DTLens: Multi-user Tabletop Spatial Data Exploration

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ABSTRACT

Supporting groups of individuals exploring large maps and design diagrams on interactive tabletops is still an open research problem. Today's geospatial, mechanical engineering and CAD design applications are mostly single-user, keyboard and mouse-based desktop applications. In this paper, we present the design of and experience with DTLens, a new zoom-in-context, multi-user, two-handed, multi-lens interaction technique that enables group exploration of spatial data with multiple individual lenses on the same direct-touch interactive tabletop. DTLens provides a set of consistent interactions on lens operations, thus minimizes tool switching by users during spatial data exploration.

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BACKGROUND AND MOTIVATION

Satellite photographs, maps, blueprints, and CAD diagrams are often presented from a "birds-eye" view and are therefore appropriate for horizontal displays. Intelligence analysts, civil engineers, architects, and city planners often gather around a horizontal tabletop on which they display and manipulate printed versions of these shared documents. These experts are comfortable viewing documents from a variety of points of view, and a group of them often need to work more closely face-to-face around a tabletop rather than shoulder-to-shoulder in front of a vertical display. Groups that wish to work with high-resolution digital files on a horizontal display face a number of challenges.

Current tabletop projector and display technology do not provide the necessary resolution to view the full details of these high-resolution documents. A typical projector displays an image at a maximum resolution of 1024x768, more expensive projectors provide 1600x1200; however, it is not uncommon for intelligence analysts to work with satellite photographs that measure 10,000 pixels on a side.

One solution is to tile multiple projectors to create a single

high-resolution display [8]. While this path is promising, multiple projector solutions are currently expensive and the physical size of a projected element on the table can be quite small. Another solution is to provide a zooming and panning interface. This poses a problem for groups, for whom choosing a single zoom level and position in the dataset may not support periods of individual work. Furthermore, it is well known that people often become "lost" within a dataset while using a pan and zoom interface, and, while a zoomed view displays the details of a region of the dataset, it sacrifices the larger context in which the details reside. Finally, for many tasks switching between pan and zoom tools becomes quite cumbersome.

Therefore, it is desirable to create a multi-user tabletop environment with which groups can easily explore high-resolution spatial data. In this paper, we propose our solution called DTLens which allows multiple simultaneous zoom-in-context lenses to be opened, interacted upon, saved with audit trails and reopened for continued ongoing work sessions on a direct-touch interactive tabletop. We present two iterations and experience of the design and subsequent prototypes of DTLens. The first version of DTLens was first demonstrated at GeoINT2004 – a symposium attended by around two thousand geospatial analysts and application builders. From our observations at GeoINT, the interaction style and features of DTLens have been enhanced and enriched.

Figure 1. A group of people sitting around the table using DTLens to view multiple portions of a 7300 x 5400 pixels image simultaneously.
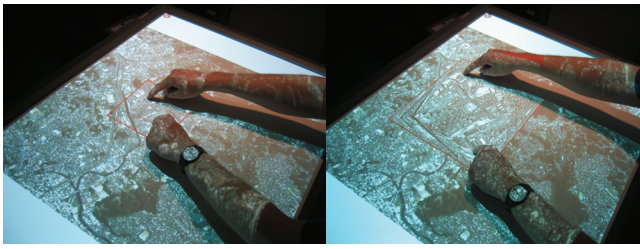
Figure 2. A user defines the region of interest by placing two fingers on the table (*left*). By moving their fingers apart, the user stretches the underlying data in order to zoom in (*right*).

RELATED WORK

Fisheye [5] and focus and context [11] visualizations provide presentation of detail in context, in many cases in a seamless and continuous fashion. In [2], Carpendale et al presented a general geometric framework for a family of these types of distortion methods. This framework has since been extended with general inversion functions for data editing purposes plus other improvements implemented as Pliable Display Technology, a commercial set of Application Programming Interfaces by IDELIX Software Inc. Previous uses of this API are almost exclusively mouse based, and therefore inappropriate for multi-user systems.

Multi-point touch technology, such as [3][9][10], allows small groups to simultaneously interact with tabletop displays. These touch surfaces allow not only mouse-like point-based input, but also enable rich gesture interaction.

A NEW INTERFACE FOR TABLETOP SPATIAL DATA EXPLORATION

Our interface aims at supporting data exploration by groups of people gathered around a direct-touch table. DTLens supports the temporary glimpsing of details within a dataset [4] as well as longer term data inspection and manipulation. We use a DiamondTouch table as our input device. This multi-touch, multi-user touch surface senses areas and intensity of contact for each user at discrete moments in time [3]. DTLens implements input gestures based on the changes in shape, size of touch, position, and pressure of these contact areas over time. We take advantage of the user identification that DiamondTouch devices provide to audit interactions, prevent conflicts among group members, and customize the appearance of lenses and annotations for each user. Our prototype uses the PDT commercial graphics package from IDELIX for rendering the lens algorithms in [2]. DTLens interprets input from the table in order to manage the creation and destruction of lenses, the animation of lenses, their level of magnification, position, and color. Finally, DTLens enables the saving and restoring of lenses. We use a standard 1024x768 pixel DLP projector positioned above the table to create our display.

