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Publication details:
Proceedings - VRST 2018: 24th ACM Symposium on Virtual Reality Software and Technology
pp. 1 - 2
9781450360869 (ISBN)

Event details:
24th ACM Symposium on Virtual Reality Software and Technology (ACM VRST)
Tokyo, Japan
2018-11-28 - 2018-12-01

Publication Date:
2018-11-28

Publisher DOI:
https://doi.org/10.1145/3281505.3281572

Design-led 3D Visualization of Nanomedicines in Virtual Reality

Extended Abstract

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ABSTRACT

Nanomedicines are a promising addition to the arsenal of new cancer therapies. During development, scientists must precisely track their distribution in the body, a task that can be severely limited by traditional 2D displays. With its stereoscopic capacity and real-time interactivity, virtual reality (VR) provides an encouraging platform to accurately visualize dynamic 3D volumetric data. In this research, we develop a prototype application to track nanomedicines in VR. This platform has the potential to enhance data assessment, comprehension and communication in preclinical research which may ultimately influence the paradigm of future clinical protocols.

CCS CONCEPTS

• **Human-centered computing → Interaction design**; **Visualization**; • **Applied computing → Life and medical sciences**; *Arts and humanities*; *Education*;

KEYWORDS

data visualization, medical imaging, virtual reality, interface design, PET-CT, science, education, nanotechnology

ACM Reference Format:
Andrew R Lilja, Campbell W Strong, Benjamin J Bailey, Kristofer J Thurecht, Zachary H Houston, Nicholas L Fletcher, and John B McGhee. 2018. Design-led 3D Visualization of Nanomedicines in Virtual Reality: Extended Abstract. In *VRST 2018: 24th ACM Symposium on Virtual Reality Software and Technology (VRST '18), November 28-December 1, 2018, Tokyo, Japan.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3281505.3281572

1 INTRODUCTION

Nanoparticle drug delivery systems provide the promise of new forms of targeted cancer treatment [8]. These nanomedicines are currently in pre-clinical development, with scientists studying the efficiency of these drugs to target tumor structures using medical imaging modalities such as Positron Emission Tomography and Computed Tomography (PET-CT) scans. The scans use 3D volumetric reconstruction to visualize the drug distribution in the organism, though current methodologies limit the viewing of the 3D outputs to traditional 2D displays. As a consequence, interpretation of 3D-spatial data is often challenging.

VR promises to resolve many of these limitations, allowing true 3D spatial perception of volumetric data by providing stereoscopic depth and real-time interactivity [3]. While previous attempts using VR to visualize medical data have been successful [9], most use static data of single data sets. The inclusion of temporal data to VR visualizations gives additional insights to dynamic changes in data distribution, yet brings about new challenges in data processing, real-time performance and human-computer interaction.

This research explores whether user interaction and comprehension of dynamic nanoparticle distribution data can be enhanced through design-led immersive VR visualizations. This interdisciplinary work involving scientists, artists and real-time developers, explores how VR can be used as a platform to understand and intuitively interact with dynamic imaging data. Through the development of bespoke data processing pipelines, unique real-time data analysis tools, design-led aesthetics and future multiuser capabilities, it is anticipated that this prototype will uncover fundamental methodologies that will dramatically enhance collaborative preclinical science discovery and education.

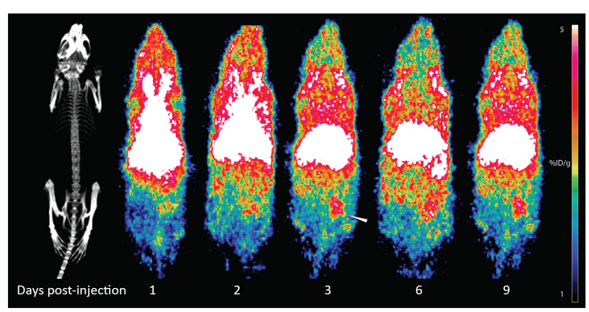

Figure 1: 2D PET-CT images of the nanoparticle distribution in the pre-clinical model. Credit: Kristofer Thurecht.

