From low-code geometric algebra to no-code geometric deep learning:

computational models, simulation algorithms and authoring platforms

for

immersive scientific visualization,

experiential visual analytics and the upcoming ***educational metaverse***

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FORTH Foundation for Research & Technology - Hellas

ORama VR

UNIVERSITÉ DE GENÈVE

Augmenting Human intellect?

Let us consider an "augmented" architect at work. He sits at a working station that has a visual display screen some three feet on a side; this is his working surface, and is controlled by a computer (his "clerk") with which he can communicate by means of a small keyboard and various other devices.

He is designing a building. He has already dreamed up several basic layouts and structural forms, and is trying them out on the screen. The surveying data for the layout he is working on now have already been entered, and he has just coaxed the "clerk" to show him a perspective view of the steep hillside building site with the roadway above, symbolic representations of the various trees that are to remain on the lot, and the service tie points for the different utilities. The view occupies the left two-thirds of the screen. With a "pointer," he indicates two points of interest, moves his left hand rapidly over the keyboard, and the distance and elevation between the points indicated appear on the right-hand third of the screen.

STANFORD RESEARCH INSTITUTE
MENLO PARK, CALIFORNIA

Republished in abridged form in ***Vistas in Information Handling***, Howerton and Weeks [Editors], Spartan Books, Washington, D.C., 1963, pp. 1-29, titled "A Conceptual Framework for the Augmentation of Man's Intellect."

October 1962

AFOSR-3223

Summary Report

AUGMENTING HUMAN INTELLECT: A CONCEPTUAL FRAMEWORK

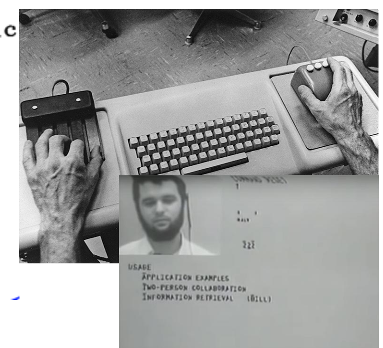
Prepared for:

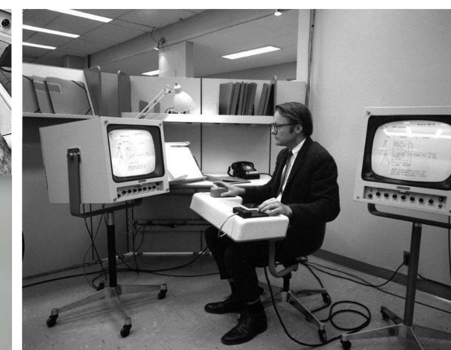
DIRECTOR OF INFORMATION SCIENCES
AIR FORCE OFFICE OF SCIENTIFIC RESEARCH
WASHINGTON 25, D.C.

CONTRACT AF 49(638)-1024

By: D. C. Engelbart

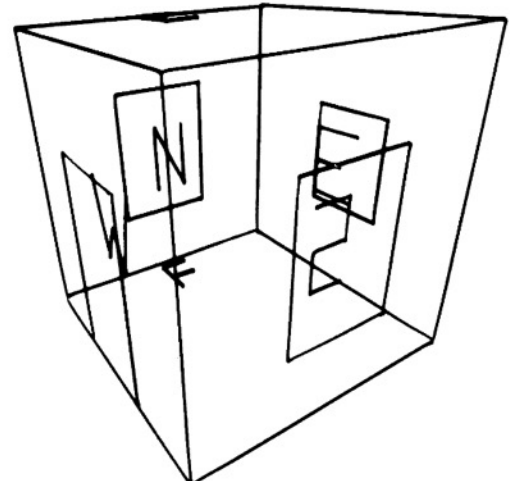
SRI Project No. 3578

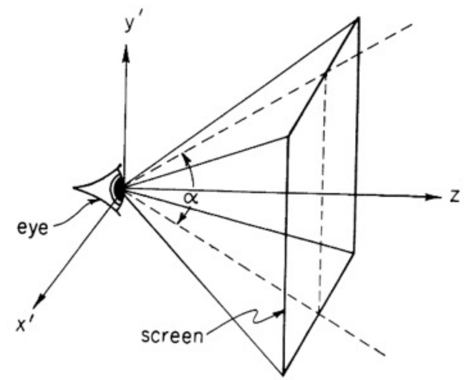


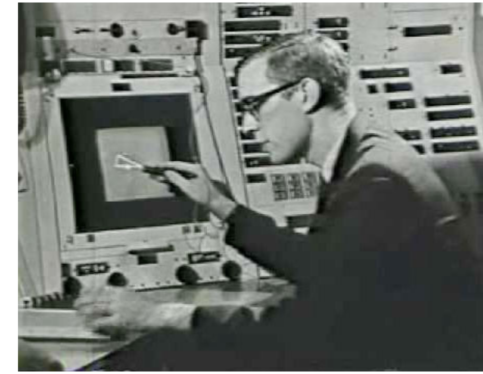


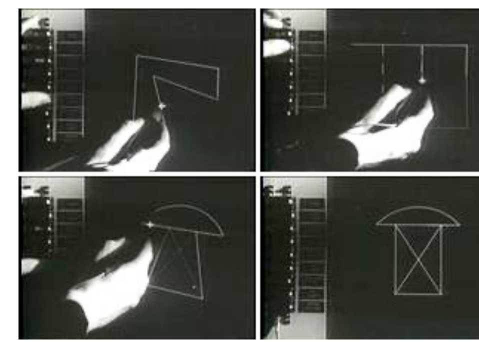
Engelbart, Douglas. "Augmenting human intellect: A conceptual framework. Summary report." *Stanford Research Institute, on Contract AF* 49, no. 638 (1962): 1024.
[“Mother of all demos”: https://youtu.be/B6rKUf9DWRI](https://youtu.be/B6rKUf9DWRI) , 1968

Head Mounted Displays and touch interfaces?









Sutherland, I. E. A head-mounted three dimensional display. *AFIPS Fall Joint Computing Conference* 757–764 (1968) doi:10.1145/1476589.1476686. https://youtu.be/eVUgfUvP4uk
The sketchpad demo: https://youtu.be/6orsmFndx_o , 1963

My personal trip

TECHNOLOGIE Réalité et images de synthèse mêlées

LE TOURISME EN 3D EST NÉ

INNOVATION Grâce à des lunettes spéciales, le touriste peut se promener dans Pompéi en voyant à la fois la pièce dans laquelle il se trouve, et des personnages d'époque, créés par ordinateur, qui évoluent à ses côtés!

GENÈVE Le système révolutionnaire, créé par une équipe de spécialistes européens, permet de visiter des sites archéologiques comme si on voyageait dans le temps

Frédéric Julliard

Une technique révolutionnaire, née en Suisse romande, pourrait bouleverser le monde du tourisme. Pour la première fois, des chercheurs sont parvenus à superposer en temps réel un paysage et des images de synthèse. Pour dire les choses en français, le système présenté à Genève permet à un touriste, muni de lunettes spéciales, de se promener dans Pompéi (site choisi pour le prototype) en voyant à la fois la pièce bien réelle dans laquelle il se trouve, et des personnages d'époque, créés par ordinateur, qui évoluent à ses côtés!

Contrairement à la réalité virtuelle, qui construit des scènes entièrement artificielles, la «réalité augmentée» mélange monde réel et images de synthèse. Le cinéma s'en sert, par exemple, pour ajouter des dinosaures à un paysage. Mais, jusqu'ici, il fallait calculer les images une à une. L'exploit de l'équipe basée à Genève a consisté à réduire le temps de calcul à une fraction de seconde. L'ordinateur peut ainsi suivre les mouvements du spectateur et lui donner l'impression qu'il se promène dans Pompéi au temps des Romains...

Un prototype à alléger

Baptisé Lifeplus, le projet est financé par l'Union européenne à hauteur de 2,8 millions de francs. Il réunit une brochette de spécialistes européens autour de Nadia Magnenat-Thalmann, de l'Université de Genève. L'équipe doit encore peaufiner le prototype, mais aussi l'alléger: l'utilisateur doit transporter avec lui un ordinateur portable, nécessaire aux calculs très complexes des images en 3D. A terme, le logiciel pourrait tenir dans un simple agenda électronique de type PDA, branché sur les lunettes servant à projeter les images.

Le XVIIIe siècle comme si on y était

Avec ce matériel réduit, on pourra arpenter n'importe quel site. «Les touristes pourraient, par exemple, se balader sur la plaine de Plainpalais, à Genève, et la voir telle qu'elle était au XVIIIe siècle», imagine Nadia Magnenat-Thalmann.

Les applications ne se limitent pas au tourisme: le système intéresse la pub, le cinéma, la télévision... Il devrait être opérationnel dans les cinq ans. «Comme l'industrie s'en mêle, explique Nadia Magnenat-Thalmann, ça pourrait même aller bien plus vite.»

SITE INTERNET

www.miralab.unige.ch/subpages/lifeplus/

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THE PROBLEM

VR training improves learning outcomes[1],
VR content creation cannot keep up with demand:

- **LENGTHY CREATION TIMES: 4 – 8 MONTHS**
- **HIGH AUTHORING COSTS[2]: MIN $20K PER MINUTE**
- **INFINITE NUMBER OF TRAINING EXPERIENCES TO BE SIMULATED AS DIGITAL TWINS**
- **LACK OF LOW/NO-CODE, CONTENT AUTHORING TOOLS**