Visual Design

We augmented the visual design of the PDT toolkit's lens (which is designed for mouse based input) with controls and interaction tools for editing and feedback on the lens's state. When a lens is open and locked in place, it is surrounded with a collection of controls, as shown in Figure 3. Pushpins are rendered in the corners of the lens to indicate its locked status. Universal controls for opening a

Figure 3. When locked into place, a lens displays controls for minimizing, closing, annotation, resizing, and for changing the magnification.

new image on the table and for exiting the application are placed in the corners of the table. Two buttons for each command are located in opposite corners of the display so that one is always reachable by everyone around the table.

Defining the Region of Interest

A user defines the area that he is interested in viewing at a higher level of detail by placing two fingers on the table, as seen in Figure 2 *left*. The bounding box that includes these two points surrounds the area of interest; a high level of accuracy is not required.

Stretching the Region

By moving their two fingers apart diagonally, the user controls the zoom level of the lens visualization, as seen in Figure 2 *right*. The amount of zoom is calculated to give the appearance that the tabletop is stretching under the user's fingers. There is an illusion of a pliable rubber surface. We preserve the aspect ratio of the dataset by uniformly scaling the image in X and Y based on the change in width of the region between one's fingers. In a variation of DTLens, we allow for the uneven stretching of the dataset by scaling independently in X and Y based on the width and height of the area between one's fingers. For both variations, a user can move their fingers toward or away from one another until the desired amount of detail is displayed. Moving their fingers in the same direction moves the lens around the table. Using both hands to simultaneously control the position and size of the lens is similar to a selection technique studied by Leganchuk et al. in [6]. Their experiments suggested that parallel bimanual input is faster than sequential single-point based input for controlling position and size.

Releasing the Region

When the user is finished examining the details of the underlying dataset, he simply lifts his fingers off the table. At this point, DTLens responds by resetting the local zoom level to its original level. This transition is animated over a
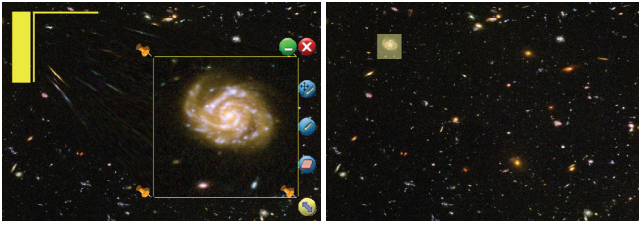
Figure 4. Pressing the green minimize button causes the position and zoom level of the lens to be saved (*left*). DTLens then animates the closing of the lens and displays a visual marker indicating the location of the lens within the scaled dataset (*right*). Pressing on this marker reopens the lens.

period of one second to preserve the illusion of a pliable surface returning to its original state.

Locking the Region
If the user wishes to view the details of a region for an extended period of time, or wishes to perform any editing operations, they can lock their lens onto the tabletop by pressing firmly down with their two fingers. DTLens responds by locking the lens onto the tabletop, and provides visual feedback in the form of thumbtacks in the corners of the lens, as shown in Figure 3. The user can now remove their fingers from the table and the lens will remain in place. Using this light-touch to heavy-touch transition to mediate temporary vs. extended visual modification is an example of the Glimpse [4] input technique.

Unlocking the Region
A user can unlock a region from the table by placing two fingers in diagonally opposite corners of the lens and pressing firmly on the table. This removes the thumbtacks from the corners of the lens, and DTLens again positions the lens under the user's fingers and zooms the lens as the user moves their fingers toward and away from each other.

Region Tools
When locked onto the tabletop, several tools appear around the outside of the lens, as shown in Figure 3. These tools are activated with single-finger touches on the tabletop.

Resize. By touching and dragging the resize handle in the lower right corner of the lens, the user can change the width and height of the lens. When resizing, the magnification level adjusts in the same manner described above – just as when the user is resizing the lens with two fingers.

Change Magnification. The IDELIX toolkit provides a visual indicator of the level of magnification of the lens. We thickened this line on the right border of the lens to be easily adjustable with a finger. By touching and dragging on this bar with their finger, the user can adjust the level of magnification of the lens.

Annotate. Pressing the Annotate button toggles annotate mode, in which the other tools are grayed out and touches within the lens result in painted strokes on the dataset.

