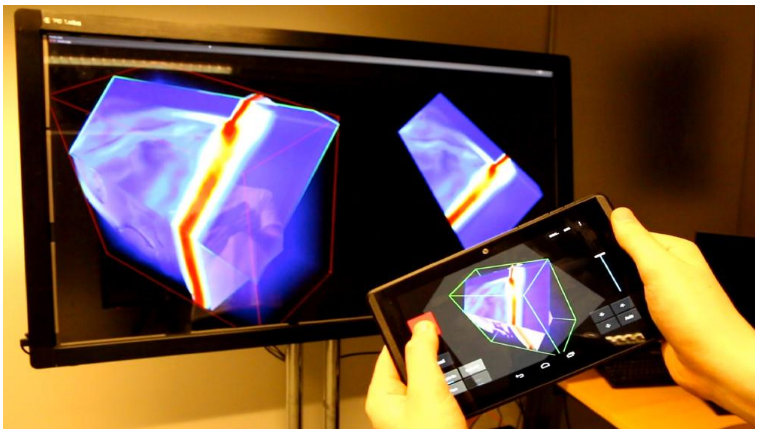
PhD Project Proposal:

Augmented Reality Environments for the Interactive Exploration of 3D Data



This PhD project will explore the exploratory visualization of 3D data using a combination of augmented reality viewing and tangible/tactile interaction using mobile devices. In general, exploratory visualization of 3D data is fundamental to many domains in the natural sciences and in medicine. Typically, researchers and practitioners use one of two major types of visualization environments in these cases. One option is to use traditional workstation setups, which provide many controls and exploration tools yet typically rely on input devices such as mouse and keyboard. The other option is that the scientist use virtual reality setups such as a CAVE to load their data and then to view it using the stereoscopic displays.

Both types of environments provide a form of immersion in the dataset that is beneficial for the scientists to understand it. The traditional setup provides immersion through interaction: by interactively manipulating the view and exploration tools scientists are able to immerse themselves in the data as they are exploring it. The VR setup, in contrast, provides immersion through vision as as single view can already effectively convey the 3D spatial character of the data, without the need for interactive navigation. Adjusting the view to the 3D tracked position and orientation of the viewer only enhances this effect.

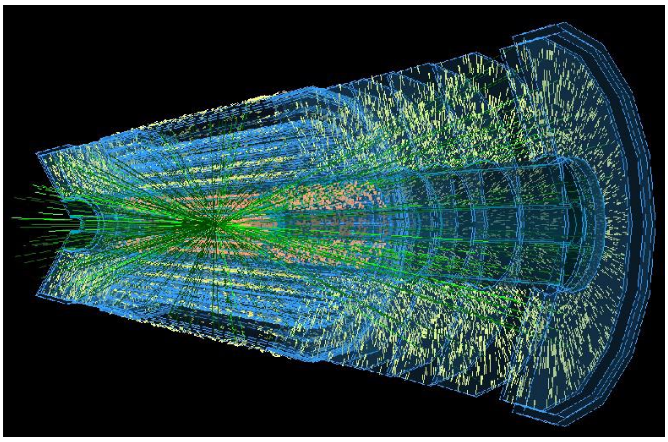
To get the best of both worlds, a combination of both types of immersion for the exploratory visualization of 3D data would be highly useful. However, it is difficult to use traditional input devices in the context of VR environments, and these environments are also difficult to maintain due to their complexity. Similarly, while stereoscopic viewing can be added to traditional workstations, their abstract input devices do not match the spatial character of the immersive view that stereoscopy provides.

This PhD project will thus investigate interaction environments that use both visual immersion through stereoscopic displays and spatial input devices that provide immersion through interaction. For this purpose we will make use of recent work by the supervisor’s team on tactile and tangible interaction for the exploration of 3D data. This input uses tangible displays that automatically capture their location and orientation in space (i.e., spatially-aware displays) and also provide the possibility to provide tactile input. We will combine this type of interaction control with an head-worn augmented reality setup.

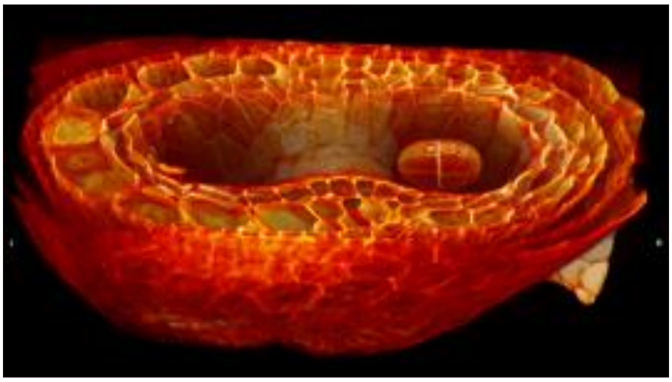
This combined setup has a number of essential advantages. Recent technological advances have led to hed-worn AR devices (e.g., Microsoft's Hololens) that are easy to maintain and which provide a stable AR view without the need of complex administration and calibration. These devices also promise to facilitate tangible and tactile input because, due to their support of augmented reality and frequently updated scans of the environment: users can see both the virtual world (in our case: the data visualization) and parts of the real world (in our case: the tangible/tactile input devices).