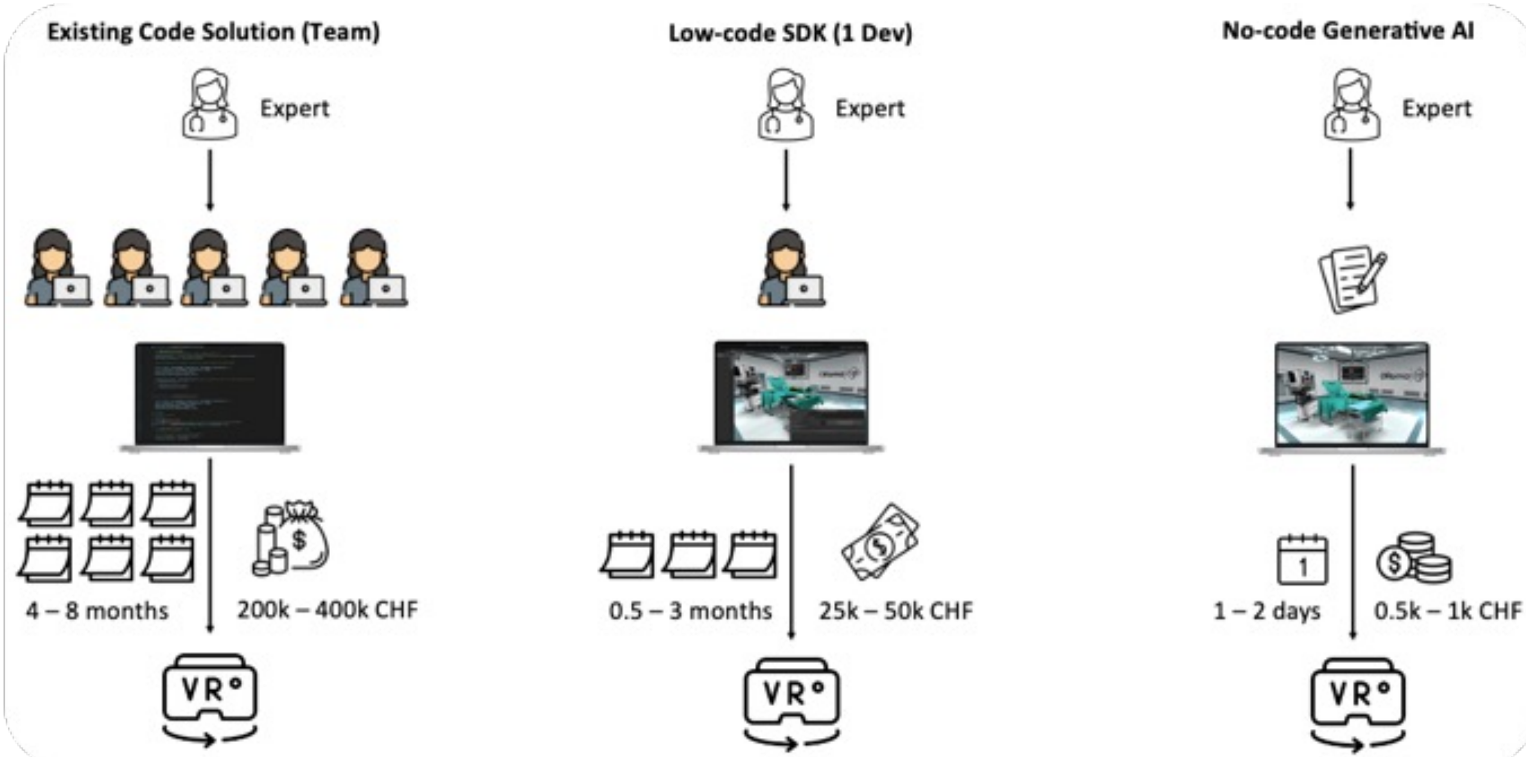
1 https://www.sciencedirect.com/science/article/pii/S0883540319303341
and more than 55 published clinical trials since 2020 verify this fact

2 https://roundtablelearning.com/cost-of-virtual-reality-training-full-vr-2020/

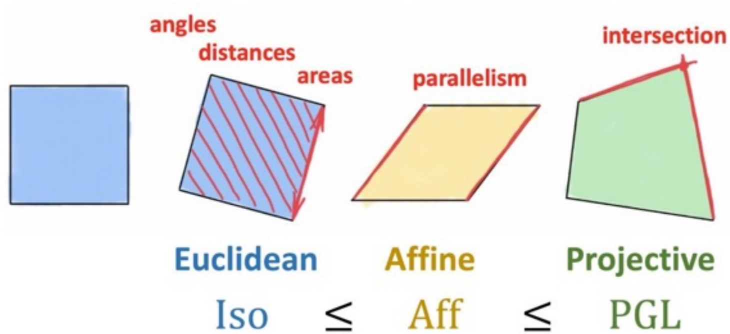
Overview

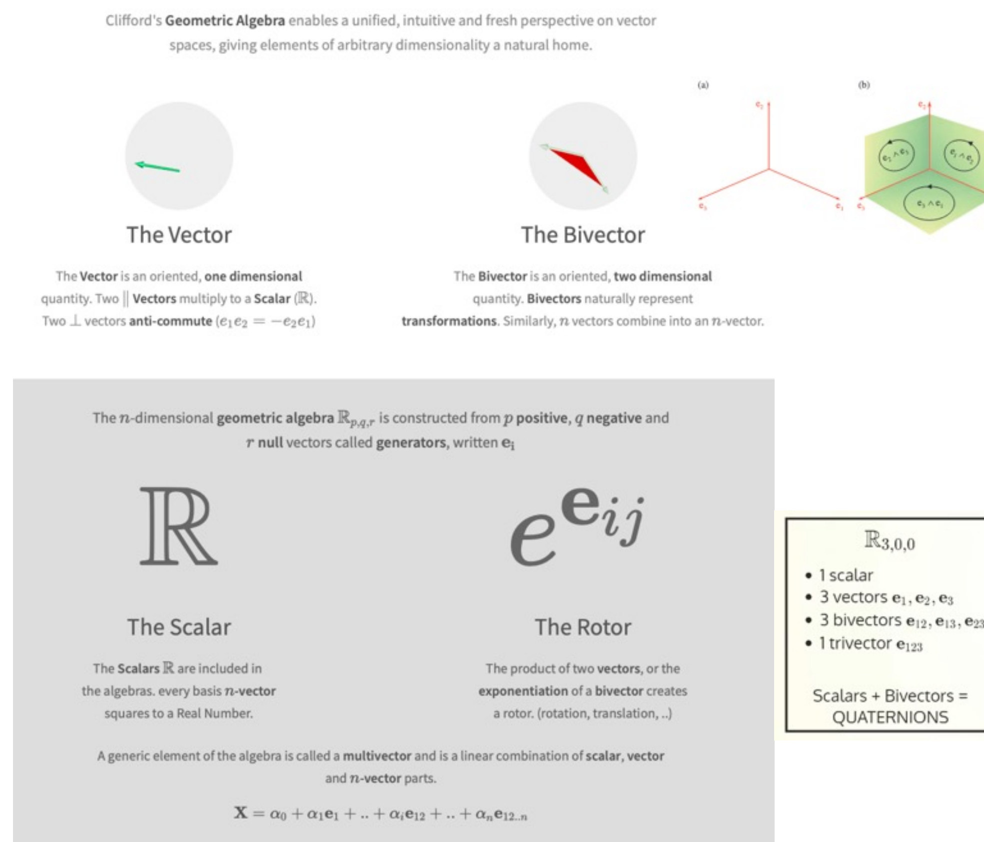
- 6Gs of low/no code
  1. Geometry
  2. Graphs
  3. Graphics Engines
  4. GPUs
  5. Games
  6. Generative AI & GNNs
- Generated realms
  - Immersive visual analytics for SciViz
  - Metaverse
    - Edverse
      - Medverse
- Computational Science & Innovation

CODE -> LOW-CODE -> NO-CODE EDUCATIONAL METAVERSE AUTHORING



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





- 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

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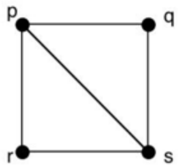
1. **GA Interpolation engine**
2. **Build-in Co-op support**
3. **Reducing network traffic up to 58%**
4. **16% performance boost**
5. **Efficient and smooth transformations**

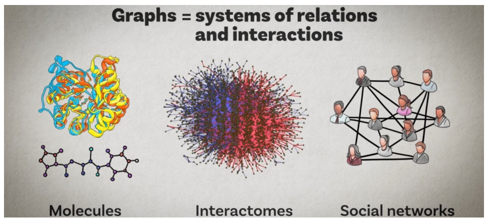
Network Quality	How to Achieve Best QoE	Metrics on Our Methods
Excellent	SoA: 30 updates/sec Ours: 20 updates/sec	33% less bandwidth 16.5% lower running time
Good	SoA: 20 updates/sec Ours: 10 updates/sec	50% less bandwidth 16.5% lower running time
Mediocre	SoA: 15 updates/sec Ours: 7 updates/sec	53%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

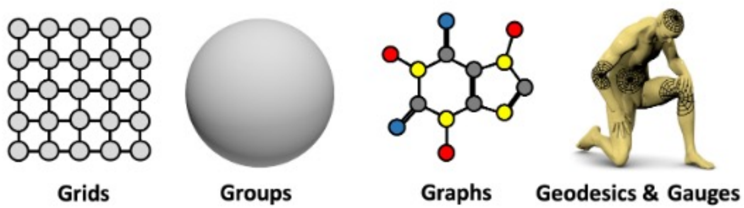
- Eckhard Hitzer, Manos Kamarianakis, George Papagiannakis, et al. Survey of New Applications of Geometric Algebra. *Authorea.* February 20, 2023, DOI: 10.22541/au.167687105.52780013/v1
- Kamarianakis, M., Chrysovergis, I., Lydatakis, N., Kentros, M. & Papagiannakis, G. Less is More: Efficient Networked 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

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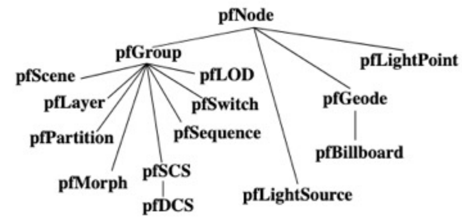
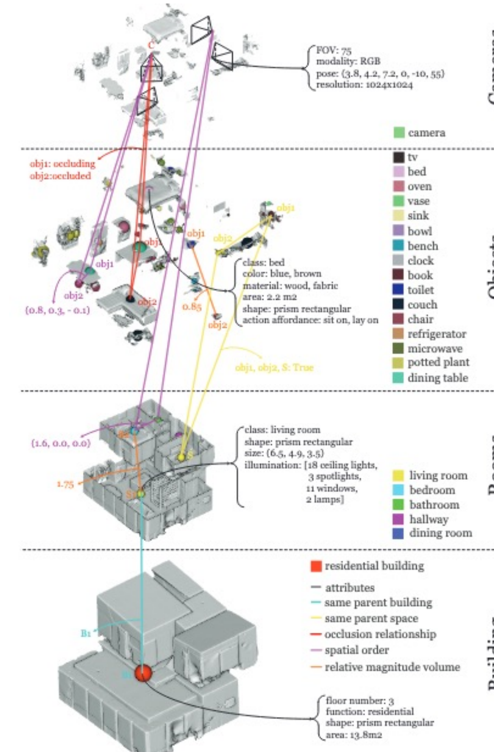
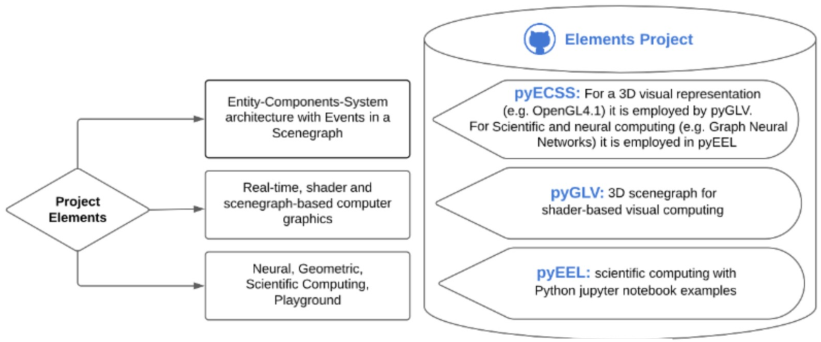