VRST '18, November 28-December 1, 2018, Tokyo, Japan

ACM ISBN 978-1-4503-6086-9/18/11.
https://doi.org/10.1145/3281505.3281572

2 PIPELINE

We have developed a novel pipeline to import volumetric data from PET-CT scans into the Unity3D gaming engine to be visualized on the HTC Vive platform. The immersive visualization is a hybrid of volumetric point data, isosurface data and 3D design-led representational approaches. This builds on previous work using clinical imaging data in VR for patient communication [7] and laboratory microscopy data for education and science discovery [5, 6].

All scientific studies were conducted in accordance with the guidelines of the local Animal Ethics Committee. Radiotracer-labelled polymeric nanoparticles were administered in a mouse model and tracked at various time points. Imaging data was acquired at 1, 2, 3, 6 and 9 days after administration (Figure 1). DICOM data sets were obtained for nanoparticle distribution and anatomical structures.

Raw PET data was opened in ParaView [1], which expresses data in the Visualization Toolkit (VTK) data model. We have written a custom translator for converting VTK data to Autodesk Maya Cache file format, allowing for import into Maya. Once imported, custom tools were used to threshold, transform, and spatially partition data based on organ occupancy. Data was imported and stored in a custom point format in Unity3D and displayed using Unity3D's Shuriken particle system, where the intensity of the nanoparticle signal was mapped to color, size and opacity. Skeletal and organ elements in the CT data were isosurface-meshed within ParaView, exported in STL format to Pixologic ZBrush for optimization and exported as OBJ for further refinement in Maya. Data was exported as FBX for import into Unity3D. See summary pipeline in Figure 2.

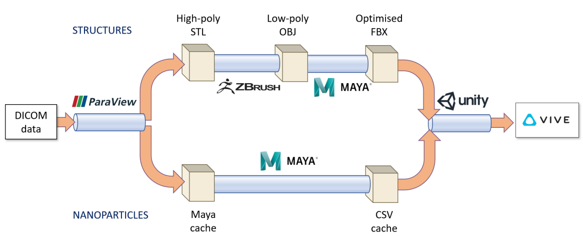

Figure 2: Pipeline from DICOM to VR HMD.

3 DESIGN AND INTERFACE

Practical aesthetic choices were implemented to enhance the visual clarity of the volumetric data, including the use of dark ambient lighting with contrasting neon-colored data. The design has focused on developing an enlarged scale virtual mouse and accompanying nanoparticle data. The user is grounded in a lab-style room with features to give the user a sense of floor and wall space. The interface features, which are a combination of direct interactions and gestural movements, are as follows:

- **Controls Guide**: accessible panel outlining user controls.
- **Teleportation**: changes user's virtual position.
- **Data interaction dashboard**: organ selection, time point slider, component visibility toggles, rotation lever, color and threshold controls, graphical readouts (Figure 3).
- **Sampling Wand Tool**: adjustable spherical volume that dynamically samples number of nanoparticles within.

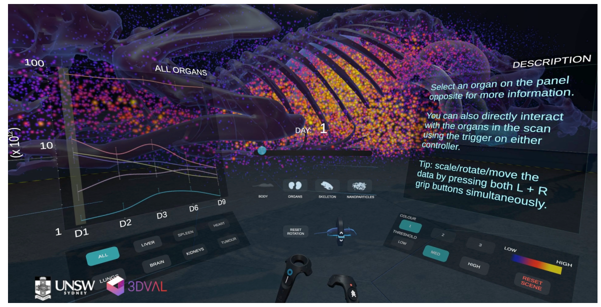

Figure 3: Screenshot of the Interaction Dashboard.

4 FUTURE DEVELOPMENT

While this VR experience is a compelling prototype, there are several areas for development. These are as follows:

- **User Evaluation**: Detailed user evaluation on the overall VR experience comparing it with current visualization tools.
- **Automation of Pipeline**: This data-to-VR pipeline requires considerable manual input. We aim to link our pipeline elements into an automated system.
- **Multiuser VR**: While currently a single user experience, we intend incorporate multiuser functionality.

There is now an expanding array of software applications that allow users to visualize and interact with biomedical imaging modalities in VR such as SyGlass [4] and Arivis [2]. Based on our prototype, we see an opportunity to enhance the user experience and improve the visual and interactive fidelity of nanoparticle data visualization. The intention is to enable users to better delineate concentrations with improved interactive access to the spatial and temporal distribution of the data. We see significant future opportunities for immersive VR as a mainstream platform in biomedical education and nanomedicine research. This will likely inform the wider clinical application for disease diagnosis and patient education.

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