Exploring One- and Two-Touch Interaction for 3D Scientific Visualization Spaces

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CONTRIBUTION

For exploring large 3D datasets, scientists often have to interactively navigate through and explore large single 3D spaces such as medical volume data or astronomical simulations. We explore the use of large and touch-sensitive displays for this task. In particular, we provide means to control 7 degrees of freedom (DOF: location, orientation, scale) for exploring these spaces with both dual-touch and single-touch interaction. Our single-touch interaction makes use of the visualization's frame and provides means for precise control for all 7 degrees of freedom.

DATASET

As our example we use astronomical visualizations that are based on cosmological simulation data [6]. By analyzing astrophysical processes and exploring such large volumes of particles, scientists are trying to understand the fine-scale structure predicted around the Milky Way. Such precise analysis requires us to provide scientists with rapid and accurate manipulation methods at various levels of precision.

INTERACTION CONCEPTS

A relatively small area of previous work deals with how to provide interaction with scientific visualizations and, in particular, 3D spaces on touch-sensitive surfaces. For example, DTLens [1] provides a set of consistent interactions for lens operations on a multi-user tabletop display in the context of geospatial data exploration. While this tool helps to explore aspects of the data and to magnify parts, it only provides exploration of 2D datasets.

To provide means of interacting in three dimensions, Hancock et al. extended traditional 2D control techniques to allow shallow-depth 3D interaction [2]. By using up to three fingers, people can have full control of five distinct degrees of freedom (5DOF) of movement and rotation in a shallow 3D environment, restricted to the same level of depth. Recently, this was extended to a full 6DOF technique [3] which allows control of both location and orientation in full 3D. While this method is well suited for manipulating several small 3D objects, we focus on controlling a single large 3D space on a 2D touch surface.

For these single large spaces as used in scientific visualization we have a number of requirements, according to which the interface and the interactions need to be designed. In particular, they comprise large amounts of data and, therefore, large displays are well suited for their display, in connection with direct-touch interaction. Here we need to provide both fast and coarse interaction to explore large-scale structures and precise interaction to examine fine details. The techniques described below provide both these types of control.

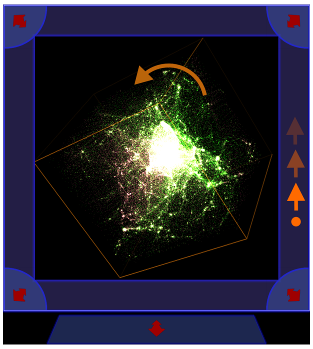
Single- and Dual-Touch Control of 3D Space

In traditional mouse-based interfaces, the manipulation of large 3D spaces (e. g., in 3D viewer applications) was often achieved with a trackball metaphor and simple panning, both controlled through the mouse and a mode switch. Each map the 2DOF of the mouse input to 2DOF of the target space. We use, in particular, the trackball interaction to control the rotation around two axes (x and y) by mapping it to single-touch interaction: the touching finger taking over the task from the mouse.

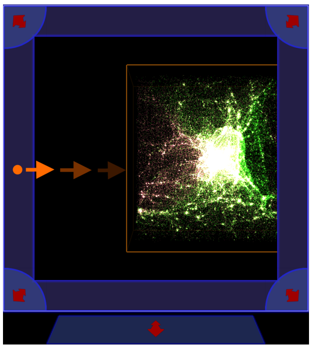
For controlling the remaining degrees of freedom we are inspired by dual-touch interaction with 2D elements [4]. With two fingers used simultaneous on the same object, we can control an additional 4DOF (2DOF from each finger). When interacting with 2D elements on a touch surface, this is commonly used to control the rotation around the remaining z axis, the 2D location of the object on the screen (in x and y), and the (uniform) scale of the object.

We use a similar interaction that we apply to 3D objects by mapping the input in a shallow depth fashion [2]. This means we assume a plane at a given distance from the viewer to which the interactions are applied. Only in this *interaction plane* are the manipulations "sticky" [3] when perspective projection in being used. This means that objects that are in this plane and initially reside under the touching finger will remain at the same relative location to the finger for the duration of the interaction. We determine the precise location of the interaction heuristically by using the middle of the part of the 3D space that resides in the view volume at the start of the interaction. This results in 6DOF being controllable with single- and dual-touch interaction.

