Data Visualization using Augmented and Virtual Reality

Ronell Sicat
KAUST Visualization Core Lab (KVL)

جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

Core Labs and Research Infrastructure

training webpage

How can AR/VR help me

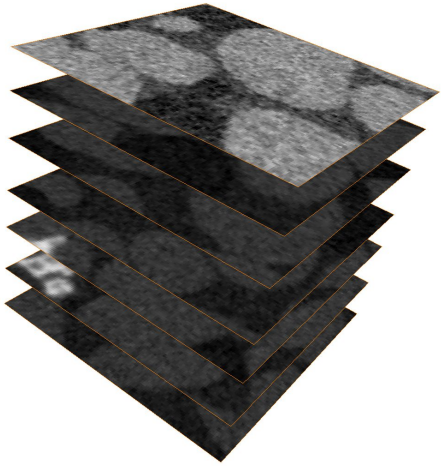
visualize

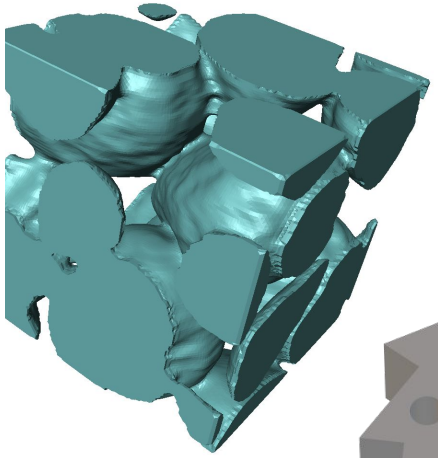
understand

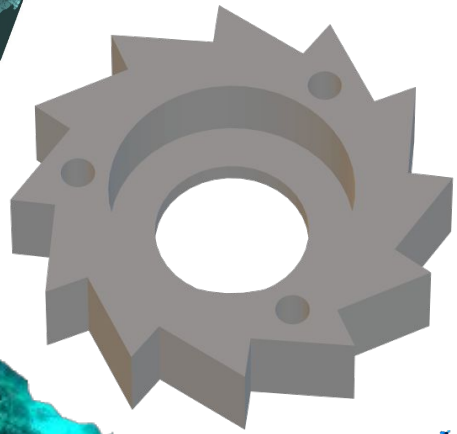
explain

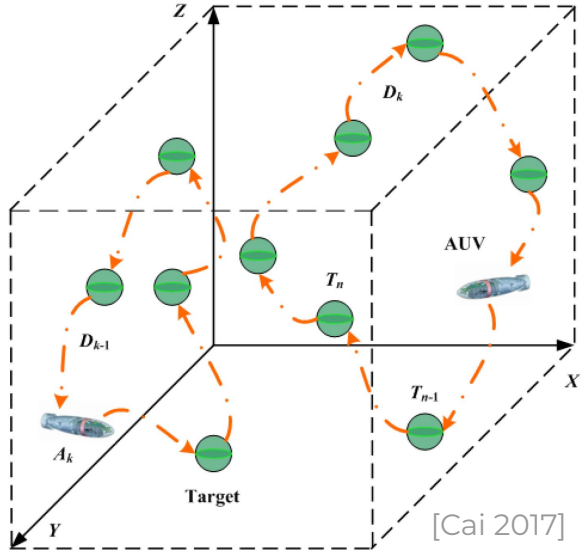
manipulate

my data better?

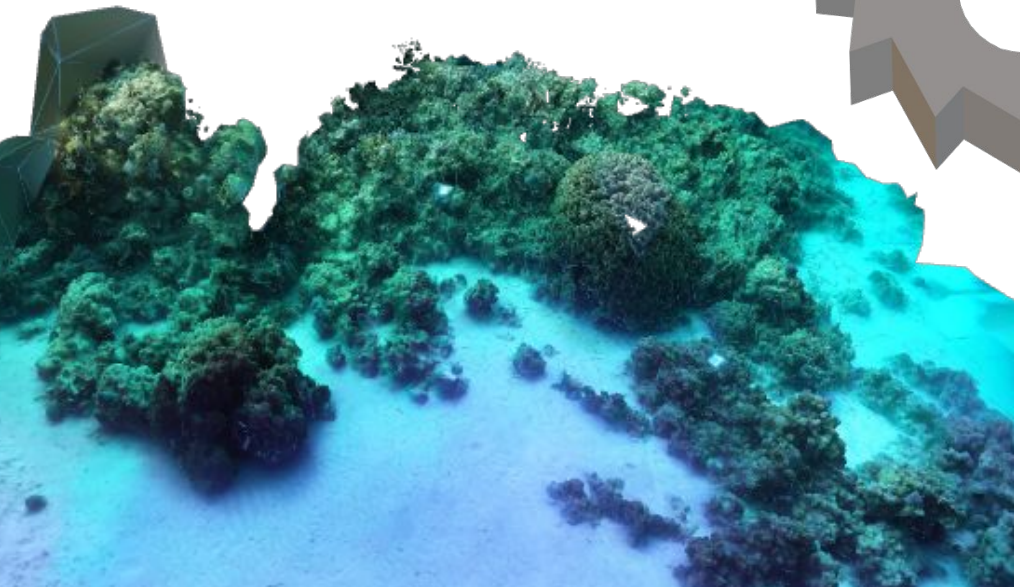


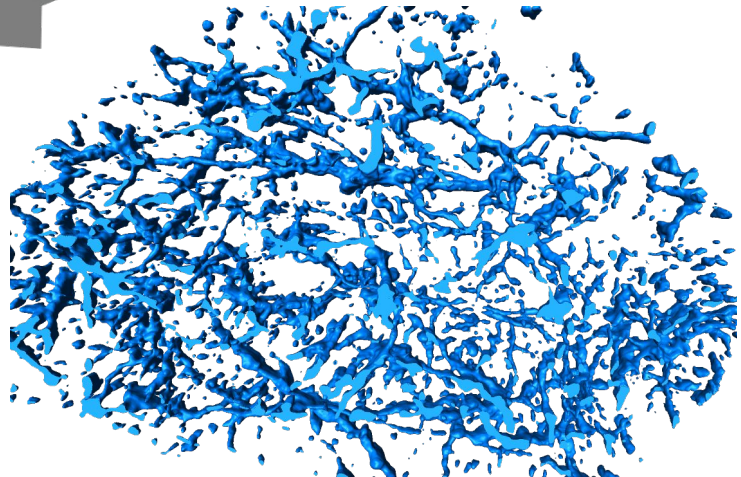






[Cai 2017]






0.03
0.02
0.01
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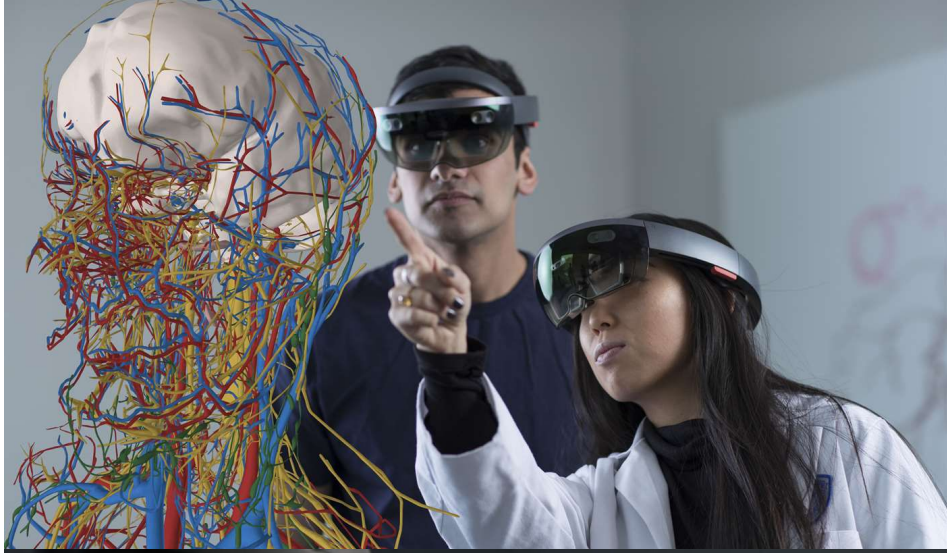
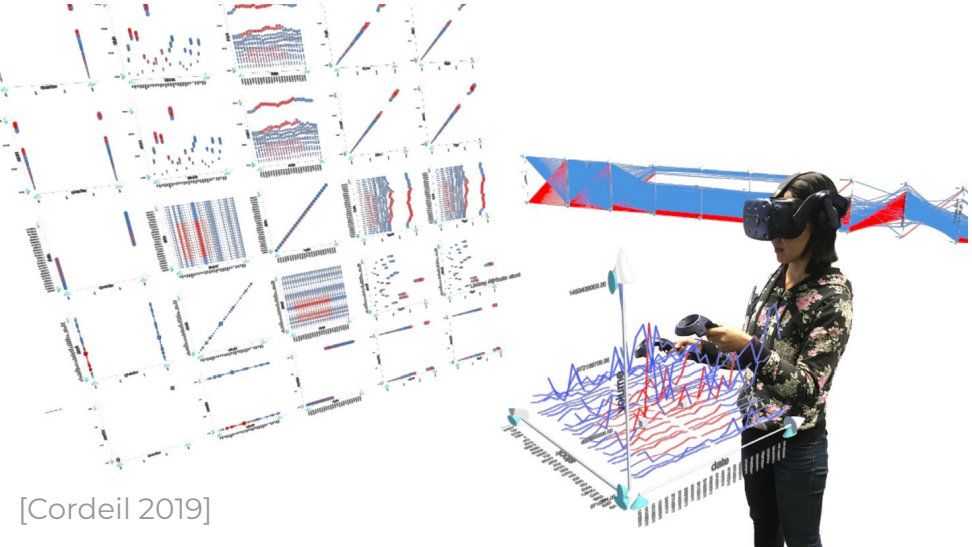
Names Popularity Index
Names Year
LookVR




[Cordeil 2019]


C3 Vertebra
Microsoft
Image: Microsoft

KVL Introduction

KVL provides expertise in **data visualization** and **data science**

- Scientific visualization
- Large data analysis
- Distributed visualization

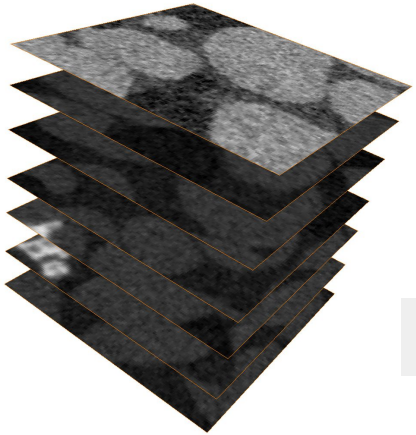
- Information visualization
- Visual analytics
- Statistical Analysis

- Data science
- Machine learning
- Deep learning

- Image segmentation
- 3D reconstruction
- *Augmented / virtual reality (AR/VR)*

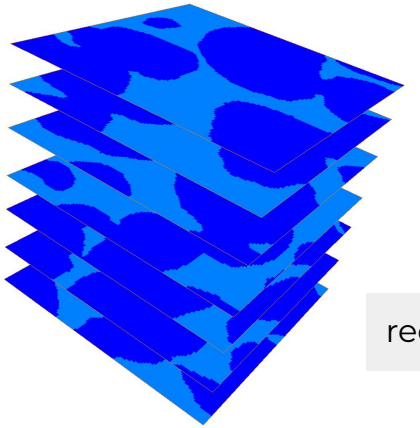
Image segmentation and 3D reconstruction

image stack



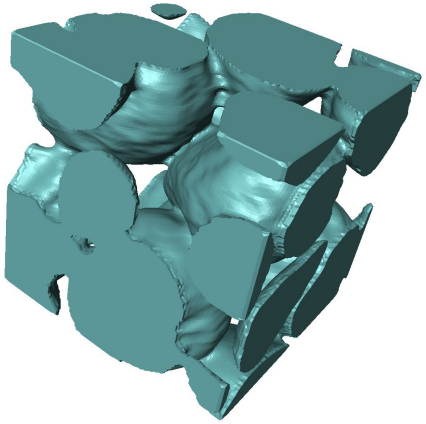
segmentation

label images



reconstruction

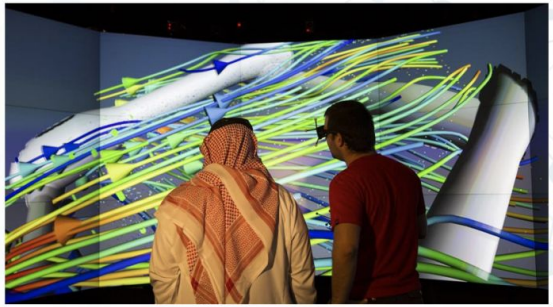
3D model



visualization
and analysis

KVL offers state-of-the-art **visualization facilities**

ZONE 1/2 DISPLAY WALLS: 2D/3D Analytics



CUBES VR

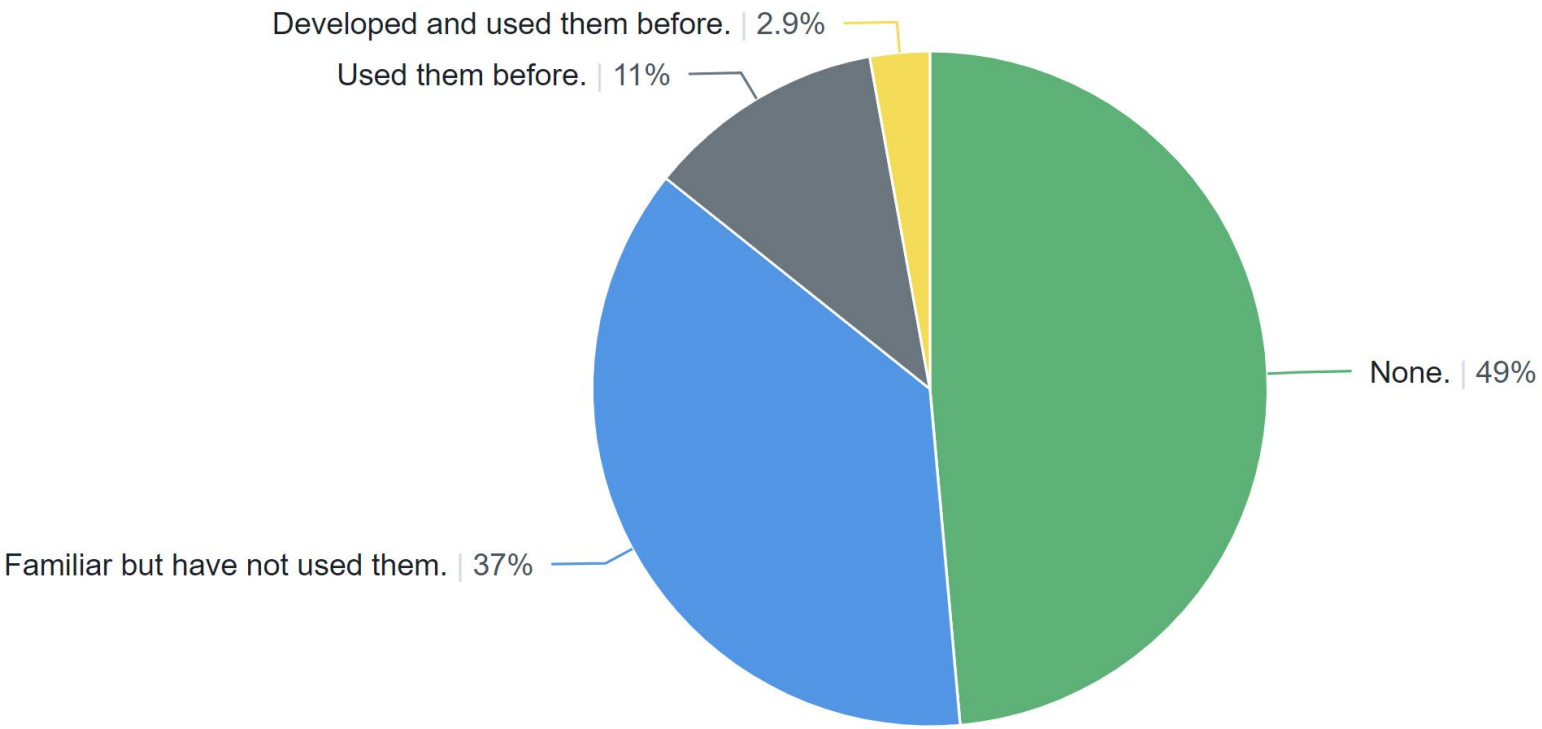
ZONE 5 VR

AR/VR HMDs

wiki.vis.kaust.edu.sa

help@vis.kaust.edu.sa

What is your previous experience with AR/VR?