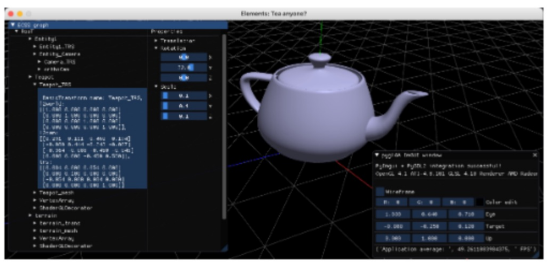
- Intersection traversal (ISECT) — processes intersection requests for collision detection and terrain following.
- Culling traversal (CULL) — rejects objects outside the viewing frustum, computes level-of-detail switches, sorts geometry by modes
- Drawing traversal (DRAW) — sends geometry and graphics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

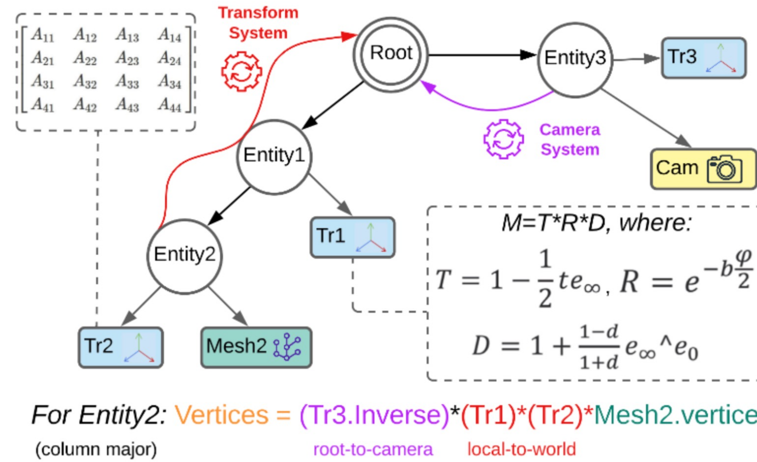


- Armeni, I. *et al.* 3D Scene Graph: A Structure for Unified Semantics, 3D Space, and Camera. 5664–5673 (2019).
- Rohlf, J. & Helman, J. IRIS performer - a high performance multiprocessing toolkit for real-time 3D graphics. *SIGGRAPH* (1994) doi:10.1145/192161.192262.

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







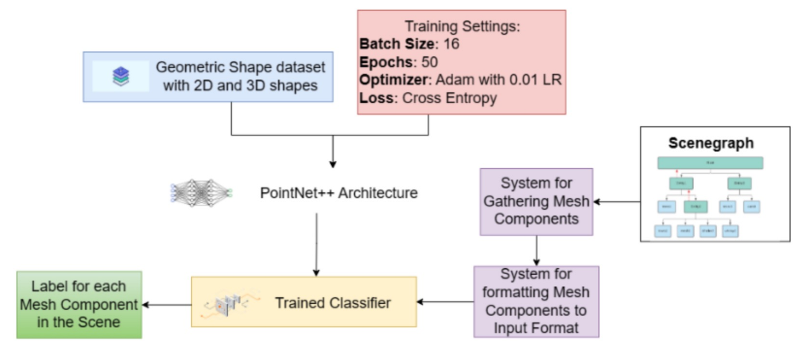
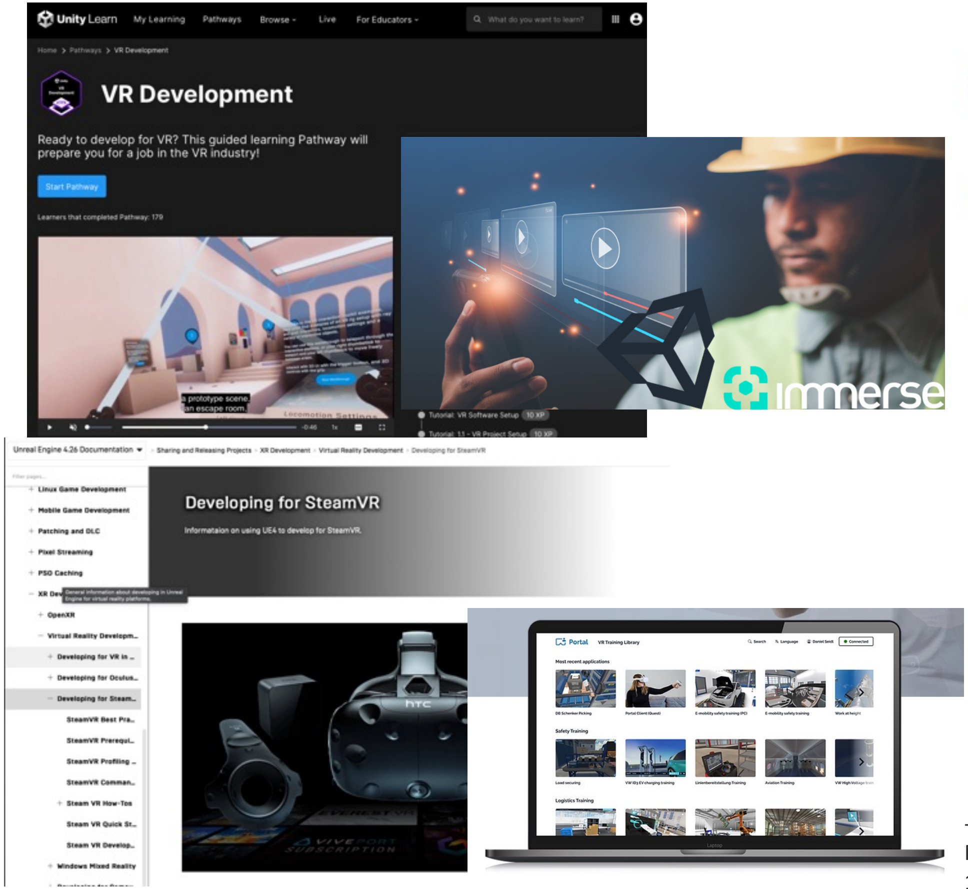


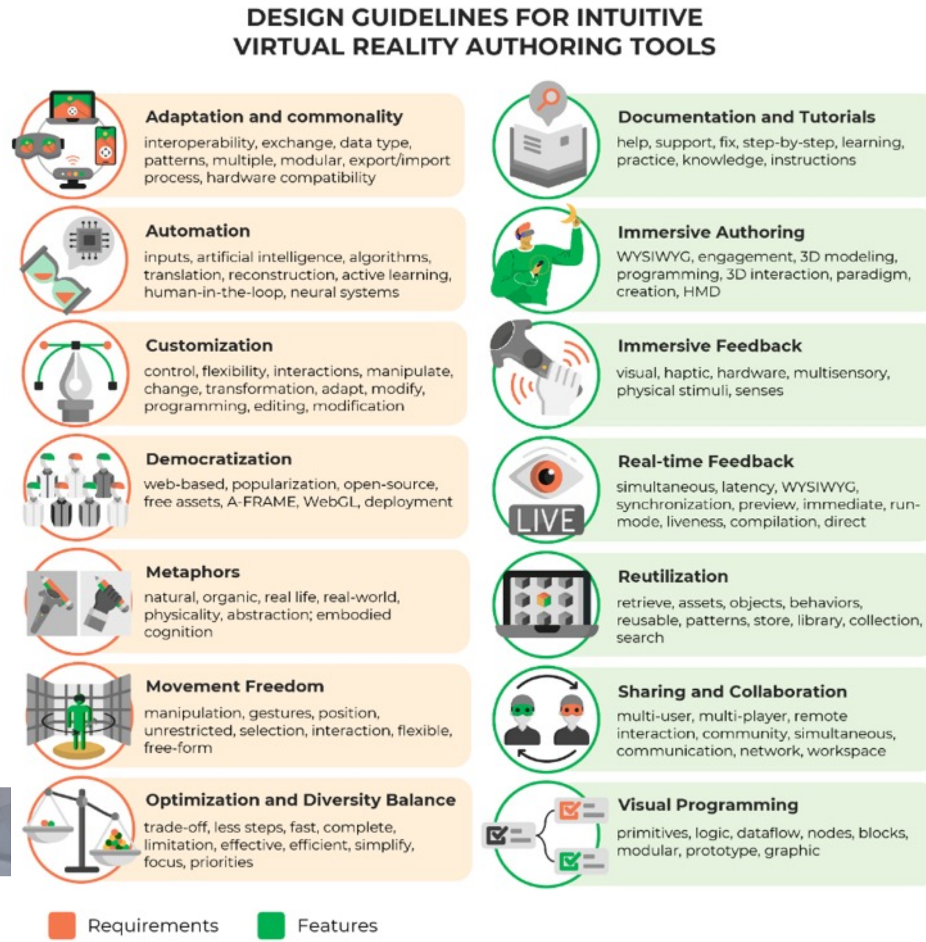
Figure 7: GNN training process - Object labelling using ECSS.

