The 6Gs of educational XR spatial computing applications:

Enabling next-gen medical XR simulations

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&
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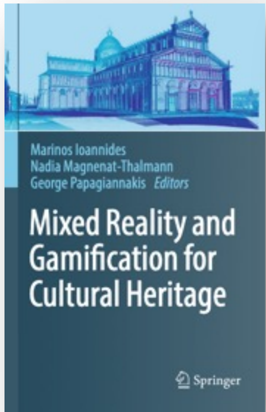
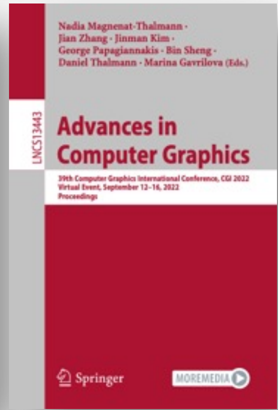
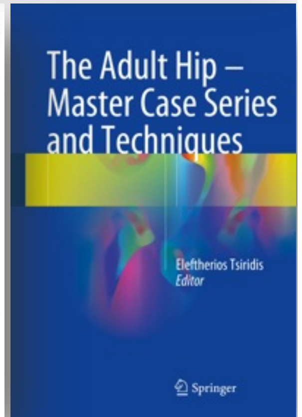
Affiliated Researcher at FORTH
Visiting Prof. University of Geneva

My Career arcs







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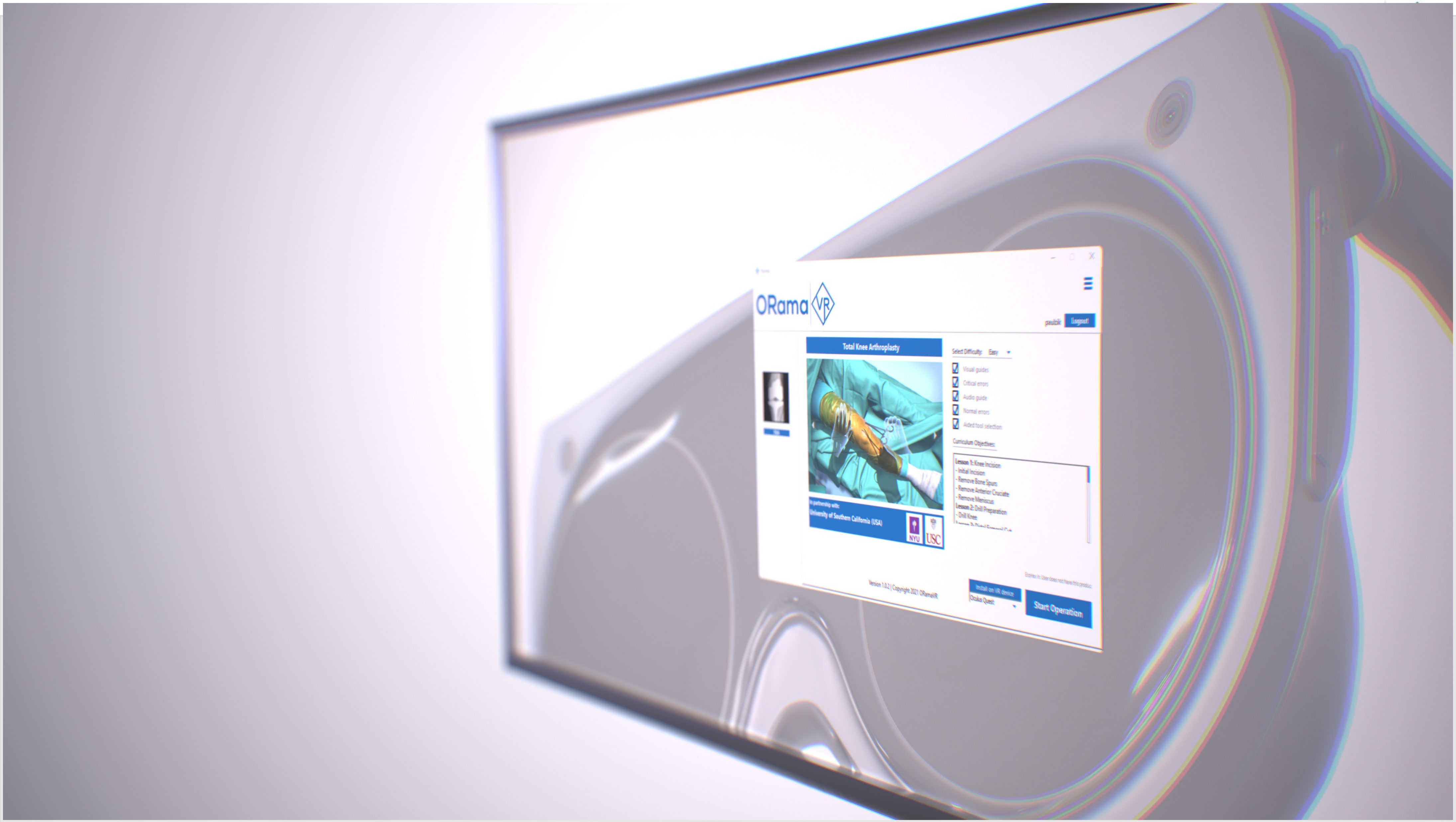
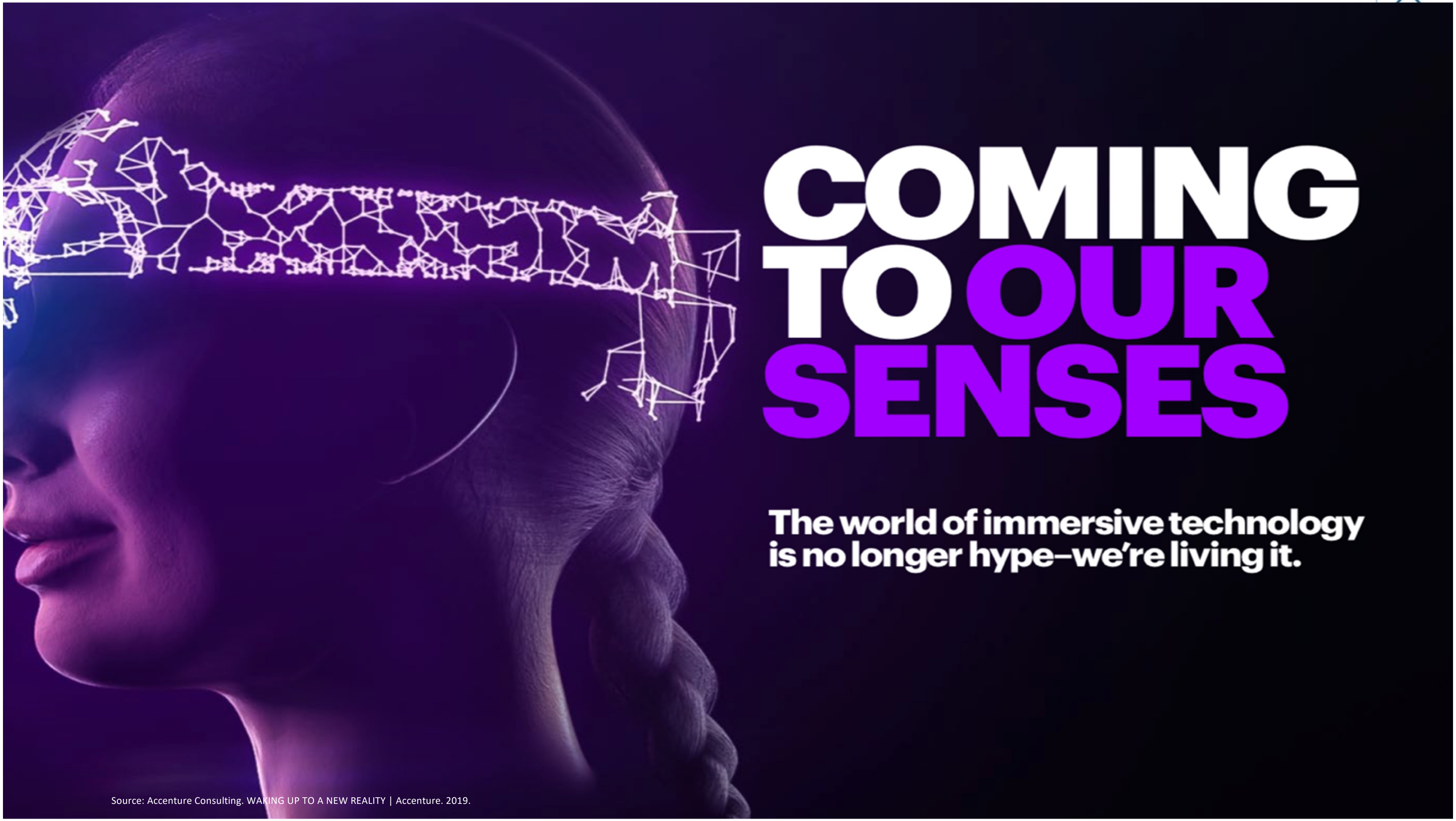
Foundation for Research & Technology - Hellas

ORama VR


ORama
VR
Total Knee Arthroplasty
Select Difficulty: Easy
Visual guides
Critical errors
Audio guide
Normal errors
Curriculum Objectives:
Lesson 1: Knee Incision
- Initial Incision
- Remove Bone Spurs
- Remove Anterior Cruciate
- Remove Meniscus
Lesson 2: Drill Preparation
- Drill Knee
In partnership with:
University of Southern California (USA)
NYU
USC
Install on VR device
Oculus Quest
Start Operation

[VIDEO →]



Source: Accenture Consulting. WAKING UP TO A NEW REALITY | Accenture. 2019.

ORama VR

Metaverse* = Internet(3D)^{AI} ⟺ XR

The Rules **

Rule #1. There is only one Metaverse.

Rule #2: The Metaverse is for everyone.

Rule #3: Nobody controls the Metaverse.

Rule #4: The Metaverse is open.

Rule #5: The Metaverse is hardware-independent.

