Volumetric X-ray Vision Using Illustrative Visual Effects

Thomas J. Clarke*
IVE, Wearable Computer Lab, University of South Australia

Wolfgang Mayer†
Industrial AI Research Centre, University of South Australia

Joanne E. Zucco‡
IVE, Wearable Computer Lab, University of South Australia

Adam Drogemuller§
IVE, Wearable Computer Lab, University of South Australia

Ross T. Smith¶
IVE, Wearable Computer Lab, University of South Australia

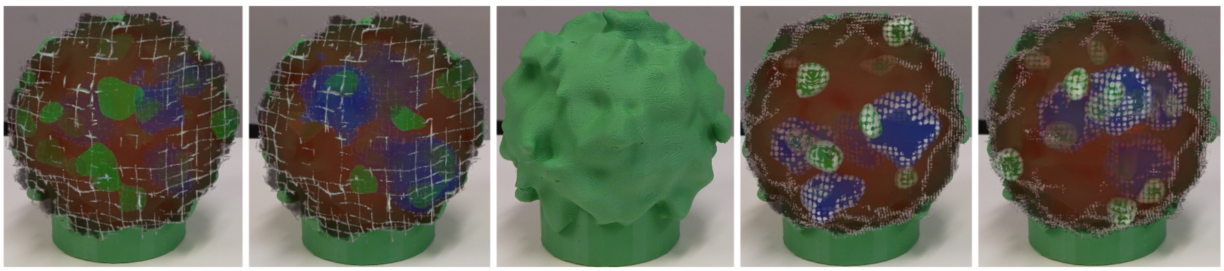

Figure 1: In the center are 3D objects to be viewed internally. The *cross-hatching* X-ray effect is shown on the two images to the right, and the *stippling* X-ray effect is shown on the two images to the left (all are using DVR). All these photos were taken through the HoloLens 2's scene viewer; as such, they are not fully representative of the experience in this demo.

Abstract

In this demonstration, we invite participants to view several objects' internal structures using direct volumetric rendering with X-ray vision techniques to understand the underlying structure. This is viewed in a Hololens 2 Optical See Through (OST) Augmented Reality (AR) display. Volumetric Rendering and X-ray Vision are two methods that can show the internal structure of a real-world object, but neither of these methods has been commonly seen using OST AR. We present a platform capable of generating volumetric datasets in a range of situations and accurately demonstrate two Illustrative Visual Effects (Stippling and Cross Hatching) that can be used for X-ray vision in AR.

Index Terms: Human-centered computing—Visualization—Visualization techniques—Treemaps; Human-centered computing—Visualization—Visualization design and evaluation methods

1 Introduction

This demonstration introduces a novel platform for Augmented Reality (AR) enabled X-ray vision. AR X-ray vision needs to show the correct depth via visualizing both the surface and the distance inside of the object [1]. Firefighters, medical practitioners, and security personnel, among others, have found benefits in using AR-enabled X-ray vision [2, 4, 6]. However, it is an open research question in the best way to implement AR X-ray vision.

This demo shows how an X-ray vision effect can be created with Direct Volume Rendering (DVR) present. Previous research has used X-ray Vision with Video See Through (VST) displays [8] or used polygonal shells [1], or a Tunneling method [1] to illustrate depth and the physical layout of the virtual internal structures to the user. Our work is novel since this is one of the first demonstrations to use DVR on a OST AR device in the last decade, and it is the only form of X-ray vision that utilizes volumetric data rather than pre-processed polygonal shells.

Optical See-Through(OST) AR allows users to see the real world directly with virtual content overlaid onto it. However, in an OST, these virtual images can be washed out by light from the real world, so X-ray vision cues are not as strong in an OST AR device compared to VST AR [5]. So, our first aim is to show that X-ray vision and illustrative effects can be effective in an OST display. The second aim of this research is to illustrate the role that transparency can play in X-ray visualization. Studies have shown that if transparency is done poorly, it can be detrimental to the user's depth perception, but when done well, it can be an effective depth cue. To illustrate how effective the transparent DVR is, we show how any information configuration can be easily understood using this cue. We present a simple-to-understand volume structure that can be randomly generated to fit within a set of parameters for proof of concept or controlled user studies.

2 X-ray Vision Implementation

This system uses two different visualizations to illustrate X-ray vision; (1) a *stippling visualization* that takes inspiration from Ghasemi et al.'s [3] and (2) a *cross-hatching method*. Both of these effects provide a form of partial occlusion and use the geometric properties of the volume like the surface curvature, the size of the shape, and the user's perspective. This gives the end user the perception that the visualization is been connected to the real world.