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

- 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

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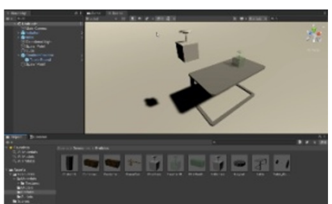
a) Insert action*,** on standard Unity:

**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:**

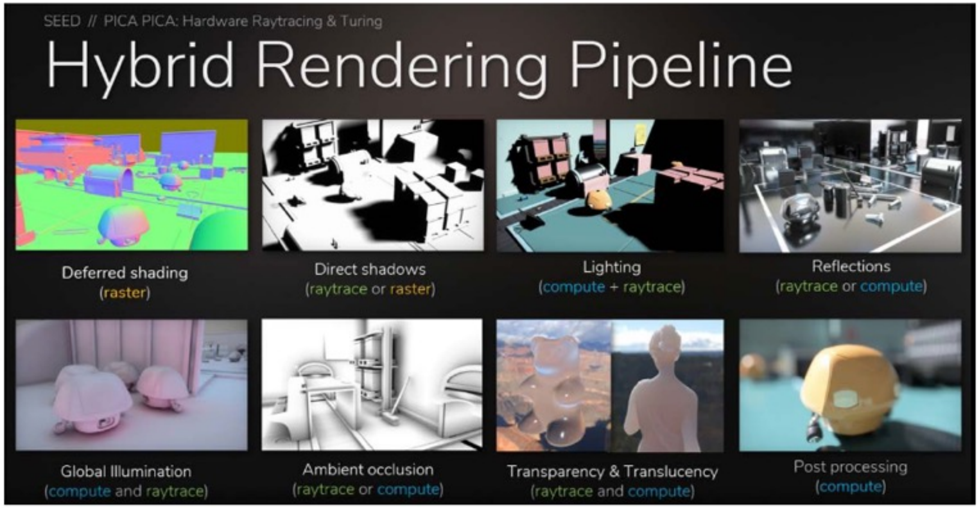
```
public class PolyethyleneTrialAction : InsertAction
{
    public override void Initialize()
    {
        SetInsertPrefab("Lesson7/Stage2/Action0/Polyethylene",
                "Lesson7/Stage2/Action0/PolyethyleneFinal");
        SetHoloObject(""Lesson7/Stage2/Action0/Hologram/HologramL7S2A0");

        base.Initialize();
    }
}
```

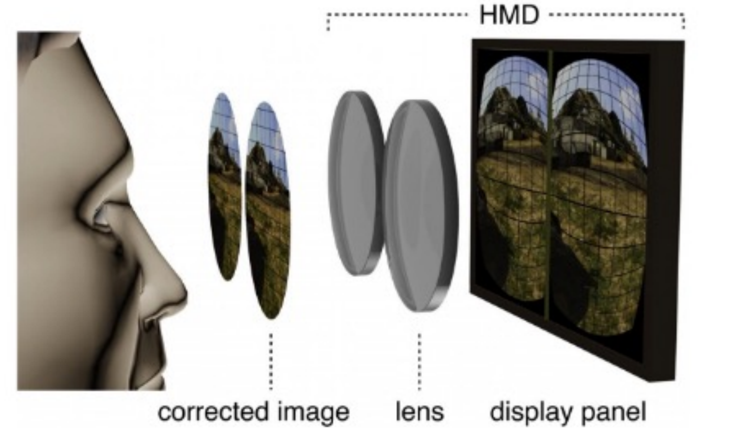
*2 feature **complete** action with a) **networked** collaborative capability, b) user **analytics and assessment**, c) different VR **HMD support** with **hand** pose **interaction**, d) **massive reusability** with any 3D assets in combination with other action prototype VR **design** patterns *

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

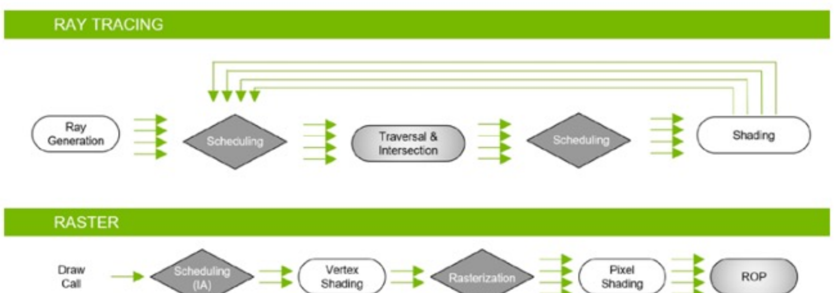
Source: Accenture Consulting. WAKING UP TO A NEW REALITY | Accenture. 2019.

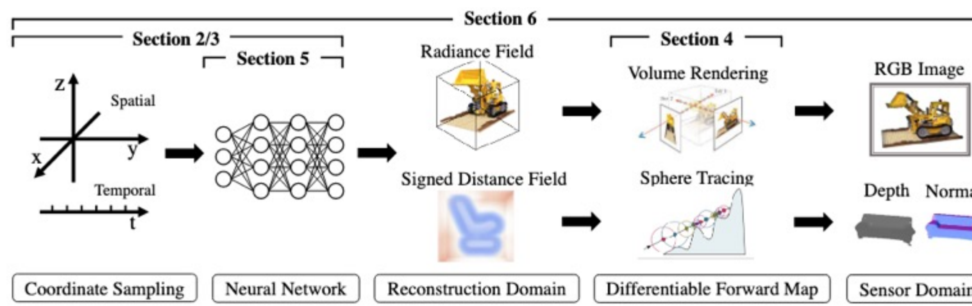
6Gs of low/no code: GPUs, state-of-the-art





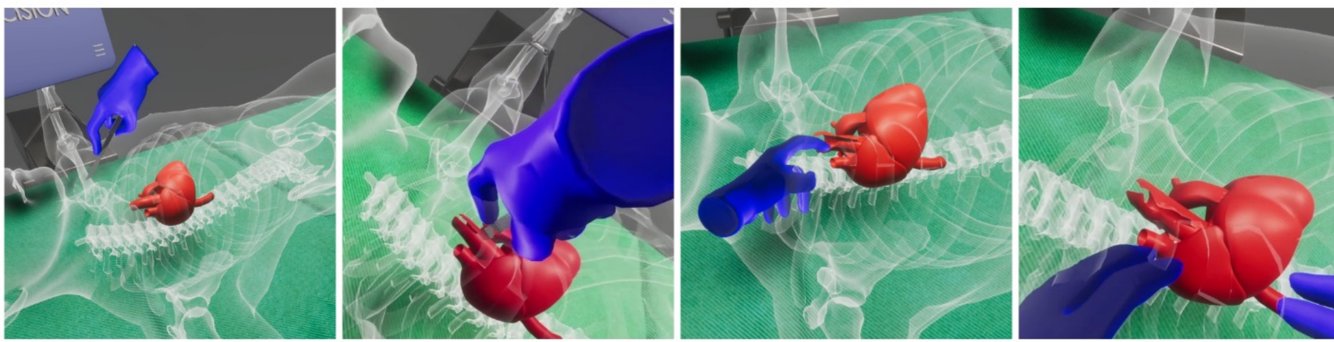
"Every single pixel will be generated soon. Not rendered: generated" J. Huang, Nvidia





- 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

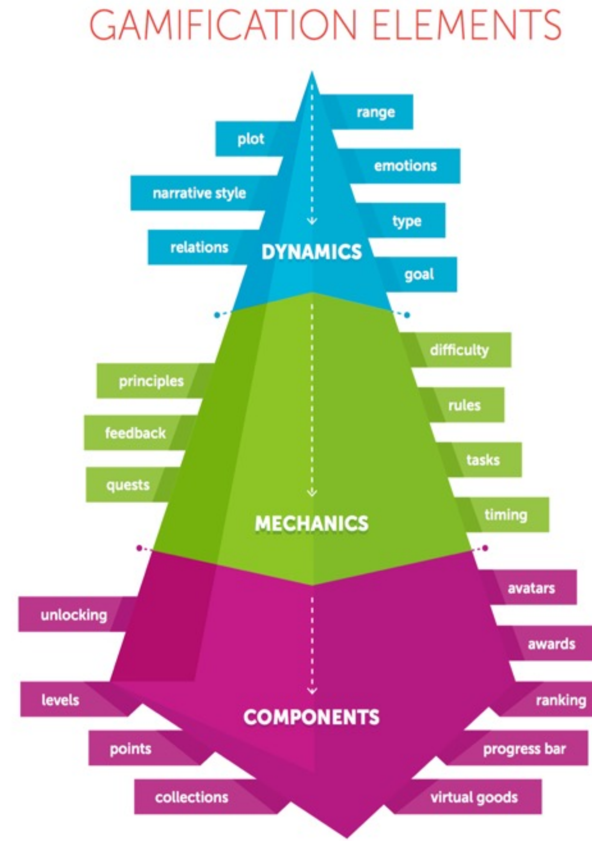
6Gs of low/no code: Games, state-of-the-art

"**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

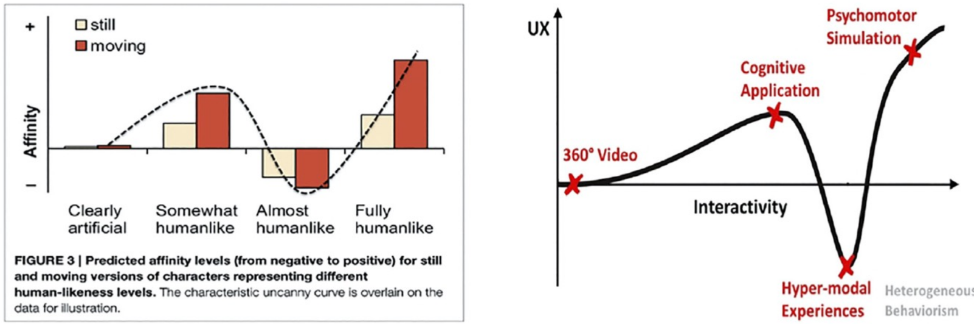
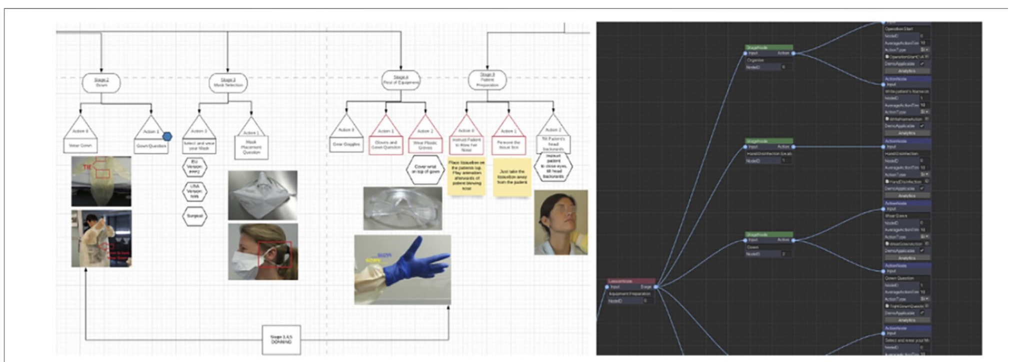
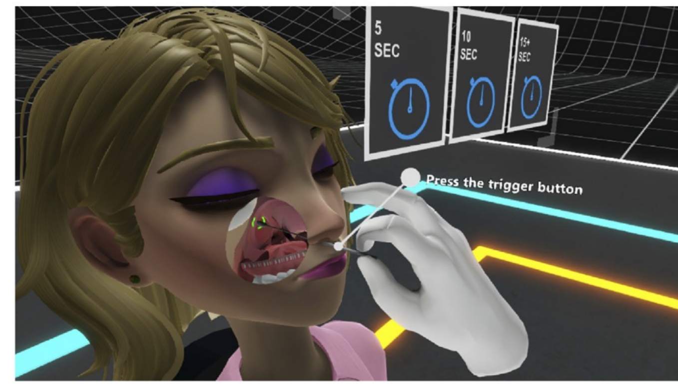


