Neurosymbolic AI for scaling Computational Medical XR

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FORTH
Foundation for Research & Technology - Hellas

ORama VR

UNIVERSITÉ DE GENÈVE

Overview

- From VR and AI to Computational Medical XR
- Neurosymbolic AI for XR?
- Our approach

Midjourney prompt:
“a there and back again hobbit house looking from inside towards outside through the open door, cinematic, atmospheric lighting”

From computer graphics **systems** to virtual human **algorithms** to geometric computational **models**


TECHNOLOGIE Réalité et images de synthèse mêlées

LE TOURISME EN 3D EST NÉ


VHD++ Development Framework:
Towards Extendible, Component Based VR/AR Simulation Engine
Featuring Advanced Virtual Character Technologies

Abstract

1. Introduction: The Demand

2. Motivation: Curbing Complexity

2.1. Common Experience: Facing Complexity


UNIVERSITÉ DE GENÈVE

FACULTÉ DES SCIENCES
ÉCONOMIQUES ET SOCIALES
Département de systèmes d'information
Professeur Nadia Magnenat-Thalmann

FACULTÉ DES SCIENCES
Département d'informatique
Professeur José Rolim

An Illumination Registration Model for Dynamic Virtual Humans in Mixed Reality
THÈSE
présentée à la Faculté des Sciences de l'Université de Genève
pour obtenir le grade de Docteur ès sciences, mention informatique

par
Georgios Papagiannakis
de
Crète (Grèce)

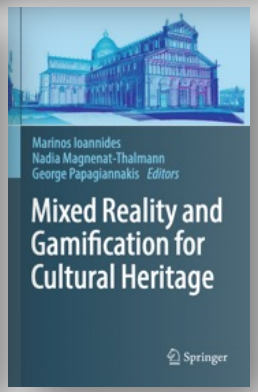
Thèse N° 3795

GENÈVE
Atelier de reproduction de la Section de physique
2006


Advances in Applied Clifford Algebras

Preface for Special Issue on Geometric Algebra in Computer Science and Engineering

Dietmar Hildenbrand, Eckhard Hitzer* and George Papagiannakis


Marinos Ioannides
Nadia Magnenat-Thalmann
George Papagiannakis Editors

Mixed Reality and Gamification for Cultural Heritage

Springer


Nadia Magnenat-Thalmann · Jian Zhang · Jinman Kim · George Papagiannakis · Bin Sheng · Daniel Thalmann · Marina Gavrilova (Eds.)

LNCS 13443

Advances in Computer Graphics

39th Computer Graphics International Conference, CGI 2022
Virtual Event, September 12–16, 2022
Proceedings

Springer

MOREMEDIA

IEEE Computer Graphics and Applications

Metaverse: Technologies for Virtual Worlds

IEEE COMPUTER SOCIETY

UNIVERSITÉ DE GENÈVE

FORTH
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Augmenting Human intellect?

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.

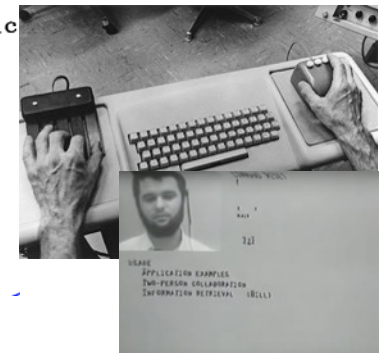
CONTRACT AF 49(638)-1024

By: D. C. Engelbart

SRI Project No. 3578

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.

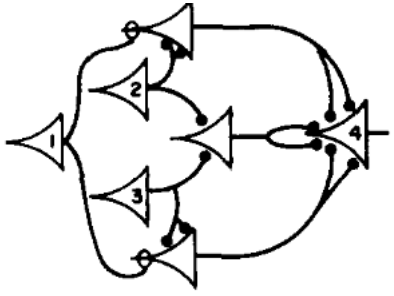
He is designing a building. He has already dreamed up several basic layouts and structural forms, and is trying them out on the screen. The surveying data for the layout he is working on now have already been entered, and he has just coaxed the "clerk" to show him a perspective view of the steep hillside 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.



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 , 1968

Simulating the human brain?