Annotate and Move. We observed that with many types of data, one oftentimes wants to annotate long stretches of the dataset that cannot fit into a single lens at one time. For example, when highlighting a road that extends across a large satellite photograph, it would be unreasonable to ask
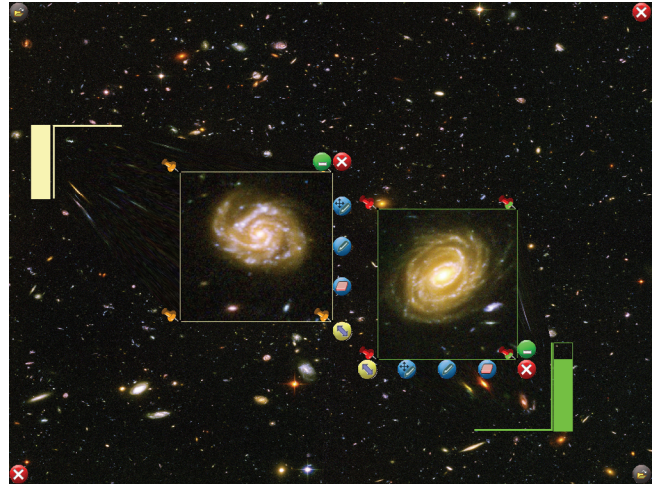

Figure 5. In this screenshot, two users fold galaxies from distant parts of an 8000 x 6000 pixel image so that they are side-by-side for easier comparison.

the user to continually switch between moving the lens and annotating the road. We provide an Annotate and Move tool for just this purpose. Pressing the Annotate and Move tool grays out the other lens tools. As the name implies, touches within the lens results in annotation within the lens and movement of the lens, which greatly facilitates certain common tasks. Pressing the Annotate and Move button a second time re-enables the other lens tools.

Erase. Pressing the erase tool disables the other tools and puts the lens into erase mode. While in erase mode, touches in the lens remove annotation marks painted by that user.

Close. Pressing the close tool has the same effect as releasing one's fingers from the table while defining a lens. The thumbtacks are removed and the lens animates closed.

Minimize. We observed that groups of people oftentimes wish to return to previous views when they return to previous points in a conversation. The minimize tool behaves just like the close tool, except that after closing, a semi-transparent rectangle remains on the table, as shown in Figure 4. This rectangle indicates the region that the lens was displaying before it was minimized. This rectangle also acts as a button. By pressing it with their finger, a user can re-open a minimized lens to its previous position and level of zoom, making it easy to return to previous view.

Folding
In a variation of DTLens, we have developed a direct-touch tabletop rendition of graph "folding", a technique first presented in [1] and now provided in the IDELIX toolkit. Folding provides the ability to pull a portion of the dataset across the table, as shown in Figure 5. This feature is desirable in two ways – distant portions of the dataset can be positioned side-by-side for easier comparison, and distant areas of the tabletop may not be comfortable for a user to work on. By providing folding on the tabletop, a user can grab a distant portion of the dataset and reposition it to a more comfortable location. He can then leisurely inspect the details of the dataset and perform manipulation of the data in a more comfortable location.

Multi-User Support

DTLens takes advantage of our tabletop's ability to distinguish different users' touches.

Auditing the Interaction. Each user is identified with a unique color so that whenever a user minimizes a lens or annotates the data, their identity is recorded along with their input. Recording this type of audit trial is important for multi-user environments in which people come and go and in which knowing what areas others have been examining and knowing who wrote what annotations would be helpful.

Avoiding Conflicting Interaction. One of the motivations that led to the development of DTLens was the problem of multiple people sharing a single zoom level and position within a dataset. What happens when one user decides to change the displayed region while another is actively viewing the current data? Because teams of people move back and forth between periods of group interaction and periods of individual work, multi-user systems must address unintentional conflicts among users' actions [7]. DTLens mediates conflicts by locking out interaction upon a lens by anyone other than that lens's creator. A future version might include tools for passing ownership to another member of the group.

Orientation of Controls. Because our DiamondTouch table identifies users by the chair they are sitting in, DTLens is able to orient lens controls to face each user. Controls remain in the same position relative to the user's point of view. For example, controls for closing and minimizing a lens are always in the upper right-hand corner of a lens from the perspective of the owner of that lens. For right handed participants, aligning controls with the right side of the lens minimizes occlusion by one's hand.

DEMONSTRATION

We were invited by IDELIX to attend GeoINT2004, a symposium attended by around two thousand geospatial analysts and application developers. We solicited feedback from these domain experts by demonstrating an early version of DTLens in the IDELIX booth on the exhibition floor. From our observations and conversations at GeoINT, the interaction style and features of DTLens have been enhanced and enriched. Specifically, the move tool was removed after it was deemed to be redundant (the lenses can be moved by dragging with one's finger anywhere on a lens). The Annotate-and-Move tool was added after we observed multiple analysts switching back and forth between annotation and moving in order to trace roadways and train tracks across large sections of a map. Additionally, the auditing of interaction by user identity was improved after it was suggested that this would be an important feature of any end system.

CONCLUSION

We have presented DTLens, a multi-user tabletop environment with which groups can simultaneously explore high-resolution spatial data in a collective or independent fashion. DTLens addresses issues that arise from viewing high-resolution data on a low resolution display. A single interaction interface allows users to take quick glimpses at the details of a dataset without lasting effect on zoom level or pan-position: by eliminating pan-and-zoom tool switching, DTLens encourages rapid exploration. Finally, DTLens takes advantage of user-identifying tabletop hardware to provide conflict resolution and auditing. At GeoINT, participation and feedback from geospatial domain experts helped drive design and development. We will continue to look for this type of feedback as we explore multi-user tabletop geospatial data exploration.

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