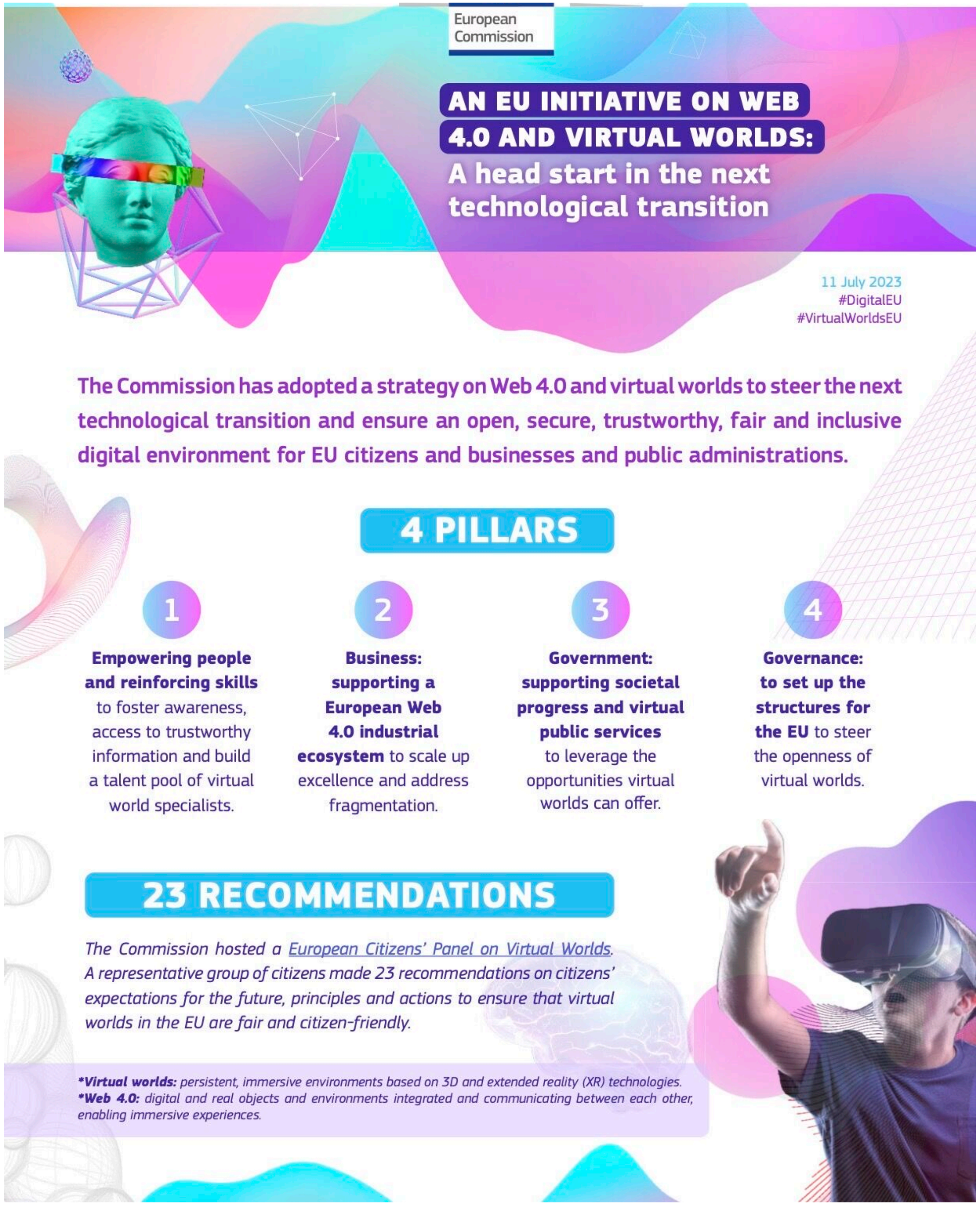
Rule #6: The Metaverse is a Network.

Rule #7: The Metaverse is the Internet.

* Source: A. Graylin, HarvardXR, April 2023

** https://medium.com/meta-verses/the-seven-rules-of-the-metaverse-7d4e06fa864c

Stable Diffusion prompt:
"a girl in VR glasses experiencing metaverse worlds"



Virtual Worlds and **Web 4.0** *

Virtual Worlds:

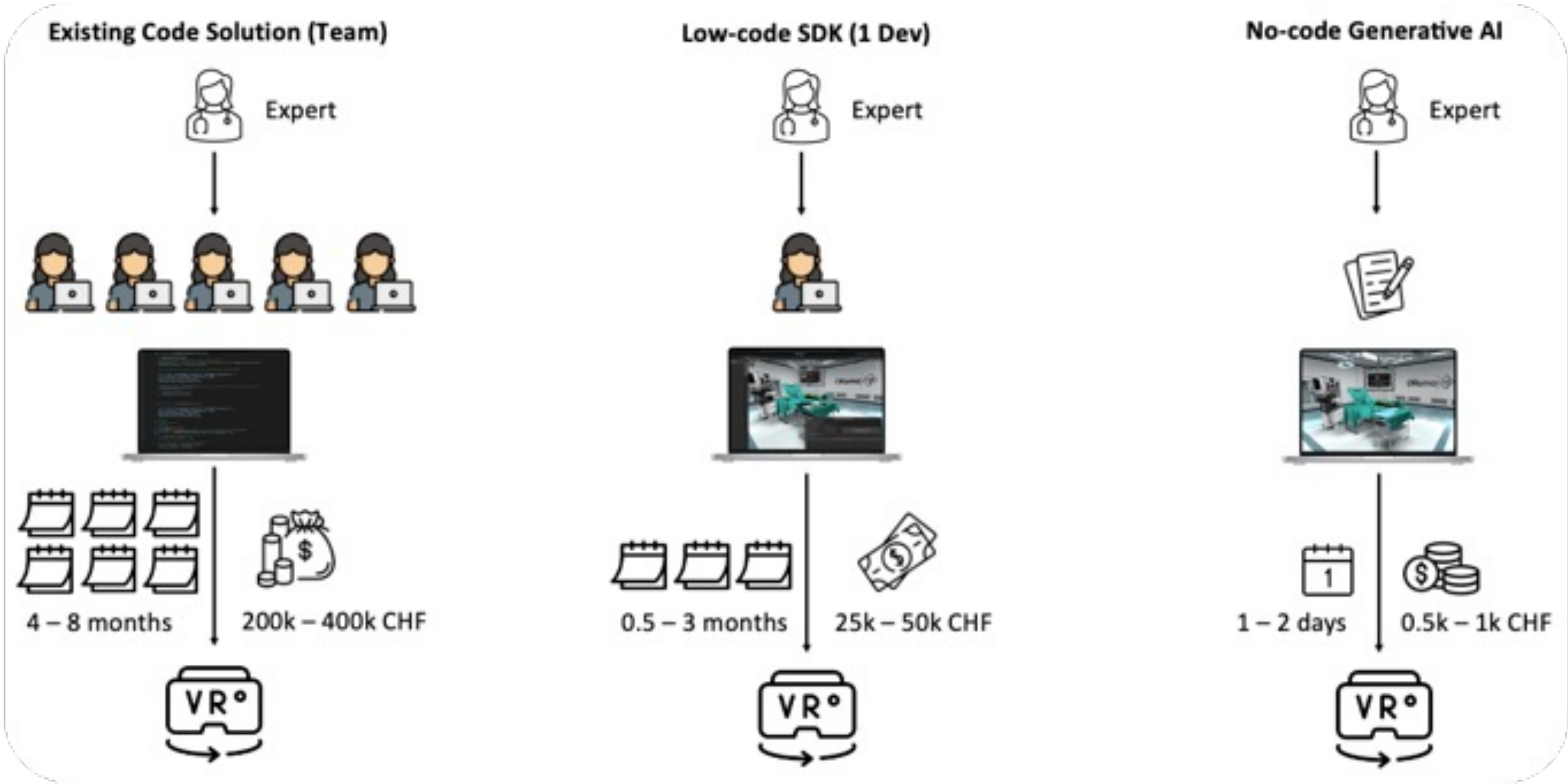
Persistent, immersive environments based on 3D and extended reality (XR) technologies

Web 4.0:

Digital and real objects and environments integrated and communicating between each other, enabling immersive experiences

* Source: https://digital-strategy.ec.europa.eu/en/library/virtual-worlds-and-web-40-factsheet

METAVERSE GENERATED REALMS (VIRTUAL WORLDS): CODE -> LOW-CODE -> NO-CODE (GENERATIVE AI)



ORama VR

Deep learning and generative AI

“Deep learning takes **data points** and turns them into a **query-able structure** that enables **retrieval** and **interpolation** between the points.

You could think of it as a continuous **generalization** of **database** technology.”

“It is categorically **different** from even the simplest of **embodied biological agents**. As in, it's an entirely different category, with no shared characteristics.

Analogies to the brain are just as misleading as when people used the same analogies to describe computers in the 1950s.”

