Lambda Table: High Resolution Tiled Display Table for Interacting with Large Visualizations

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Abstract

To explore new methods of interaction with large scientific datasets, we have developed a high resolution visualization table. This system merges table interaction and Tangible User Interfaces (TUIs) with current tiled display technology. We discuss the advantages of tiled Liquid Crystal Display (LCD) systems over projector based displays, and present the LambdaTable, our implementation of a tiled LCD table. We also discuss camera tracking of tangible interface devices on the table, and present a system for validating this interface against Fitts' Law.

1. Introduction

Current scientific visualization research has produced large scale display systems capable of rendering very high resolution datasets without sacrificing context or detail. To support scientific collaboration, these display systems have been connected via high bandwidth optical networks. Extending this research, we have developed a horizontal tiled display and interface system called the LambdaTable (figure 1). This system merges table interaction and tangible user interfaces with current tiled display technology. The LambdaTable will be used to investigate multi-user, multi-modal interaction over a shared visualization "sand-box" using a variety of physical data manipulation tools.

2. Related Work

The LambdaTable draws on results from three overlapping areas of research - table top human computer interaction, TUIs and large display systems. Previous table interaction research has explored issues such as personal and shared space management [11], orientation [15], territory [23] and document passing [6, 21]. With respect to TUIs, two projects are of particular relevance; graspable bricks [9] and the metaDesk [25], which uses physical icons, handles and instruments on a table to manipulate a map application. Many other projects also employ physical objects on a table to facilitate human-computer interaction [19, 20, 26]. Two areas of display research are relevant to the Lambda Table- tiled high resolution displays and room based "ubiquitous" display systems. The Electronic Visualization Laboratory (EVL) specializes in developing advanced display systems. EVL produced the CAVE in 1992 [8]. Following the CAVE, tiled display systems were built with projectors driven by multiple computers [3, 10, 18, 22]. EVL extended this research by building the Geowall2 [13], and recently the LambdaVision display [2]. Previous room based "ubiquitous" display systems include i-Land [24] and iRoom [12]. At EVL, we have continued this research with the Continuum project [16], the Scalable Adaptive Graphics Environment (SAGE) [4], and LambdaVision.

Figure 1. The LambdaTable.

2. Tiled LCD Displays

EVL has researched tiled displays using high-end as well as commodity projectors. In our most recent work in developing tiled displays, we have chosen to use LCD panels. These panels are an extremely desirable solution for viewing large images because they are cheap, bright (viewable in standard office lighting), require no projection distance, are rather-well color-matched, and provide a wide-field of view.

While it is possible to build tiled displays with projectors, the costs are prohibitively high for extremely large high resolution screens. For example, a high-end 1600x1200 20-inch LCD panel costs approximately $1000 (without DVI cables). A 1024x768 2000 lumen projector costs about $1600. Hence a 55 panel array of LCDs costs approximately $55,000 whereas a projector-based display with the equivalent resolution will require 136 projectors and cost $217,600, roughly four times the cost of an LCD panel based solution. Furthermore the bulb-life of LCD panels is approximately 20000 to 30000 hours, or 3.5 years if the screen were left on permanently. Projectors have a bulb life of about 2000 hours, and each bulb replacement costs $350- one complete bulb change for all the projectors will cost a total of $47,600- almost the cost of the entire tiled LCD screen[1].

LCD screens however have one minor drawback at the present time - borders around them that are about 10mm thick on all sides. We mitigate their impact by explicitly hiding the pixels under the borders- the net effect is akin to looking out of a set of French windows. This ensures that lines that cross borders appear to be continuous. We anticipate that over time border widths on panels will diminish. Furthermore, promising new display technologies such as Organic LEDs and optical devices are emerging that will aid in eliminating the borders altogether.

[1] Estimations based on numbers from August, 2005.

3. LambdaTable implementation

Drawing upon our experience with display systems for scientific visualization and collaboration, we have built a table that is uniquely capable of facilitating group interaction with large datasets. Multi-terabyte datasets are becoming more prevalent and important in medical and geoscience research. The goal of the LambdaTable is to provide scientists with a new method for visualizing, understanding manipulating, and sharing their high-resolution data.

In 2004, we took our first step towards this goal by converting one of our tiled displays, the Geowall2 (figure 2), to a table configuration. This 5x3 tile display is driven by a cluster of 10 PCs each with high-performance graphics cards. Each display has a maximum resolution of 1600 x 1200, creating an 8000 x 3600 pixel display, over 28 million pixels in all. This display is 38 in. by 78 in. and can comfortably fit 15 users around its perimeter. None of the previously built projector based table systems have close to this resolution, in fact most rated fewer pixels than one of the LCD tiles. As a result, the LambdaTable makes much more visual data available to collaborators, providing both detail and context information simultaneously and eliminating interruptions caused by panning and zooming.

