Immersive Data Visualization with Virtual Reality

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ABSTRACT
There has been a resurgence of interest in Virtual Reality (VR) with the advent of several consumer-ready head mounted displays. And while VR has a long standing tradition in graphics literature traceable to the early 90's, little research has been done on the implications of modern VR and 3D displays on Data Visualization. In this work we explore how to create immersive 3D data visualizations and subsequently interact with them effectively using novel modalities such as gaze and touch. We hypothesize that an immersive data visualization experience provides benefits beyond traditional desktop counterparts and that a user is better connected to the data, both perceptually and emotionally.

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Data Visualization; Virtual Reality; Human Factors;
Progress Report;

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

MOTIVATION
Traditional data visualization displays are typically two dimensional. They are relatively easy to render, more familiar and well studied. However, they are limited by screen real estate and must resort to interactions such as panning and zooming to present datasets that do not fit into the bounds of the screen. Occasionally, 3D visualizations are projected down onto a 2D screen for consumption, but these tend to provide little cognitive benefit, since the viewer only observes foreshortening and occlusion, but does not experience the critical depth cues provided by parallax.

Researchers have used virtual reality displays such as caves [3], hyperwalls etc. in order to alleviate some of the limitations of 2D displays. However, cost is a prohibiting factor in these systems, ranging from several thousand to multiple millions of dollars in set up.

Recently, inexpensive commercially developed VR hardware such as Oculus Rift, Samsung Gear VR, Valve SteamVR have opened up a possibility of creating powerful and portable 3D experiences on affordable desktop, laptop or mobile hardware. Virtual reality has demonstrable benefits of traditional 2D displays.

- Images are presented in stereoscopic 3D: This provides a strong sense of parallax and absolute scale (that far surpasses 2D renderings of 3D scenes on flat displays)
- The viewer's gaze/head movements are tracked in 6-dof, providing an novel interaction mechanism.
- Much more portable and cost effective, compared to cave installations.

In this work, we plan to use Oculus Rift [9] (Figure 1) to visualize a 3D spatial-temporal dataset of asteroids in our solar system. The goal is to enable the viewer to get a better sense for the 3D data and interact with the data via gaze (and potentially touch interaction using a trackpad) and experience immersion in the data visualization. We would also like to evaluate the tradeoffs of using virtual reality and also reflect upon the equivalent of vis. principles such as data-ink ratio, in the context of this new medium.

Figure 1. Oculus Rift DK2.

RELATED WORK
VR has demonstrable benefits in analysis of spatial and volumetric data. Early work has investigated the advantages of VR displays in the fields of entomology [8], Brain MRI [11], shape understanding [4] and 3d path understanding [10]. While these studies unanimously describe VR as having a positive impact on perception, they all rely on CAVE-like displays that are expensive and not widely available. Possibly

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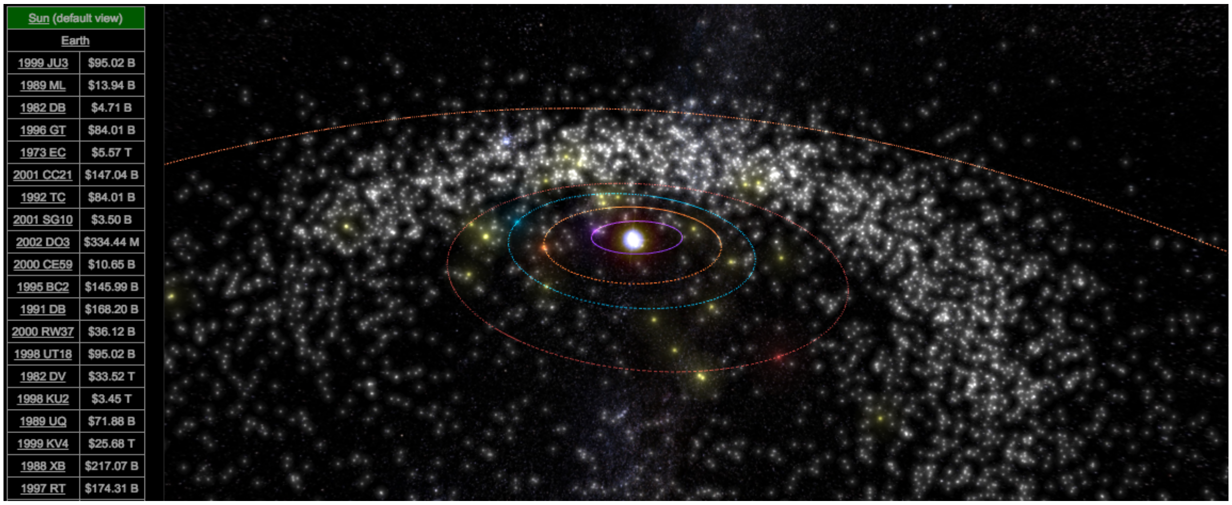

Figure 2. Web visualization of Asterank data, projected and displayed in 2D.

because most of the work was conducted prior to the popularity of low cost VR display technology.

[5] conducts some closely related preliminary work on benefits of VR using commercially available head mounted displays. Their focus is on high-dimensional "big data" and their work primarily explores how 8-dimensional data can be projected down and displayed in 3 dimensions using VR. While high dimensional visualization is a useful task, I would like to focus this work on spatial-temporal data that is intuitive for users as it is the exact visual stimuli processed by us every waking minute.