F. Chollet, Google AI

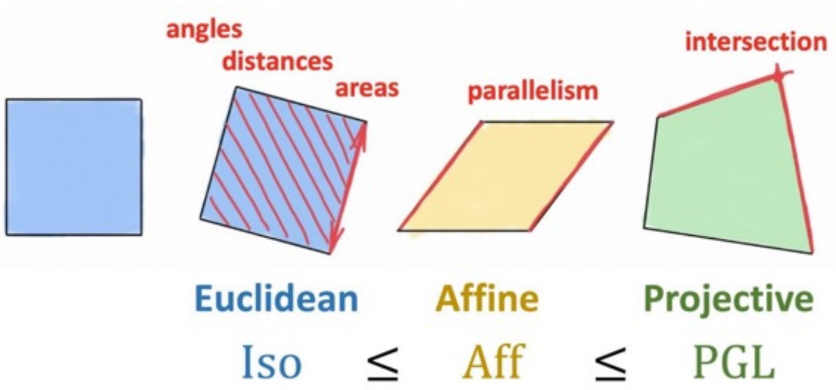
Stable Diffusion prompt:
“an explosion of colorful powder”

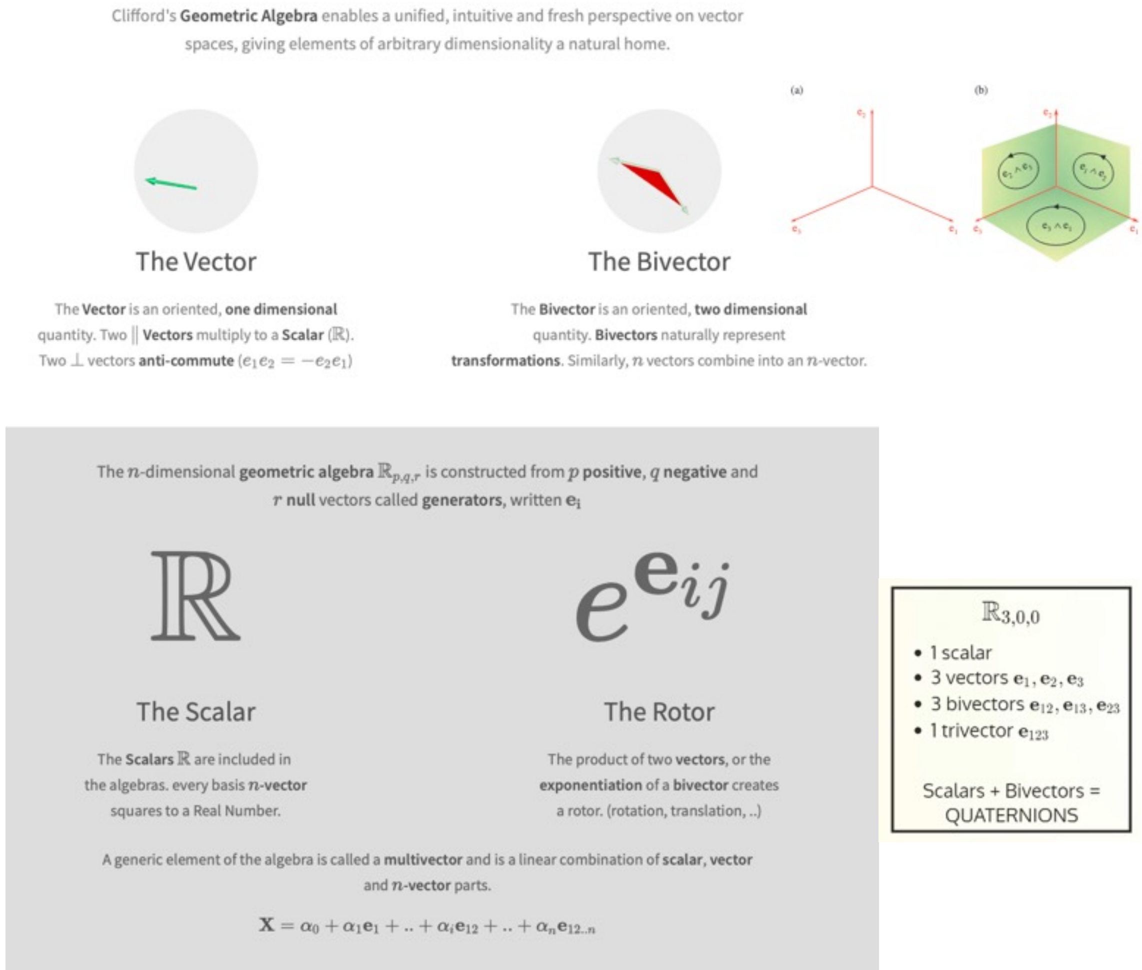
6Gs of low/no code virtual worlds authoring:

1. Geometry,
2. Graphs,
3. Graphics,
4. GPUs,
5. Games,
6. Generative AI

Stable Diffusion prompt:
“geometry, graphics, gpus, games in generative AI”

6Gs of low/no code: Geometry, state-of-the-art





$\mathbb{R}_{3,0,0}$

- 1 scalar
- 3 vectors $\mathbf{e}_1, \mathbf{e}_2, \mathbf{e}_3$
- 3 bivectors $\mathbf{e}_{12}, \mathbf{e}_{13}, \mathbf{e}_{23}$
- 1 trivector $\mathbf{e}_{123}$

Scalars + Bivectors = QUATERNIONS

- Geometry Through History, Euclidean, Hyperbolic, and Projective Geometries, Meighan I. Dillon, Doi: 10.1007/978-3-319-74135-2
- Klein's Erlangen programme: https://math.ucr.edu/home/baez/erlangen/erlangen_tex.pdf

- Course notes Geometric Algebra for Computer Graphics, SIGGRAPH 2019 https://arxiv.org/abs/2002.04509, https://bivector.net
- HESTENES, D. SPACE-TIME ALGEBRA. (BIRKHÄUSER, 2015). DOI:10.1007/978-3-319-18413-5.
- CLIFFORD, W.K. 1878. Applications of Grassmann's extensive algebra. *American Journal of Mathematics 1*, 4, 350–358.

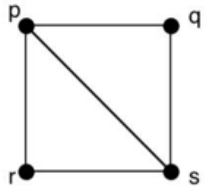
6Gs of low/no code:
Geometry, our approach

1. **GA Interpolation engine**
2. **Build-in Co-op support**
3. **Reducing network traffic up to 58%**
4. **16% performance boost**
5. **Efficient and smooth transformations**

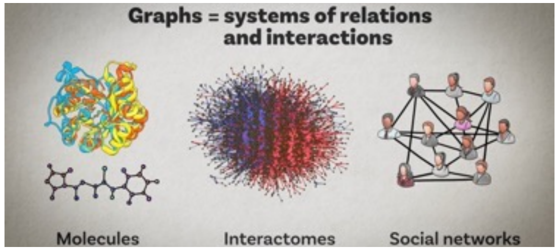
Network Quality	How to Achieve Best QoE	Metrics on Our Methods
Excellent	SoA: 30 updates/sec Ours: 20 updates/sec	33% less bandwidth 16.5% lower running time
Good	SoA: 20 updates/sec Ours: 10 updates/sec	50% less bandwidth 16.5% lower running time
Mediocre	SoA: 15 updates/sec Ours: 7 updates/sec	53% less bandwidth 16.5% lower running time
Poor	SoA: 12 updates/sec Ours: 5 updates/sec	58% less bandwidth 16.5% lower running time

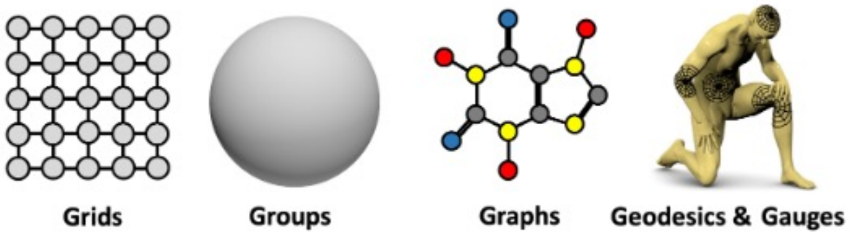
- Eckhard Hitzer, Manos Kamarianakis, George Papagiannakis, et al. Survey of New Applications of Geometric Algebra. *Authorea.* February 20, 2023, DOI: 10.22541/au.167687105.52780013/v1
- Kamarianakis, M., Chrysovergis, I., Lydatakis, N., Kentros, M. & Papagiannakis, G. Less is More: Efficient Networked VR Transformation Handling Using Geometric Algebra. *Adv Appl Clifford Al* 33, 6 (2023).

6Gs of low/no code: Graphs, state-of-the-art



$p: \; q \; r \; s$
$q: \; p \; s$
$r: \; p \; s$
$s: \; p \; q \; r$

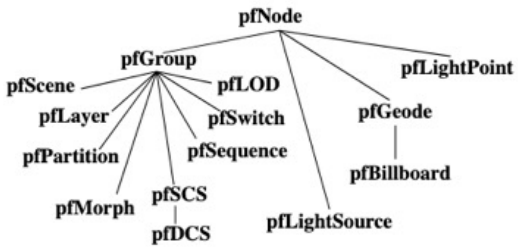




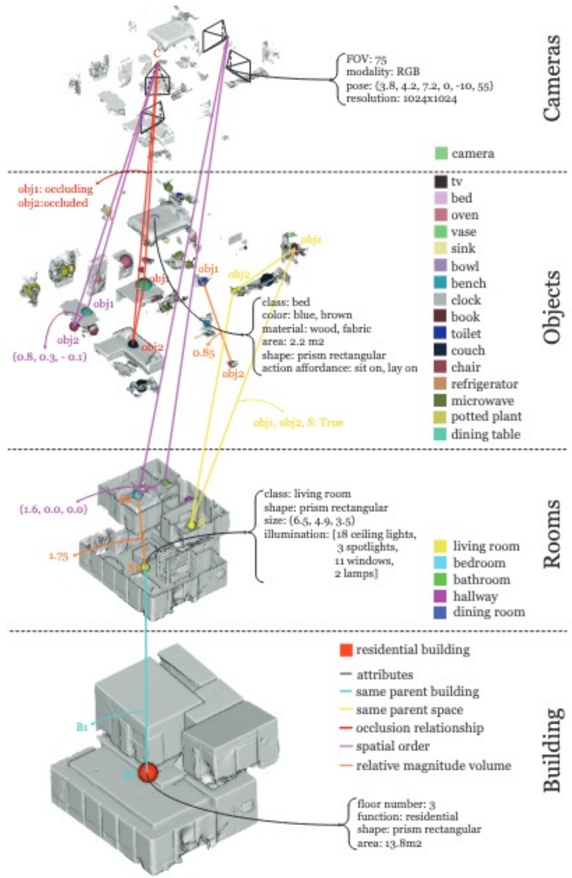
Geometric Deep Learning is an umbrella term introduced in [Bronstein et al] referring to recent attempts to come up with a geometric unification of ML similar to Klein's Erlangen Programme.

DEFINITION: A ***graph*** $G = (V, E)$ is a mathematical structure consisting of two finite sets V and E. The elements of V are called ***vertices*** (or ***nodes***), and the elements of E are called ***edges***. Each edge has a set of one or two vertices associated to it, which are called its ***endpoints***.