To facilitate group interaction, and to explore a variety of user interface paradigms as applied to

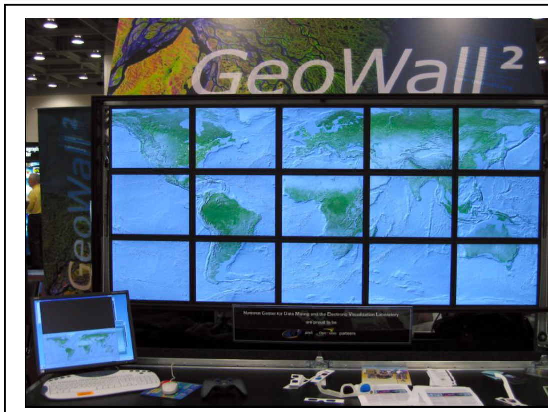

Figure 2. The GeoWall2.

scientific visualization, we have implemented a tracking system for tangible user interface devices on the table's surface. The system employs cameras mounted overhead to track objects that are identified by a unique pattern of embedded infrared LEDs (figure 3). This approach constrains the tracking task to an easily segmented, two dimensional pattern matching problem. Initial tests yield frame-rates of 30 HZ with latency below 100ms on a 3 GHZ Pentium4 PC. Any number of devices can be tracked simultaneously, as long as each pattern is unique. Currently, a "mouse" style interface device has been built using an arrangement of 5 LEDs (figure 4), three to indicate position and orientation, and two as indicators for the mouse buttons (figure 5). The main drawback to this implementation is that occasionally one or more LEDs are occluded by the user's hand or head. Alternate approaches such as using RFID markers, touch screens or different camera configurations are either not feasible with an LCD display, or do not offer the same flexibility of design and arbitrary number of tracked objects. Alternatives to LED patterns are being investigated, such as IR illuminators and reflective markers.

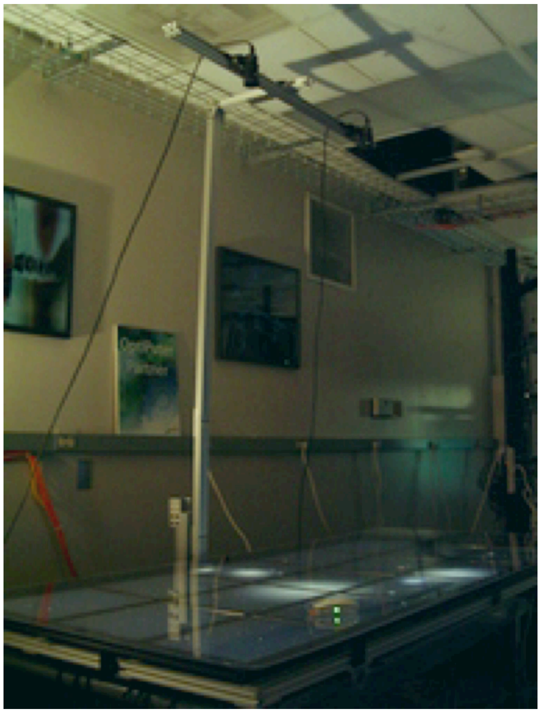

Figure 3. Cameras mounted above the table.

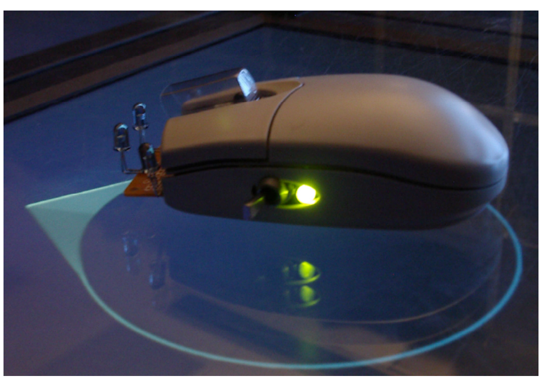

Figure 4. The tracked "mouse".

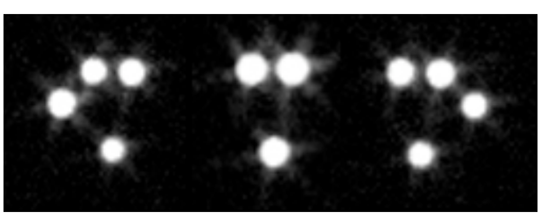

Figure 5. The tracked pattern.