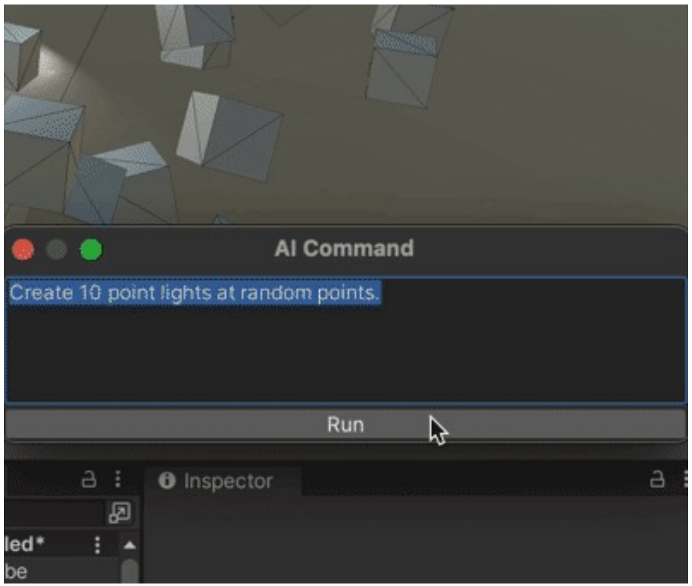
FIGURE 7 | Left: The Uncanny Valley (UV) effect: affinity (empathy, likeness, attractiveness) vs human-likeness from (Kätsyri et al., 2015). Right: The same phenomenon is observed when comparing the user experience vs the interactivity (level of detail and automation of every action) (Zikas et al., 2020).





- 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



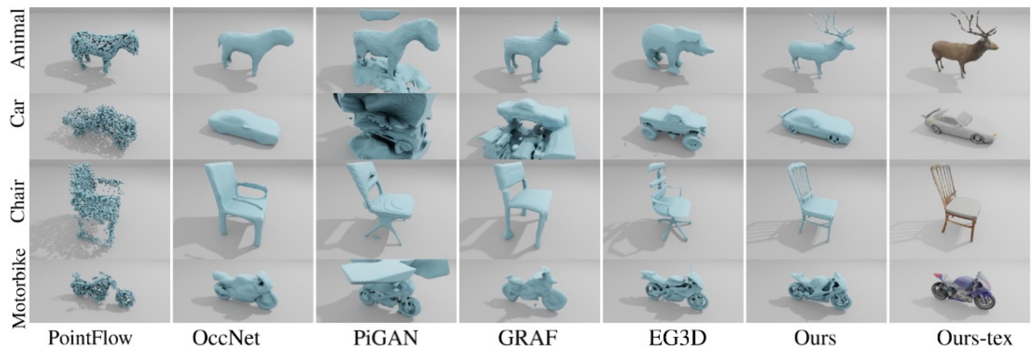


Figure 3: Qualitative comparison of GET3D to the baseline methods in terms of extracted 3D geometry. GET3D is able to generate shapes with much higher geometric detail across all categories.

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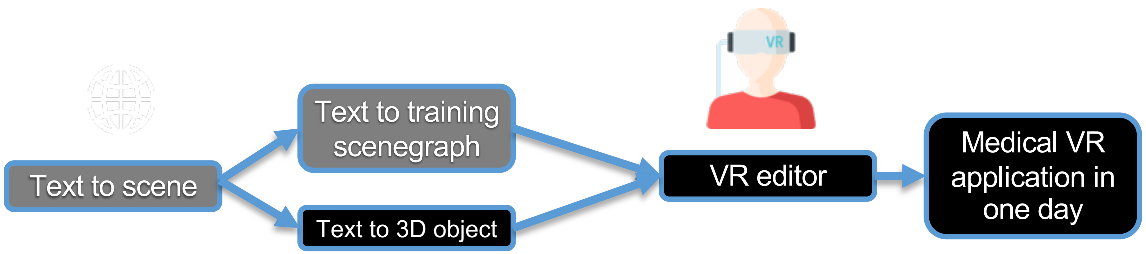
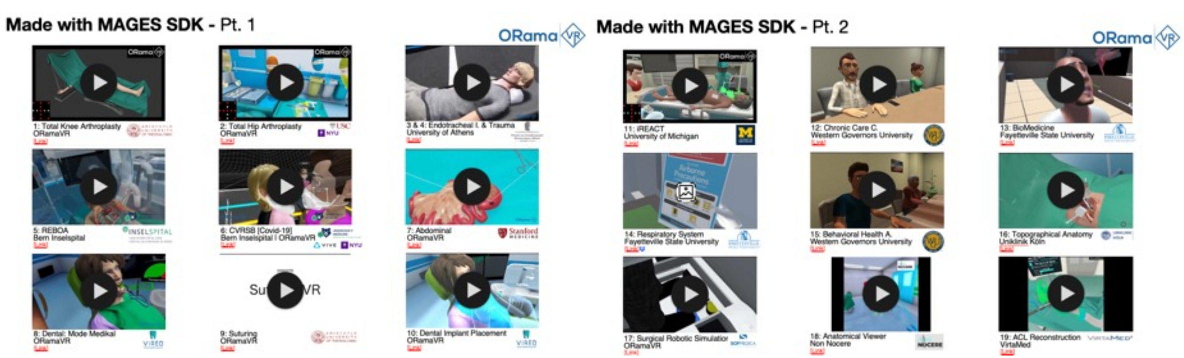
6Gs of low/no code:
Generative AI & GNNs, our approach

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

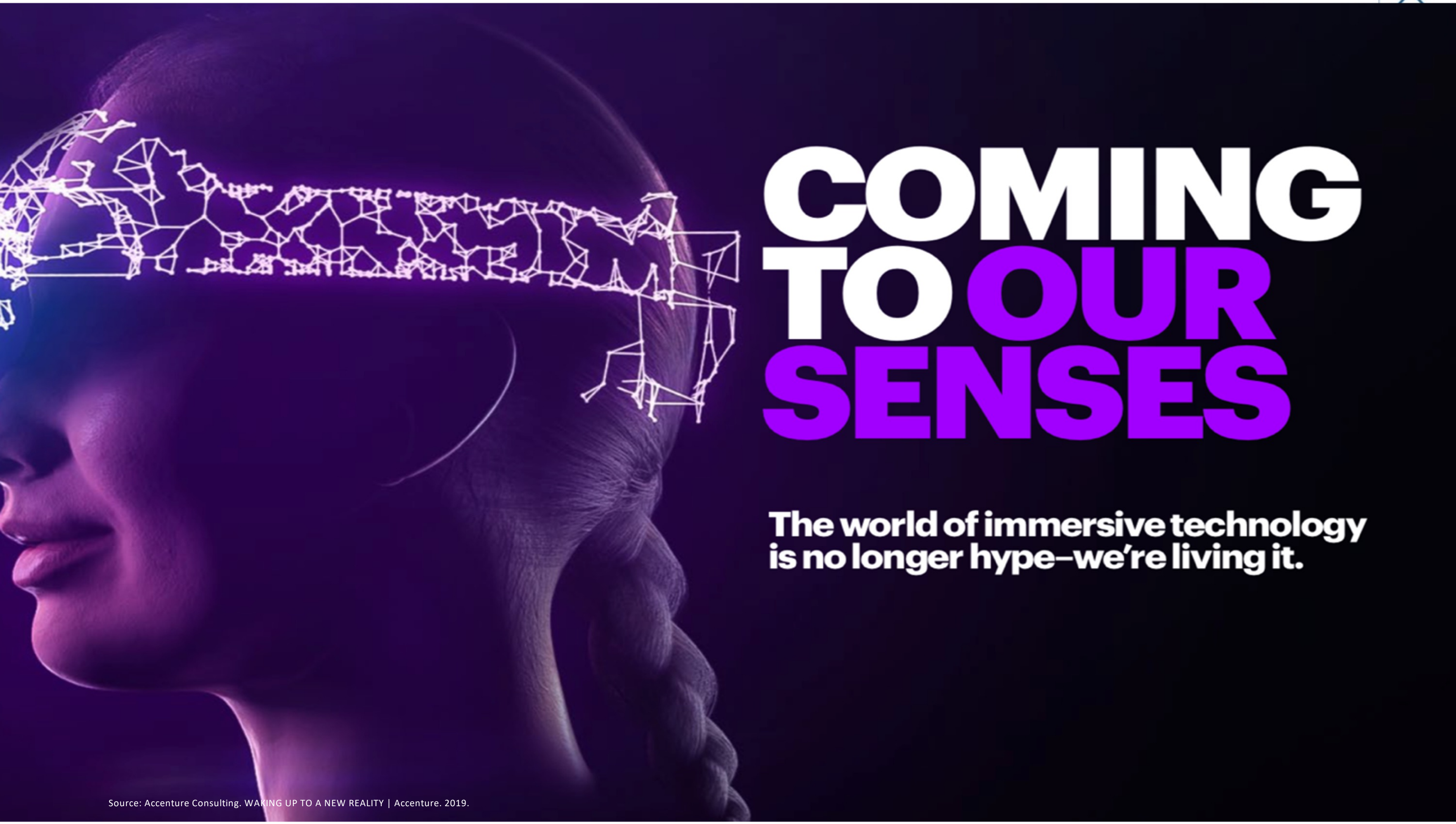


MAGES SDK Low-code platform*
(*support all VR/AR/mobile h/w devices, 1 developer needed*)