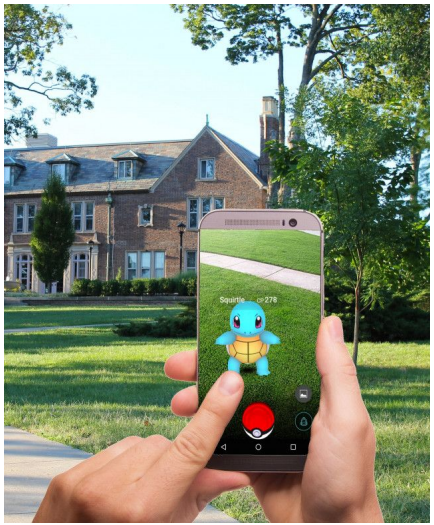
Schedule

- AR/VR Introduction
- AR/VR Capabilities @ KVL
- **10 min. Break + Sign-Ups**
- Example Scenarios
- **10 min. Break + Sign-Ups**
- Hands-on Example
- Open Discussion

AR/VR Introduction

What is AR/VR?

Hardware and software systems to interact with and display a blend of real and virtual objects.

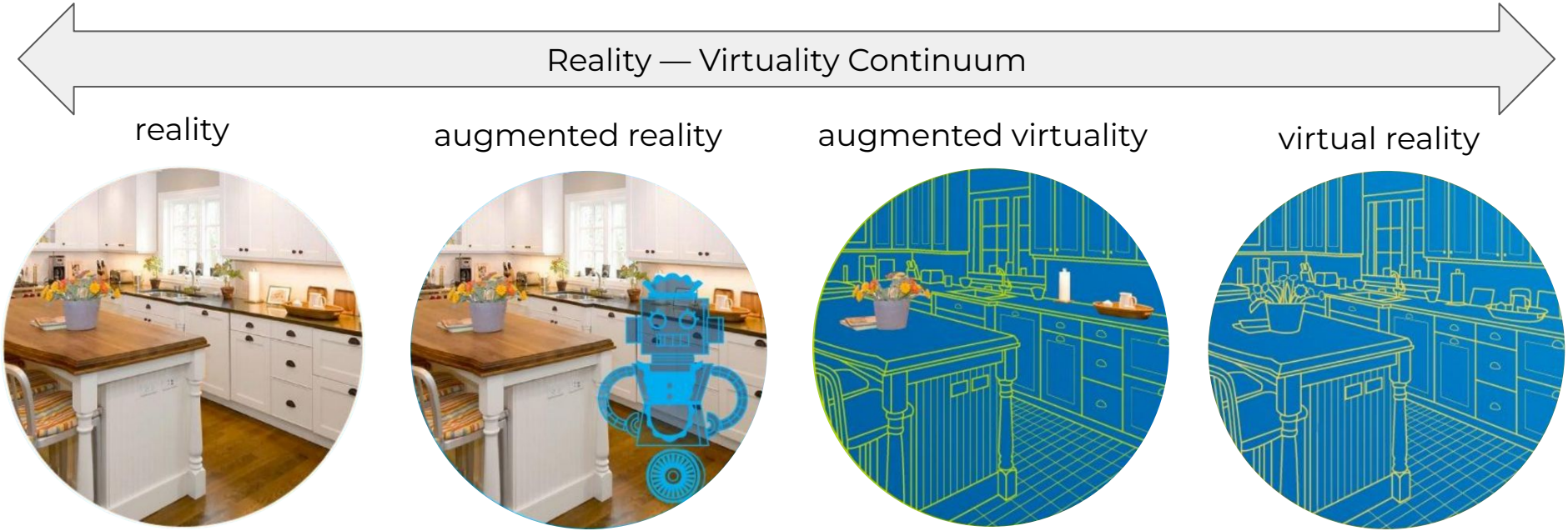


https://pxhere.com/en/photo/556168

https://www.spheregen.com/hololens-2-faq/

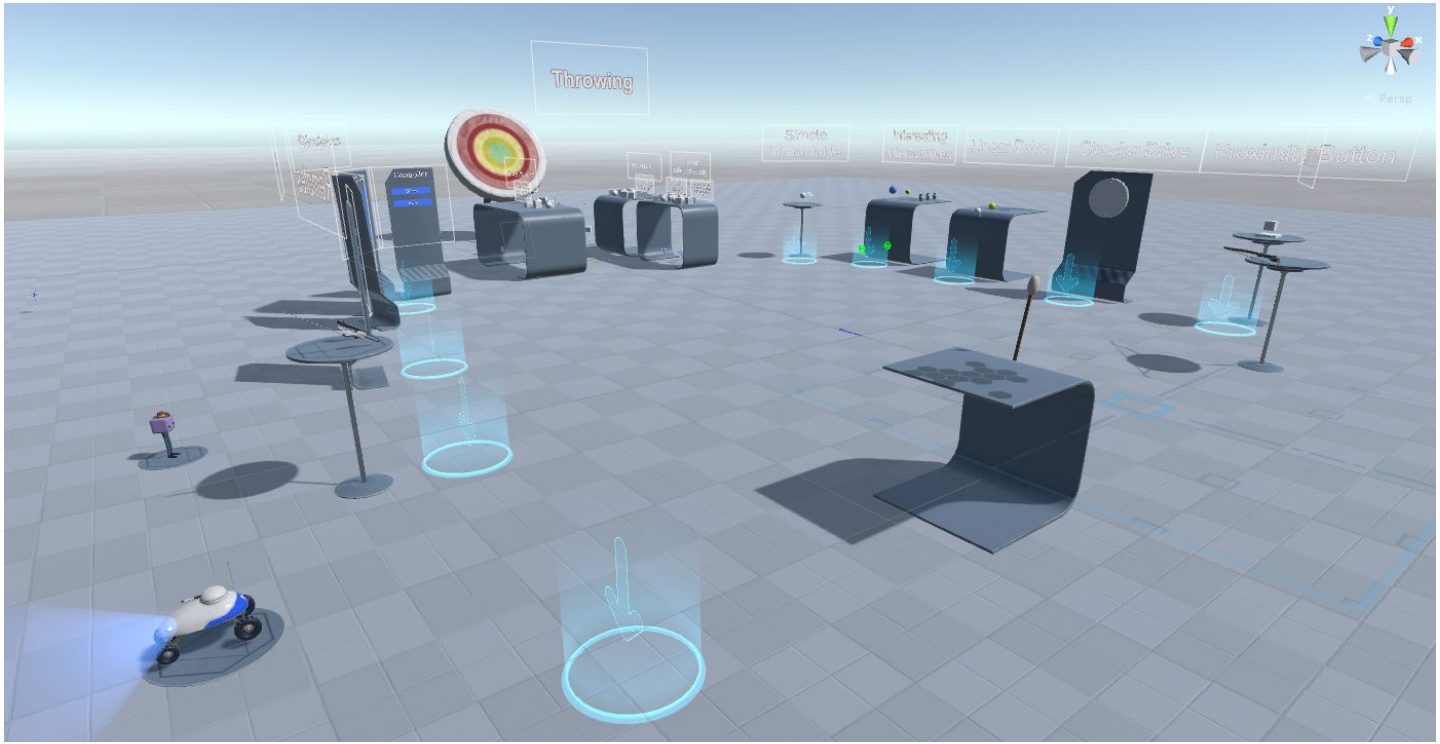
[Riegler et al. 2019]

What is AR/VR?



http://www.kacpr.org/popup/file/20180913/Virtual%20reality%20in%20CPR%20training.pdf

Demo: VR template



https://valvesoftware.github.io/steamvr_unity_plugin/tutorials/SteamVR-Input.html

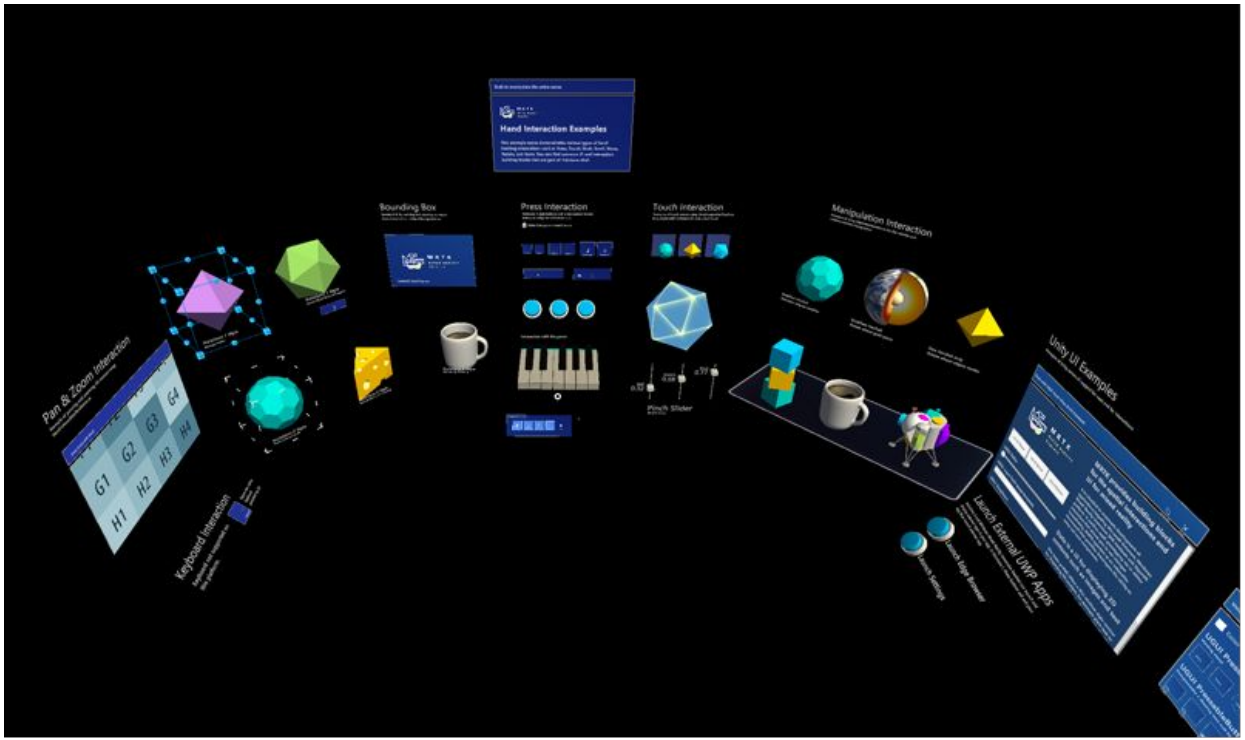
VR examples

https://www.youtube.com/watch?v=SCrkZOx5Q1M

VR examples

https://techcrunch.com/2023/01/31/meta-starts-testing-members-only-worlds-in-horizon-worlds/

Demo: AR template



https://github.com/microsoft/MixedRealityToolkit-Unity

AR examples

https://www.ikea.com/au/en/customer-service/mobile-apps/...
say-hej-to-ikea-place-pub1f8af050

https://mashable.com/article/facebook-
messenger-ar-effects

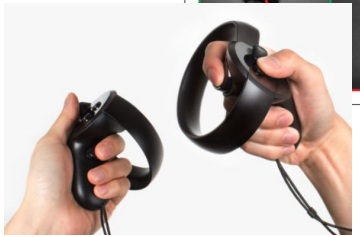
AR examples

https://news.microsoft.com/videos/introducing-dynamics-365-remote-assist-for-hololens-2-and-mobile-devices/

AR examples

https://www.spheregen.com/hololens-2-faq/

How does AR/VR work?



output

input

computer

application

virtual content

hardware + software

https://www.digitalspy.com/videogames/a790819/how-to-set-up-the-oculus-rift/
https://arstechnica.com/gaming/2016/10/why-oculus-has-my-favorite-vr-hand-tracking-controller/
Hubner et al. 2020: https://www.mdpi.com/1424-8220/20/4/1021

Hardware

Head-Mounted Displays (HMDs)

Immersive Environments (CAVEs)

Software

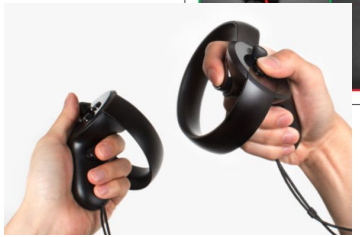
AR/VR-ready Applications

- “App” Stores (Steam, Microsoft, Oculus, etc.)
- **Avizo + TechViz**
- 3DSlicer
- Paraview

AR/VR Development Tools

- **SimLab**
- Game Engines (**Unity**, Unreal, Godot)
- Low-level programming using OpenXR, OpenGL, Vulkan, C/C++, etc.

AR/VR application development



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https://arstechnica.com/gaming/2016/10/why-oculus-has-my-favorite-vr-hand-tracking-controller/
Hubner et al. 2020: https://www.mdpi.com/1424-8220/20/4/1021

Data Visualization using AR/VR

Data visualization using AR/VR

output

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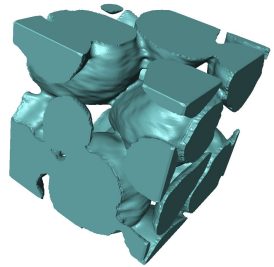
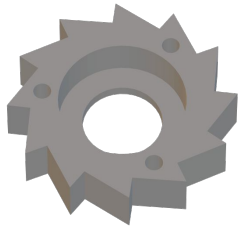
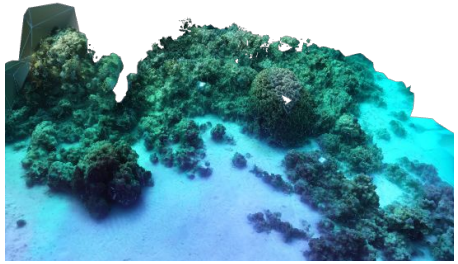
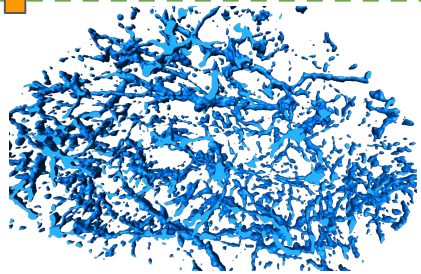
AR/VR application

virtual content









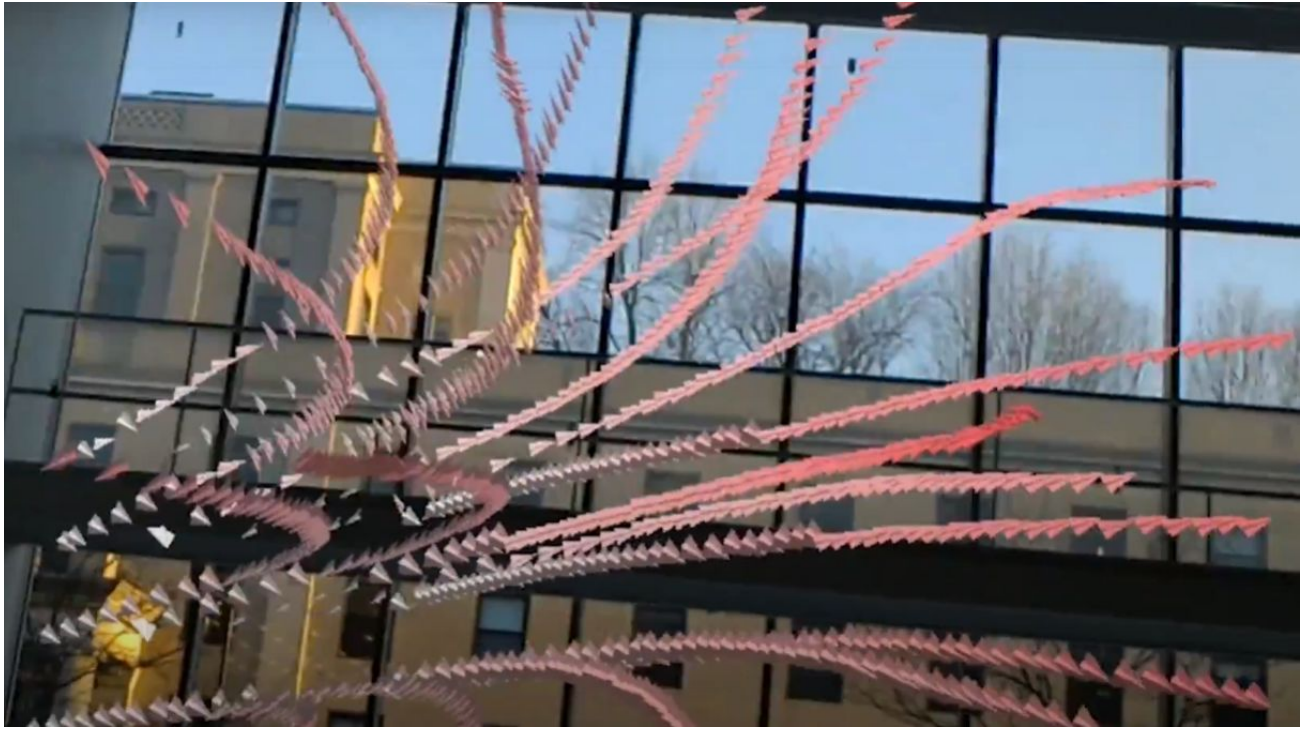
Immersive analytics

- Leverages new interaction and display technologies, e.g., AR/VR, to support data understanding and analysis.
- Can be useful for:
  - understanding **3D spatial data**
  - analyzing **situated data**
  - performing direct **natural interactions**
  - **immersive storytelling**
  - and more!

