Design of the Bare-Hand Volume Cracker for Analysis of Raw Volumetric Data

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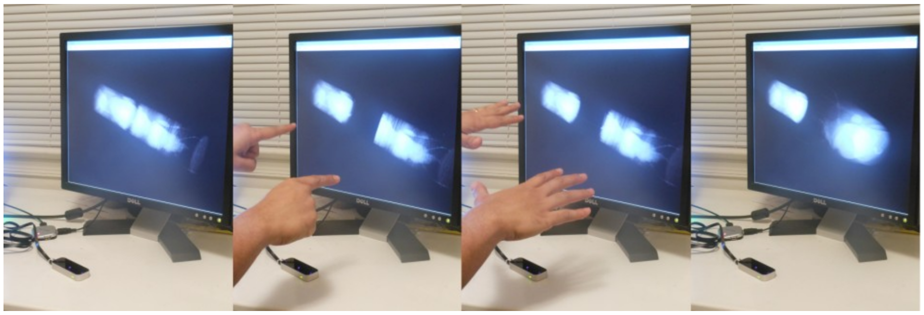

(a) Micro-CT scan of a beetle; (b) Cracking preview; (c) Cracking the beetle; (d) Cracked and rotated sub-volumes;

Figure 1: The Bare-Hand Volume Cracker interaction technique on real-world raw volume datasets.

Abstract

The Volume Cracker is a 3D interaction technique designed to allow rapid and intuitive visual analysis of raw volume data. However, the original Volume Cracker design was limited due to cumbersome and expensive hardware and the inability to interact with real volume data. New input devices such as the Leap Motion Controller enable 6-DOF tracking of bare hands and fingers, inspiring us to design a new version of the Volume Cracker addressing its prior limitations. We present a prototype of the Bare-Hand Volume Cracker that works directly on real volume datasets. We discuss the challenges we faced and the design choices we made while designing the Bare-Hand Volume Cracker based on the Leap Motion Controller.

Keywords: 3D interaction, 3D visualization, volume data analysis, bimanual, two-handed interaction, virtual reality.

Index Terms: I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism-Virtual reality; H.5.2 [Information Interfaces And Presentation]: User Interfaces-Input devices and strategies.

1 Introduction

Scientists and technicians analyzing datasets generated from computed tomography (CT), magnetic resonance imaging (MRI), confocal microscopy and other modalities need to perform tasks for understanding structures and connections inside a dense volume. These involve peering inside dense masses from different viewpoints around the volume [4]. The most widely-used approach involves segmenting volumes using transfer functions. This process involves a tradeoff: manual segmentation is accurate but quite time-consuming; automated segmentation is fast but usually less accurate. Traditional alternatives of slicing and focus + context techniques have limitations, or do not work directly on raw volume data.

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Recently, we proposed a bimanual Volume Cracker technique that iteratively cracks open a volume into connected sub-volumes [3]. The Volume Cracker seeks to address the limitations of the prior approaches by working directly on raw volumes, preserving context at all times, while leveraging the benefits of bimanual real-world actions.

The first prototype of Volume Cracker used tethered and expensive tracking hardware, and was developed to work with simulated volumes [3]. With the advent of cheap commodity tracking devices like the Leap Motion Controller, we were able to design a *bare-hand* prototype of the Volume Cracker. Our prototype works directly on real-world raw as well as segmented volume data.

In this paper, we describe the challenges we faced while migrating the Volume Cracker technique from traditional 6-DOF tracking systems to the Leap Motion Controller, and discuss the design decisions we made to overcome the challenges.

2 Related Work

Traditional interaction methods for analyzing raw volumes slice through the volume along orthogonal axes, or along some arbitrary axis, thus losing valuable context. Focus + context techniques highlight regions of interest (ROI) while preserving the whole volume at all times, but they may require prior definition of ROI, cause partial distortion, or assume semantic layers.

The Volume Cracker technique was developed to address these limitations of the prior approaches [3]. Inspired by a real-world bimanual metaphor, it was shown to have significant advantages over axis-aligned slicing and arbitrary slicing techniques, for search and pattern recognition tasks in volume datasets. But we have yet to realize these benefits with real-world datasets, as the prior evaluation used simulated volume data.

More recently, Jackson et al. created a prop-based tangible interface for volume data analysis [2]. Their interface, although lightweight, relies on the affordances of the prop and does not leverage the freedoms of movement of the human hand. Recent work on bimanual interaction techniques have created symmetric asynchronous bimanual techniques for medical data exploration [5]. Researchers are also exploring a variety of free-hand gestures for point cloud selection [1].