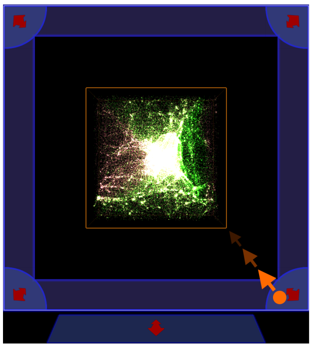
This combined single- and dual-touch interaction for controlling a single large 3D space, however, has a number of problems in the context of scientific visualization. While the single-touch rotation can control the orientation without affecting the scale of the space, this is not easily possible with the two-touch technique. As both fingers are controlled by the user to some degree independently, it is difficult to achieve translation or rotation while leaving the scale of the space unaffected. Similarly, translation in x and y cannot be performed independently from and rotation around z. Fi-



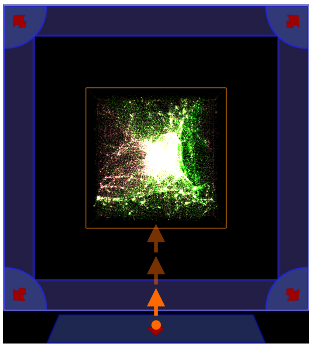
(a) Rotation around the z-axis.



(b) Translation along x and y.



(c) Scaling.



(d) Translation along the z-axis.

Figure 1. Frame interaction.

nally, we are only able to control 6DOF and it is not possible to manipulate the space's location along the z-axis.

Frame Interaction

To address both the issue of independent transformation and to provide the missing 7^{th} degree of freedom we introduce what we call *frame interaction*, inspired by Nijboer et al.'s [5] interface to ease the interaction with a drawing canvas for concept sketching. The idea is to use, in our case, the viewport's border to provide additional means of control for the location, orientation, and scale of the displayed space. These are used with a single touch and the invoked action depends on the initial direction of the finger's motion. Motions initially parallel to the frame (Figure 1(a)) invoke rotation around the z-axis, while touching the border and dragging the finger initially perpendicular to the frame results in translation along x and y (Figure 1(b)). In addition, we employ the corners to enable resizing of the object (Figure 1(c)).

The one manipulation that still remains to be mapped for full 7DOF control is translation along the z-axis. For this purpose we introduce a dedicated area below the viewport frame to translate along this axis (Figure 1(d)).

RESULT

Together with the single-touch trackball interaction that we continue to use when touching inside the viewport, these frame interaction allow us to replicate the same manipulations as with the combined single- and dual-touch method. Moreover, they allow to separate out the interactions and, consequently, permit users to control the viewport more precisely. For example, users can now affect the rotation around z independent from translation along x and y and both without affecting the scale, and vice versa. Therefore, we are able to control all 7DOF with only a single touch and, thus, this technique can also be used on touch-displays that only provide a single simultaneous touch location.

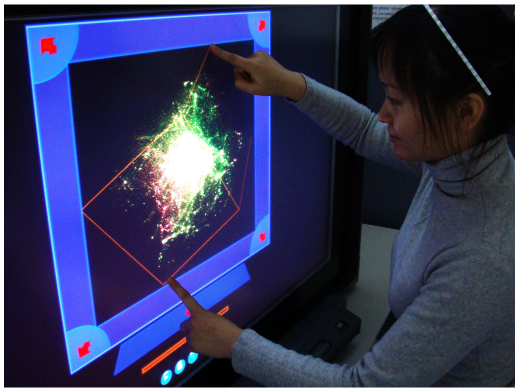


Figure 2. Interacting with visualizations of cosmological simulations using our interface.

However, as nowadays many people expect two-touch rotation and scaling in touch-enabled interfaces we continue to provide this technique when people start their interaction with two fingers inside the viewport and if the touch surface has this capability. This way we give the user the choice of either fast and integrated interaction with two fingers or precise and separate interaction when using the frame. We continue to explore this interaction in the context of scientific visualization and hope that these will be useful for scientists exploring their data (Figure 2).

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