same relative to the table coordinate system.



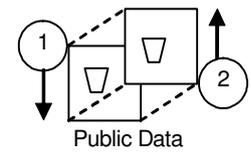
When using a unique position, each user can alter the position of the data to different locations on the table.



### 5.3 Public/Private Data

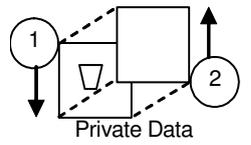
When data is made public, users seated at the table can both view the same data. Private data allows only the owner to view the data. A window may contain a combination of both private and public data. Consider a classified document, the owner may choose to make some

of the text public, excluding names that remain private. All of the other users would effectively see the body of the document with the names blacked out.



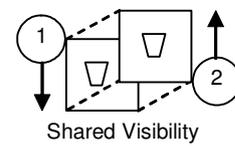
## 6 Discussion

To better understand the characteristics of a multi-view tabletop display, we have categorized the features using shared/unique orientation and position, as well as public/private data sharing, as the three significant axes. When considering the possible different axes we also considered scale to supplement orientation. We found that scaling has the same implications and features as orientation. We have chosen to use only orientation, based on the study Kruger et al. that demonstrates the significant effects of orientation while using a tabletop collaborative work environment (Kruger et al. 2003).

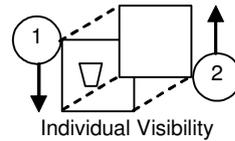


Each of the cells in Table 1 support different operating features. When using a tabletop environment it is often desirable to use one's fingers to point out objects of interest - we refer to this as gesture pointing. To achieve gesture pointing there must be a common reference point between orientation and position and as such this is only supported in C1 & C2. It is possible to use gesture pointing with private data only if there is some portion of the data that is public so that there is a common reference point between the data sets.

The features of C1 can all be achieved using a single-view display, with a multi-view display effectively emulating a single-view display. When using this mode of operation, we refer to this as a shared visibility. Shared visibility allows any window to be visible to all users sitting at the table, however the orientation and position, which is relative to table coordinates, is kept exactly the same. Unlike public data, this guarantees individuals are able to use gestures such as pointing with their fingers, where mice and other digital pointing devices are not desirable.



C3 and C4 supports separate orientations, which is well suited to annotations since it is possible to alter the orientation of the text so as to appear in the correct direction for each user. This mode may be used in conjunction with other modes, for example a 3D model may be displayed using shared orientation, position, and public data (C1) while text annotations are presented using unique orientation, shared position and public data. This hybrid operating mode allows gesture pointing referring to the model as a reference point while annotations are oriented correctly for all users.



C5, C6, C7 and C8 all allow each user to control the organization of their windows on the appropriate data separately, since the viewports are effectively detached.

		Shared Orientation	Unique Orientation
Shared Position	Public Data	Allows Gesture Pointing C1 Single View Display Shared Visibility Table co-ordinates Application co-ordinates	No Gesture Pointing C3 Allows upright text orientation User co-coordinates Application co-ordinates
	Private Data	Single View Display C2 Allows Gesture Pointing Table co-ordinates Application co-ordinates	No Gesture Pointing C4 User co-coordinates Application co-ordinates
Unique Position	Public Data	No Gesture Pointing C5 Common orientation is useful for 3D model discussions User co-coordinates Application co-ordinates	No Gesture Pointing C7 Individual user controlled layout User co-coordinates Application co-ordinates
	Private Data	No Gesture Pointing C6 User co-coordinates Application co-ordinates	No Gesture Pointing C8 User co-coordinates Application co-ordinates

**Table 1: Taxonomy describing tabletop view characteristics**

In the case of C3, C4, C5, C6, C7 and C8 with unique orientation, unique position, and shared visibility there is a conflict, it is not possible to have both unique orientation or unique position and shared visibility at the same time according to our definition.

## 7 Initial Application

Since the development of our multi-view display, we have considered a large number of different applications to demonstrate the new techniques we can achieve on this particular type of system. To demonstrate the public/private data concept within a collaborative work environment, we have written a simple window manager with some extended features. Each user controls their environment with a separate mouse cursor, in the future we plan to implement interactive pointing with the user's hands.

The window manager allows the user to create a new window and dynamically control the orientation, position, data privacy, and visibility. When either user creates a window, the applications actually generate two copies – one for the owner and one for the other users to look at. The owner can control whether the public version is actually visible or not, and whether it contains the same or a different set of data. The position of the window can then be moved with the mouse using standard dragging techniques. However, when the window is marked as public there are two modes the position operation follows. Either the position is inverted and copied on the second user's display, or the second user can control the location individually using their mouse. Orientation operates in a similar way to that of position. The orientation can be copied on the second user's display or controlled individually by each user.

## 8 Conclusion

The first contribution of this paper is the use of a display mask designed specifically for a tabletop to support multiple views on a standard LCD display. Secondly, we used this to introduce the public/private data concept for use in a collaborative tabletop work environment. To understand the new characteristics of the multi-view display, we have produced a taxonomy that categorizes the different view techniques used on such a display.

## 9 References

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