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3 Bare-Hand Volume Cracker Design

3.1 Original Volume Cracker design

The key features of the first prototype of Volume Cracker [3] were the volume cracking preview (updated in real-time), recursive cracking of a volume, and joining back of connected sub-volumes. Supporting features included preservation of the hierarchy of cracking (by connecting the cracked faces of sub-volumes), and restricting the movements and rotations of connected sub-volumes on a plane. Aside from these, it also had a single-handed 6-DOF grab action, and a bimanual grab of connected sub-volumes, for relative movement and the joining back capability.

The first prototype of the Volume Cracker used 5DT data gloves and Intersense IS-900 trackers for mapping the gestures from the users. An evaluation of the prototype had tasks from two generic categories (search and pattern recognition) on simulated volume data, and compared performance against axis-aligned slicing and arbitrary slicing techniques.

3.2 Design Goals

Our primary design goals for this version of the prototype were to be able to work with real volume datasets and to avoid tethering the user.

The volume cracking preview with real volume datasets requires specialized volume visualization, as we need to access and shift a dynamically changing group of individual voxels in real time. The constructor API from NGRAIN[1] gave us that capability. The Leap Motion Controller[2] allowed us to avoid cumbersome tracking hardware, but presented us with several new design challenges.

3.3 Challenges with the Leap Motion Controller

The Leap Motion Controller is a commodity-level device providing real-time tracking of bare human hands and fingers. It tracks with low latency and high accuracy, comparable to the best in the current line of 3D tracking devices. But it also has several challenges, which are mainly due to its reliance on infrared tracking technology.

The major limitation is due to *occlusion*, as the Leap sits on a desk, with a fixed field of view and line of sight. Occlusion problems include one hand hiding the other (limiting the hand movements), the palm hiding the fingers (limiting the amount of wrist rotation), and fingers hiding other fingers (resulting in the detected number of fingers changing randomly between frames). The tracking data also has significant jitter between frames. Palm orientation may change between frames, causing inversion of the palm normal. The Leap also has trouble consistently tracking a hand, resulting in the hand identification changing randomly between frames.

3.4 Design details for Bare-Hand version

Some of the challenges with Leap might fade with future versions of its firmware. But as user interface designers for camera-based tracking devices, we needed to work around the limitations so that user actions have sufficient predictability, and do not suffer from tracking issues. Also, while porting techniques from the previous tracking hardware, we had to keep in mind that our new design choices should not significantly alter the qualities of the interaction techniques that contributed to its benefits in the earlier evaluation.

Previously, researchers have looked at addressing the problems we face while migrating techniques across tracking hardware [6]. One main problem with camera based trackers is that of occlusion. Migrating the VC from a hybrid tracking (IS-900) system [3], we had to alter basic rotation metaphors, as well as many other features.

In the Bare-Hand version, we decided to activate the volume cracking preview when the user extends a single finger on each of her two hands within the Leap's FOV. This is different from the previously used open-hand cracking preview. The reason is that with the open hand movements, there is a much higher chance of finger occlusion with the Leap, which we want to avoid.

The cracking in this version occurs when the user opens up fingers on both of her hands, instead of the closed fists used previously. The cracked sub-volumes are attached right after the crack to the individual hands, for an immediate bimanual grab action, like before.

We have replaced the closed-fist-grab with an open-fist-palm-down gesture. We now have 3-DOF rate-controlled rotation (instead of the previous 3-DOF position-controlled rotation) to fit within the limited wrist rotation space allowed by the Leap. We have preserved the 3-DOF position-controlled movement during the grab action.

The features of the bare-hand volume cracker that are comparable to those from the previous version are the joining back of sub-volumes and the movement restriction of sub-volumes on a plane.

Currently, we are working on obtaining perspective rendering, and, if needed, higher levels of display fidelity (e.g., stereo and head tracking) with the Bare-Hand Volume Cracker, for comparability with the previous version for a formal evaluation. We are also identifying the real-world datasets that we want to use for evaluation.

4 Conclusions and Future work

In this tech-note we summarized our current efforts in designing a Bare-Hand version of the Volume Cracker technique. We outlined the problems we faced using the Leap Motion Controller to have a non-tethered tracking of human hands. We discussed the design decisions we made to work around these problems but preserve the efficacy of the original Volume Cracker technique.

We are currently getting this Bare-Hand prototype of the Volume Cracker ready for a formal evaluation with real-world volume datasets, and with domain experts as well as non-expert participants.

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