4. Interface Validation

In order to validate the tracking system as an appropriate user interface, we constructed a smaller version of the Lambda Table with four LCD screens and developed an application to determine if the table functioned according to the expectations of Fitts' Law. The application generates a series of circular targets at varying positions and the user's objective is to click on the targets as quickly as possible. The targets were defined by three different criteria: size, angle from horizontal, and distance along the axis defined by the angle. The distance and angle combinations were specifically chosen to prevent any part of the targets from being occluded by the borders of the LCD monitors (figure 6). Addressing the variability introduced by partial target occlusion was outside the scope of this experiment.

Qualitatively the distances can be described as near, medium and far, but because of the layout of the displays, the distances turned out to be unique for each angle. This created nine different target distances, seen in Table 1. The farthest target positions were far enough from the home point as to require an average user to stretch slightly in order to reach the target, using more than just arm muscles.

The Index of difficulty for each target acquisition can be computed using the formulation of Fitts' Law based on the size of the target and its distance from the home point [17]. Based on our interaction with the program we are confident that the LambdaTable is a Fitts' Device. We intend to continue to explore the Fitts' Law properties of the table, and will publish the results separately.

	0 deg.	45 deg.	90 deg.
Near	7.58	8.6	4.07
Medium	14.45	17.84	10.46
Far	22.03	26.39	14.53

Table 1. Physical distances (inches) at each angle

5. Current Applications

Two applications are being developed to experiment with interaction on the tiled display surface and to begin addressing some potential uses for the table. The first is a galaxy simulation and the second is a large-scale "google" style map and satellite overlay. The space simulator application was developed to provide a first look at direct data manipulation on the LambdaTable. The application uses an in-house graphics development environment called Electro [1] to render a model of the galaxy, and uses the tracked mouse input to control a first person fly-through. This program has provided some encouraging insights into the effect of the screen borders on the user's experience- as the user interacts with the simulation, the screen borders become less noticeable. The map application is much earlier in development, and will be useful for testing special-purpose tangible interface devices that pan, zoom, rotate and query multi-layer datasets.

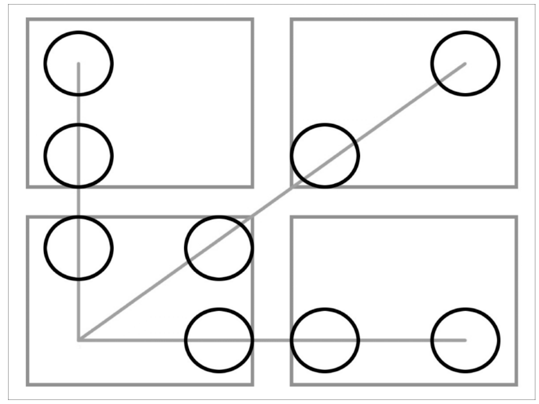

Figure 6. Three targets per angle, not occluded.

Figure 7. Home point.

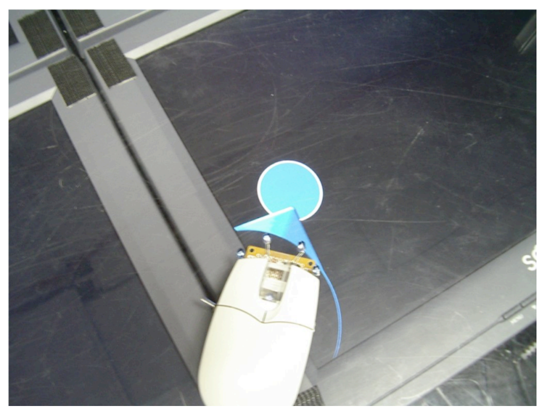

Figure 8. Acquired target.

In July 2005, EVL completed construction of LambdaVision [2], a vertical 55 tiled LCD display. We intend to use the LambdaTable as one method for controlling the visualizations on the vertical tile display. Our goal is to incorporate the table into an integrated room based collaborative solution centered on tiled display technology. Using SAGE [4], users will have a common display manager, affectively merging the table and wall systems into a single display. In this environment, data can be spread across the wall for presentation, and brought down to the table when necessary for annotation or closer inspection. In effect, LambdaTable will give users a large, direct manipulation, high-resolution table within arm's reach that they can work on while simultaneously seeing contextual information on the vertical tiled display. Current tiled systems require scientists to walk up to the display to point out things to their colleagues; the table will allow them to bring those visualizations within reach.

Figure 9. Using the LambdaVision display.