Situated Data: sensor data visualization in AR

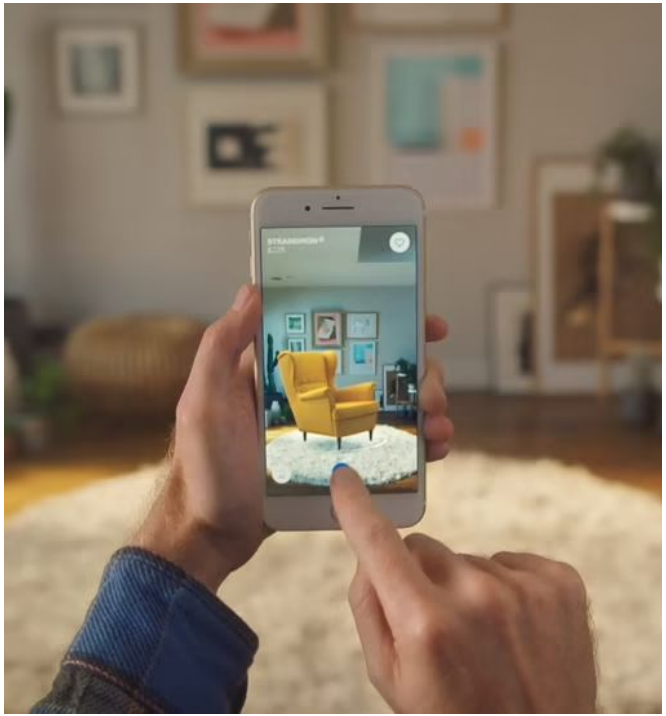
https://er.educause.edu/blogs/2018/8/using-augmented-reality-to-promote-making-with-understanding

Situated Data: wind flow visualization in AR



[Sicat et al. 2019]

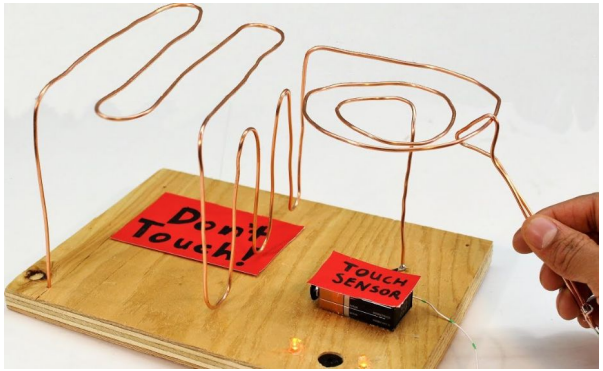
Situated Data: planning/prototyping in AR

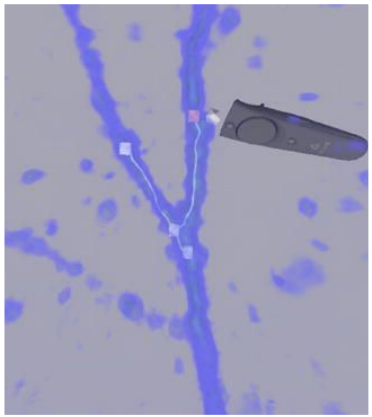


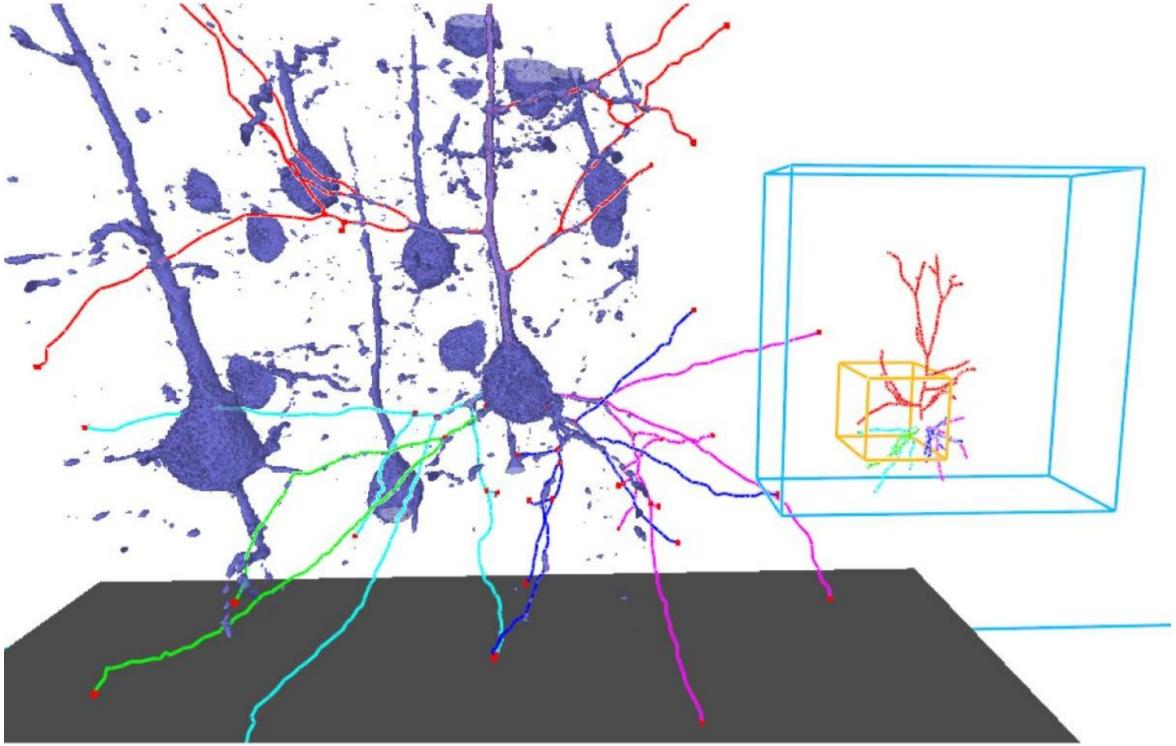
https://www.ikea.com/au/en/customer-service/mobile-apps/say-hej-to-ikea-place-pub1f8af050

https://adsknews.autodesk.com/news/microsoft-hololens-autodesk-fusion-360-mixed-reality-for-product-design-and-engineering