In this context this PhD project will investigate how both general as well as domain-specific interaction techniques can be realized in a combined AR/tangible/tactile data exploration environment. In particular, we need to explore general interaction techniques such as navigation, spatial selection, data highlighting, data filtering, the generation of graphs and plots for selected data subsets, and many more. Within this context, the PhD student will have to address a number of important research questions such as the following ones:

1. What should a data exploration environment look like that combines an augmented reality with tactile and tangible input? How can the spatially-aware input be incorporated in the AR environment such that it both feels like a natural extension to the user's hands and that it can meaningfully be used to control the visualization as well as data exploration tools?
2. How does the use of AR (as opposed to VR) benefit the exploration of data, or are there limitations because some part of the real world is always visible in the AR setup?
3. What challenges arise from the fact that the the images on the tangible display are shown as monoscopic 2D projections, while the data is shown as a stereoscopic 3D view? How should interaction techniques evolve to address these challenges?
4. Does the proposed setup allow to effectively address the parallax issue that tactile input in pure VR environments exhibits?
5. Can we study, measure, and evaluate the directness provided by the proposed environment such that we can better understand in what situations a hybrid AR/tactile/tangible environment is best to use, and in what situations more traditional setup shine?
6. How can the mentioned general tasks be realized in the combined AR/tactile/tangible setup, and how well do the interaction designs generalize to several different application domains?
7. How can we enable domain-specific tasks in this context, to what degree do the interaction techniques depend on the respective data types and visualization techniques?



8. How can we establish collaborative setups in which several researchers or practitioners can work together on the same dataset, potentially using the same shared physical visualization space so that real-world actions such as pointing and gesturing are possible and meaningful?



The PhD research will be conducted under the supervision of Tobias Isenberg and within the AVIZ research team at Inria Saclay—Île-de-France which concentrates on the visualization of complex data. AVIZ is one of the most respected research labs in information visualization and visual analytics worldwide. The PhD student will closely collaborate, in particular, with Mehdi Ammi from the LIMSI lab at CNRS whose expertise in haptics for virtual reality and human-machine interaction will be essential for the work. In addition, we will work with domain experts in fluid mechanics, medicine, and structural biology to demonstrate the general applicability of the developed techniques. In particular, we will be collaborating with David Rousseau from the Laboratory of the Linear Accelerator (LAL, Orsay) to interactively explore the traces that are generated in modern particle collision experiments. Another envisioned application domain is the visualization of the development of plant embryos; here we collaborate with Alain Trubuil from INRA (MIA-Jouy). Both application domains are very different from each other and will allow us to explore both the generic as well as domain-specific interaction requirements.

References:

- L. Besançon, P. Issartel, M. Ammi, and T. Isenberg. Hybrid Tactile/Tangible Interaction for 3D Data Exploration. IEEE Transactions on Visualization and Computer Graphics, 23(1):881–890, January 2017.
- L. Besançon, P. Issartel, M. Ammi, and T. Isenberg. Mouse, Tactile, and Tangible Input for 3D Manipulation. In Proc. CHI, ACM, New York, 2017. To appear
- L. Besançon, M. Ammi, and T. Isenberg. Pressure-Based Gain Factor Control for Mobile 3D Interaction using Locally-Coupled Devices. Proc. CHI, ACM, New York, 2017. To appear.
- T. Isenberg. Interactive Exploration of Three-Dimensional Scientific Visualizations on Large Display Surfaces. In C. Anslow, P. Campos, and J. Jorge, editors, Collaboration Meets Interactive Spaces, chapter 6, pages 97–123. Springer, Berlin/Heidelberg, 2016.
- P. Issartel, L. Besançon, T. Isenberg, and M. Ammi. A Tangible Volume for Portable 3D Interaction. In Proc. ISMAR, pages 215–220, IEEE Computer Society, Los Alamitos, 2016.
- D. López, L. Oehlberg, C. Doger, and T. Isenberg. Towards an Understanding of Mobile Touch Navigation in a Stereoscopic Viewing Environment for 3D Data Exploration. IEEE Transactions on Visualization and Computer Graphics, 22(5):1616–1629, May 2016.
- L. Yu, K. Efstathiou, P. Isenberg, and T. Isenberg. CAST: Effective and Efficient User Interaction for Context-Aware Selection in 3D Particle Clouds. IEEE Transactions on Visualization and Computer Graphics, 22(1):886–895, January 2016.

- P. Isenberg, T. Isenberg, T. Hesselmann, B. Lee, U. von Zadow, and A. Tang. Data Visualization on Interactive Surfaces: A Research Agenda. IEEE Computer Graphics and Applications, 33(2):16–24, March/April 2013.
- D. F. Keefe and T. Isenberg. Reimagining the Scientific Visualization Interaction Paradigm. IEEE Computer, 46(5):51–57, May 2013.
- T. Klein, F. Guéniat, L. Pastur, F. Vernier, and T. Isenberg. A Design Study of Direct-Touch Interaction for Exploratory 3D Scientific Visualization. Computer Graphics Forum, 31(3):1225–1234, June 2012.
- L. Yu, K. Efstathiou, P. Isenberg, and T. Isenberg. Efficient Structure-Aware Selection Techniques for 3D Point Cloud Visualizations with 2DOF Input. IEEE Transactions on Visualization and Computer Graphics, 18(12):2245–2254, December 2012.
- L. Yu, P. Svetachov, P. Isenberg, M. H. Everts, and T. Isenberg. FI3D: Direct-Touch Interaction for the Exploration of 3D Scientific Visualization Spaces. IEEE Transactions on Visualization and Computer Graphics, 16(6):1613–1622, November/December 2010.

Contact: Dr. Tobias Isenberg <tobias.isenberg@inria.fr>
(http://tobias.isenberg.cc/)

Group: AVIZ team, INRIA Saclay
(http://www.aviz.fr/)

Lab: AVIZ-INRIA, Université Paris Sud
Bâtiment 660 (Digiteo-Moulon)
91405 Orsay Cedex