- Bronstein, M. M., Bruna, J., Cohen, T. & Velickovic, P. Geometric Deep Learning - Grids, Groups, Graphs, Geodesics, and Gauges. arXiv (2021).
- Introduction to Graph Theory, Richard J. Trudeau, 2003

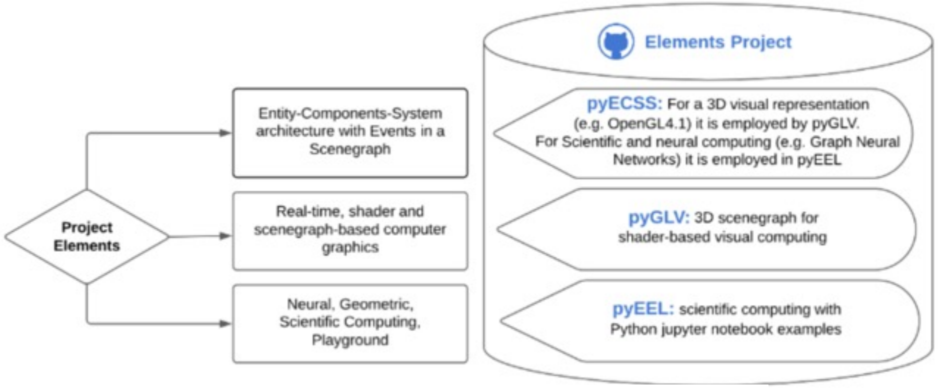


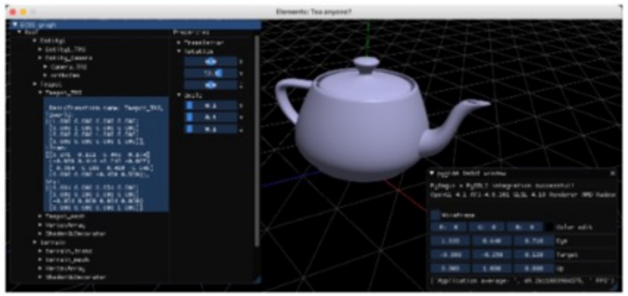
- Intersection traversal (ISECT) — processes intersection requests for collision detection and terrain following.
- Culling traversal (CULL) — rejects objects outside the viewing frustum, computes level-of-detail switches, sorts geometry by modes
- Drawing traversal (DRAW) — sends geometry and graphics commands to the graphics subsystem.

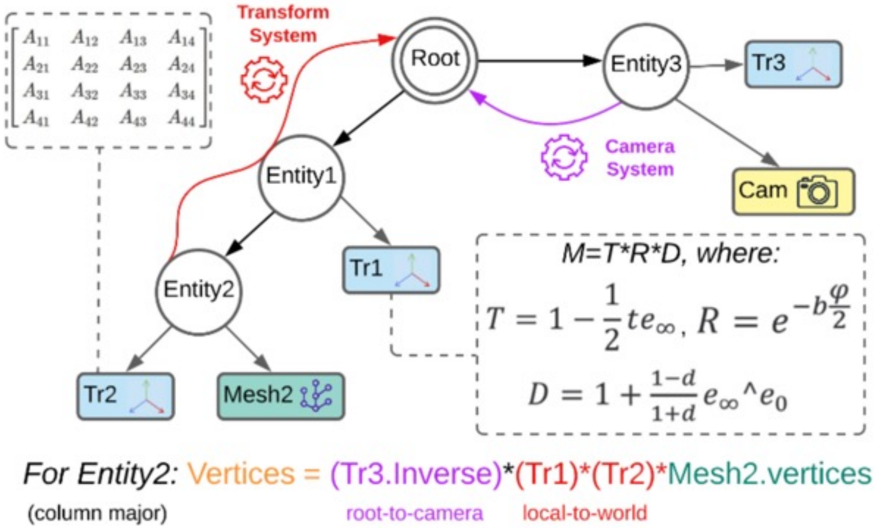


- Armeni, I. *et al.* 3D Scene Graph: A Structure for Unified Semantics, 3D Space, and Camera. 5664–5673 (2019).
- Rohlf, J. & Helman, J. IRIS performer - a high performance multiprocessing toolkit for real-time 3D graphics. *SIGGRAPH* (1994) doi:10.1145/192161.192262.

6Gs of low/no code: Graphs, our approach







- https://elementsproject.readthedocs.io
- Using s/w design patterns, implement Entity-Component-Systems in a scenegraph and GNN approach

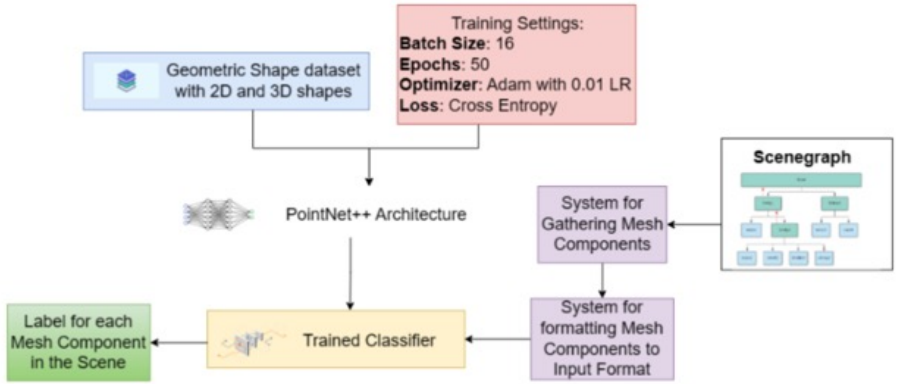
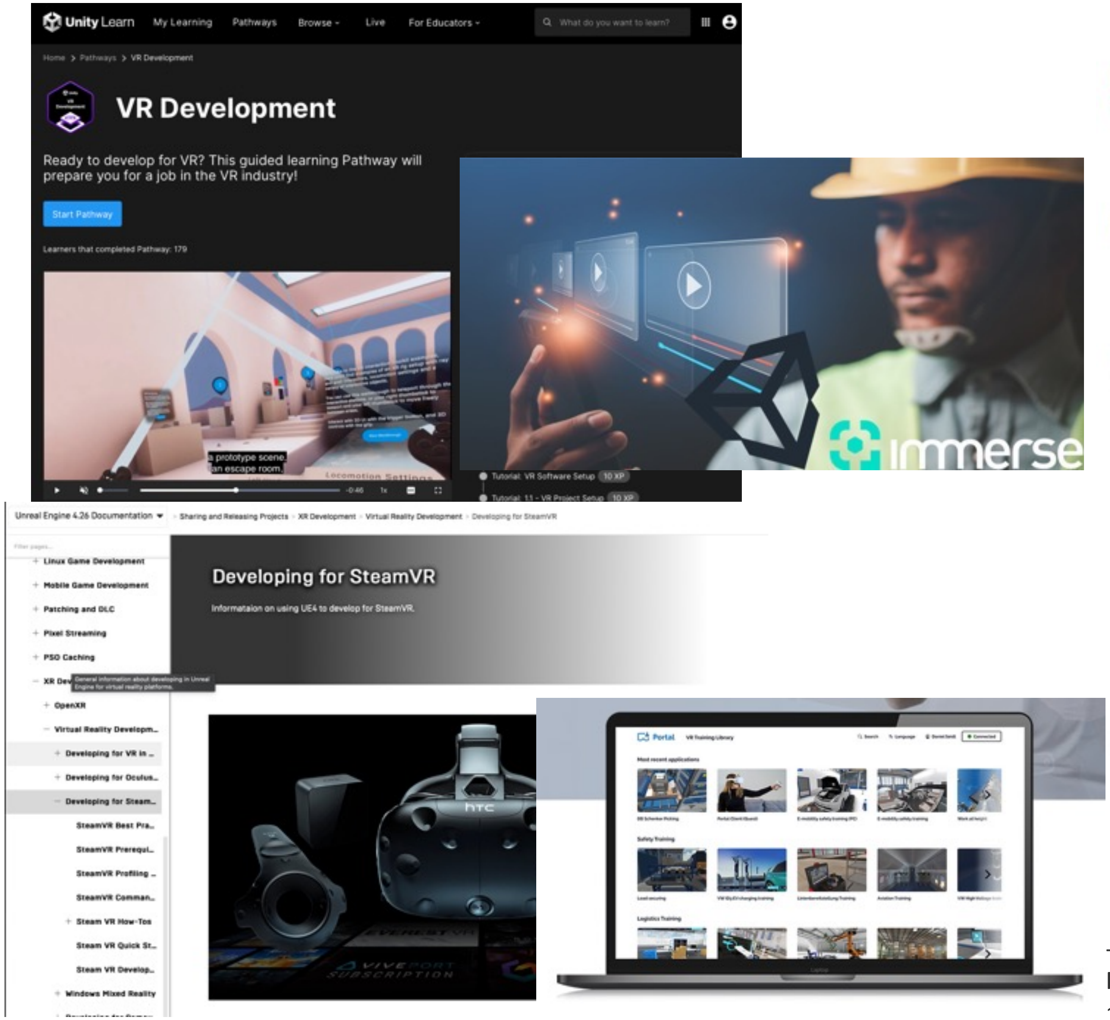
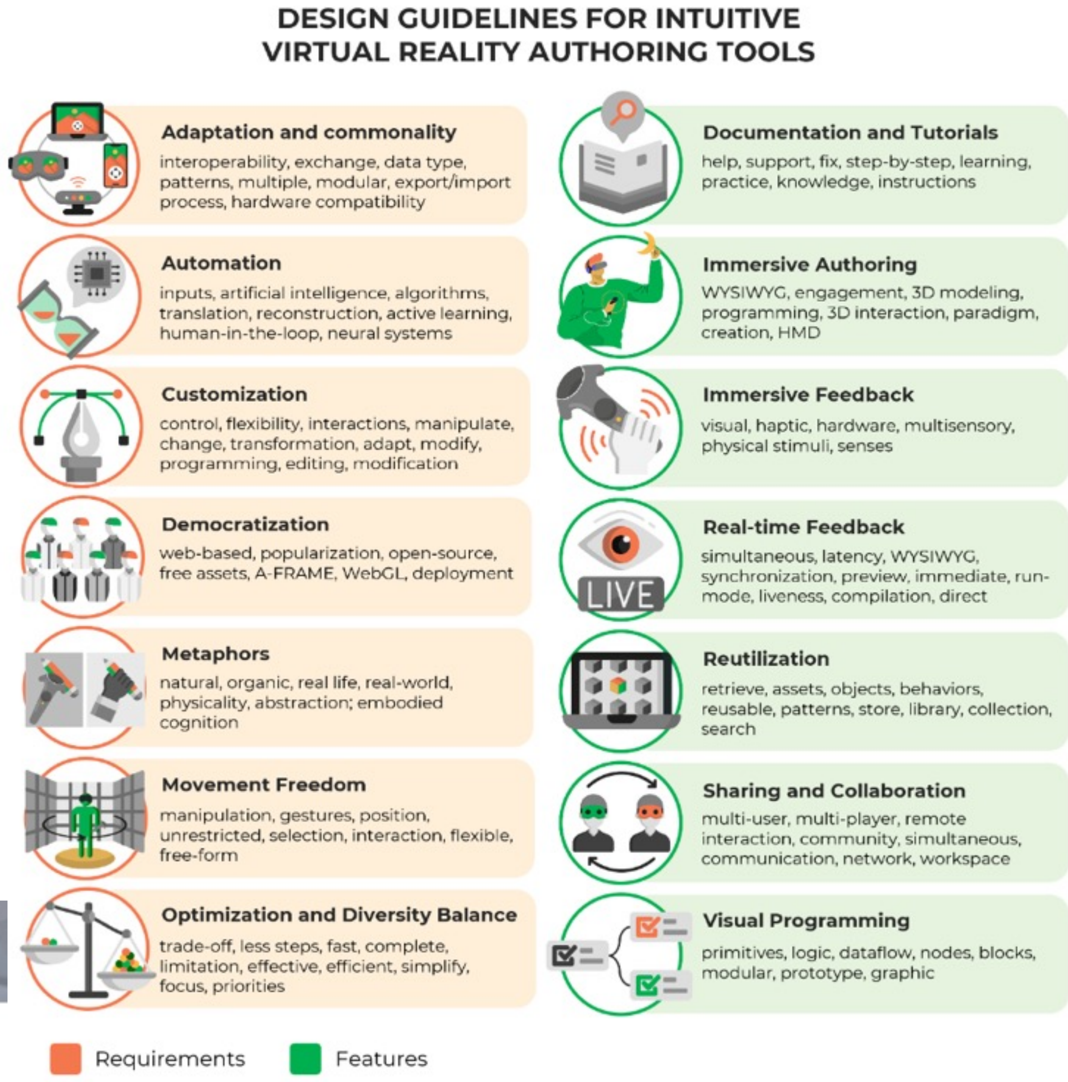


