

# Multi-Layer Interaction for Digital Tables

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## ABSTRACT

Interaction on digital tables has been restricted to a single layer on the table's active work-surface. We extend the design space of digital tables to include multiple layers of interaction. We leverage 3D position information of a pointing device to support interaction in the space above the active work-surface by creating multiple layers with drift-correction in which the user can interact with an application. We also illustrate through a point-design that designers can use multiple-layers to create a rich and clutter free application. A subjective evaluation showed that users liked the interaction techniques and found that, because of the drift correction we use, they could control the pointer when working in any layer.

**ACM Classification:** H.5.2 [User Interfaces]: Interaction styles; I.3.6 [Methodology and Techniques]: Interaction techniques.

**General terms:** Design, Human Factors

**Keywords:** Interaction Techniques, Pen Input devices, Pointing Techniques, Multi-layer interaction.

## INTRODUCTION

Digital tables are a new range of pen-based devices that are growing in popularity in many design and architectural firms. A common feature of all these systems is the pen or pen-like pointing device they use for interaction. These pen-based devices offer several benefits; not least of which is the users' ability to sketch, edit and annotate digital documents by offering familiar established practices.

A wide variety of research has been done into ways that users can interact with data and with each other through digital tables. Users can work together on tabletop displays using single input devices (such as tangible blocks, styluses, mice, or fingers), or using multiple-touch input devices such as that used with the DiamondTouch table [4]. Wu and Balakrishnan [12] present multiple-finger and two-handed gestures to allow users to increase the input bandwidth.

Most of the tabletop techniques restrict the physical space for interaction to the table's active surface and offer limited

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use of the space above the work-surface. Balakrishnan and Ramos [6] explored the role of pen pressure in creating another interaction layer below the active work-surface, Parker et. al [8] explored reaching distant targets by moving the pen above the table's (active) work-surface and the Responsive Workbench [6] employs shutter-glasses and virtual-reality tools to support continuous 3D interaction in the space above the table. There is however, no exploration of a systematic use of the space above the table for discrete layers of interaction.

We extend the design space of digital tables by exploring multi-layer interaction techniques. Here the user can maintain multiple-layers of visual content and move between layers by moving their pen in the space between their body and the tabletop. This space is divided into multiple parallel-planes with each plane corresponding to a layer. Figure 1 illustrates the multi-layer interaction technique for a sketching application. Here, the layer farthest from the work-surface consists of several piles which the user browses in successive layers to select and edit an image in the layer closest to the tabletop.

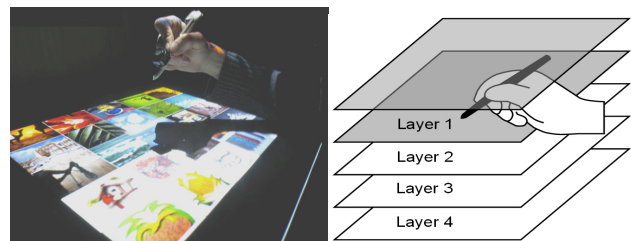


Figure 1: Multi-layer interaction Technique with a cross-section of the interaction space.

One problem with multi-layer techniques is maintaining the interaction to a fixed height above the physical surface. Users, during the course of interaction, drift to a different height above the physical surface thereby entering a different layer. To overcome this we devised a drift correction technique where the layer's height is dynamically adjusted to maintain the cursor within a layer.

We investigated through an informal experiment the user's ability to select and position objects within and between layers. We explored various selection schemes, with and without drift correction. The results show that users found the technique intuitive to work with; they felt they had complete control of the interaction when drift correction was active; and could control layers more than 4cm in thickness.

The main contribution of this paper is a multi-layer interaction technique with a user-controlled drift correction that offers designers a new set of interaction techniques for developing applications with complex functionalities. We could further identify the optimal selection technique and the number and thickness of layers for better user control.

### MULTI-LAYER INTERACTION

Previous work on Wall-display [11] focused mainly on being able to interact with large wall-displays from a distance. Here we mainly develop a technique that supports user interaction in the range of 0 to 16cm above the work-surface. We restrict ourselves to this range so that users can move their hands freely without having to remove their forearm or elbow from its resting position on the table or chair arm-rest.

The active area above the work-surface is divided into multiple layers. Each layer extends to the length and width of the work-surface but is at different heights from the work-surface and about 4 cm in thickness (we later test various other layer thicknesses). Figure 1 illustrates the multi-layer configuration with Layer 1 active. Each layer invokes different commands, menu items and input functionalities in the display surface.