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

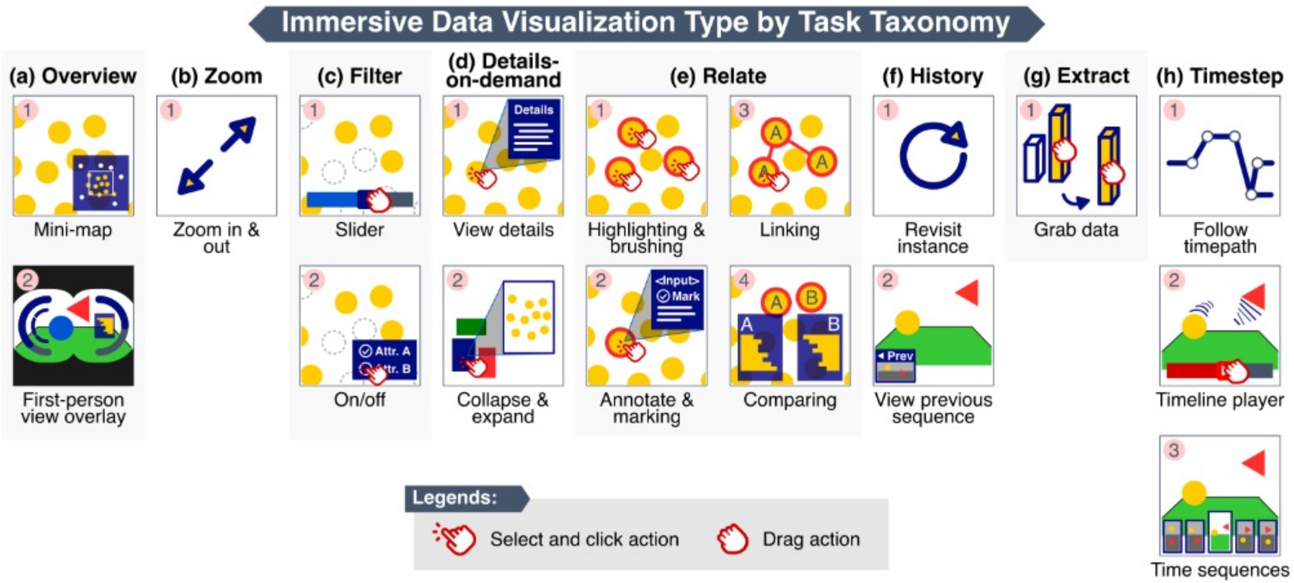


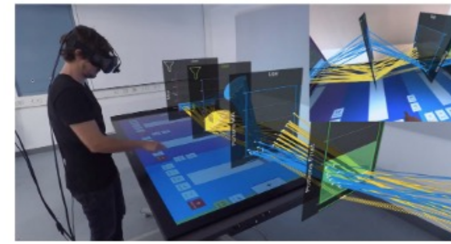
* P. Zikas *et al.*, "MAGES 4.0: Accelerating the World's Transition to VR Training and Democratizing the Authoring of the Medical Metaverse," in *IEEE Computer Graphics and Applications*, vol. 43, no. 2, pp. 43-56, 1 March-April 2023, doi: 10.1109/MCG.2023.3242686., https://ieeexplore.ieee.org/document/10038619

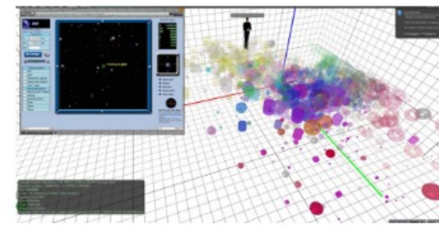


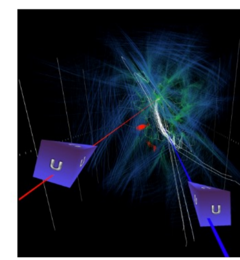
Source: Accenture Consulting. WAKING UP TO A NEW REALITY | Accenture. 2019.

Generated realms:
Immersive visual analytics, state-of-the-art









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Generated realms:
Immersive visual analytics, our approach

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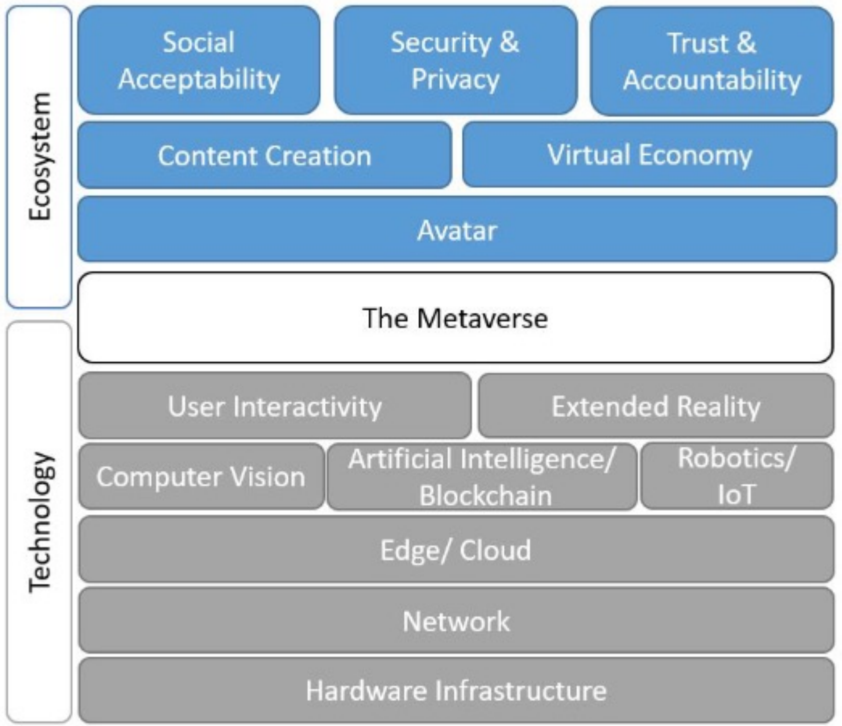
Generated realms:
Metaverse, state-of-the-art

Technology terms use

and tec

2020
Multiplayer game
Virtual Reality experience
Augmented Reality filter
5G Connection
AR Cloud
Digital Avatar
Digital Event
ML classifier
E-commerce
Blockchain
Internet
Social Media
Videocall



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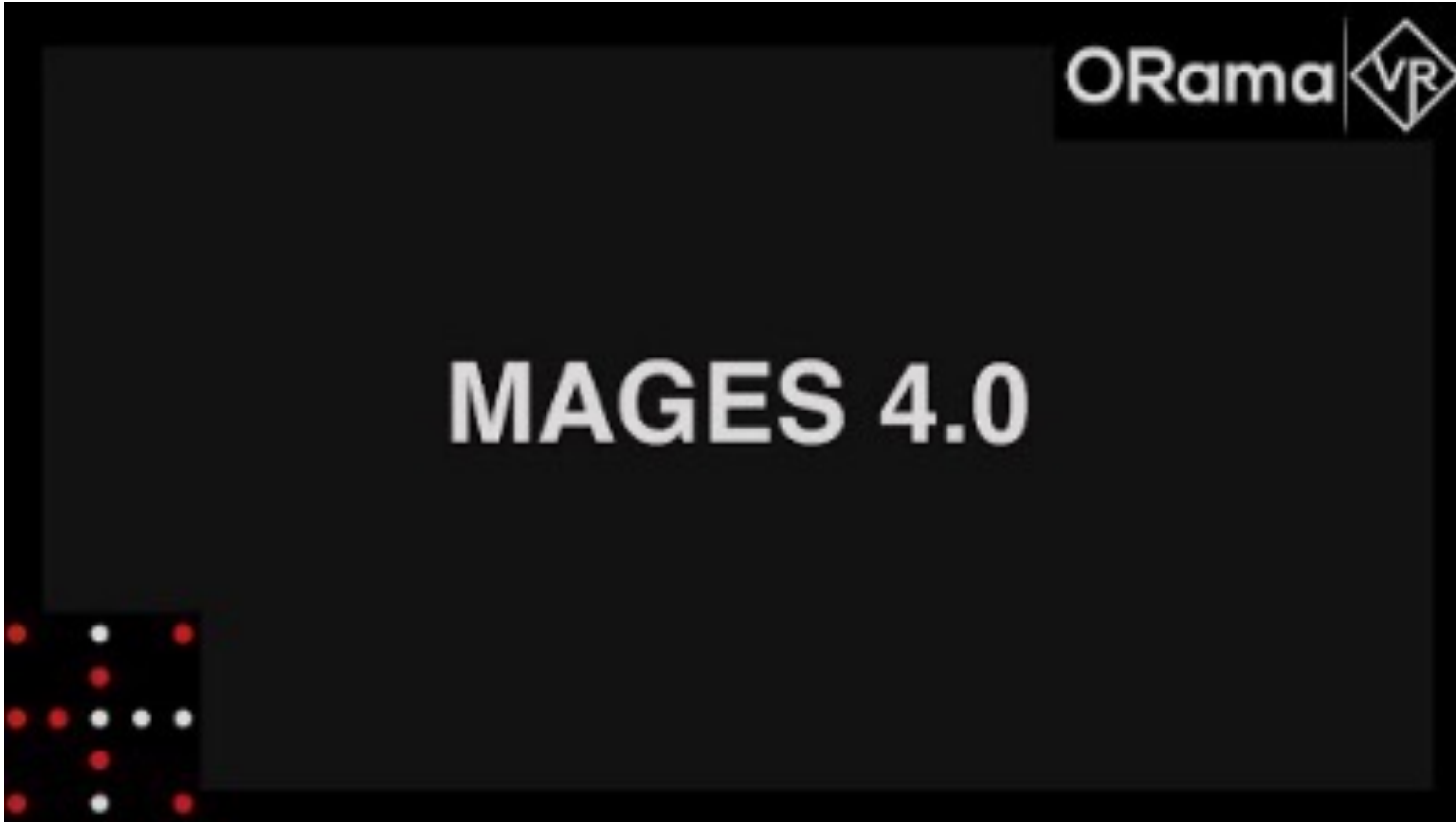
- https://george-papagiannakis.medium.com/my-two-cents-on-the-metaverse-why-it-is-important-and-how-to-build-it-using-latest-computational-e6428666a57c