Figure 7: GNN training process - Object labelling using ECSS.

- Papagiannakis, G., Kamarianakis, M., Protopsaltis, A., Angelis, D. & Zikas, P. Project Elements: A computational entity-component-system in a scene-graph pythonic framework, for a neural, geometric computer graphics curriculum. *Arxiv* (2023), accepted also in Eurographis 2023

6Gs of low/no code:
Graphics engines, state-of-the-art





- https://learn.unity.com/pathway/vr-development
- https://docs.unrealengine.com/4.26/en-US/SharingAndReleasing/XRDevelopment/VR/SteamVR/

- Chamusca IL, Ferreira CV, Murari TB, Apolinario AL Jr., Winkler I. Towards Sustainable Virtual Reality: Gathering Design Guidelines for Intuitive Authoring Tools. Sustainability. 2023; 15(4):2924. https://doi.org/10.3390/su15042924
- Coelho, H., Monteiro, P., Gonçalves, G. *et al.* Authoring tools for virtual reality experiences: a systematic review. *Multimed Tools Appl* **81**, 28037–28060 (2022). https://doi.org/10.1007/s11042-022-12829-9

6Gs of low/no code:
Graphics engines, our approach

a) Insert action*,** on standard Unity:

TWO FULL DAYS FOR
AN EXPERIENCED DEVELOPER
AND ~150 LINES OF CODE

*only **visual correspondence** between two examples a) and b). This code example a) is **lacking**:
1) **networked collaborative** capability
2) user **analytics** and **task performance assessment**
3) support for **different** VR **HMDs** and **hand** interaction,
4) **reusability** with **different** 3D assets
** Insert action is used to teach trainees how to insert a specific item at a correct position, orientation via holographic aids and automatic snapping under certain conditions/constraints

b) Insert action*² on MAGES

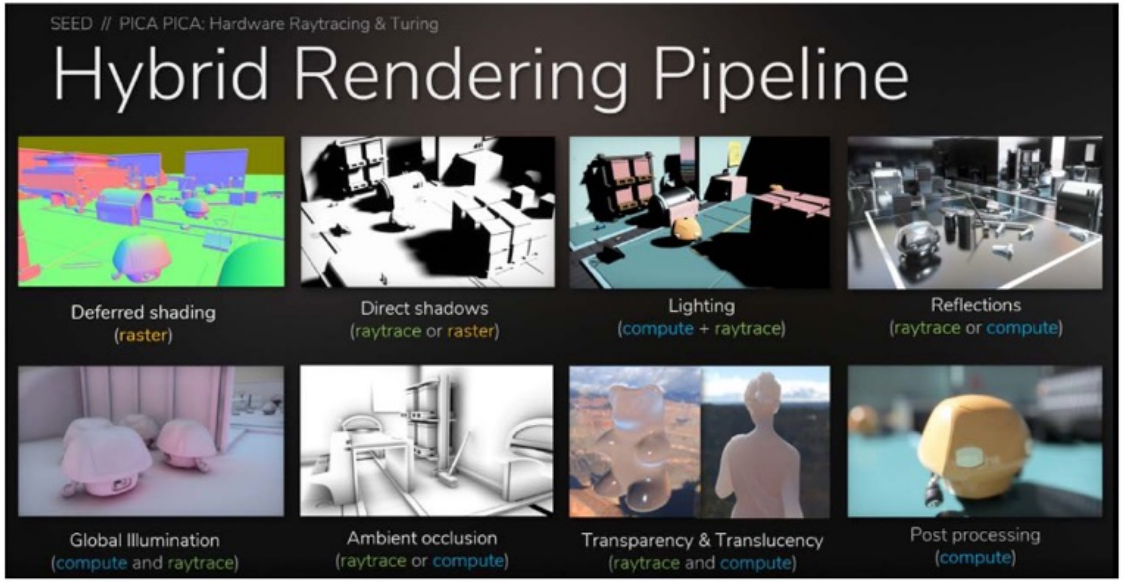
COUPLE OF HOURS TO PARSE
ONLINE DOCS/TUTORIALS/EXAMPLES AND
DEPLOY IN 5 LINES OF CODE:

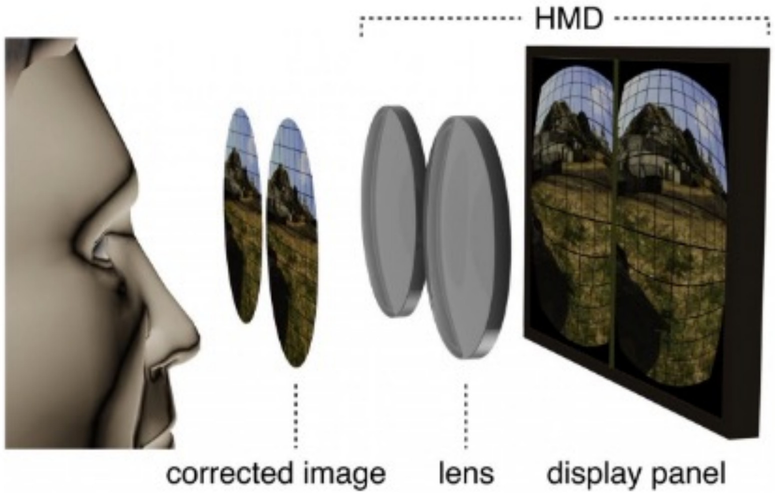
```
public class PolyethyleneTrialAction : InsertAction
{
    public override void Initialize()
    {
        SetInsertPrefab("Lesson7/Stage2/Action0/Polyethylene",
                        "Lesson7/Stage2/Action0/PolyethyleneFinal");
        SetHoloObject(""Lesson7/Stage2/Action0/Hologram/HologramL7S2A0");

        base.Initialize();
    }
}
```

*² feature **complete** action with a) **networked** collaborative capability, b) user **analytics and assessment**, c) different VR **HMD support** with **hand** pose **interaction**, d) **massive reusability** with any 3D assets in combination with other action prototype VR **design** patterns *

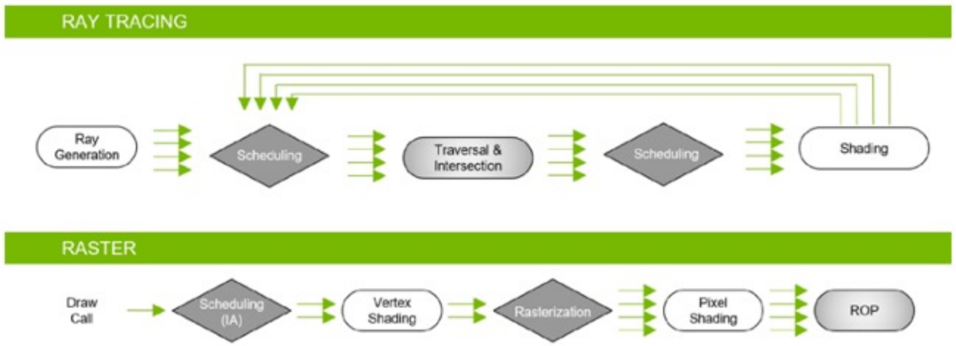
Zikas, P., **Papagiannakis, G.**, Lydatakis, N., Kateros, S., Ntoa, S., Adami, I., Stephanidis, C., “Immersive visual scripting based on VR software design patterns for experiential training”, Visual Computer Journal, https://doi.org/10.1007/s00371-020- 01919-0, also presented in Computer Graphics International 2020, CGI’20, Geneva, Switzerland, 2020

