Interactive Exploration and Selection in Volumetric Datasets with Color Tunneling

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ABSTRACT

Interactive data exploration and manipulation are often hindered by dataset sizes. For 3D data, occlusion, important adjacencies, and entangled patterns make visual interaction via common filtering techniques hard. This demonstration presents Color Tunneling, a toolset for interactive exploration and selection in large datasets. Our toolset uses a set of real-time multi-dimensional exploration techniques (animation between view configurations, semantic filtering and view deformation) to help users to easily select, analyze, and eliminate spatial-and-data patterns. Any data subset can be selected at any step along the animation. Data can be filtered and deformed to reduce occlusion and ease complex data selections. Our techniques are simple to learn and implement, flexible, and real-time interactive with datasets of tens of millions of data points. We demonstrate our toolset on three domain areas: 2D image segmentation and manipulation, 3D medical volume exploration, and astrophysical exploration.

Author Keywords
Data cube visualization, data exploration, GPU techniques

ACM Classification Keywords
I.3.6 [Methodology and Techniques]: Interaction techniques

INTRODUCTION
Interactive data exploration and manipulation are often hindered by dataset sizes. For 3D data, occlusion, important adjacencies, and entangled patterns make visual interaction via common filtering techniques hard. To this end, we developed Color Tunneling [1], a set of techniques to interactively unveil occluded structures of interest in dense 3D multivariate datasets which exhibit significant overlap between groups of voxels or pixels. Color Tunneling extends Focus + Context interactive exploration of 2D and 3D datasets in several directions. It proposes a set of linked *views* that display subsets of data attributes: 3D volume rendering plots, 2D scatterplots, and 2D and 3D histograms.

Views are linked by brushing and free-form selection. Using the optimal view(s), one can find structures of interest, e.g. spatially compact zones in images/volumes or peaks in histograms, and highlight or erase such structures in all views at once. We enhance classical *histogram* views with shading, sorting, and depth, to allow spotting complex patterns with greater ease. We propose a smooth *animation* between multiple views, to locate (and select) data patterns which are hard to isolate in single views. We integrate a focus + context *deformation* that adds the ability to uncover locally-occluded spatial patterns in any view. For this, we propose five interactive techniques (Figure 1) as follows:

- **View linking:** Three configurable views (2 exploration views and one lock view) are linked for data exploration.
- **Warp:** Animates any view between two configurations.
- **Lock:** Locks items not to be affected by brush or dig.
- **Brush:** With the lock view, brushing allows adding or removing data in any view.
- **Dig:** With the lock view, digging pushes data points away from the lens center to unveil occluded structures.

EXPLORATION EXAMPLES
Color Tunneling can handle large datasets (up to tens million records with a modern graphics card). We next demonstrate Color Tuneling on three use-cases involving different datasets in three application domains.

Medical imaging: Consider the 3D CT scans in Figure 1 and in the video. We want to "peek" inside the head and expose the *top part* of the brain structure in our head scan. Simply filtering out the bone voxels does not display the brain since the skin will not be filtered and will occlude it. Conversely, filtering out the skin will also remove the brain which has a similar density value. To solve our task, we use Color Tunneling and its associated tools. This effectively produces a combination of density-based, gradient-based, and geometry-based filtering that lets us remove the upper skin and skull cap, and unveil the brain in its spatial context, by means of just a few mouse clicks (video; 37 seconds).
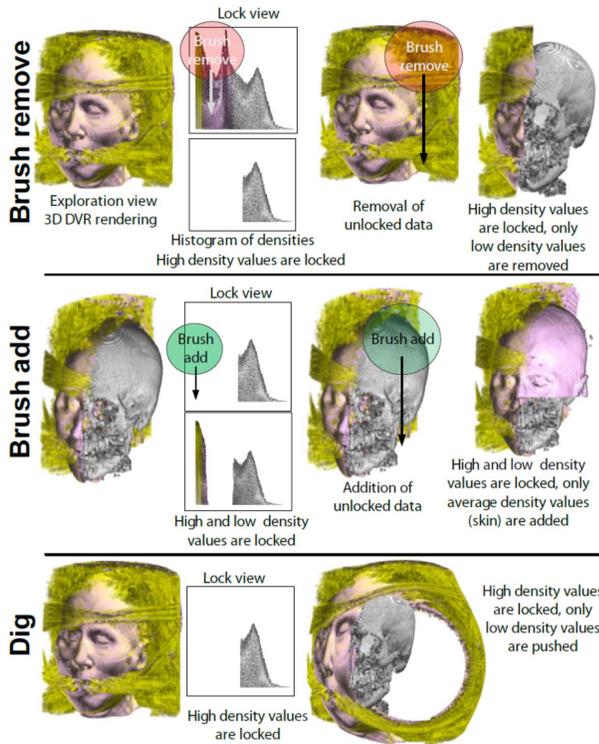
Figure 1: Brush, dig, and lock tools with Color Tunneling.