Generated realms: Metaverse, our approach



*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

Generated realms:
Edverse, state-of-the-art

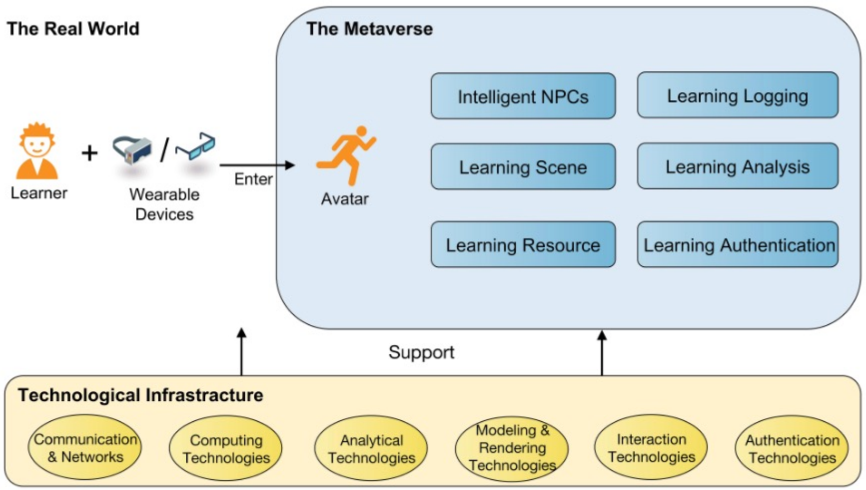
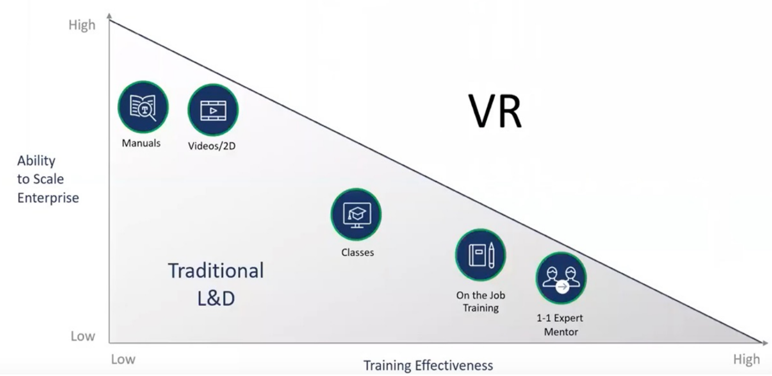


FIGURE 1
The framework of the metaverse in education.

Strong Use Cases

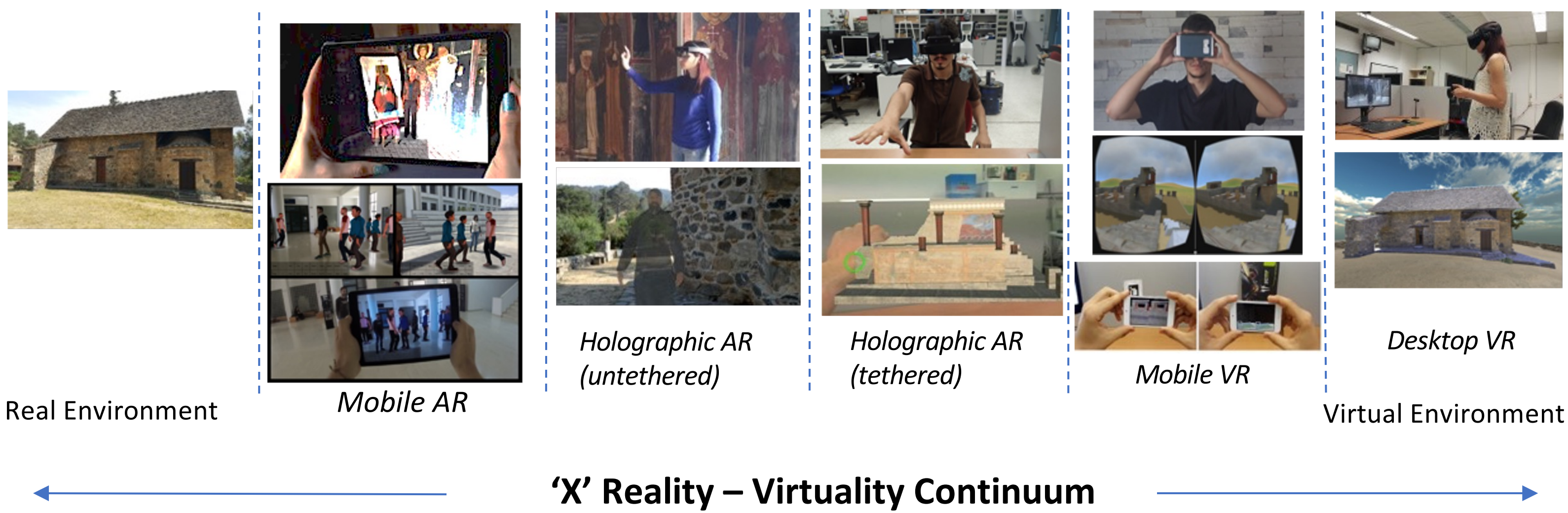
Best Way is "Learning by Doing", BUT...

Transforming the Enterprise Training Landscape



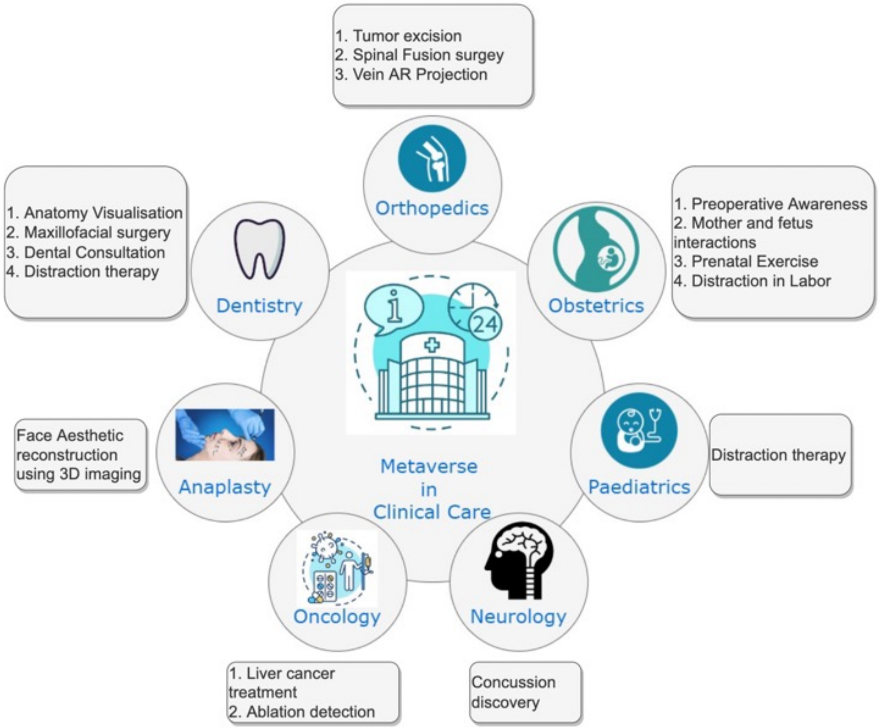
- Zhang, X., Chen, Y., Hu, L. & Wang, Y. The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. *Front Psychol* **13**, 1016300 (2022)
- Source: STRIVR webinar: http://www.virtualrealityrental.co/blog-post/applications-of-virtual-reality Webinar - STRIVR - Virtual Reality for Employee Training

Generated realms: Edverse, our approach



Ioannides, M., Magnenat-Thalmann, N., Papagiannakis, G., (Eds), Mixed Reality and Gamification for Cultural Heritage, Springer-Nature, DOI: 10.1007/978-3-319-49607-8, 2017

Generated realms: Medverse, state-of-the-art



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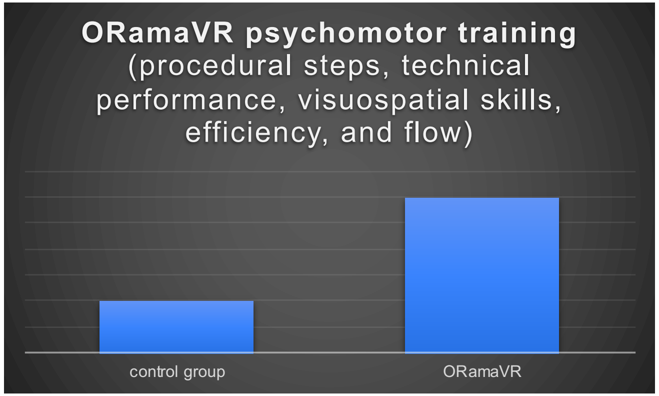
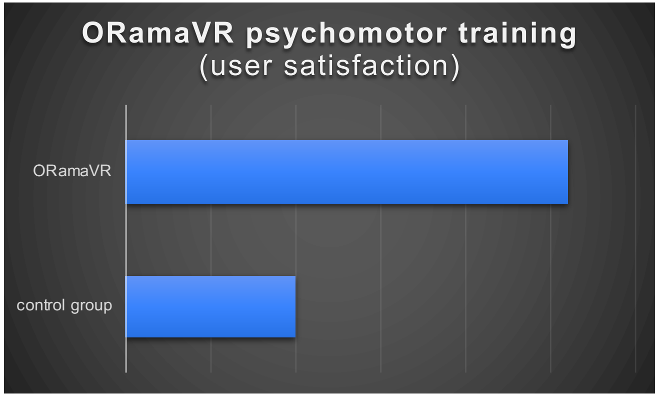
Generated realms: Medverse, our approach

We have proven that medical VR training facilitates skills transfer from the virtual world to the real



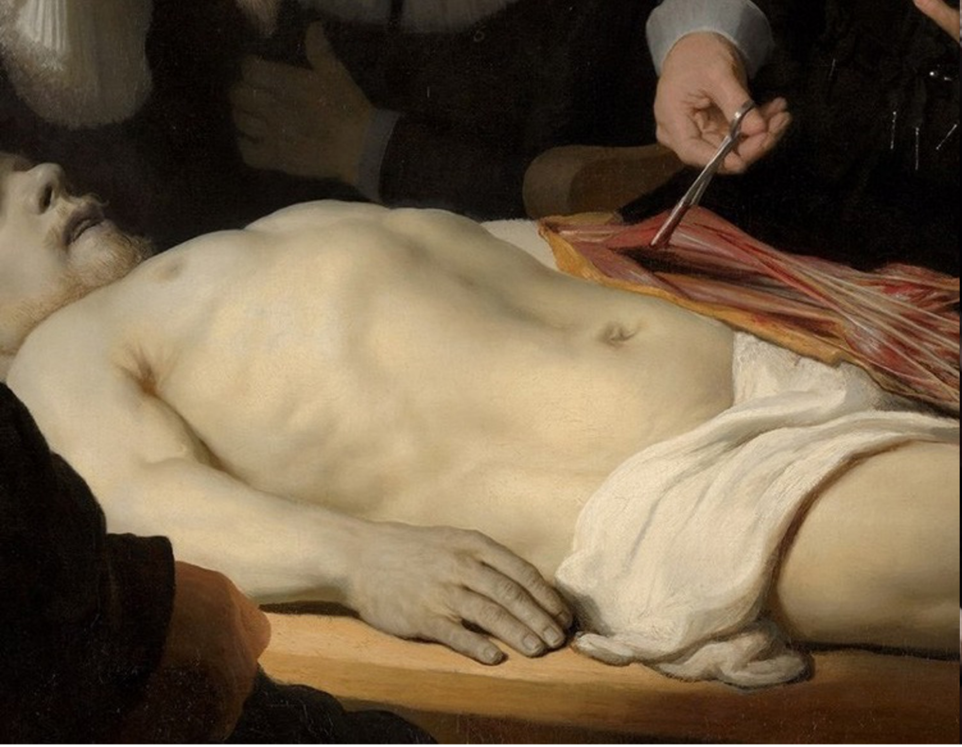
Hooper et al 2019, NYU, USA (N=14), Journal of Arthroplasty*



Birrenbach et al 2021, Inselspital, Switzerland (N=29), Journal of Medical Internet Research*

- *https://www.sciencedirect.com/science/article/pii/S0883540319303341
- https://games.jmir.org/2021/4/e29586/

https://www.mauritshuis.nl/en/press/persarchief/2019/rembrandt-reality/



Computational science + XR experiential technologies ?