Natural Interactions: neuron tracing in VR

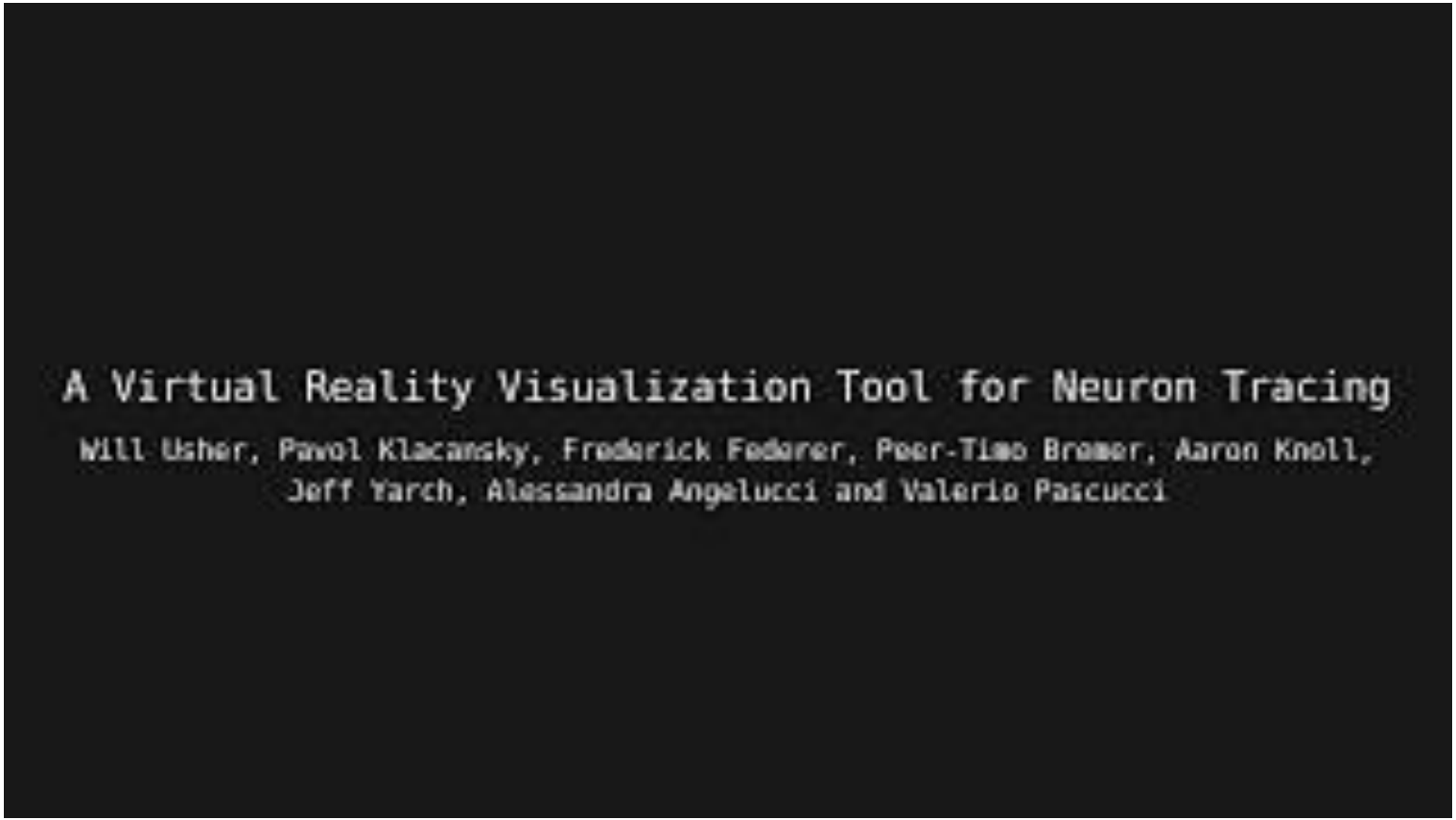




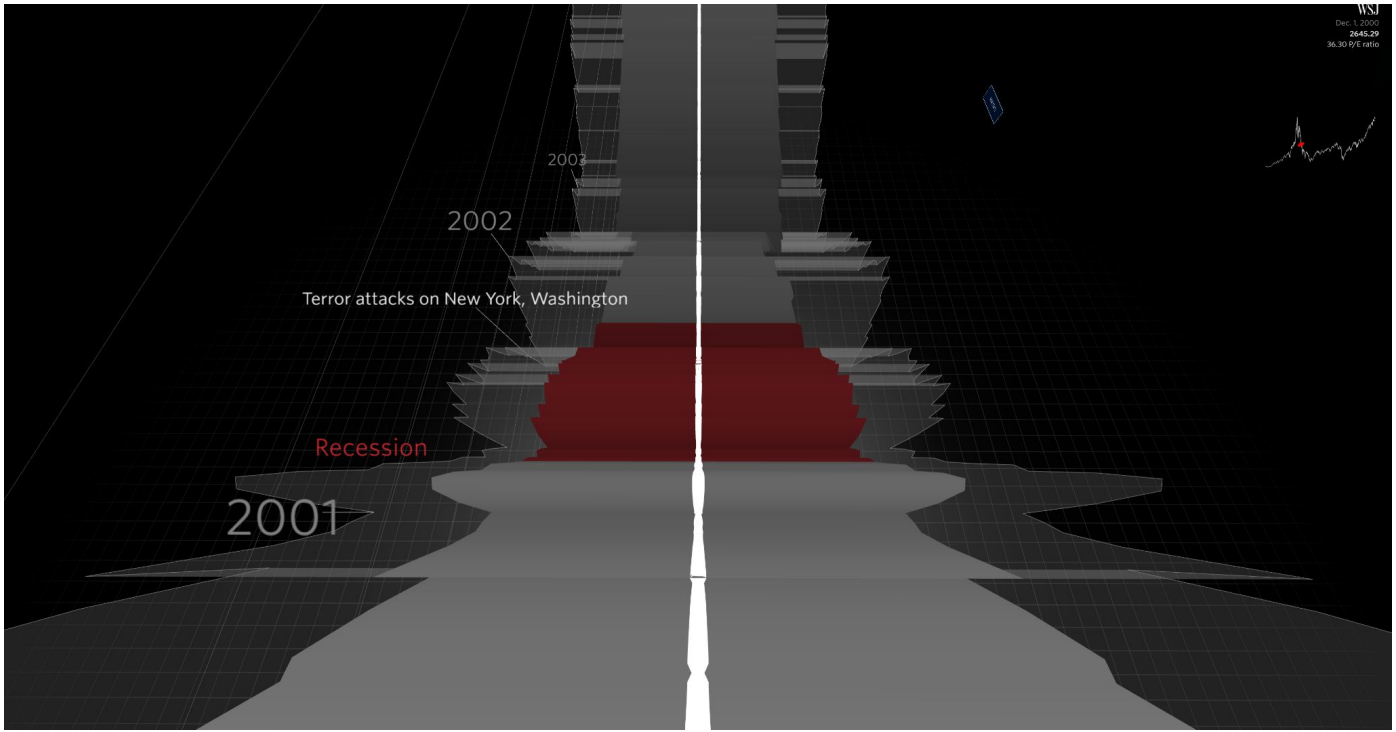


[Usher et al. 2018], https://www.youtube.com/watch?v=7KZgD053xXI

Natural Interactions: neuron tracing in VR

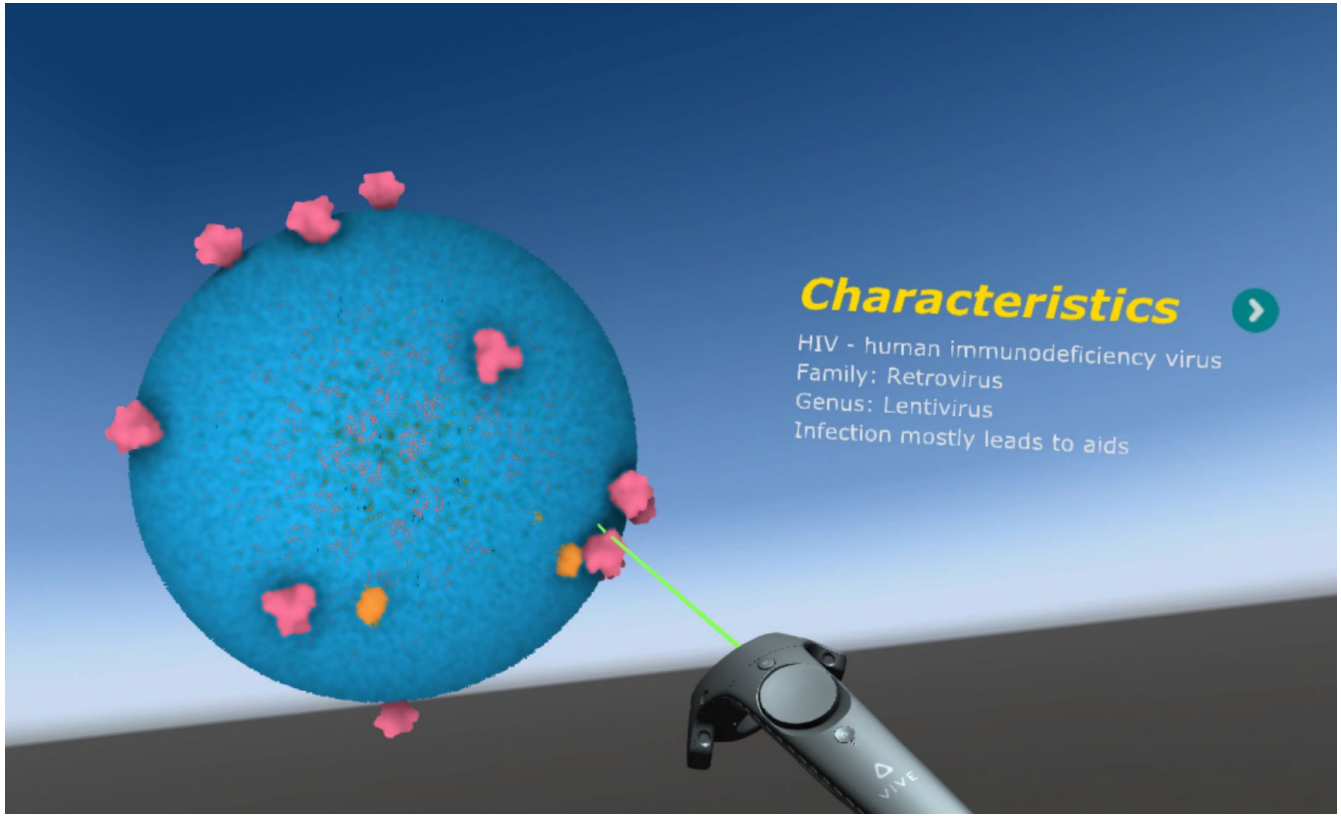


Immersive Storytelling: NASDAQ rise and fall in VR

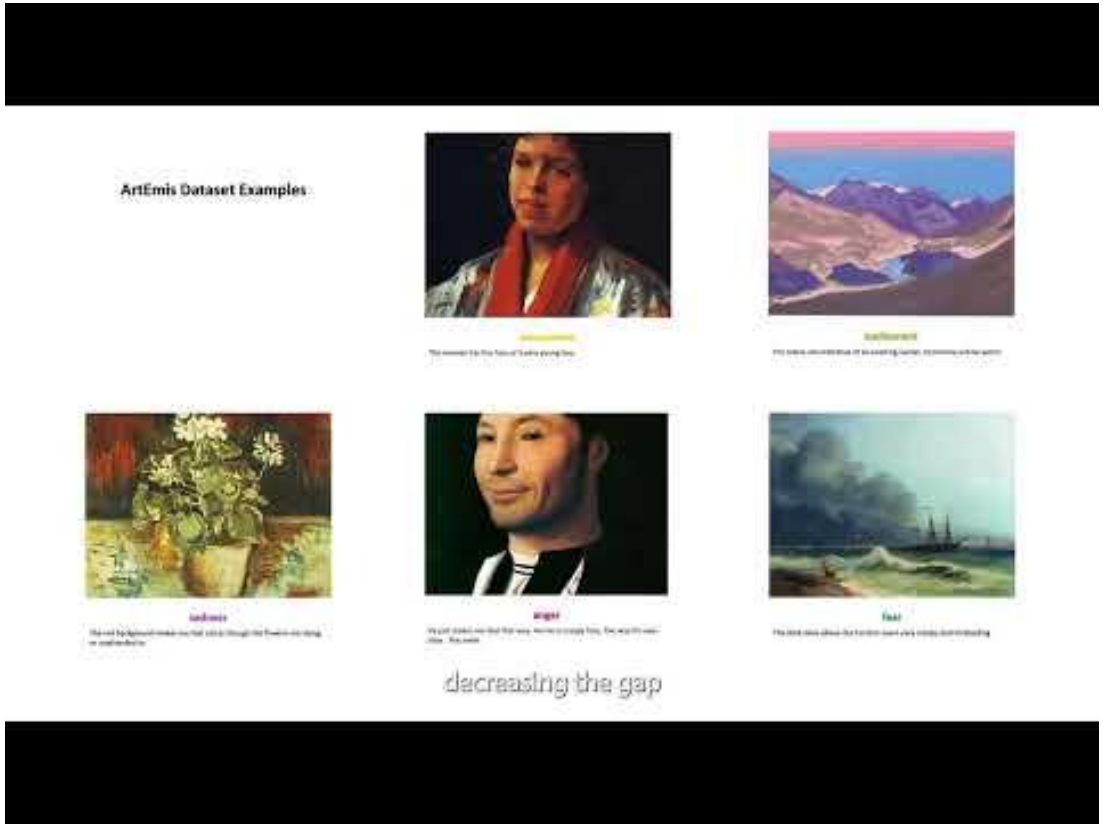


http://graphics.wsj.com/3d-nasdaq/?mod=e2tw

Immersive Storytelling: CellView VR



3D Spatial Data and Natural Interactions: Nanovis



AR/VR Capabilities @ KVL

How can AR/VR **+ KVL** help me

visualize

understand

explain

manipulate

my data better?

Overview of AR/VR Capabilities @ KVL

output

input

computer

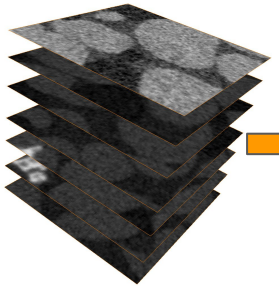
AR/VR application

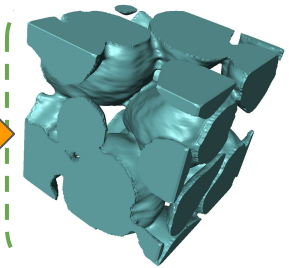
virtual content

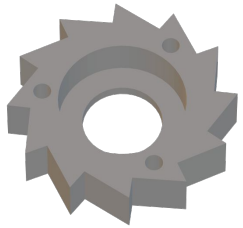
TECHVIZ

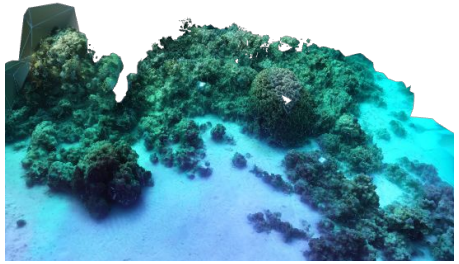
SimLab

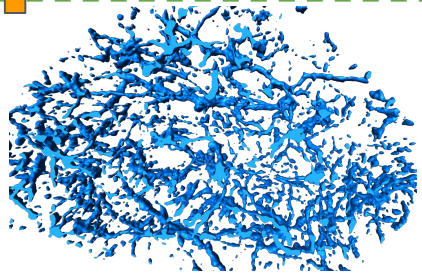
unity











Hardware + Software + Expertise

Hardware

VR Head-Mounted Displays

Device	#	Release
HTC Vive	5	2016
HTC Vive Pro	1	2018
Meta Quest 2	2	2020
HTC Vive Pro 2	2	2021
HTC Vive Focus 3	2	2021
Meta Quest Pro	1	2022

AR Head-Mounted Displays

Device	#	Release
Magic Leap 1	1	2018
HoloLens 2	2	2019

AR/VR-Ready Computers

3 AR/VR-ready desktop workstations

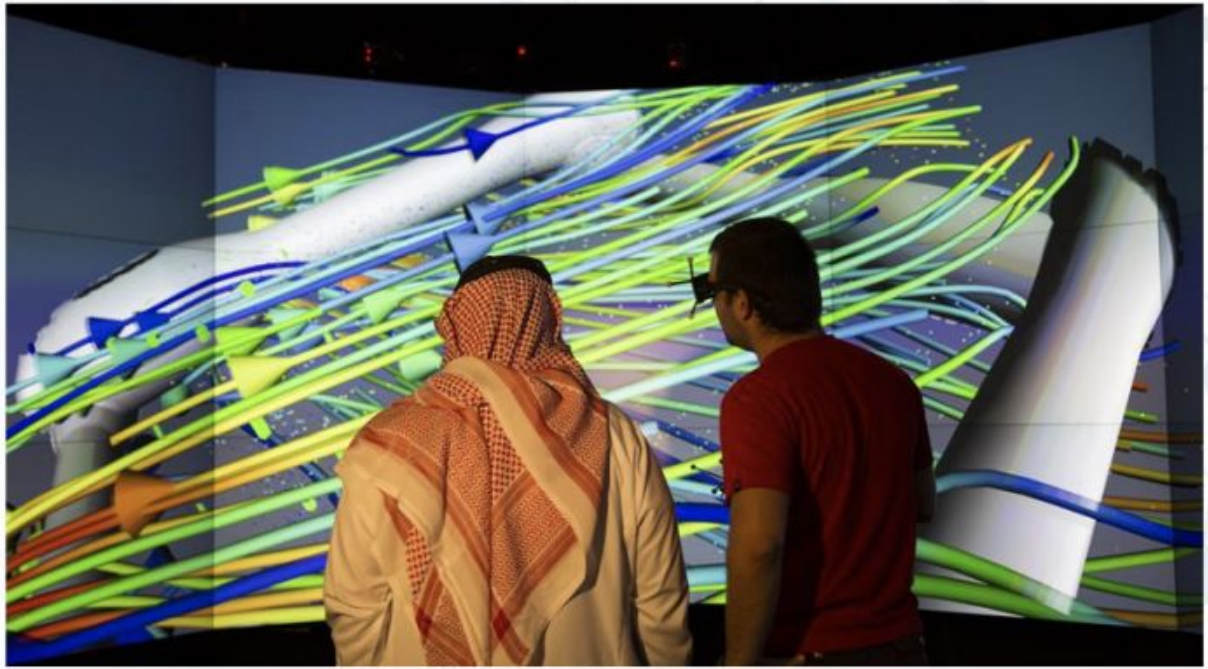
2 AR/VR-ready laptops

Immersive Environments: Zone 5

- Bldg 1 (West), Level 2
- 7 x 3 config
- 3D TVs
- 1 head node
- 3 render nodes
- tracking

Immersive Environments: CUBEs

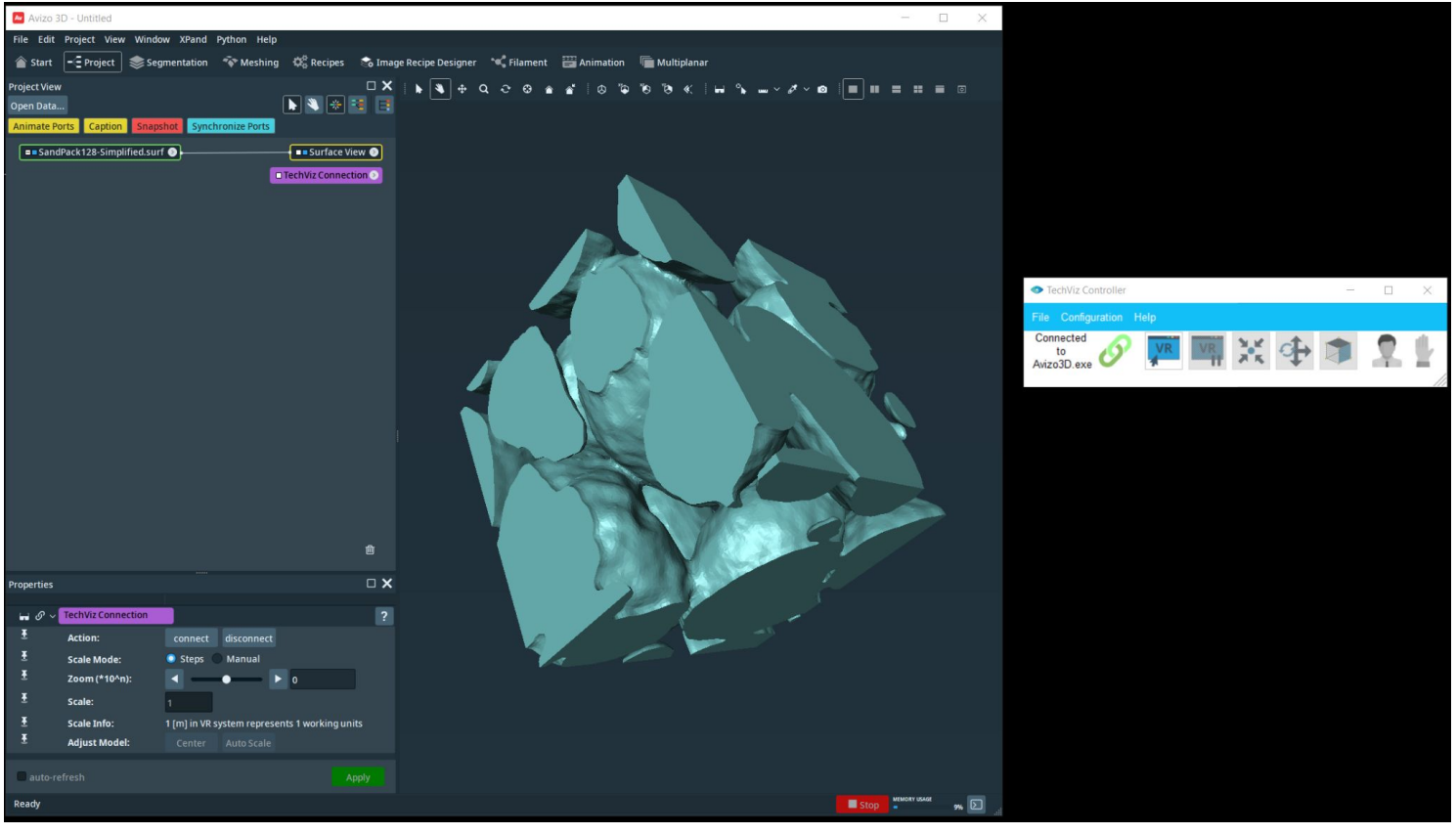
- Bldg 1 (East), Level 2
- 7 x 3 config
- 3D projectors
- 1 head node
- 7 render nodes
- tracking
- surround sound



Book via
https://wiki.vis.kaust.edu.sa/booking

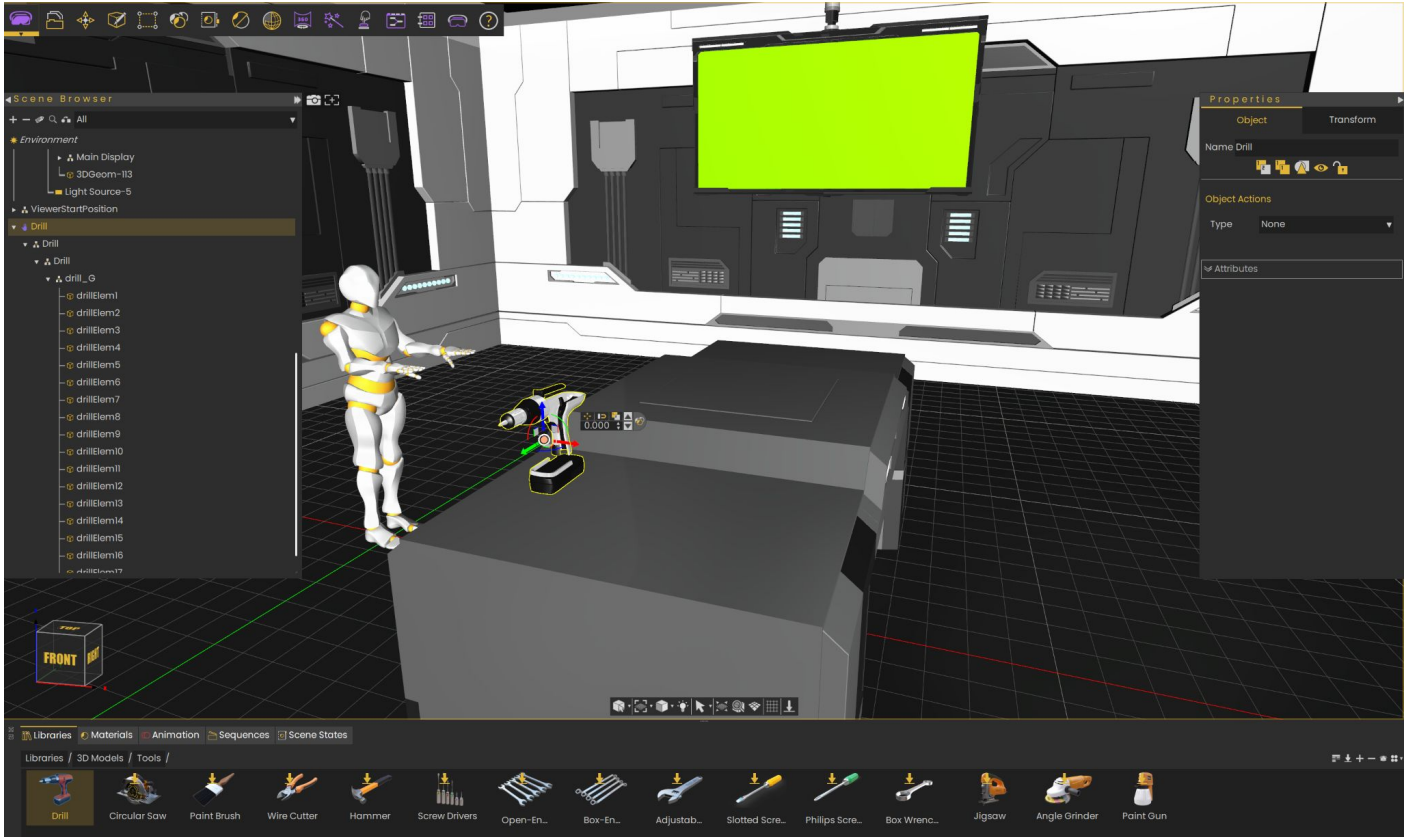
Software

TechViz (2 licenses)