Astrophysical data: We consider a cube of astro-physical measurements of the large-scale structure of hydrogen gas intensities in our Milky Way Galaxy in 3D polar-coordinate-wavelength space. Thanks to the animation between the 3D cube and the density histogram, we can easily brush and extract constant-intensity outliers which are deep buried in the data cube (Fig. 3; video, 51 seconds). Astronomers require isolating such outliers for reasoning about various early-Universe formation patterns [6].
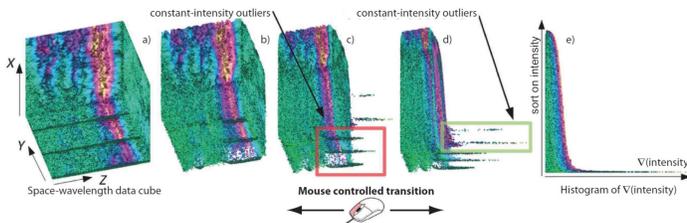

Figure 2: Locating constant-intensity line outliers in a 3D astronomical data cube.
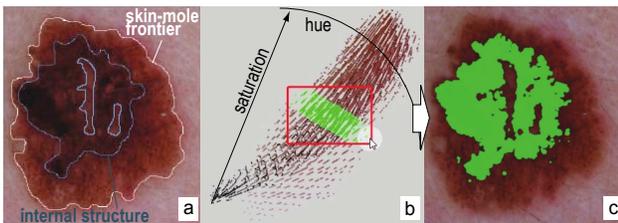

Figure 3: Skin tumor segmentation.

Image segmentation: Figure 3 shows a skin scan of a naevus, or mole. Dermatologists need to segment such scans into normal skin, the mole, and the internal mole structure prior to applying various metrics to predict the mole's potential malignity, such as shown in Fig. 2a. Producing such segmentations in the RGB image space is a delicate manual process. Using Color Tunneling, a dermatologist could produce comparable segmentations in a fraction of the time, by using brushing in a hue-saturation plot and animation towards the classical RGB image plot (Fig. 2c; video 3 minutes 20 seconds).

CONCLUSION

We have presented Color Tunneling, a set of interactive techniques for exploration and selection of structures from multidimensional datasets. In contrast to earlier animation techniques [2] [3], users can control and stop the animation at any stage. This yields an *infinite* set of in-between views where one can brush, dig, select, and explore the data. We thus use animation as a first-class exploration tool rather than only to preserve the mental-map between two views. We also present a new interaction tool: the lock view. Locked items are not affected by our dig, warp and brush tools. Locking leverages brushing by allowing complex selections of brushable items, in contrast to brushing compact ranges [4] [5]. Concluding, Color Tunneling's contributions are as follows:

- using **animation** as a controlled data exploration-and-selection technique,
- improved **brushing** with a flexible selection of brushable items,
- improved lens deformation (**dig tool**) with a flexible selection of pushable items,
- a simple implementation able to handle over 10M displayed data points at over 20 images/second on a modern GPU (e.g. NVidia 750m) on a recent PC computer (e.g. core I7 processor).

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