To this end, our ideal dataset is spatio-temporal, centered around the observer. Astronomical data is a natural fit for this. Asterank [1] (Figure 2) is one such accessible data source that catalogs 600,000 asteroids based on orbital parameters, mass, composition, estimated mining value etc. The underlying data is sourced from the Minor Planet Center and Nasa JPL. Currently the Asterank 3D interface allows the user to pan and zoom, but they cannot directly interact with the data points. Instead they must click on a table to highlight the corresponding asteroid in the visualization. This interaction can be greatly improved.

To interact more effectively with this data, we will build upon well studied principles of 3D interaction [2] for view manipulation and drill-down. Ray casting [7] controlled by gaze and focus+context techniques such as Fisheye [6] can be used for interacting with the data.

CURRENT PROGRESS

So far most of the effort has been focused on setting up the development environment and wrangling the experimental hardware driers to get the Oculus Rift platform working. I have the first working VR demo (a simple roll-a-ball game) shown in Figure 3.

In parallel I have been looking into the Asterank data source and am able to query for the *n* most valuable asteroids along with their orbital parameters. Asterank also provides code for

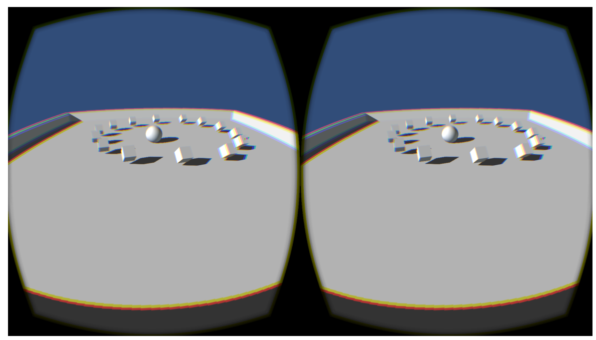

Figure 3. Oculus Rift DK2.

their rendering system, which will be useful to build upon, especially the orbital physics that contains high order polynomial math.

PROJECT PLAN

Next steps would involve creating a solar system simulation in Unity and importing and rendering the asteroid data with appropriate orbital physics. The asteroids would most likely be rendered as a particle system that obeys laws of gravity, with each asteroid having a mass and initial velocity.

Adding an oculus as a display interface to the project is relatively easy, now that the environment is configured. The oculus returns a head position and rotation and requires a stereoscopic rendering of the scene for the display. These are produced by the Oculus SDK, out of the box.

Once the rendering is complete, I will focus on the interaction. The returned head position and rotation would indicate which direction the viewer is looking. By casting a ray and intersecting it with the particle system, I should be able to determine which particle is closest to the viewing ray. That particle can then be augmented with information about the asteroid (name, estimated value etc.). If needed, it may also be possible to implement a lens effect around the viewing ray to improve the spatial resolution and make selection tasks easier.

The final aspect of the project would be to evaluate the pros and cons of using virtual reality anecdotally and with the help of an informal user study, if time permits. I would also like to revisit data visualization principles such as data-ink ratio and chart junk and comment on them in the context of this new display medium.

REFERENCES

1. Ian Webster, Asterank. `http://www.asterank.com`.
2. Bowman, D. A., Kruijff, E., LaViola, J. J., and Poupyrev, I. *3D User Interfaces: Theory and Practice*. Addison Wesley Longman Publishing Co., Inc., Redwood City, CA, USA, 2004.
3. Cruz-Neira, C., Sandin, D. J., and DeFanti, T. A. Surround-screen projection-based virtual reality: The design and implementation of the cave. In *Proceedings of the 20th Annual Conference on Computer Graphics and Interactive Techniques*, SIGGRAPH '93, ACM (New York, NY, USA, 1993), 135–142.
4. Demiralp, C., Jackson, C. D., Karelitz, D. B., Zhang, S., and Laidlaw, D. H. Cave and fishtank virtual-reality displays: A qualitative and quantitative comparison. *IEEE Transactions on Visualization and Computer Graphics 12*, 3 (May 2006), 323–330.
5. Donalek, C., Djorgovski, S. G., Davidoff, S., Cioc, A., Wang, A., Longo, G., Norris, J. S., Zhang, J., Lawler, E., Yeh, S., Mahabal, A., Graham, M. J., and Drake, A. J. Immersive and collaborative data visualization using virtual reality platforms. *CoRR abs/1410.7670* (2014).
6. Furnas, G. W. A fisheye follow-up: Further reflections on focus + context. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '06, ACM (New York, NY, USA, 2006), 999–1008.
7. Hinckley, K., Pausch, R., Goble, J. C., and Kassell, N. F. A survey of design issues in spatial input. In *Proceedings of the 7th Annual ACM Symposium on User Interface Software and Technology*, UIST '94, ACM (New York, NY, USA, 1994), 213–222.
8. Laha, B., Bowman, D. A., and Socha, J. J. Effects of vr system fidelity on analyzing isosurface visualization of volume datasets. *IEEE Transactions on Visualization and Computer Graphics 20*, 4 (2014), 513–522.
9. Oculus, Rift. `https://www.oculus.com/rift/`.
10. Ragan, E. D., Kopper, R., Schuchardt, P., and Bowman, D. A. Studying the effects of stereo, head tracking, and field of regard on a small-scale spatial judgment task. *IEEE Transactions on Visualization and Computer Graphics 19*, 5 (May 2013), 886–896.
11. Zhang, S., Demiralp, ., Keefe, D. F., DaSilva, M., Laidlaw, D. H., Greenberg, B. D., Basser, P. J., Pierpaoli, C., Chiocca, E. A., and Deisboeck, T. S. An immersive virtual environment for dt-mri volume visualization applications: A case study. In *IEEE Visualization*, T. Ertl, K. I. Joy, and A. Varshney, Eds., IEEE Computer Society (2001), 437–440.