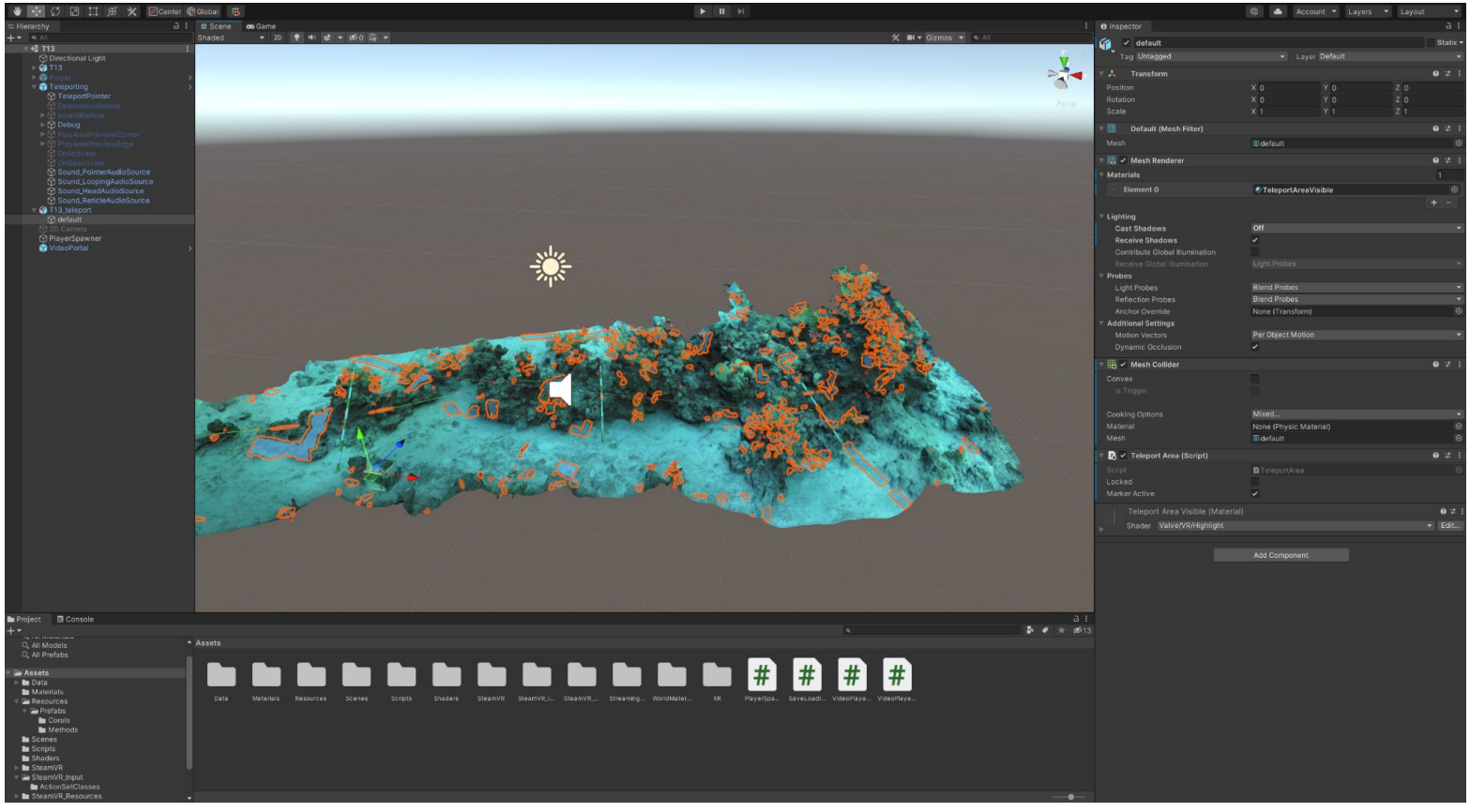
TECHVIZ

SimLab (2 licenses)



SimLab

Unity (50 licenses)



unity

Request via
help@vis.kaust.edu.sa

Expert Support and Collaboration

Ronell Sicat

FOLLOWING

Visualization Scientist @ Visualization Core Lab, King Abdullah University of Science and Technology
Verified email at kaust.edu.sa - Homepage

Data Visualization Large-scale Images and Vo… Mixed/Augmented/Virtual R… Immersive Analytics

TITLE	CITED BY	YEAR
Multivariate Probabilistic Range Queries for Scalable Interactive 3D Visualization A Ageeli, A Jaspe-Villanueva, R Sicat, F Mannuss, P Rautek, M Hadwiger IEEE Transactions on Visualization and Computer Graphics 29 (1), 646-656		2022
Real-Time Visualization of Large-Scale Geological Models with Nonlinear Feature-Preserving Levels of Detail R Sicat, M Ibrahim, A Ageeli, F Mannuss, P Rautek, M Hadwiger IEEE Transactions on Visualization and Computer Graphics		2021
Virtual reality framework for editing and exploring medial axis representations of nanometric scale neural structures D Boges, M Agus, R Sicat, PJ Magistretti, M Hadwiger, C Cali Computers & Graphics 91, 12-24	9	2020
Virtual environment for processing medial axis representations of 3D nanoscale reconstructions of brain cellular structures D Boges, C Cali', PJ Magistretti, M Hadwiger, R Sicat, M Agus Proceedings of the 25th ACM Symposium on Virtual Reality Software and …	2	2019
Immersive environment for creating, proofreading, and exploring skeletons of nanometric scale neural structures D Boges, C Cali, PJ Magistretti, M Hadwiger, RB Sicat, M Agus Eurographics Association	3	2019
DXR: A toolkit for building immersive data visualizations R Sicat, J Li, JY Choi, M Cordeil, WK Jeong, B Bach, H Pfister IEEE transactions on visualization and computer graphics 25 (1), 715-725	142	2018
The hologram in my hand: How effective is interactive exploration of 3D visualizations in immersive tangible augmented reality? B Bach, R Sicat, J Beyer, M Cordeil, H Pfister IEEE transactions on visualization and computer graphics 24 (1), 457-467	211	2017
Comparative Visual Analysis of Structure-Performance Relations in Complex Bulk-Heterojunction Morphologies A Aboulhassan, R Sicat, D Baum, O Wodo, M Hadwiger Computer Graphics Forum 36 (3), 329-339	6	2017
Drawing into the AR-CANVAS: Designing embedded visualizations for augmented reality B Bach, R Sicat, H Pfister, A Quigley Workshop on Immersive Analytics, IEEE Vis	35	2017
Large-Scale Multi-Resolution Representations for Accurate Interactive Image and Volume Operations RB Sicat		2015
Sparse PDF Volumes for Consistent Multi-Resolution Volume Rendering R Sicat, J Krueger, T Moeller, M Hadwiger IEEE	33	2014
Graph Abstraction for Simplified Proofreading of Slice-based Volume Segmentation R Sicat, M Hadwiger, N Mitra Eurographics 2013-Short Papers, 77-80	5	2013
Sparse PDF Maps for Non-linear Multi-resolution Image Operations M Hadwiger, R Sicat, J Beyer, J Krueger, T Moeller ACM Transaction on Graphics 31 (6), 133:1-133:12	22	2012
Bit Error Probability Computations for M-ary Quadrature Amplitude Modulation RB Sicat, TY Al-Naffouri Digital communications and coding, King Abdullah University of Science and …	4	2009
Patient-Centric Medical Database with Remote Urinalysis Test R Sicat, G Tangonan, ML Guico, N Libatique, C Ramos, M Siapno, … World Congress on Computer Science and Information Engineering 6, 250-254	2	2009

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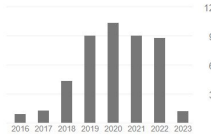

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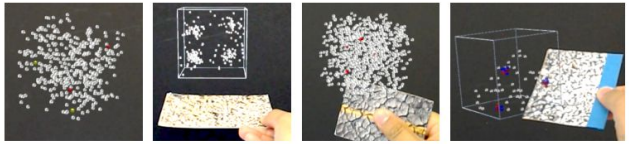
The Hologram in My Hand: How Effective is Interactive Exploration of 3D Visualizations in Immersive Tangible Augmented Reality?

Benjamin Bach, Ronell Sicat, Johanna Beyer, Maxime Cordeil, Hanspeter Pfister



(a) Distance task (b) Cluster task (c) Selection task (d) Cutting plane task

Fig. 1. Monoscopic and low-resolution approximations of hologram visualizations of 3D scatterplots using immersive tangible augmented reality with the HoloLens. Actual perception through the HoloLens provides stereoscopic images and higher resolution.

Abstract—We report on a controlled user study comparing three visualization environments for common 3D exploration. Our environments differ in how they exploit natural human perception and interaction capabilities. We compare an augmented-reality head-mounted display (Microsoft HoloLens), a handheld tablet, and a desktop setup. The novel head-mounted HoloLens display projects stereoscopic images of virtual content into a user's real world and allows for interaction in-situ at the spatial position of the 3D hologram. The tablet is able to interact with 3D content through touch, spatial positioning, and tangible markers, however, 3D content is still presented on a 2D surface. Our hypothesis is that *visualization environments that match human perceptual and interaction capabilities better to the task at hand improve understanding of 3D visualizations.* To better understand the space of display and

DXR: A Toolkit for Building Immersive Data Visualizations

Ronell Sicat, Jiabao Li, JunYoung Choi, Maxime Cordeil, Won-Ki Jeong, Benjamin Bach, and Hanspeter Pfister

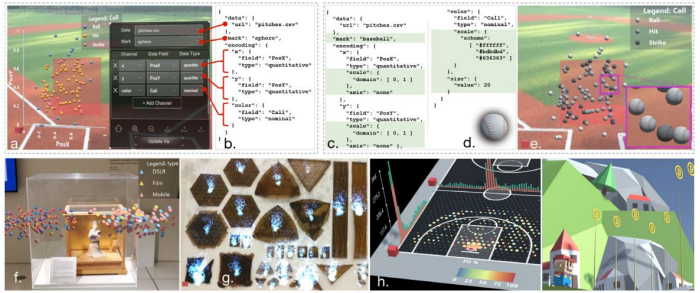


Fig. 1. DXR enables rapid prototyping of immersive data visualizations: (b,c) declarative specifications concisely represent visualizations; (a:right) DXR's graphical user interface (GUI) within the virtual world enables quick iteration over visualization parameters such as data sources, graphical marks, and visual encodings; (b) the GUI modifies the underlying design specifications; (c) specifications can be fine-tuned by the designer in a text editor; (d) the designer can add 3D models as custom graphical marks to achieve (e) novel immersive visualization designs. Example visualizations built using DXR: (f) a 3D vector field plot showing locations of photographs of an exhibit; (g) flames representing the remaining lifetime of real-world organic materials as they decay; (h) bar charts and scatter plots embedding sports data in a virtual basketball court; and (i) coins showing Bitcoin prices in a 3D game.

Others

- Low-level programming consultation
- Data mapping and conversion to 3D assets
- Commercial software testing
- AR/VR facilities consultation
- And more...

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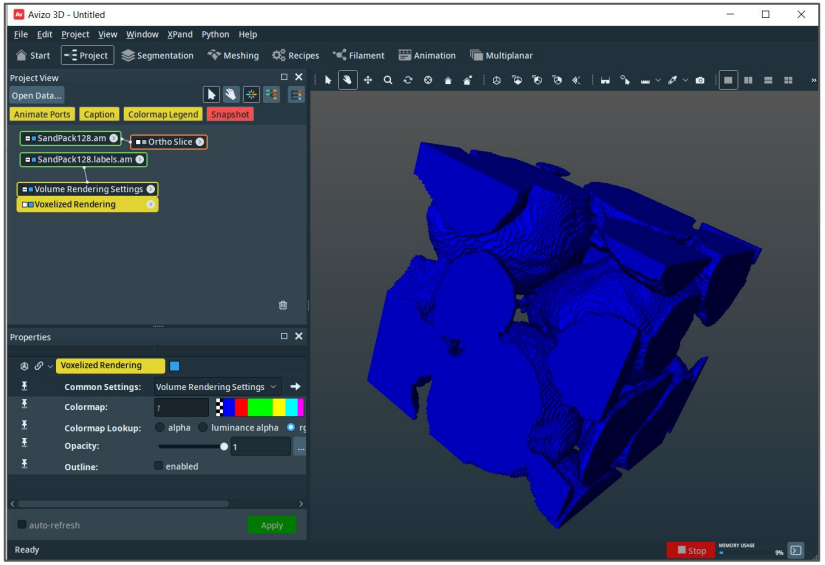
10-minute Break

March 20 one-on-one sessions sign ups

Example Scenarios

Scenario: Avizo-compatible data + TechViz



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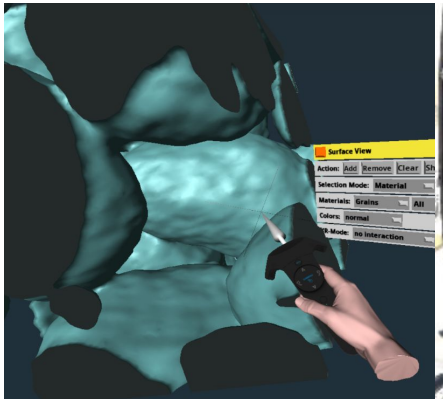