Moving the pen into a layer updates the display with matching visual information and allows user access to the layer's functionalities. The user moves the pen parallel to the work-surface to position the cursor.

The two main challenges of multi-layer techniques are overcoming user's drift between layers and supporting selection.

#### Drifting

If the user's hand movements take the pen outside the upper and lower boundaries of a layer then the system detects a change in layers and updates the system state. Even though the user is resting their arm comfortably when interacting, the lack of any physical feedback when moving the pen and the two-dimensional nature of the tasks makes the user prone to drifting between layers. For the multi-layer technique to be effective we need to minimize unintentional changes in layer.

We overcome drifting by using several measures. First when the user enters a new layer we recalibrate the position of that layer such that the pen tip is at middle of the layer (see Figure 2, point A). Thus only pen movements greater than 2 cm towards or away from the work-surface can result in a layer change. We also continuously reposition the layer, with respect to the work-surface, when the pen has reached its initial boundaries (see Figure 2, point B). If the pen drifts by  $dZ$  then we displace the layer by  $dZ$ , however this only happens when the displacement  $dZ$  occurred slower than a predefined speed. Users can change layers by quickly moving the pen beyond the boundaries of the current layer in less than 100 ms. At this speed the system interprets the pen movement as a layer change and does not perform drift correction. Drift correction starts at the initial

boundary of a layer and stops when the layer overlaps an adjacent layer by more than 50% (see Figure 2, point C).

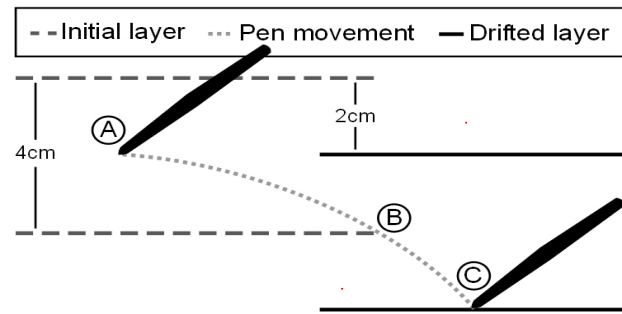


Figure 2: As the pen drifts to the bottom of a layer (B) the application “drifts” the current layer together with the pen.

We use visual feedback on the position cursor to warn users if they are drifting. The cursor is partially filled to indicate three drift scenarios. Red to indicate the cursor is drifting too close to the boundary of the layer and drift correction is not effective anymore, Yellow to indicate that the user is in the limit of drifting but our correction is effective in adjusting the layers and Green to indicate that there is very little drift and no need for drift correction. The upper or lower half of the cursor is filled to indicate which boundary they are approaching.

#### Selection

We investigated four selection techniques (Figure 3), Button, Pen-AirTap, Pin-Though, and Crossing.

**Button:** Mode-switching is analogous to command selection; based on an investigation of various mode-switching strategies in pen-based systems Li et al [7] found the non-preferred hand button to be the most effective and preferred technique. In our system, users were provided with a button close to their non-preferred hand to function as the selection switch. Here a switch has its limitations; due to the large area of the work-surface and multiple layers, users have to switch visual context when acquiring the button. This could make it difficult for the user to hold their dominant hand in a steady position while pressing the button.

**Pen-AirTap:** Vogel and Balakrishnan [11] proposed Air-Tap, a clicking scheme for selecting distant targets in large wall displays analogous to the index finger movement when clicking a mouse. The Pen-AirTap technique works on a similar principle where selection requires a tiny and quick ( $<0.5s$ ) displacement of the pen just enough to register the movement without users moving to a different layer. Through an informal pilot test we calibrated the technique and fixed the width of the displacement to be at least 4mm towards the work-surface and 4mm back-up. The net pen displacement is not large enough for users to accidentally change layers. In the layer closest to the work-surface users can benefit from the use of the familiar double-tap gesture for selection. Another advantage of the technique is its support for the entire point-and-click user interface.

**Pin-Through:** The Pin-Through technique is an adaptation of the Pen-AirTap and Space Touch [10]. It works by plac-

ing a thin activation plane within each layer. The activation layer is fixed with respect to the layer's lower boundary and drifts with the layer during active drift correction. To select an object the user has to move into and out of this activation layer. The technique does not depend on how fast the users move their pen. This technique is not affected by drift correction as it requires a high-frequency action whereas our correction only affects low-frequency drifts.