The *cross-hatching visualization* uses a grid with infinite depth facing the user. Lines on this grid were drawn along the interests of the grid, with thickness varying based on the curvature of the surface of the volume. The lines become invisible when facing the user so they can easily see into the volume.

The *stippling visualization* also uses a grid; however, this includes a sphere at a random place within its bounds, leading to variation in the size of the depth and a less ordered visualization. These dots transition from opaque to clear in the user's line of sight and the object's curvature to allow the user to view the inside of the object.

*e-mail: thomas.clarke@mymail.unisa.edu.au
†e-mail: wolfgang.mayer@unisa.edu.au
‡e-mail: joanne.zucco@unisa.edu.au
§e-mail: adam.drogemuller@mymail.unisa.edu.au
¶e-mail: ross.smith@unisa.edu.au

Figure 2: On the left is the target model, while the right shows the same model with AR X-ray vision applied.

The internal contents of our visualizations are created from a set of randomly generated noisy hierarchical spheres. These are generated in real-time and must ensure that no object may touch another unless it is inside of it completely. These volumes will then be constructed as a small file and sent over a TCP connection to the system that renders the volume within the X-rayable fields. This allows users to view many different volumes appearing inside the various physical objects.

2.1 X-ray vision of CT and MRI data

We will be showcasing this technique using visualizations of MRI and CT data. The data is preprocessed to calculate the areas where we would expect surface normals defined using a tetrahedra-defining volume and then calculated for all exterior voxels the distance away from the volume they were. A similar implementation to this was previously done by Rocha et al. [7].

By preprocessing the surface of the volume and all of the voxels outside of this space, representing the skin, we can determine the ray's relation to the surface, showing an effect slightly over the top of the skin.

Making it possible to perform the same algorithm to perform the previously mentioned prior in Section 2.

2.2 Volumetric Items Builder

To generate new and unique random objects, we present a modular system allowing users to determine the internal hierarchy of the objects they interact with. This system uses three main phases. First, it randomly selects a range of noisy objects to add to a given space. Next, The system performs two checks to ensure that the objects are not touching and are inside and outside of another object. The second is a thorough oct-tree search to check that each sub-section of voxels will fit the rules mentioned. After all the volumes are in and have been checked, a brute force check on the volume looks at each pixel and determines if the voxel will appear correctly.

3 The User Experience

For our ISMAR demo, users can view a volumetric X-ray vision using a HoloLens 2 tethered to a PC. Since the volumes are locked to real world objects, users cannot move or expand them. Instead, This demo will enable users to feel they can see inside the real world object and understand how the structures are composed. Some AR content will show noisy hierarchical spheres in a 3D-printed model, some will show CT and MRI data representations, and others will show simple geographic shapes unrelated to their contents. These will be placed over a desk where the user can see and look into these volumes using the HoloLens2.

The noisy hierarchical spheres will have dynamic qualities allowing them to change over time using the Volumetric Items Builder

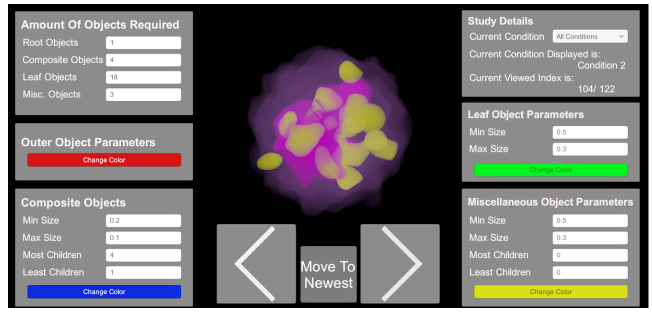

Figure 3: The UI of the Volumetric Items Builder

(Section 2.2). Figure 3 shows the UI that will enable users to both be able to change how future objects are generated and also be able to scroll and change the volume to choose a volume they are currently looking at. The real world CT and MRI are composed of high volumes of real world data, causing them to have no real interactable qualities other than to be visualized.

The real 3D objects used were printed out in the system detailed in Section 2.2 by converting the volume into an iso-surface to 3D print. All MRT and CT scans were collected from the Open Scientific Visualization Dataset [1] and were converted into an iso-surface to be 3D printed.

4 Conclusion and Next Steps

X-ray vision for DVR on OST AR devices is essential for many professions. This demo presents a model for that allows a user to create an unimaginable amount of random but unique volumes, allowing for highly controlled research. While also presenting a method to validate these results by having a direct comparison by allowing the same X-ray visualizations to be used on real world data. Using this demo, we present a method that allows showcases that makes the user feel as if they are looking inside of an object when viewing the surrounding area of the volume and utilizes Direct Volume Rendering to showcase the depth past the X-ray visualization.

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