Establishment of a new research program at Cornell Aeronautical Laboratory, Inc. is proposed, with the objective of designing, fabricating, and evaluating an electronic brain model, the photoperceptron. The proposed pilot model will be capable of "learning" responses to ordinary visual patterns, or forms. The system will employ a new theory of memory storage, (the theory of statistical separability), which permits the recognition of complex patterns with an efficiency far greater than that attainable by existing computers. Devices of this sort are expected ultimately to be capable of concept formation, language translation, collation of military intelligence, and the solution of problems through inductive logic.



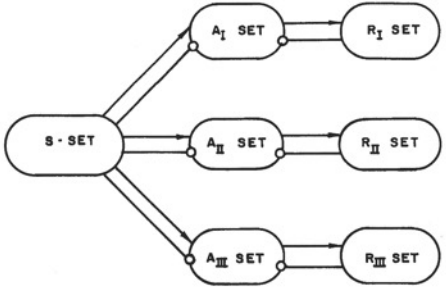
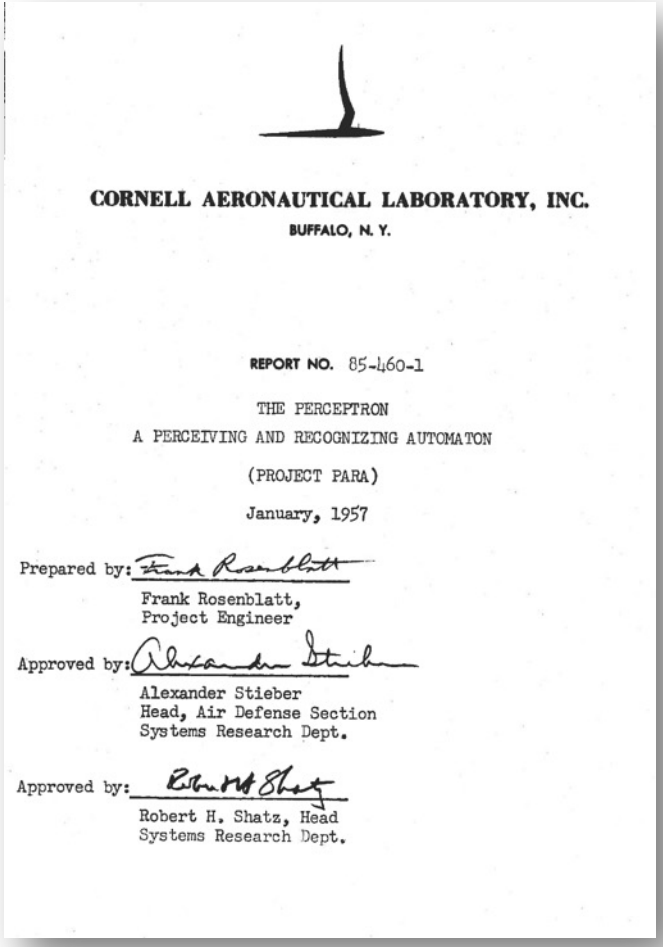


FIGURE 2

ORGANIZATION OF A PERCEPTRON WITH THREE INDEPENDENT OUTPUT-SETS



CORNELL AERONAUTICAL LABORATORY, INC.

BUFFALO, N. Y.

REPORT NO. 85-460-1

THE PERCEPTRON

A PERCEIVING AND RECOGNIZING AUTOMATON

(PROJECT PARA)

January, 1957

Prepared by: Frank Rosenblatt

Frank Rosenblatt,
Project Engineer

Approved by: Alexander Stieber

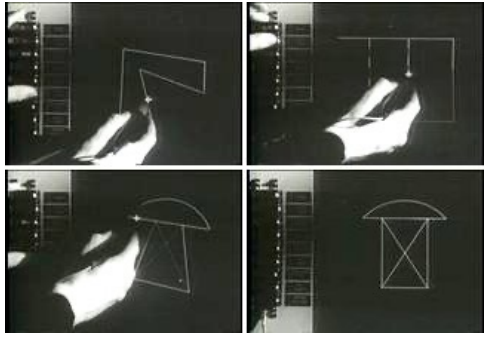
Alexander Stieber
Head, Air Defense Section
Systems Research Dept.