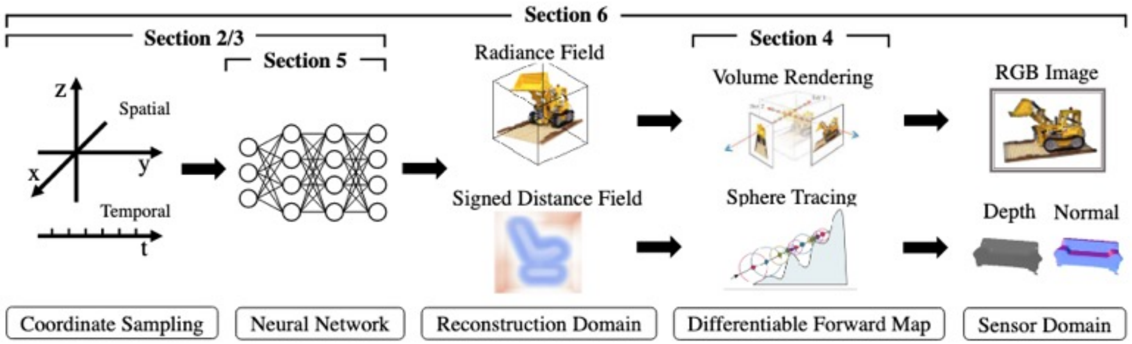
6Gs of low/no code:
GPUs, state-of-the-art





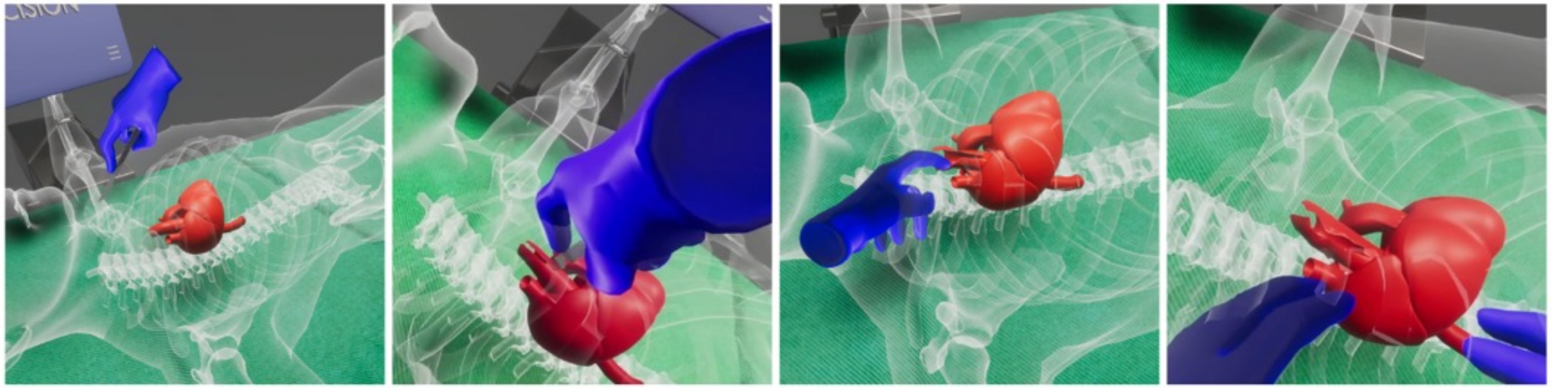
"Every single pixel will be generated soon. Not rendered: generated" J. Huang, Nvidia





- Xie, Y. et al. Neural Fields in Visual Computing and Beyond. Arxiv (2021).
- NVIDIA & nV. NVIDIA Turing GPU Architecture. 1–87 (2018)
- Beyer, J., Hadwiger, M. & Pfister, H. State-of-the-Art in GPU-Based Large-Scale Volume Visualization. Comput Graph Forum 34, 13–37 (2015).

6Gs of low/no code:
GPUs, our approach



Kamarianakis, M., Protopsaltis, A., Angelis, D., Tamiolakis, M. & Papagiannakis, G. Progressive tearing and cutting of soft-bodies in high-performance virtual reality. *Arxiv* (2022) doi:10.48550/arxiv.2209.08531, also presented in ICAT-EGVE 2022 - International Conference on Artificial Reality and Telexistence and Eurographics Symposium on Virtual Environments

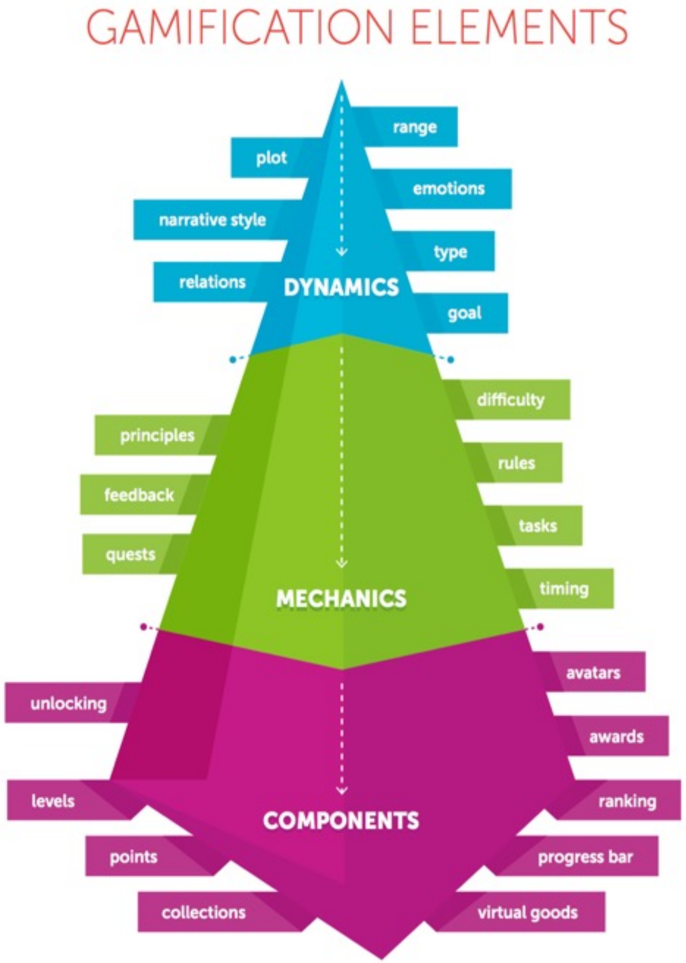
6Gs of low/no code: Games, state-of-the-art

"**gamification**": as *the use of game design elements in non-game contexts* [Deterding et al 11]

- Use of game dynamics (e.g. plot), game mechanics (e.g. rules) and game components (e.g. points, avatars) in order to engage more people

"**Serious games**": *computer games that are not limited to the aim of providing entertainment* [Chon et al 2019]

- that allow for collaborative use of 3D spaces that are used for learning and educational purposes in a number of application domains [Macedonia 2002]



- Chon, S.-H. et al. Serious Games in Surgical Medical Education: A Virtual Emergency Department as a Tool for Teaching Clinical Reasoning to Medical Students. Jmir Serious Games 7, e13028 (2019).
- S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "From game design elements to gamefulness," presented at the the 15th International Academic MindTrek Conference, New York, New York, USA, 2011, p. 9.
- Macedonia M (2002) Games soldiers play. IEEE Spectrum 39(3): 32–37

6Gs of low/no code:
Games, our approach

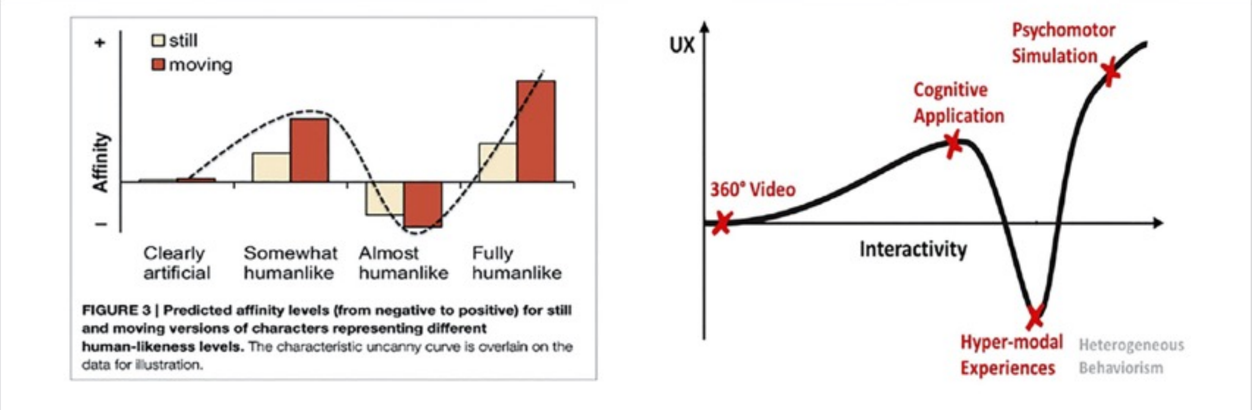
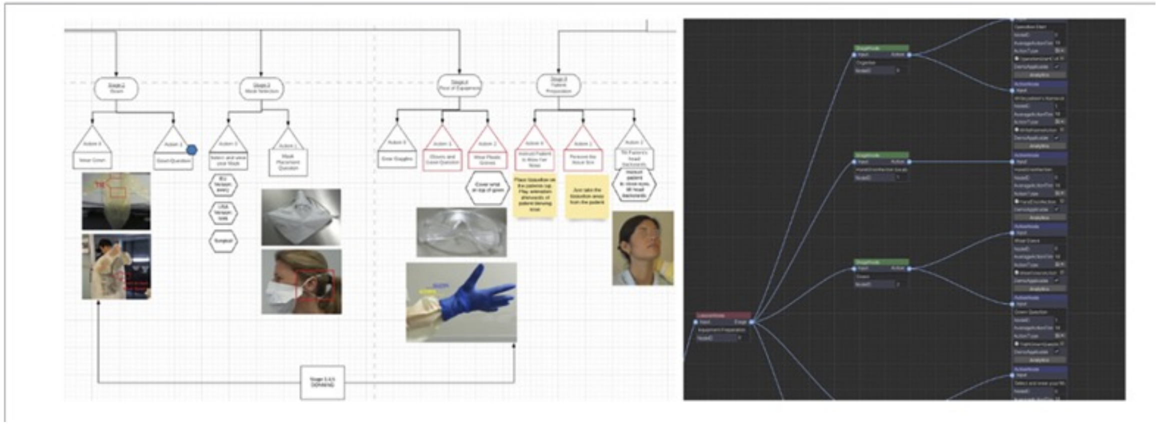
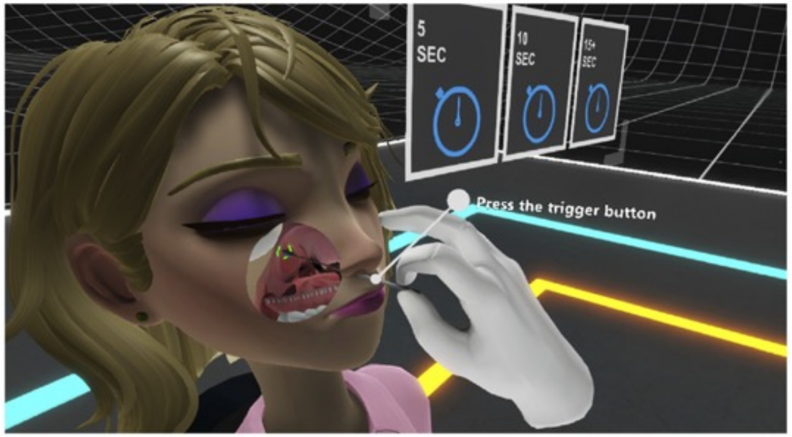


