Hands-On, Large Display Visual Data Exploration

Andrew Dai* Ramik Sadana* Charles D. Stolper* John Stasko*

School of Interactive Computing
Georgia Institute of Technology

ABSTRACT

We have developed an updated version of the Dust and Magnet visualization technique for large, multitouch displays. Multiple users can interactively manipulate magnets (data attributes) to observe how iron dust (the data items) changes its positions, and thus gain insight about the data. This type of visualization provides a very direct engagement with the data and thus a very "hands on" analytic experience.

1 INTRODUCTION

New display technologies providing more flexible interaction methods are becoming increasingly common and more widely used. Some of these displays support pen, finger, and mouse input with multiple concurrent touch input points. Will such display and interaction technologies facilitate new forms of data visualization and enhance collaboration? Early indications are that they will [2] with example prototypes running on tabletop displays [1] and tablet computers [3], among others.

We have developed an interactive data visualization application for the Microsoft PPI Display in an effort to push this "hands on the data" notion even further. Our system draws inspiration from the Dust and Magnet (DnM) multivariate visualization technique [4] that uses a physical metaphor for representing data. DnM represents data items as specks of iron "dust" particles on a canvas and the data's attributes/variables as "magnets". Magnets attract data items with higher values of their attributes more strongly. Users explore the dataset by interactively manipulating the arrangement and strength of the magnets to observe how the dust reacts. The physical metaphor makes the technique particularly conducive to multitouch, multi-user interaction.

2 SYSTEM DESCRIPTION

Our visualization (Figure 1) largely follows the metaphor of the original DnM. We represent data items (dust) as small circles. Initially, all data items appear scattered in random positions on the canvas. We represent each magnet as a larger circle with the name of the attribute at its center. As users add magnets to the view, dust particles begin moving towards the magnet with speeds relative to each item's value of the attribute. Here, our implementation differs from the original where dust particles only moved when a user dragged a magnet with the mouse. In our system, particle movements are not dependent on the movement of a magnet. Instead, they update to reflect the absolute positions of the magnets. In other words, for a given configuration of magnets on the canvas, the dust particles will always move to a specific equilibrium position, irrespective of whether a user is moving a magnet or not. We discuss the reasons behind this further in the discussion section.

An accompanying video shows the system in action. Our objective was literally to allow multiple users to "wade through" the data, manipulating both data items and attribute strengths by hand. Below, we describe key additional capabilities beyond the original.

Adding and Removing Magnets: Users create attribute magnets by dragging the corresponding block onto the canvas from a menu at the top. To remove a magnet from the canvas, a user drags the magnet to a trash icon at the bottom right.

Scaling Magnets: As in the original DnM, we enable users to adjust the strength of a given magnet. Rather than using sliders, as in the original system, we take advantage of the multitouch support of the display and enable a user to perform a two-finger pinch operation within the bounds of a magnet to scale its size up or down. This size change correspondingly changes the magnet's strength of attraction.

Selecting and Highlighting Dust: Tapping on a dust item highlights it and displays a label with the (auto-identified) primary attribute. The label remains visible to help in tracking the position of the dust item as the user interacts with the magnets. Tapping on the dust item again hides the label. A menu on the left of the display contains buttons for the different values of each categorical attribute from the data set. Users can tap the buttons to highlight all dust items with that value for that attribute.

Minimizing Occlusion: Occlusion of dust particles (e.g., when data items have similar attribute values) is a problem both for observation and selection in DnM. To counteract this, our system allows users to tap the display to cause each of the dust particles to repel each other, while each particle still attempts to reach its calculated appropriate position.

Collaboration: All the actions described above are enabled for multi-user interactions. Multiple people can simultaneously select and highlight dust and add, reposition, scale, and remove magnets.

3 DISCUSSION

Developing the DnM technique for a large-screen, multitouch display introduced several design challenges. In this section we discuss a few of these and the ultimate decisions we made.

Single vs. Multitouch: In the original DnM interface, the (single) user had a single point of input to control a single magnet at a time. Even in a single-user environment, multitouch provides a noticeable benefit over single-touch alternatives. Multitouch enables users to simultaneously manipulate multiple magnets leading to more nuanced and flexible control. Careful manipulation of multiple magnets can help separate items that are attracted by two magnets from items not attracted by either, as well as help users identify relationships between attributes. Multitouch also enables more direct manipulation of the visualization, such as adjusting magnets' strengths by manipulating the magnet glyphs directly rather than remotely-located widgets controls. Furthermore, unlike in a single-touch environment, multitouch enables multiple users to concurrently interact with the visualization.

Large Display vs. Desktop vs. Tablet: We designed the system for a large display environment. Our intention was to enable teams of analysts to collaborate using the technique, either by simultaneously manipulating the display or by taking advantage of the large display to communicate among each other. Many of our design decisions would be effective in other environments as well

