Exploring Data in VR: Opportunities and Challenges

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A Note on Nomenclature

- Virtual reality, augmented reality, mixed reality, hybrid reality – what does it all mean?
The Reality-Virtuality Continuum

- Milgram & Kishino (1994) proposed a spectrum to describe the reality-virtuality continuum
- Along three dimensions
  - Extent of World Knowledge (EWK)
  - Extent of Presence Metaphor (EPM)
  - Reproduction Fidelity (RF)
What We Mean by “VR” in This Talk
Introduction

• Recent rise of consumer-grade VR
• Many options
  • price
  • resolution
  • field of view
  • size
  • Tracking
• Content delivery platforms
  • Steam
  • Oculus Store
  • WebXR (browser)

HTC Vive
Oculus Quest 2
Vision...

https://www.reddit.com/r/Thatsabooklight/comments/kf2ve0/the_medical_infusion_devices_center_background/

...and Reality


https://cgvr.cs.uni-bremen.de/research/atlas_19/

Use Cases

• Training
  • Vehicles
  • Machines
  • HUDs
  • Mission planning
  • Studying information processing and overload

• Tactical Augmented Reality (TAR)
  • Enhance what is already there

• Measuring and timing movement and interaction between user and environment

https://www.youtube.com/watch?v=0NormS9S1ow
https://www.roadtovr.com/iti-vr-crane-training-simulator-test/
Input devices

- Left mouse button
- Right mouse button
- Middle mouse button/wheel
- x, y-position

Left analog stick
Menu button
X-button
Y-button
Left trigger button
Left grip button
Right analog stick
Oculus button
B-button
A-button
Right trigger button
Right grip button
x, y, z-position
x, y, z-rotation
Where is the Data?
Data Visualization in VR: Vision

“Visual data exploration seeks to integrate humans in the data exploration process, applying their perceptual abilities [...]. The basic idea is to present the data in some visual form, allowing data analysts to [...] interact with it.” (Keim, 2001)

- Symbiosis of computers and humans
- Visualization is for humans only
- Many formalizations for making, interpreting, and teaching data visualization
Perceptual Challenges for vis in VR

• 2D is simplicity
• VR is 3D by nature

• Occlusion
  • Depth cue -> limits what we can see in 3D
  • We experience the world in 2.05D (Munzner, 2014; Ware, 2008)

• Foreshortening
  • Shows size difference where there should be none

• 3D costs time and cognitive effort
  • No 3D as purely aesthetic choice! (Few, 2012)
Information-Rich Virtual Environments (IRVE)

• “An information-rich virtual environment (IRVE) is a realistic VE that is enhanced with the addition of related abstract information.”

Project 1: Optimizing Movement in VR
We can show someone in VR visualizations of their own movement data. Then maybe they can learn from it.
In a recent paper, we asked people to travel through a virtual building as fast as possible.
We wanted to check if they can beat their own time in a 2\textsuperscript{nd} trial after having seen a visualization of their own movement.
Study design
Study overview

• 4 x 6 tasks
• 1st task is practice
• Movement methods
• Tasks get harder
Study overview (cont’d)

To finish this task, hold your controller against this sphere for 1 second.

Walk

Submission in progress...
Movement methods

- **Walking**
- **Teleport**
- **Free-fly**

Choice between all 3
Data is beautiful
Did it work?

- Yes!
- People who saw their own data were faster by 1 second:
  - $m_{\text{control}} = 16.44$ s
  - $m_{\text{experiment}} = 15.44$ s

$(t = 2.465, p = 0.01383)$ ✔
Project 2: The Common Coordinate Framework (CCF) Organ VR Gallery

Also called the “Human Reference Atlas in 3D VR”
The CCF Organ VR Gallery

- Human BioMolecular Atlas Program (HuBMAP) and other single-cell mapping efforts
- Integrates 3 data types for human tissue:
  - Spatial
  - Biological structure
  - Specimen/clinical metadata (not covered in this talk)
- Code: https://github.com/cns-iu/ccf-organ-vr-gallery
Spatial Data

Warning: graphical image of a kidney coming up!
The Meat of the Matter

• Documenting tissue extraction sites is non-trivial

• Photos of reference organs (if available) on cutting boards with spatial markers

• We used the Visible Human male, left kidney (100 mm high, 60 mm wide, 40 mm deep)

Mapping to the CCF

4.3.6.20 Colon

4.3.6.20.1 Preferred Location: Transverse colon. Gently rinse mucosa with normal saline before aliquot preparation. Aliquots should contain the full thickness of the colonic wall, i.e., mucosa and muscularis propria. Trim adjacent adipose tissue.

4.3.6.20.2 Preferred Aliquot: 20 mm x 10 mm x thickness (≤4 mm), divided into two adjacent 10 mm x 10 mm x thickness aliquots. Each cassette should contain two 10 mm x 10 mm x thickness aliquots.

4.3.6.20.3 Preferred Location: Sigmoid colon. Preferred Location: Sigmoid colon. Gently rinse mucosa with normal saline before aliquot preparation. Obtain only muscularis propria, discard mucosa and any seminal adipose tissue.

4.3.6.20.4 Preferred Aliquot: 20 mm x 10 mm x thickness (≤4 mm), divided into two adjacent 10 mm x 10 mm x thickness aliquots. Each cassette should contain two 10 mm x 10 mm x thickness aliquots.

**Sigmoid Colon (pelvic colon) Dissection Guide (Diagram 4)**

Recover the transverse colon starting 10 cm back from the right colic (hepatic) flexure.
CCF Registration User Interface (RUI)

https://hubmapconsortium.github.io/ccf-ui/rui/
CCF Exploration User Interface (EUI)

https://portal.hubmapconsortium.org/ccf-eui
CCF

Allows us to 3D register tissue and explore tissue blocks spatially and semantically across macro-, meso-, and micro-scale.
Biological Structure
Linked Open Data (LOD)
Anatomical Structure, Cell Type, Plus Biomarker (ASCT+B) Table
Background—Structuring Knowledge: What does an ASCT+B Table Do?

Structured knowledge unifies nomenclature that describes datasets so we are all speaking in the same language.

Standardize how information is captured, formatted, labeled

Knowledge about organs, anatomical structures, cell types, biomarker sets that uniquely define cell types

Ontologies like the multi-species Uber Anatomy (Uberon) and Cell Ontology (CL) capture nomenclature, synonyms, descriptions, relationships between entities, provenance for knowledge, assigns unique ID for this unit of knowledge.

Unstructured knowledge sources ~80% of biomedical knowledge
Tie to Spatial Data: 3D Reference Models

- Custom built by our medical illustrator team with input from subject matter experts
- Support the RUI, EUI, and CCF Organ VR Gallery
- Anatomical structures labeled with ontology IDs

A Closer Look at the Gallery
Conclusion

• VR + data visualization = superpower

• Challenges:
  • Perception
  • Complexity
  • Use cases
  • AR hardware

• Information-Rich Virtual Environments in VR

• Integrate spatial and abstract data in one continuous immersive environment
Become a Tester!

• Documentation: https://www.figma.com/file/TopdFvriKNCv9Af2Hgo8aK/Documentation-Organ?node-id=0%3A1
• Feedback: https://forms.gle/wnGnZLKyDVU9MEs5o8
• Meta Quest 2 setup (general introduction): https://www.figma.com/file/0MgWkoPyuWLWb8esFsYya5/CNS-Documentation?node-id=0%3A1
• GitHub issues: https://github.com/cns-iu/ccf-organ-vr-gallery/issues
• Please contact Andreas Bueckle at abueckle@iu.edu!
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References


Your Turn