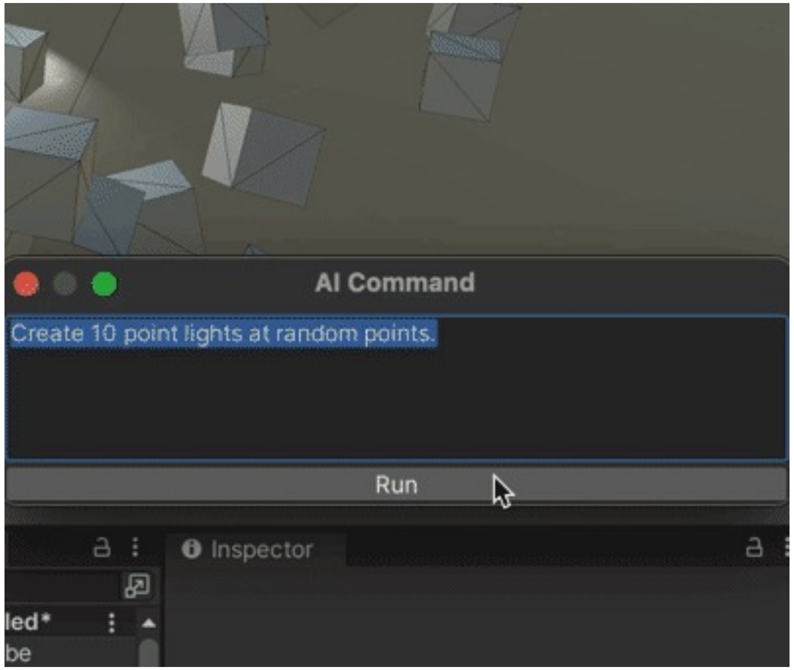
FIGURE 7 | Left: The Uncanny Valley (UV) effect: affinity (empathy, likeness, attractiveness) vs human-likeness from (Kätsyri et al., 2015). Right: The same phenomenon is observed when comparing the user experience vs the interactivity (level of detail and automation of every action) (Zikas et al., 2020).

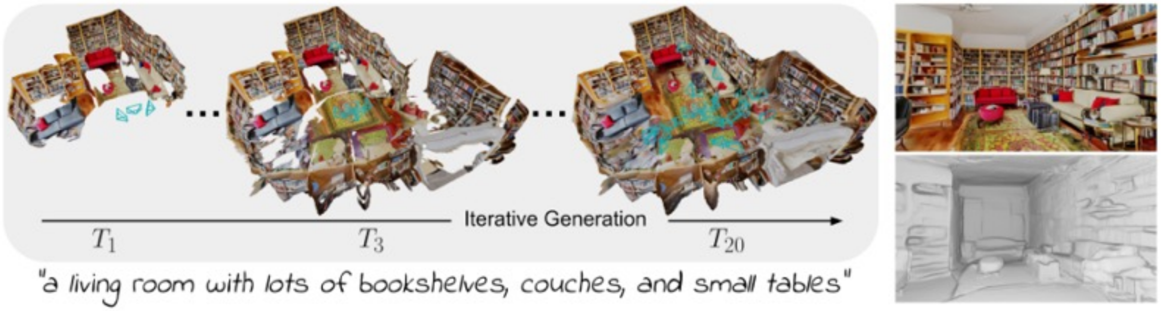




- Zikas, P. *et al.* Virtual Reality Medical Training for COVID-19 Swab Testing and Proper Handling of Personal Protective Equipment: Development and Usability. *Frontiers Virtual Real* **2**, (2022).
- Papagiannakis, G., Gamification and Serious Games. in *Encyclopedia of Computer Graphics and Games* vol. 21 1–4 (Encyclopedia of Computer Graphics and Games, 2018).

6Gs of low/no code:
Generative AI & GNNs, state-of-the-art





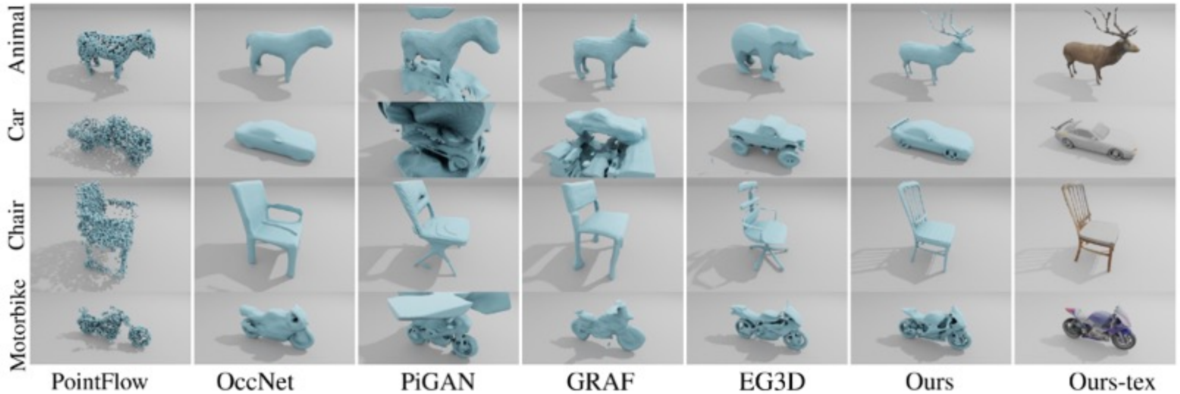
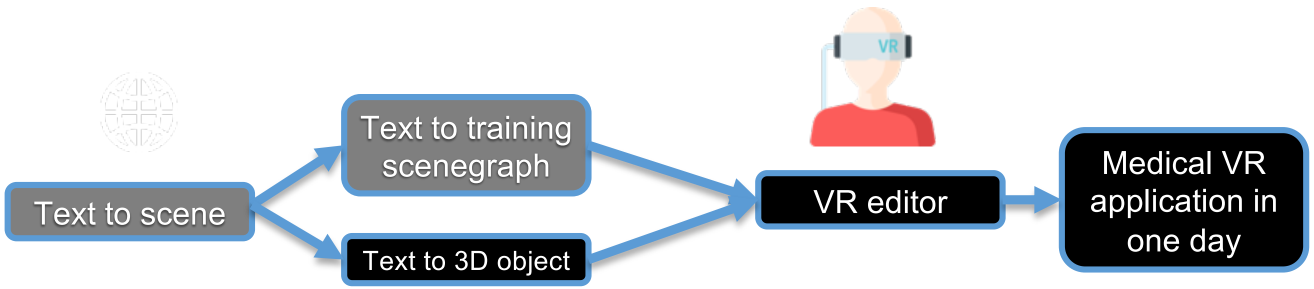


Figure 3: Qualitative comparison of GET3D to the baseline methods in terms of extracted 3D geometry. GET3D is able to generate shapes with much higher geometric detail across all categories.

- https://github.com/keijiro/AICommand
- Text2Room: Extracting Textured 3D Meshes from 2D Text-to-Image Models, https://arxiv.org/abs/2303.11989
- https://pinar-seyhan-demirdag.medium.com/the-ultimate-guide-to-3d-model-and-scene-generation-papers-feb-2023-befea0c24967
- Gao, J. et al. GET3D: A Generative Model of High Quality 3D Textured Shapes Learned from Images. (2022)
- Wu, Z. et al. A Comprehensive Survey on Graph Neural Networks. IEEE T Neur Net Lear 32, 4–24 (2021).