Computational Science & Innovation

Science, Computational Science, and Computer Science: **At a Crossroads**

The U.S. Congress passed the High Performance Computing and Communications Act, commonly known as the HPCC, in December 1991. This act focuses on several aspects of computing technology, but two have received the most attention: computational science as embodied in the Grand Challenges (Table 1) and the National Research and Educational Network (NREN). The Grand Challenges are engineering and scientific problems considered vital to the economic well-being of the U.S. Many of these problems, such as drug design and global climate modeling, have worldwide impact. The NREN is to be an extremely high speed network, capable of transmitting in the terabit-per-second range—approximately ten times faster than we can currently transmit data. The exact goals of the HPCC are published in a pamphlet and updated annually [7].

The science and engineering components of the HPCC require an interdisciplinary approach to solving very difficult problems. The solutions require the concerted actions of physical scientists, engineers, mathematical scientists, and computer scientists. Computational science embraces this collaborative effort among many diverse disciplines. In the final analysis, the "answer" may have to be pieced together from the many viewpoints.

Our purpose is to ask whether today's computer scientists are able to take up the challenge of computational science. Some might argue that computational science is not an interest of computer science; that current areas of interest comprise the total domain. Indeed, it is strange that one has to argue for scientific applications as a part of computer science, since, after all, modern computing's roots are in scientific and engineering applications.

An exact definition of *computational science* is open to debate. There are many programs in the U.S. and elsewhere that use the term, and each program probably has its own view of computational science. We outline the Clemson University view of computational science as one possible approach. That view recognizes three components to computational science: applications, algorithms, and architectures. We visualize this as a pyramid supporting the science and engineering. Applications need not be restricted to the traditional science and engineering applications; for example, complex econometric models can also benefit from computational science.

The conduct of computational science, in the Clemson view, is interdisciplinary. This interdisciplinary thinking demands that the constituent disciplines (physical sciences, engineering, mathematics, computer science) maintain their autonomy. Within computational science, a computer scientist retains expertise in computer science, but emphasizes applications in science or engineering.

Although computational science is not for every computer scientist, computational science is an idea whose time has come—again. Our premises:

1. Computational science is addressing problems that have important implications for humankind. These problems are complex and their

D. E. Stevenson. 1994. Science, computational science, and computer science: at a crossroads. Commun. ACM 37, 12 (Dec. 1994), 85–96. DOI:https://doi.org/10.1145/198366.198386

Why Computational Science?

An interdisciplinary field (physical sciences, engineering, mathematics, computer science) whose time has come – again:

- Addressing complex problems that have important implications to humankind,
- Unlikely to succeed in near term without further advances in software and hardware
- Computer science is generally not participating in science or engineering applications or preparing students to do so

Computational Science & Innovation: Computational medical XR

***Computational medical XR** is a new interdisciplinary field, bridging life sciences, with mathematics, engineering and computer science.*
*It unifies **computational** science (scientific computing) with intelligent **extended reality** and spatial computing for the **medical** field.*

It extends significantly [clinical XR]() by

- *bringing on computer **simulation** and other forms of **computation***
- *from **numerical** analysis, computational **geometry**, computational **vision** and computer **graphics** with theoretical computer science and machine **learning**, in order to solve **hard problems** in medicine*

Papagiannakis, G., "A computational medical XR discipline", https://arxiv.org/abs/2108.04136,

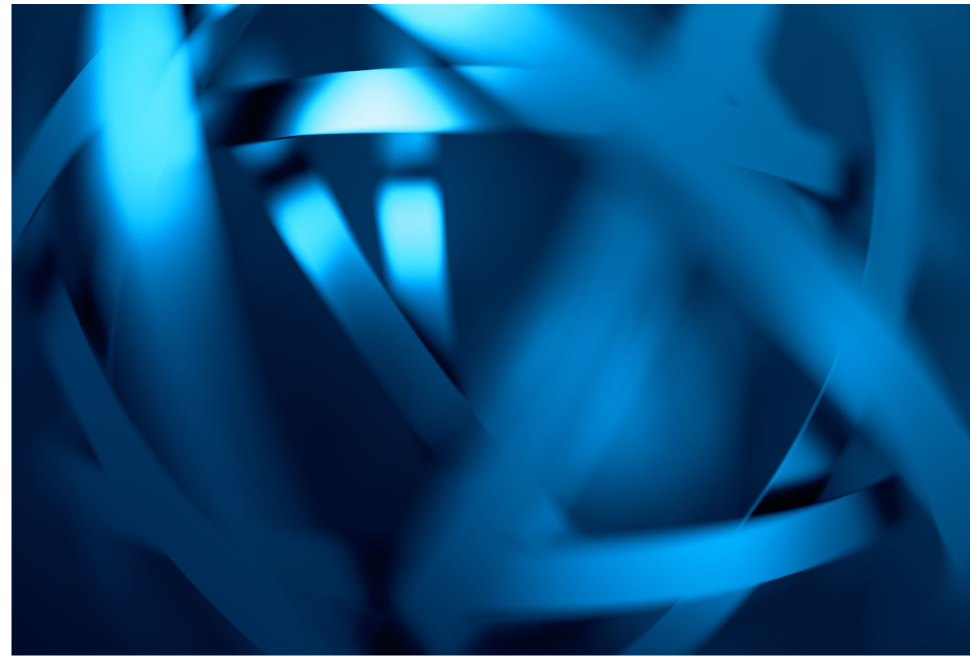
Computational Science & Innovation:
"do good" (while making $)

ORama VR

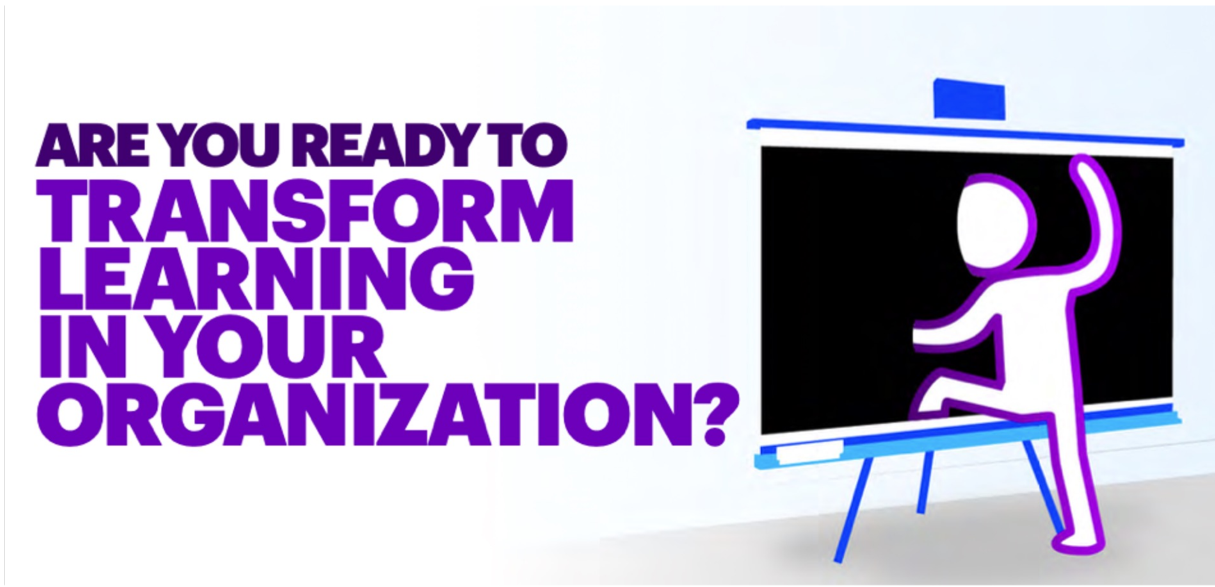
- Fast-growing FORCE in Universitiies:
  - Influence technology and business models: **<u>"do good" (while making $)</u>**
  - Growing realization that you can actually set norms, guidelines and even standards in new ventures for positive social purpose, and do this as a FOR-PROFIT *(not as NFP)*
  - Over the 30 social innovation champion students at Stanford GSB, 26 are working on big, social problems and are for profits! *(complete flip form 7-10 years ago!) [Steve Ciesinski, Stanford GSB and ex-SRI president]*

Computational Science & Innovation: Linear model of innovation?

- Propagated by Vannevar Bush, 1945: **basic curiosity-driven science is the seed corn that eventually leads to new technologies and innovations**
- Matt Ridley points out in his book How Innovation Works, sometimes it's a two-way street: "**It is just as often the case that invention is the parent of science: techniques and processes are developed that work, but the understanding of them comes later**



Conclusions



- XR computing is transforming education & training
- Several grand challenges still exist on authoring the forthcoming metaverse
- No-code (generative AI) tools have arrived and are transforming software 2.0

Final quotes

The scene is set for massive change

"Geometry will draw the soul towards truth and create the spirit of philosophy"
Plato

"You keep on learning and learning, and pretty soon you learn something no one has learned before"
Richard Feynman

“Meaninglessness inhibits fullness of life and is therefore equivalent to illness. Meaning makes a great many things endurable—perhaps everything”
C. Jung

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

Let’s accelerate world’s transition to VR training!

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Visiting Prof. University of Geneva
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