6. Future Applications

By merging current visualization technology with previous research on table interfaces, new scenarios can be envisioned that expand upon previously presented applications such as the metaDesk [25], and responsive workbench [14]. We propose two future applications for the LambdaTable: a terabyte imagery workbench, and a multi-sensor situation table. These concepts take advantage of advanced collaboration and visualization technology (i.e. high speed optical networks and multi-megapixel displays) combined with tracked tangible interface elements to enhance the capabilities of the traditional table interface and expand the types of interaction possible.

6a. Terabyte Imagery Workbench:
Scientists in the fields of biology, chemistry and geology currently have specialized scopes and scanner systems capable of generating high resolution images containing hundreds of megapixels. Organizations like the National Center for Microscopy and Imaging Research (NCMIR) and Joint Oceanographic Institutions (JOI) require new methods for displaying and manipulating multi-gigabyte to terabyte images. Based on LambdaTable technology, we propose a high resolution imagery workbench for arranging, inspecting, annotating and linking multiple images. In this scenario, scientists will use tracked tangible markers to position, stack, and scale images to reflect or reinforce relationships between datasets. Textual data will rotate to match the user's location and position itself to avoid screen borders. Coupled with LambdaVision, the table can be used to designate areas for magnification on the wall display, or the wall display can provide context for detail regions under investigation on the table.

One specific application for which the workbench would be valuable is to assist scientists who manipulate high-resolution microscope images. These scientists build three dimensional models by outlining the two dimensional form of an object on each slice of a stack of samples. Regions of interest must be manually extracted using a mouse, a process that requires several months of effort. Using special tracked curve manipulators, similar to those proposed by Bae [5], scientists could more easily segment the regions of interest. The curve manipulators would provide a more natural method for defining a two dimensional shape and allow the user to work directly on the image. Additional controls could be developed that permit the user to quickly scroll up and down the image stack, and the evolving three dimensional model could be displayed simultaneously in a nearby window on the workbench.

For geoscientists working with core imagery, multiple samples could be displayed at once and moved independently, facilitating depth-age correlation between different cores taken from different parts of a lake basin. Also meta-data could be displayed next to core images, or on tracked tablets or hand held computing devices.

To assist scientists working with multi-spectral map imagery, special tracked lenses can be developed, similar to the passive lens proposed for the metaDesk [25]. These lenses will apply a filter that will reveal or suppress imagery from different wavelength bands. It will also be possible to overlap the lenses in order to create composite filters, similar to the magic lens effects described by Beir [7].

The system will be designed to allow multiple users with independently tracked controls to work with the same set of images simultaneously. Using physical icons (phicons), users will be able to "grab" images, dragging and rotating them to create personal, correctly oriented workspaces within the larger general table space. By associating multiple data objects or configurations with a "workspace" phicon that can be minimized and restored, a persistent multi-user environment could be developed. Multiple ongoing projects could be stored or arranged on the table, facilitating long-term collaborative efforts.

6b. Multi-sensor Situation Table:

Emergency response, military, and airport control centers employ systems to maintain situational awareness amongst decision makers during potentially dangerous operations. These systems, whether electronic or procedural, must integrate information from sensors and human controllers in order to communicate a coordinated "big-picture" to all participants. Expanding on Juxtaview [13], a multi-resolution viewer for georefrenced imagery, and drawing from the Tangible Geospace concept [25], we propose LambdaTable as a centerpiece for tomorrow's control center. In this scenario, the LambdaTable serves as a common high resolution display where maps, aerial imagery, and high-definition video streams from field mounted sensors are integrated into a single coherent visualization. Tracked physical icons are used by controllers to augment digital maps, indicating persistent conditions such as runway status, traffic routes for emergency vehicles or threat axes for military formations. Hand-held lenses, similar to those described in the previous scenario, provide a means to apply graphical filters containing weather or multi-spectral satellite overlays. Graspable probes provide information about units such as departure time, personnel on board, or maintenance histories. At any given time the most relevant data, identified and arranged by table operators, can be simultaneously presented on display covered walls within the control center, and selectively broadcast to other participating sites. The cumulative effect is enhanced situational awareness within the control center, and fluid exchange of information and intent between collaborating teams.

7. Conclusion

By bringing together table interaction, a tangible interface system and a high resolution tiled display, the LambdaTable presents an ideal environment for group-based interaction with large visualizations. We are encouraged by our investigation into the Fitts' Law properties of the table, and will continue to design tracked tangible interface devices in order to experiment with new interaction paradigms for the LambdaTable. We believe that this research, and the related research in display technology at EVL, will yield truly new forms of interaction with visualizations, and help define a new genre of advanced collaborative environments.

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