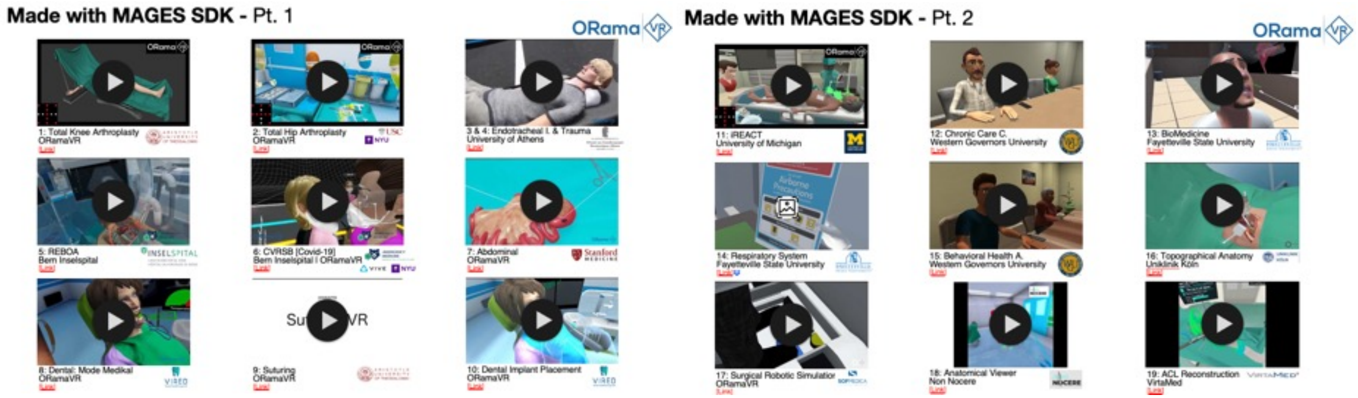
6Gs of low/no code:
Generative AI & GNNs, our approach

MAGES No-code platform
(*Generative-AI based, no developer needed*)

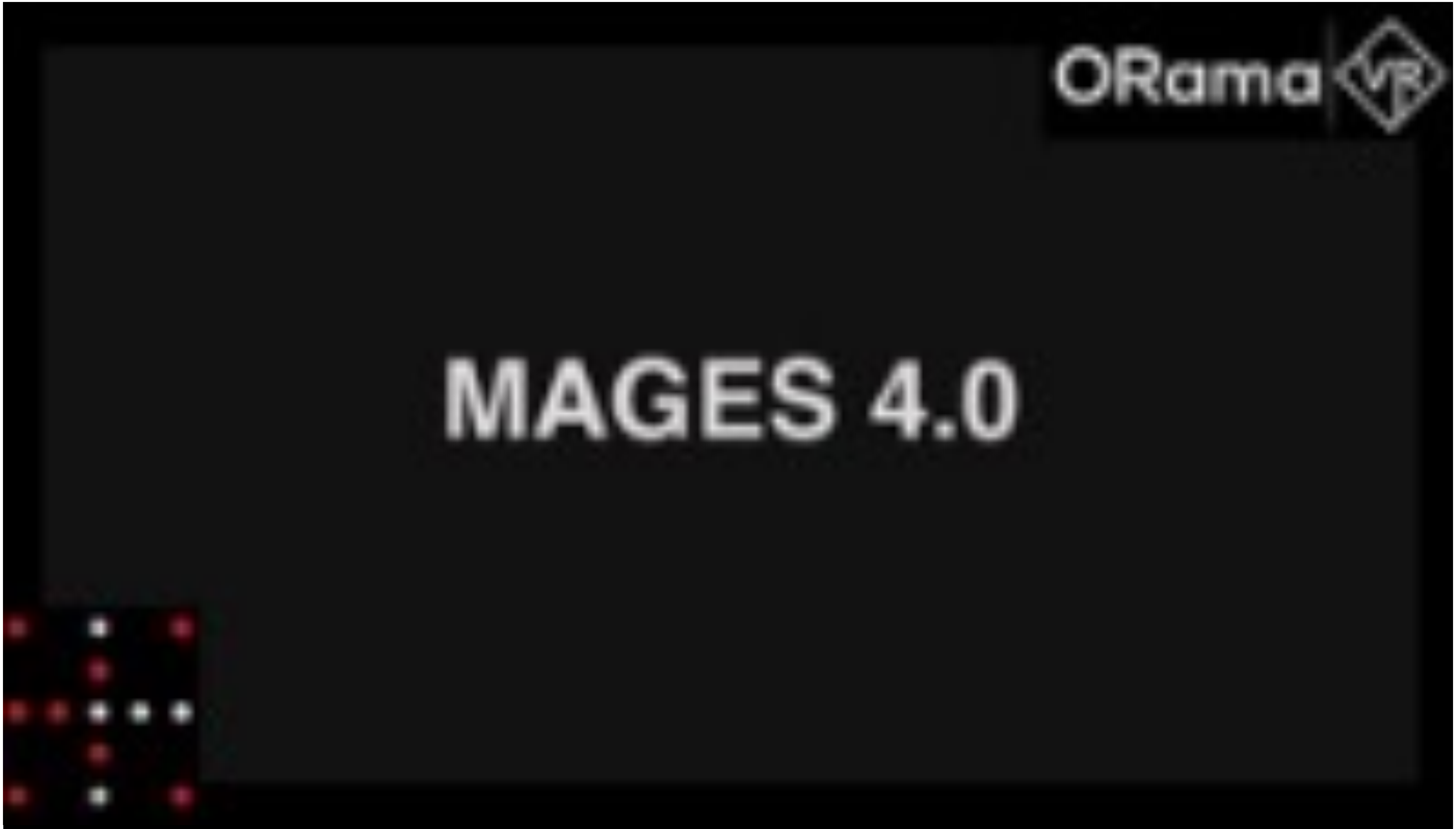


MAGES SDK Low-code platform*
(*support all VR/AR/mobile h/w devices, 1 developer needed*)

MAGES SIM template Library (*reach 100 sims as medical VR apps*)

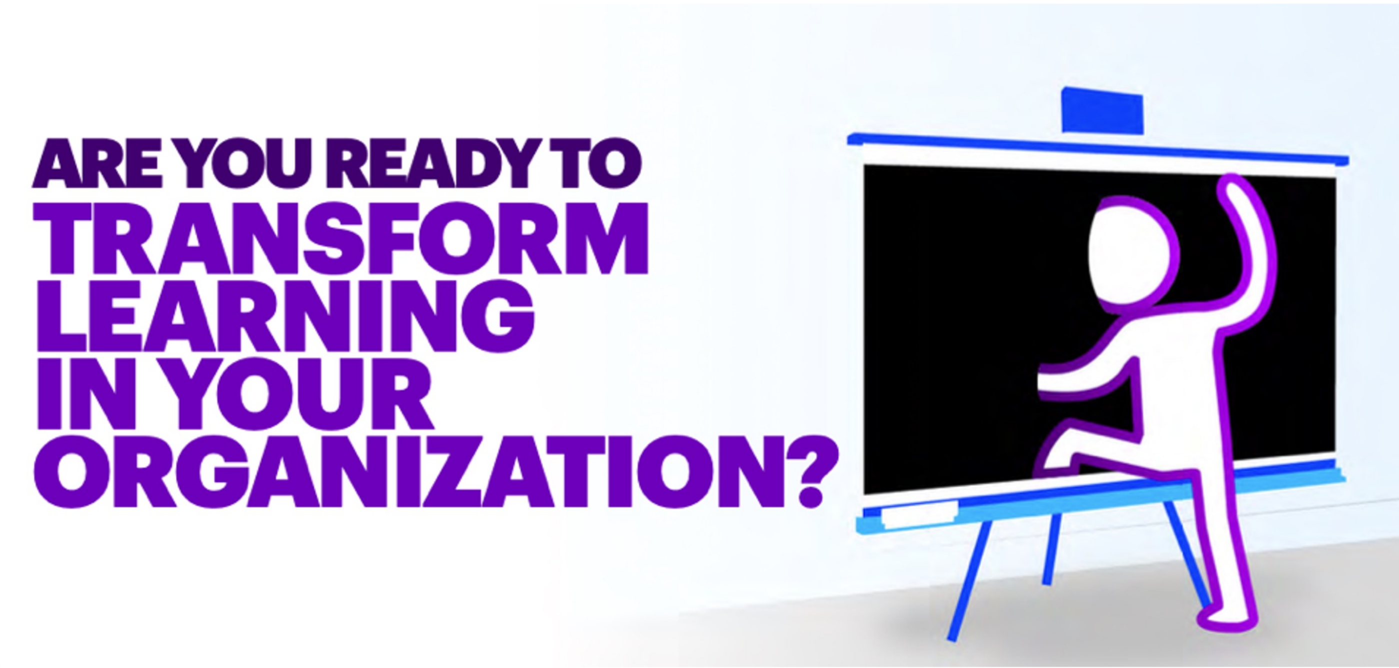


* P. Zikas *et al.*, "MAGES 4.0: Accelerating the World's Transition to VR Training and Democratizing the Authoring of the Medical Metaverse," in *IEEE Computer Graphics and Applications*, vol. 43, no. 2, pp. 43-56, 1 March-April 2023, doi: 10.1109/MCG.2023.3242686., https://ieeexplore.ieee.org/document/10038619



MAGES 4.0: Accelerating the world's transition to medical VR training

Conclusions



- The 6Gs of educational XR are transforming spatial computing apps
- 6Gs are transforming creativity - new creativity tools are required
- 6Gs R&D opens up new possibilities for next-gen medical simulations

> The scene is set for massive change

One last thing

Source: Accenture Consulting. WAKING UP TO A NEW REALITY | Accenture. 2019.

SIGGRAPH 2023
LOS ANGELES+ 6-10 AUG

ABOUT THE CONFERENCE | PROGRAMS & EVENTS | THE EXHIBITION | PLAN TO ATTEND | VOLUNTEER WITH US | SUBMIT TO SIGGRAPH

ORama VR

PRESENTATION

FULL PROGRAM | CONTRIBUTORS | ORGANIZATIONS | SEARCH PROGRAM

Frontiers Workshop: Computational Medical XR

Description

Computational medical XR brings together life sciences and neuroscience with mathematics, engineering, and computer science. It unifies computational science (scientific computing) with intelligent extended reality and spatial computing for the medical field. It significantly extends previous "Clinical XR", by integrating computational methods from neural simulation to computational geometry, computational vision and computer graphics up to theoretical computer science and deep learning to solve hard problems in medicine and neuroscience. In this workshop we present the most recent advances in the computational medical XR field.

Organizer

George Papagiannakis - ORamaVR, University of Crete & ICS-FORTH

Speakers

George Papagiannakis - ORamaVR, ICS-FORTH, University of Crete

Oliver Kannape - Geneva University Hospital, MindMaze SA

Walter Greenleaf - Stanford University

Michael Cole - University of Michigan

Gabe Jones - Proprio Vision

Mark Zhang - Harvard University

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Let’s accelerate world’s transition to XR!

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