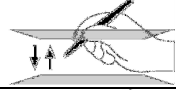
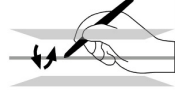

Selection Techniques	Actions
<b>Button</b> (non-dominant hand)	
<b>Pen-Air Tap</b> (rapid movement within layer)	
<b>Pin-Through</b> (crossing activation plane)	
<b>Crossing</b> (entering and exiting element)	

Figure 3: Selection Techniques: Button, Pen-AirTap, Pin-Through and Crossing.

**Crossing:** The crossing technique works similar to CrossY[2] and Slide Off [10]. If pen enters the object and then exist it close to the entering point the object is selected. The obvious advantage of this technique is that it does not require vertical movement, therefore its easier to stay within one layer when selecting an object whereas it is currently not possible to deselect the object.

### Multi-layer Applications

Multi-layer approach can be beneficial to applications like interactive map visualization and photo- annotation and-browsing that support different functionalities clustered into logical groups. For example in the map-visualization application, each layer can be used to represent bus-lines, nearby restaurants, attractions, live summer events and traffic-updates. By quickly moving the pen a user can easily explore different representations. Below we describe a sketching application to illustrate the usefulness of the multi-layer interaction techniques.

#### A Sketching Application

The application is inspired by the need for designers and architects to browse through image piles and easily edit individual images [1, 6]. The application allows users to move from browsing through several image piles to choosing a particular pile for closer examination and selecting a specific image for sketching and annotating. The main purpose of this application is to illustrate the potential of multi-layer techniques. We used A2 Wacom tablet (for sketching and writing) with top projection in combination with an InterSense 3D positional tracker (to track the pen).

The system consists of four layers. The topmost layer, farthest from the work-surface, consists of a collection of piles. Users can select the pile to move it to a different location or see the meta-tags associated with the pile in the

work-surface. In the next layer users can examine the contents of the pile selected from the previous layer. In this layer, users can read details about the image (like when the image was taken or name of the building and its architect) and browse through them to see slightly enlarged versions of images. Further moving the pen closer to the table expands the highlighted image to cover the entire workspace and pops open a floating toolbar to allow tool selection for editing the image. In the final layer users can edit the image with the tool selected from the previous layer.

The final layer corresponds to a familiar pen-based digital canvas for image editing with the toolbars hidden in the layer above but easily accessible by lifting the pen. Similarly user can change the image on the editing canvas by lifting the pen higher to get access to the active pile for reselecting a new image.

### SUBJECTIVE EVALUATION

We first investigated the optimum thickness for each layer in a pilot experiment with 4 users. We tested 6 thicknesses 1, 2, 4, 6 and 8 cm thickness for each layer. Users were asked to move various objects between and within layers in our system with 4 layers. We found that at 1 and 2 cm thickness users committed too many errors and it was hard to stay within a layer. At thickness of 6 and 8 cm users were able to easily stay within the layer but had to lift their arm too often to complete the interaction and felt fatigued within 10 mins of system use. Users were most comfortable and least error-prone when working with 4cm layers.

The usability and usefulness of the multilayer technique was tested in a user study. The main goal of the study was to identify any problem with the interaction technique. We focused on whether users were able to navigate between and within layers with and without drift adaptation and perform selection with the different selection schemes. The experiment was conducted with 5 participants (2 females, 3 males), all right-handed. The study was performed using the sketch application described above. Users were instructed to focus on the interaction technique rather than the richness of the application. Following a description of the interaction, subjects were allowed 10 minutes to gather initial experience with application functionality. After that they were asked to perform several tasks that involved moving between layers, to stay within one layer (browse through images, reposition piles of images), perform selection on the toolbar (select pen color, thickness, and transparency) and write or sketch on an image. Finally, subjects were asked to rank the different selection techniques and comment on the interaction. Average time per user was 45 mins.

### Results

All users felt that the interaction technique was intuitive, flexible and easy to use. Most users (4 out of 5) felt they were able to stay within the layers when actively correcting for drift, while 3 out of 5 did not notice any difference when moving between layers. Two users commented that even-though it was easier to move between layers without drift control they could easily learn the gesture to move

between layers with drift control. Most users (4 out of 5) commented that the feedback was marginally useful in the beginning while after some training they felt no need for any feedback. The users were able to remain within the layer without any feedback as long as drift control was active. However, we observed that with feedback users were less error-prone than without feedback.