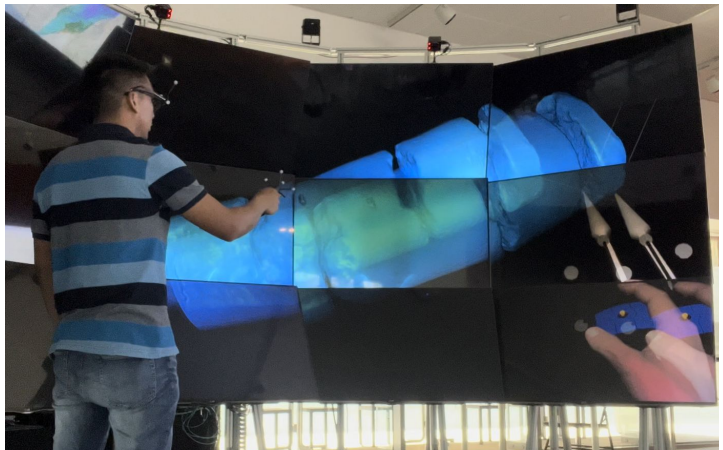

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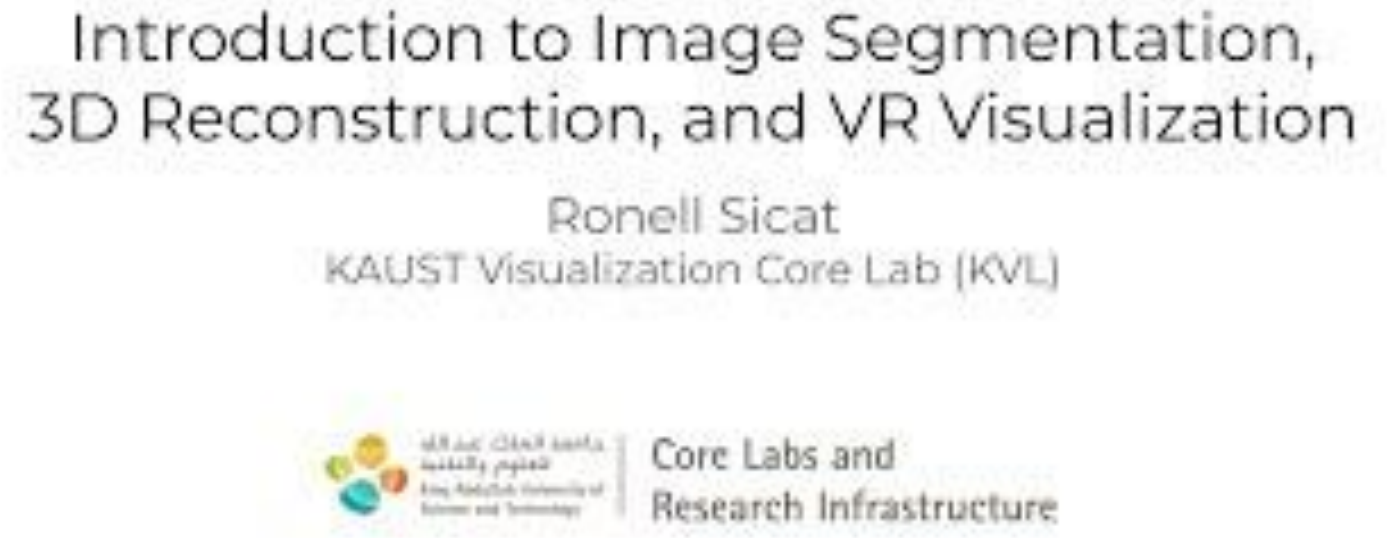
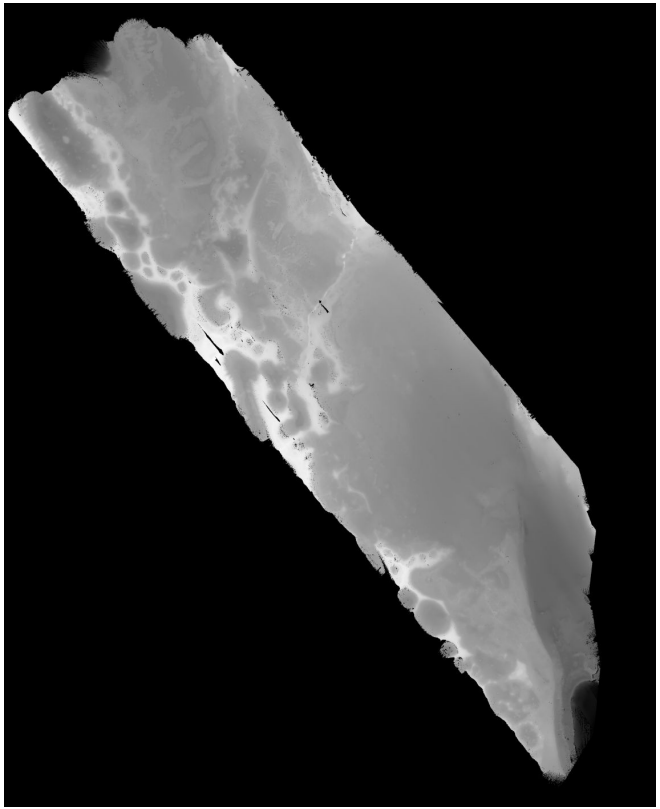
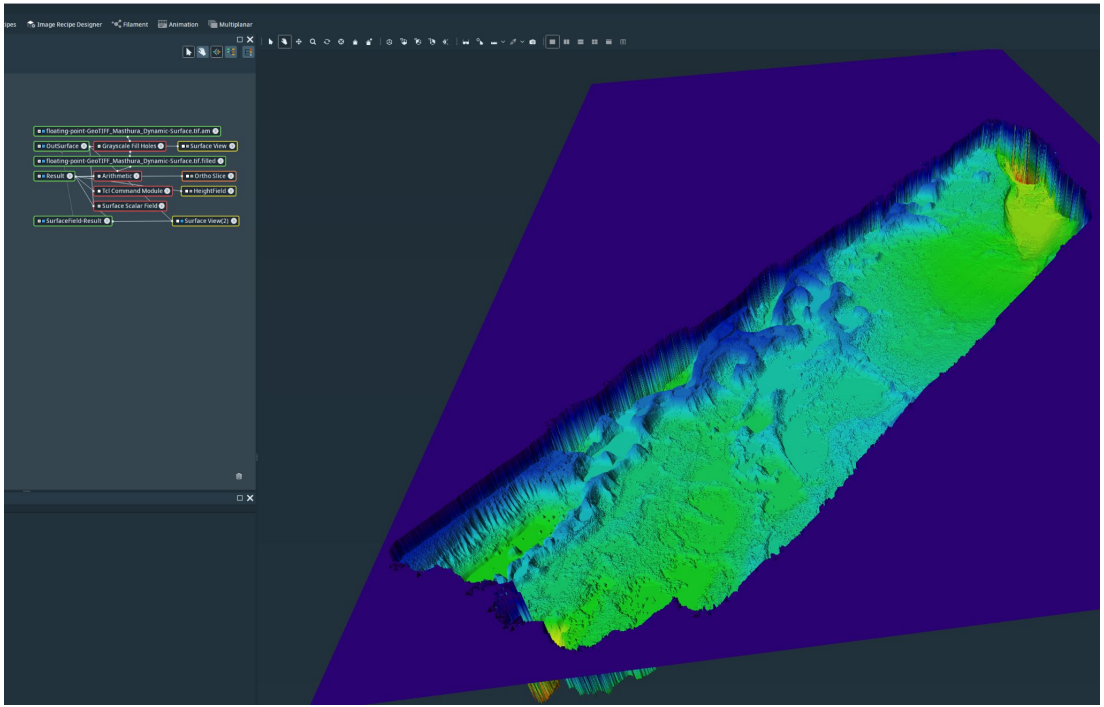


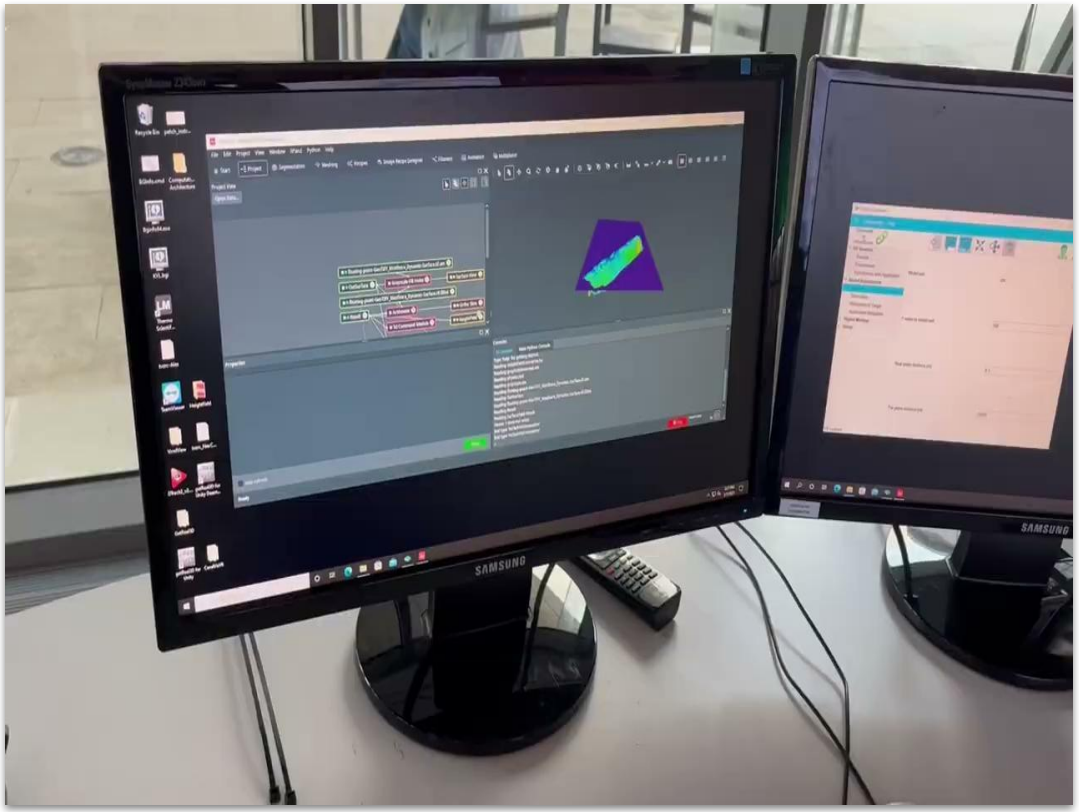
Scenario: Avizo-compatible data + TechViz



geoTIFF image c/o CMR



Scenario: Avizo-compatible data + TechViz



Scenario: Avizo-compatible data + TechViz

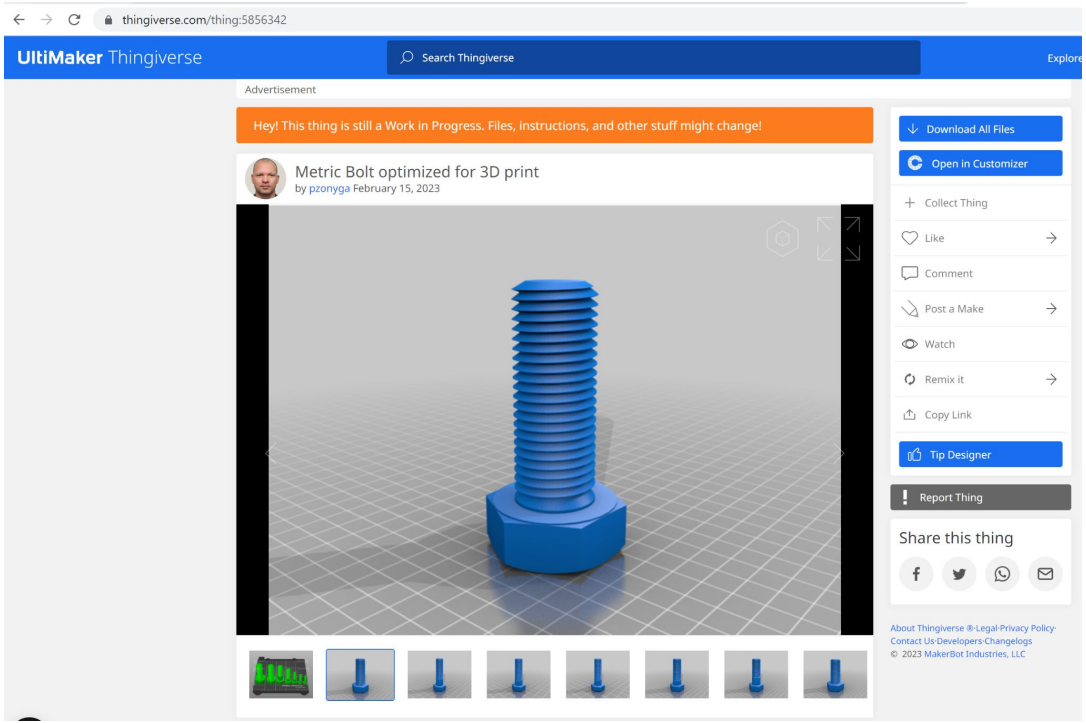
Pros:

- Great for Avizo users
- Interaction works with most Avizo modules
- Very easy to run
- No programming
- Works on HMD and CAVEs
- Technical support from developers

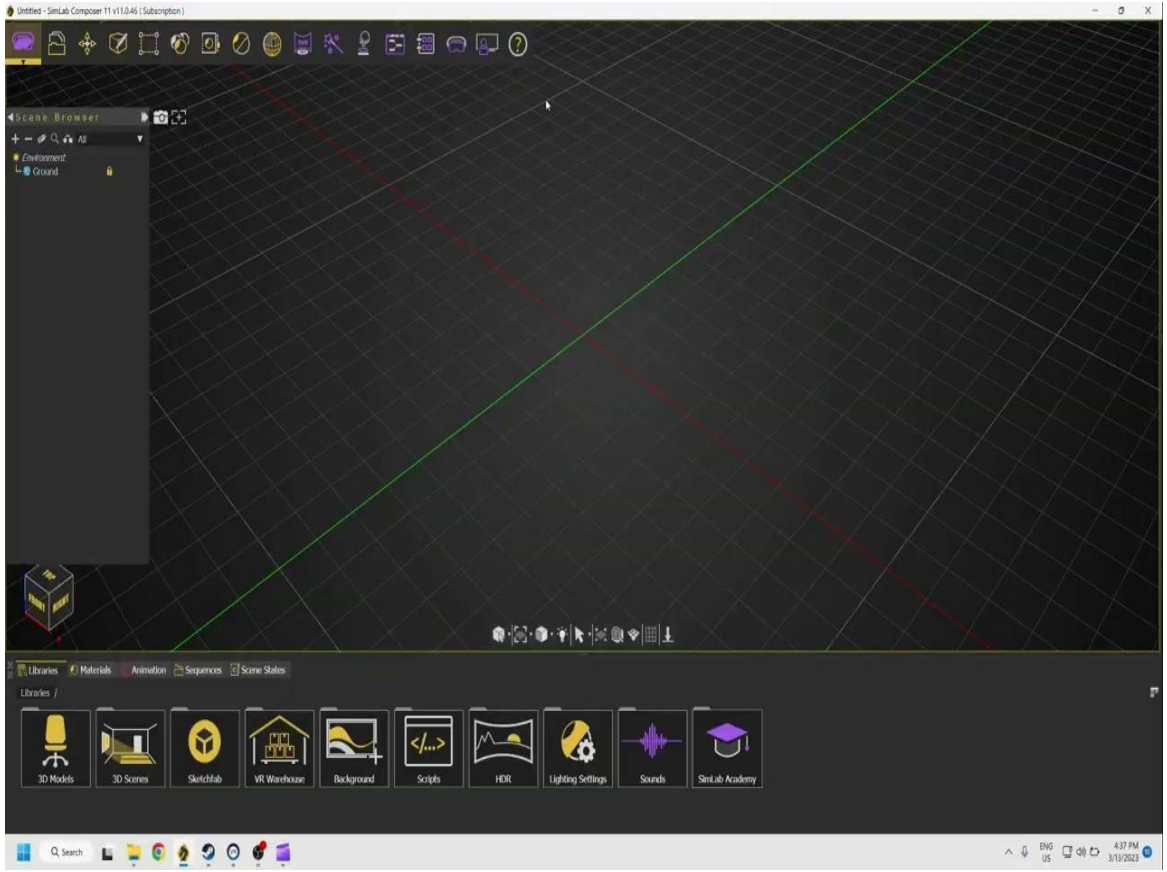
Cons:

- Difficult to add custom interactions
- Only three machine-locked licenses
- Limited support for 3D model formats

Scenario: Data in 3D modeling format + SimLab



Scenario: Data in 3D modeling format + SimLab



Scenario: Data in 3D modeling format + SimLab

Pros:

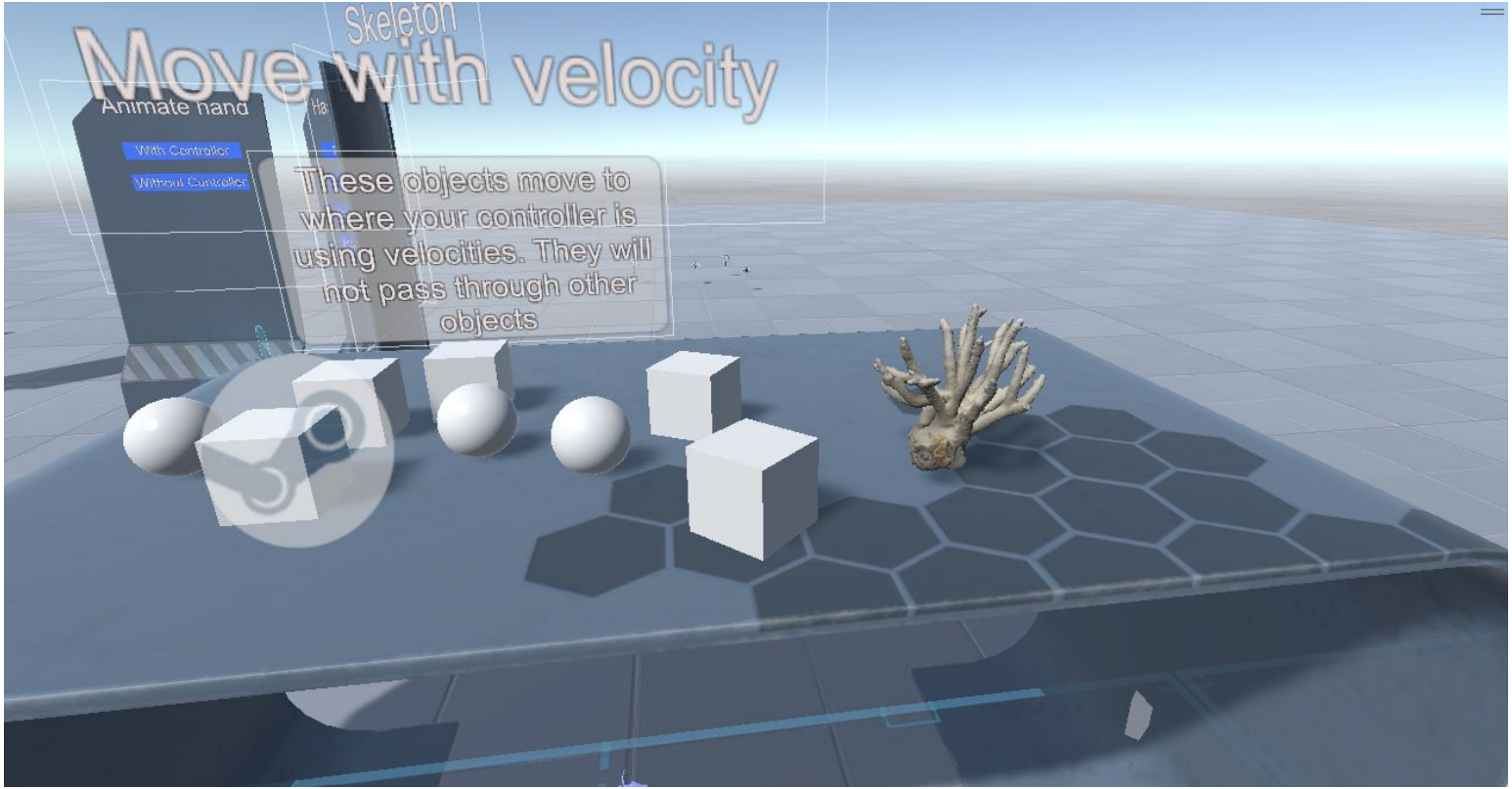
- Easy to use
- No programming
- Built-in library of 3D models
- Built-in basic movement and interactions
- Easy to deploy/distribute
- Can load many 3D model formats

3DS (*.3ds)
3DXML (*.3dxml)
ACIS (*.sat)
Collada (*.dae)
Creo (*.prt *.prt.* *.asm *.asm.*)
CTM (*.ctm)
DWF (*.dwf *.dwfx)
DWG (*.dwg *.dxf)
FBX (*.fbx)
GLTF Importer (*.gltf *.glb)
IFC (*.ifc)
IGES (*.igs *.iges)
Inventor (*.iam *.ipt)
JT (*.jt)
MSC Adams (*.res)
NX (*.prt)
OBJ (*.obj)
OSG (*.osg)
Parasolid (*.x_b *.x_t *.xmt_txt *.xmt_bin)
PDF (*.pdf)
PointCloud (*.xyz *.pcd *.e57 *.las *.laz)
PRC (*.prc)
Rhino (*.3dm)
SAP Visual Author (*.vds)
SimLab Archive (*.zim)

custom

SimLab Composer (*.sim)
SimLab Composer Package (*.zim)
SimLab VR Package (*.vrpackage)
Simulation (*.json)
SketchUp (*.skp)
SolidEdge (*.asm *.par *.psm)
SolidWorks (*.sldasm *.sldprt)
Step (*.step *.stp)
STL (*.stl)
U3D (*.u3d)
USDZ (*.usdz)
ZBrush (*.GoZ)

Scenario: Data in 3D modeling format + Unity AR/VR



Scenario: Data in 3D modeling format + Unity AR/VR

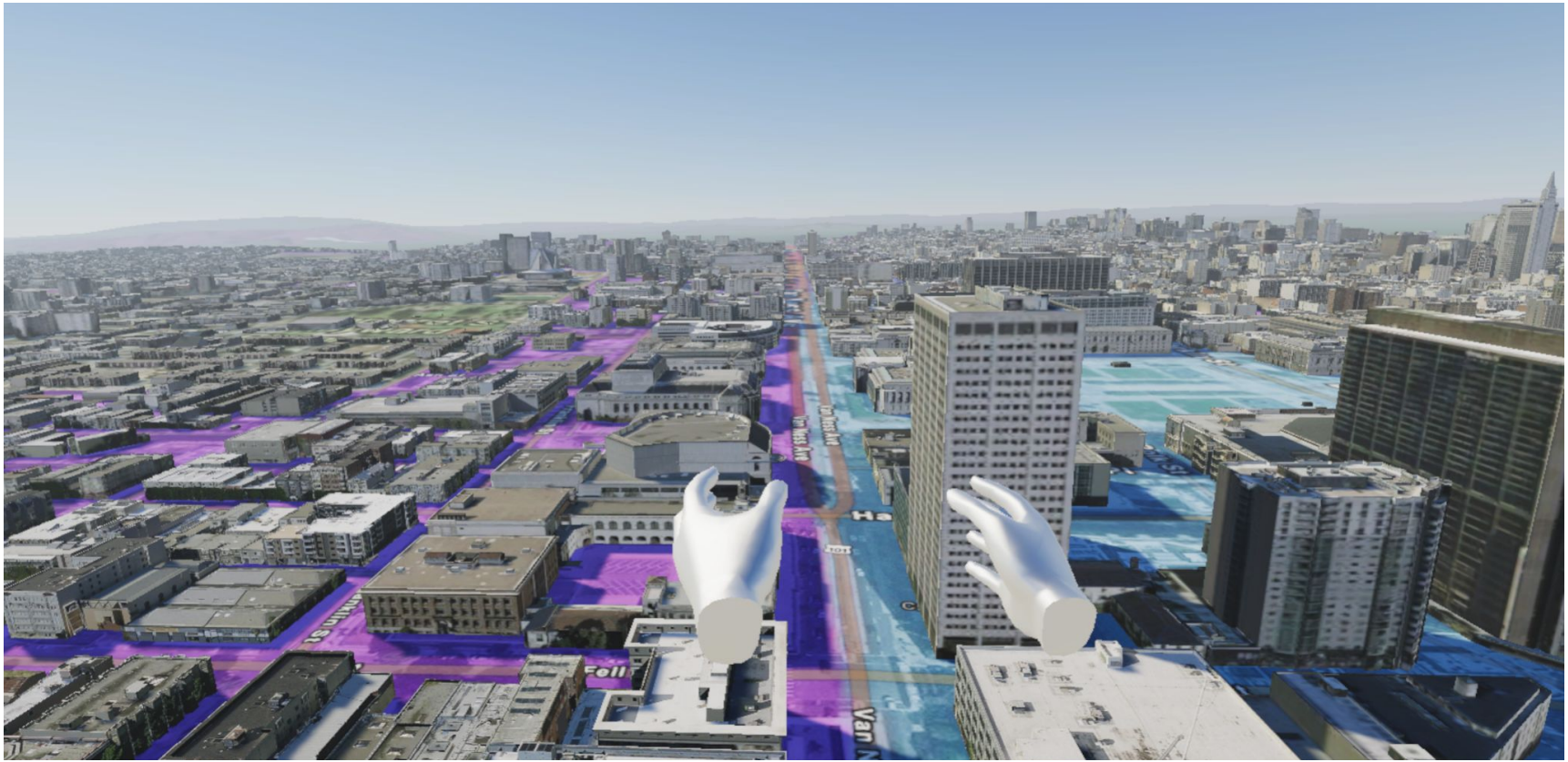
Pros:

- Advanced interactions possible
- Basic templates available
- Support for many devices and platforms
- Many 3D models and scripts in asset store

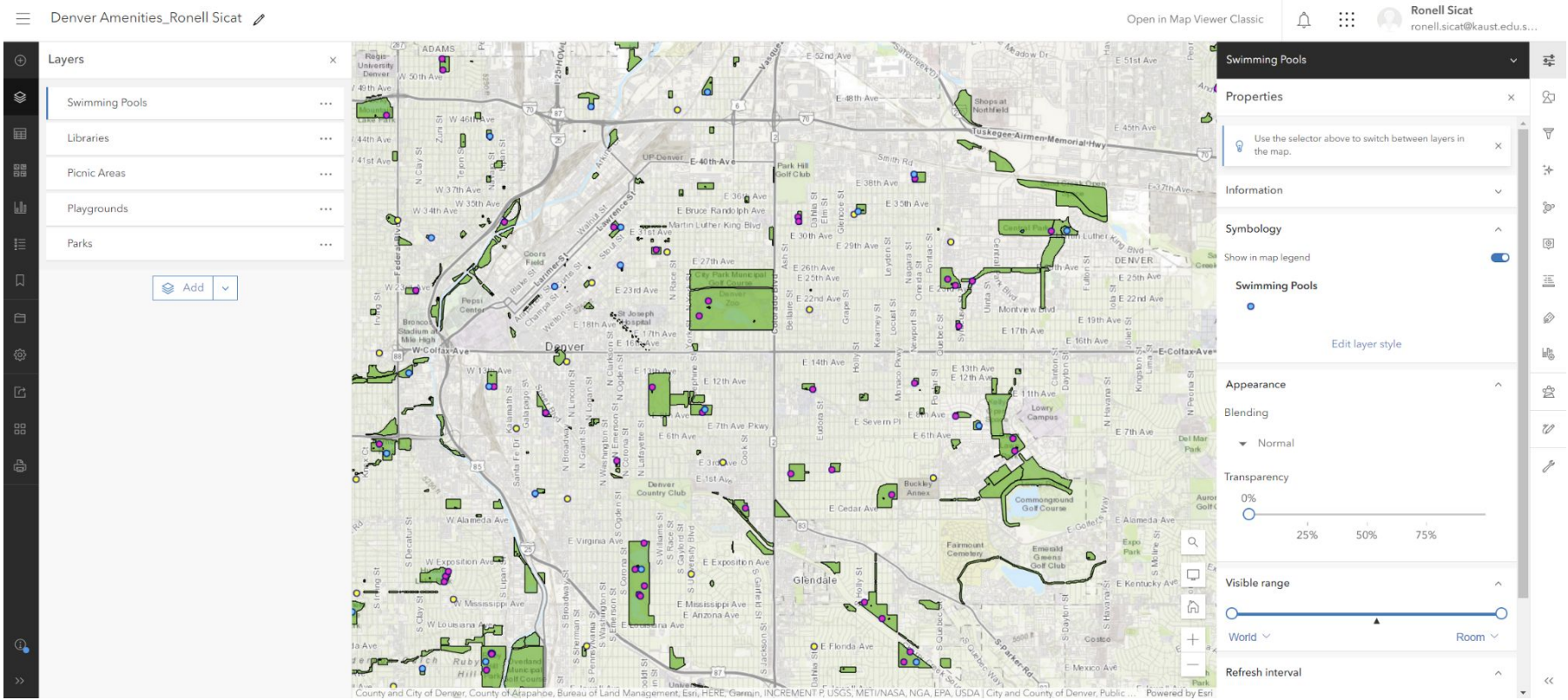
Cons:

- Needs familiarity with Unity and SDKs
- Needs basic programming concepts
- Complex development setup
- Software evolves fast