*e-mail: {adai,ramik,chadstolper,stasko}@gatech.edu

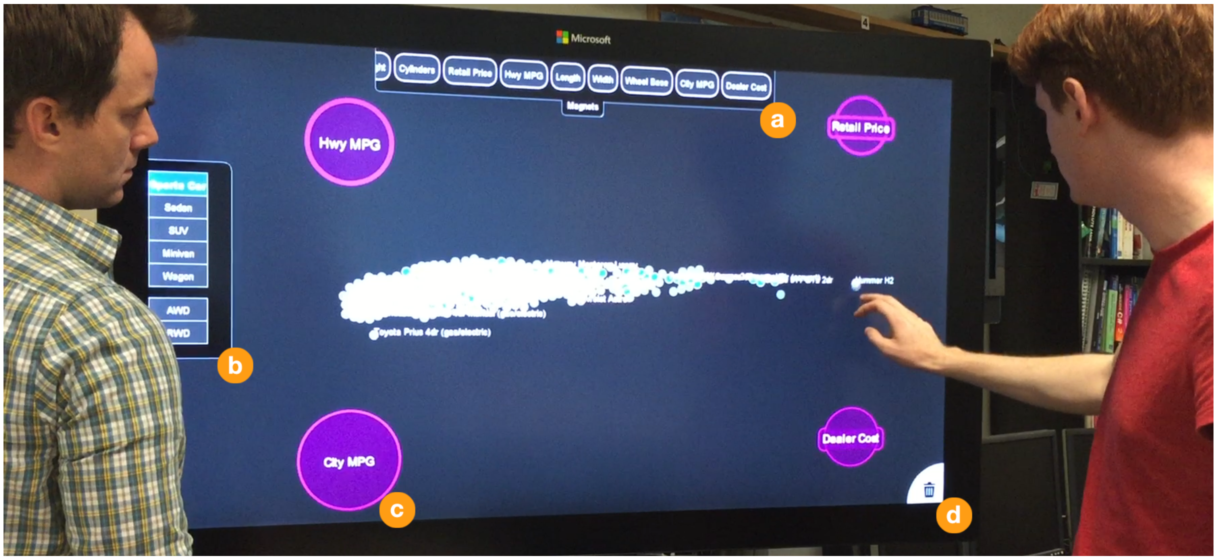

Figure 1: Two users collaborate around the new Dust and Magnet, running on a 55-inch Microsoft PPI Display. a) Magnet menu b) Categorical filters c) Magnet d) Magnet removal drop zone.

though. A user of a multitouch tablet would benefit from the collapsible menus, allowing for more of the valuable screen real-estate to be used by the canvas. A user of a multitouch enabled desktop also could take advantage of the visualization technique. However, the space afforded by a large display is especially helpful for DnM, where occlusion among the dust can be a significant issue. The larger screen provides more room for spreading the dust and observing finer-grained differences between data items.

Shake vs. Always Update: One of the features we presented earlier that differentiates the system from the original implementation is the positional properties of dust particles. In the original work, dust only moved when the user interacted with a magnet. The benefit of this approach was that users had fine-grained control over the positions of dust particles. Since dust positions were not fixed, shaking the magnets further separated particles with otherwise similar values. However, the approach had the drawback that achieving a useful visual layout of dust particles required considerable user interaction. Simply introducing a magnet to the view did not produce substantial visual change and the user had to continuously shake magnets to identify the differences between dust particles. In addition to effectively becoming a non-deterministic visual display, this continuous input has ergonomic implications on a large touch screen. User fatigue from prolonged hand/arm interactions could become a problem. Our implementation overcomes all of these drawbacks.

Precision vs. Occlusion-Free: As mentioned above, DnM is particularly susceptible to occlusion of the dust particles. We decided to support both the precise positioning of each particle based on the current magnet layout (thus potentially introducing occlusion) as well as an occlusion-free mode where the particles repel each other. The latter mode is computationally more expensive and visually less stable than the precision mode. The physics-based repulsion leads to subtle jittering of the dust. While mode-based solutions are generally not so desirable, the presence here is mitigated by the mode being obvious to the user (either there is occlusion or there is no occlusion and the dust is jittering). Through our initial use of the system, we have found that we usually leave the system in precision mode except to briefly reduce occlusion to select data items clustered together.

4 Conclusion and Future Work

We have presented an updated version of the Dust and Magnet visualization technique built for collaborative visual exploration on large, multitouch displays. Whereas many visualization techniques employ interaction only for selection, highlighting, or linking between multiple views, interaction is fundamental to this technique. Viewers collaboratively put their hands on the data and manipulate it to gain a better understanding of the data.

We still envision additional capabilities for the system given our initial use of it. A primary missing capability is the ability to identify precise values of data items' attributes. We are working on the design of a data table component that can provide details-on-demand for the data items. We also have identified a desire for inverse magnets, that is, magnets that repel high-valued items rather than attracting them (a capability of the original implementation). One use case of these is to pair a magnet with the matching inverse magnet to create an axis. Finally, we hope to evaluate our implementation with users to better understand whether the interactive operations are easy to learn and natural to use, whether users can identify important features in a dataset using the technique, which particular methods of data analysis the technique best supports, and how users collaborate using the system.

Acknowledgements

We thank Microsoft Research for donating the PPI Display. This work was supported in part by a grant from NSF (IIS-1320537) and DARPA's XDATA program.

References

[1] P. Isenberg, D. Fisher, S. A. Paul, M. R. Morris, K. Inkpen, and M. Czerwinski. Co-located collaborative visual analytics around a tabletop display. *IEEE TVCG*, 18(5):689–702, 2012.

[2] B. Lee, P. Isenberg, N. Riche, and S. Carpendale. Beyond mouse and keyboard: Expanding design considerations for information visualization interactions. *IEEE TVCG*, 18(12):2689–2698, Dec 2012.

[3] J. Rzeszotarski and A. Kittur. Kinetica: Naturalistic multi-touch data visualization. In *ACM CHI '14*, pages 897–906, 2014.

[4] J. S. Yi, R. Melton, J. Stasko, and J. A. Jacko. Dust & Magnet: Multivariate information visualization using a magnet metaphor. *Information Visualization*, 4(4):239–256, Oct. 2005.