Users found it easy to navigate. They were able to quickly learn how to use the techniques and had little problems with moving within and between layers. Most users preferred the non-preferred hand button followed by the Crossing based selection technique over Pen-AirTap or Pin-Through.

## DISCUSSION AND CONCLUSIONS

All users felt they could see themselves working with a commercial application that used this kind of interaction techniques. Users also had no difficulty staying within the layer when drift correction was active.

In the application we developed, users found it natural and intuitive to move between layers. They clearly understood the layout of functions across layers. Users also appreciated that they performed coarse-level interaction at upper layers and progressed to fine motor control in the layers closest to the table surface. Application developers need to carefully design the various layers so that the progression from a top to a bottom layer is logical and does not require users to remember each layer's functions.

Our pilot study also showed that interactions at height greater than 16cm from the work-surface can cause user fatigue whereas interacting with layers less than 4 cm in thickness can cause too much frustration due to increased errors (accidentally changing layers). We thus believe that 4 layers at about 4 cm thickness each leads to optimal user performance in such environments. We also found that layers where users only navigate can be thinner than layers where selection is necessary similarly layers closer to the work-surface can be thinner than others.

Of the various selection schemes we tested, users most preferred the non-dominant hand button. In our experiment targets were not small enough to cause any selection errors due to temporary loss of focus. Clever distribution of objects over multiple layers can minimize the need for small targets making the button a powerful selection technique. Techniques like Pen-AirTap and Pin-Through were not well received by the user. We plan to investigate stronger cues to overcome ambiguities between these selection techniques and moving between layers.

Even though we only tested our technique on a mid-size table suitable for single user applications we believe the technique can be extended to larger surfaces. However as with any technique that expects a user to interact with their arms stretched out, fatigue can affect performance. Smarter segmentation of layers and more aggressive compensation for drifting can alleviate user fatigue. An alternative approach is to augment our technique with long-distance reaching techniques like drag-and-pop [3] to support inter-

action without having to extend the arm beyond a user's immediate reach. However further user-testing with larger tables is needed to access effect of fatigue on performance.

This paper extends the design space of digital tables by investigating multi-layer interaction techniques. Multi-layer interaction technique with drift correction can be controlled by users and offer designers with a new set of tools for developing novel interaction techniques. In the future we plan to define layers that follow the hand movement dynamics and perform Fitts' law type studies.

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## REFERENCES

1. Aliakseyeu, D. (2003) A Computer Support Tool for the Early Stages of Architectural Design. PhD thesis, Eindhoven University of Technology, The Netherlands.
2. Apitz, G. and Guimbretière, F. 2004. CrossY: a crossing-based drawing application. In *Proc. ACM UIST '04*.
3. Baudisch, P., Cutrell, E., Robbins, D., Czerwinski, M., Tandler, P. Bederson, B., and Zierlinger, A. Drag-and-Pop and Drag-and-Pick: Techniques for Accessing Remote Screen Content on Touch- and Pen-operated Systems. In *Proc. of Interact '03*.
4. Deitz, P. and Leigh D., DiamondTouch: A Multi-User Touch Technology, In *Proc. ACM UIST '01*.
5. Keller, I., Hoeben, A., van der Helm, A. Cabinet: merging designers' digital and physical collections of visual materials. In *Proc. 3AD '05*, Bristol, UK.
6. Krüger, W. and Fröhlich, B. The responsive workbench. *IEEE Computer Graphics and Applications*, vol. 14, no. 3, pages 12–15, May 1994.
7. Li, Y., Hinckley, K., Guan, Z., Landay, J. A. Experimental Analysis of Mode Switching Techniques in Pen-based User Interfaces. In *Proc. ACM CHI '05*.
8. Parker, J. K., Mandryk, R. L., Inkpen, K. M. Tractor-Beam: Seamless Integration of Local and Remote Pointing for Tabletop Displays. *Proc. Graphics Interface '05*.
9. Ramos, G. and Balakrishnan, R. Zliding: fluid zooming and sliding for high precision parameter manipulation. In *Proc. ACM UIST '05*.
10. Ren, X. and Moriya, S. Improving Selection Performance on Pen-Based Systems: A Study of Pen-Based Interaction for Selection Tasks. *ACM ToCHI*, 7(3), 2000.
11. Vogel, D. and Balakrishnan, R. Distant freehand pointing and clicking on very large, high resolution displays. In *Proc. UIST '05*.
12. Wu, M., and Balakrishnan, R. Multi-finger and whole hand gestural interaction techniques for multi-user tabletop displays. In *Proc. ACM UIST '03*.