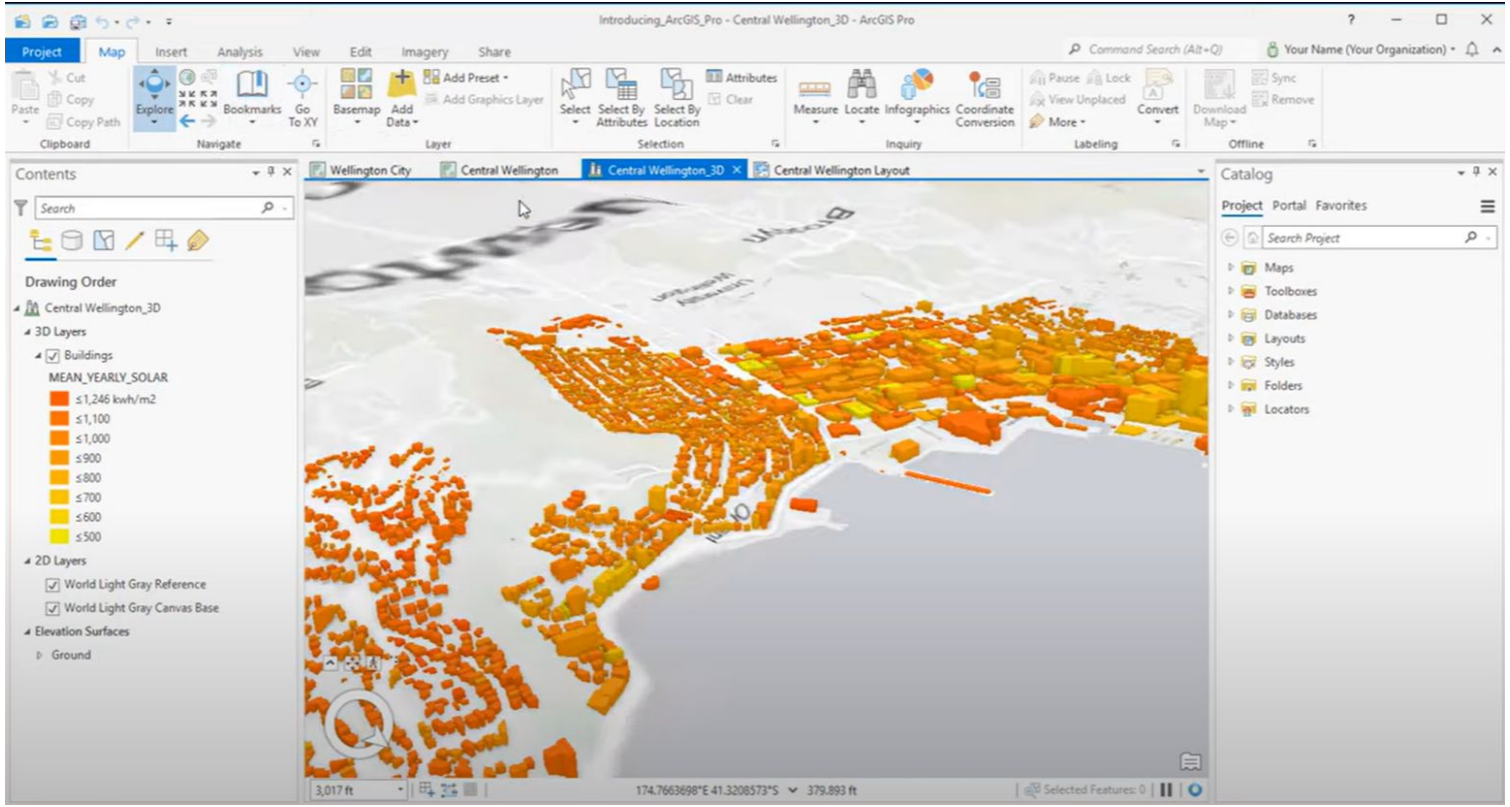
Scenario: ArcGIS data + Unity VR



Scenario: ArcGIS data + Unity VR



Scenario: ArcGIS data + Unity VR



Scenario: ArcGIS data + Unity AR/VR

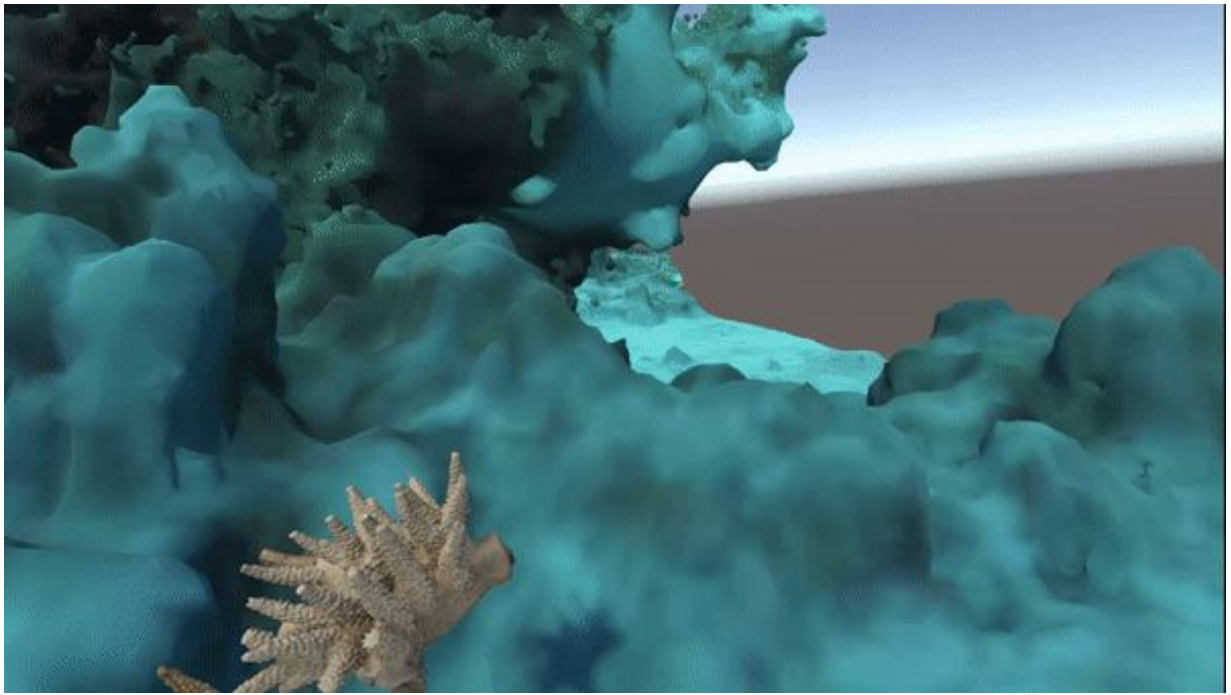
Pros:

- Great for ArcGIS users
- Advanced data management by ArcGIS SDK
- Advanced interactions possible
- Can work with offline data

Cons:

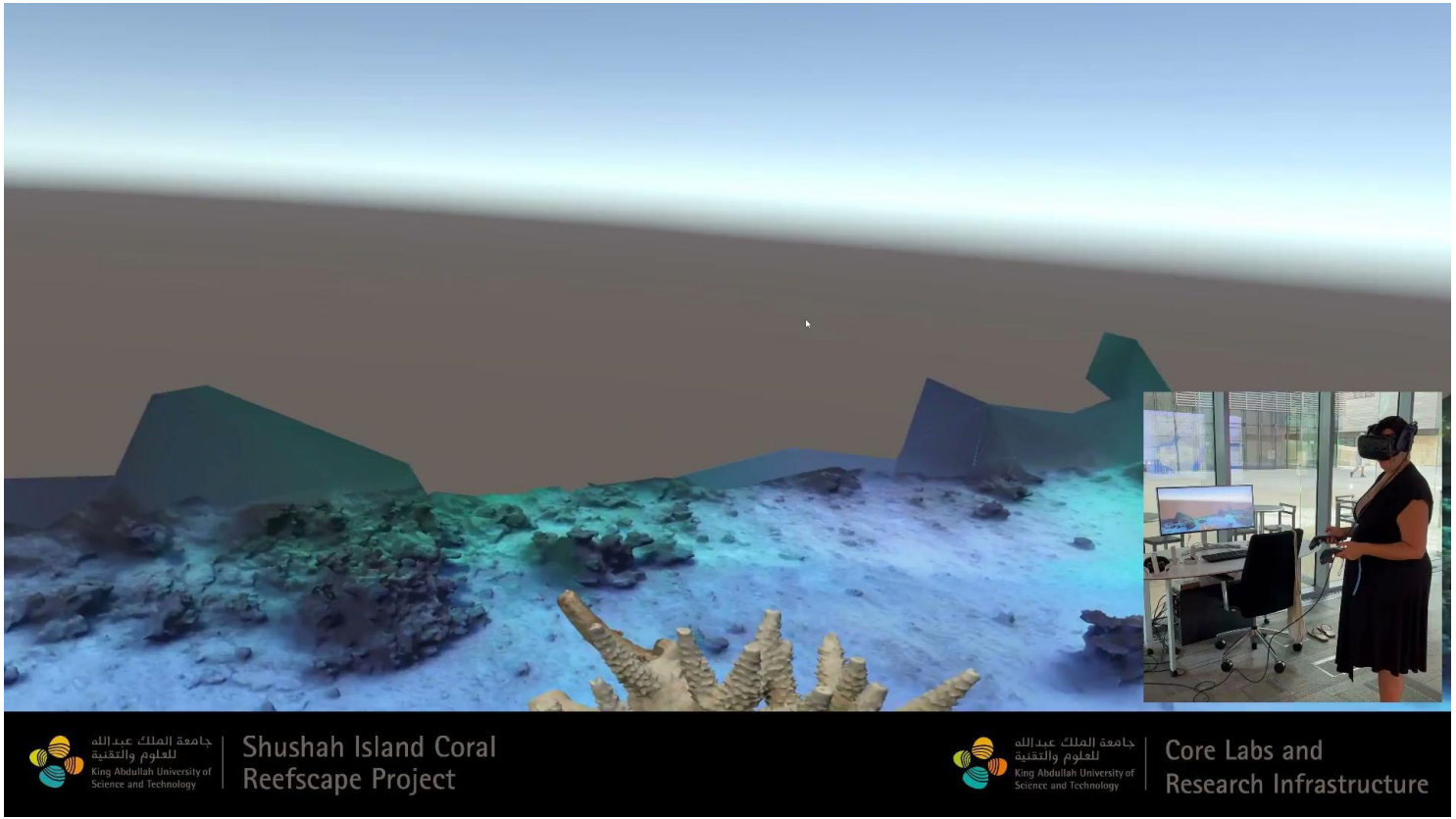
- Requires ArcGIS license
- May cost money depending on data size and usage amount
- Requires Unity and ArcGIS familiarity
- Does not support all layer types

Scenario: Complex 3D data and interactions



Coral Vis VR

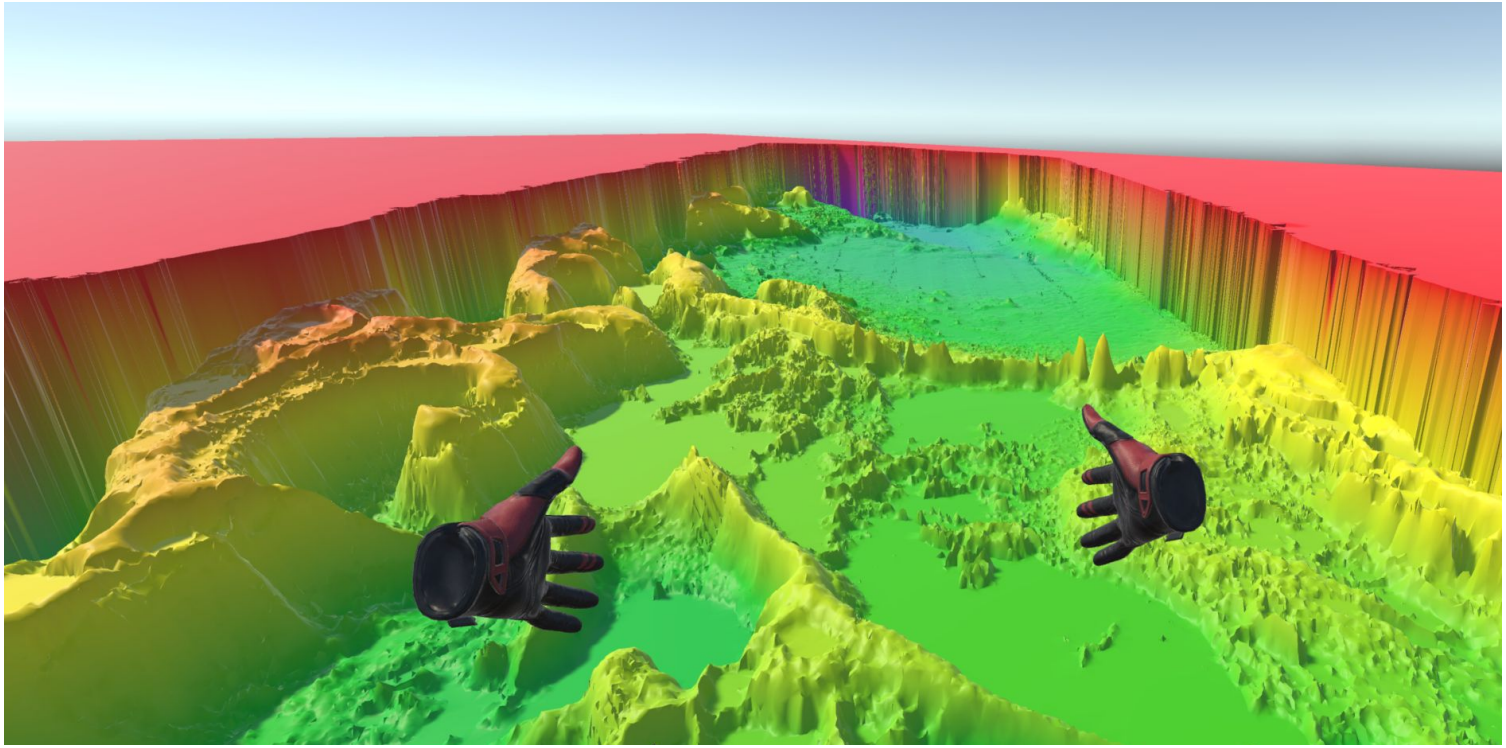
Scenario: Complex 3D data and interactions



Scenario: Complex 3D data and interactions

Brain Vis VR

Scenario: Complex 3D data and interactions



Bathymetry Vis VR

Data c/o CMR Core Lab

Scenario: Complex 3D data and interactions

Pros:

- Flexible application
- More complex tasks and analysis
- Interesting research field

Cons:

- Requires Unity familiarity
- May require programming
- UI design can be challenging
- Can take longer time to develop

10-minute Break

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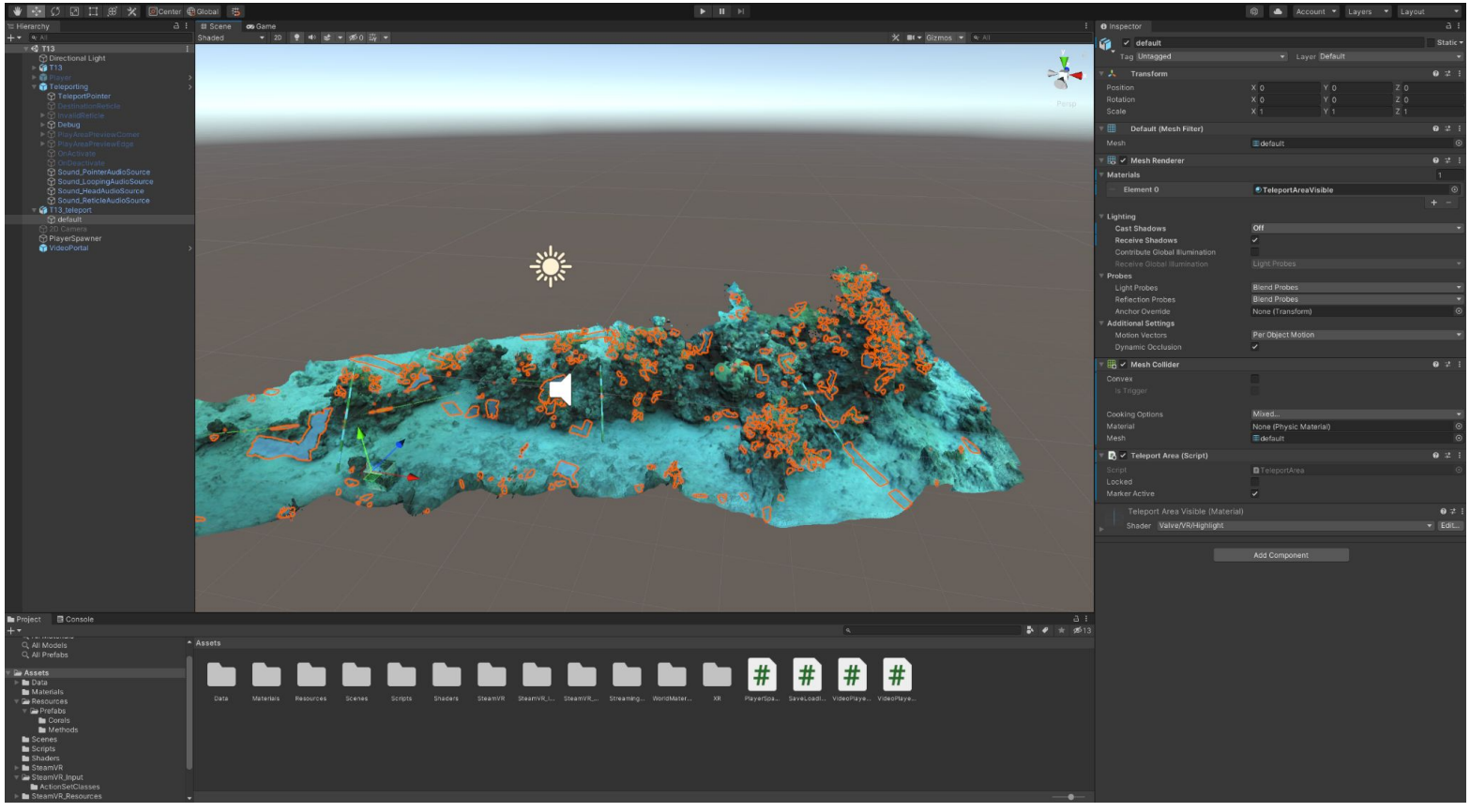
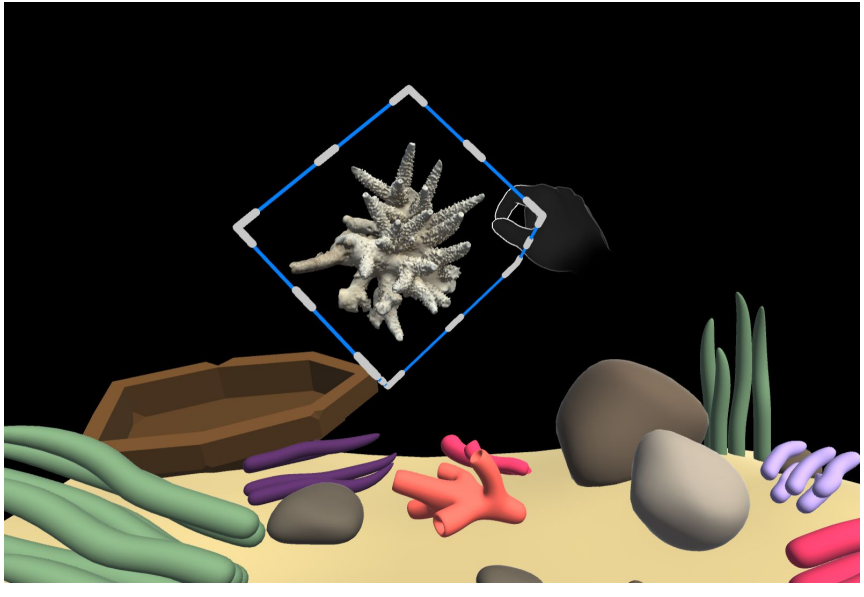
Hands-on Example

Unity Basics



Hands-on Example

- Set-up Unity + MRTK3 project
- Run MRTK3 tutorial
- Add interactable 3D model of coral (https://3d.si.edu/corals)



Thank you!

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