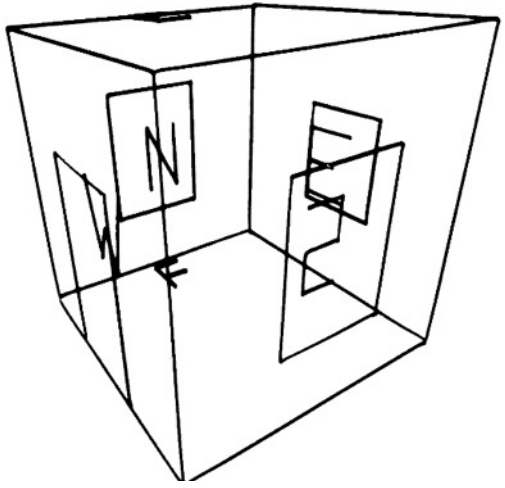
Approved by: Robert H. Shatz

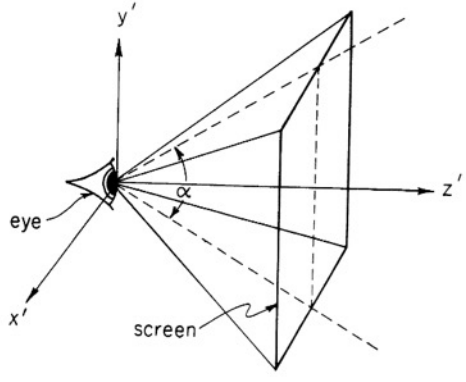
Robert H. Shatz, Head
Systems Research Dept.

- F. Rosenblatt, the perceptron - a perceiving and recognizing automaton, 1957
- McCulloch, W. & Pitts, W. A LOGICAL CALCULUS OF THE IDEAS IMMANENT INNERVOUS ACTIVITY. Bulletin of MathematicalBiophysics, Vol. 5, pp. 115-133 (1943)

Head Mounted Displays and natural user interaction?

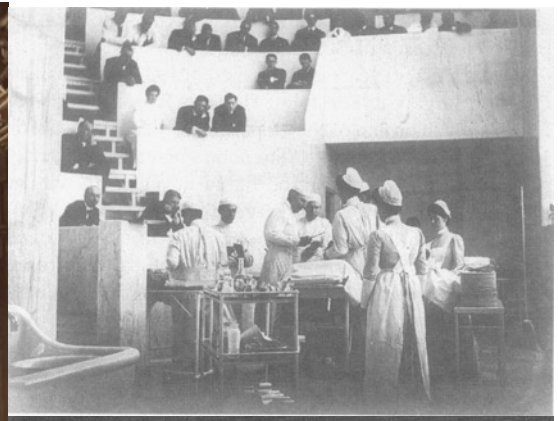


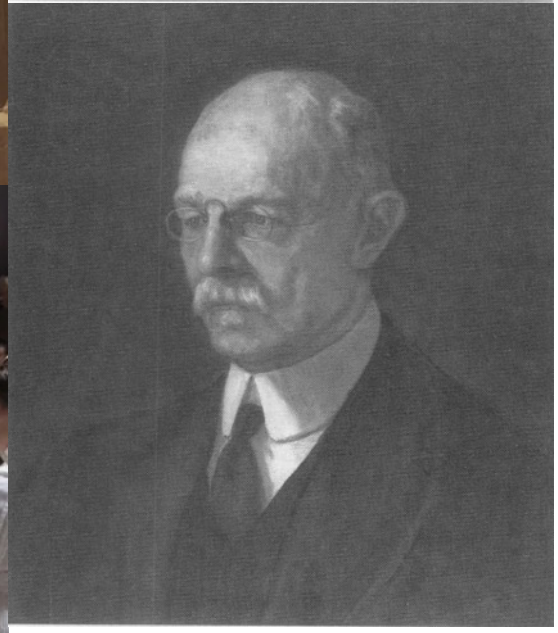




The sketchpad demo: https://youtu.be/6orsmFndx_o,1963
Sutherland, I. E. A head-mounted three dimensional display. *AFIPS Fall Joint Computing Conference* 757–764 (1968) doi:10.1145/1476589.1476686. https://youtu.be/eVUgfUvP4uk

Modern medical training apprenticeship era (residency model)





1878

Dr. W. Halsted, after finishing medical school in Yale, went to Europe to study with the finest doctors of his time, including Dr. Kölliker in Switzerland and Dr. Braun in Germany

1890

Halsted introduces staggering contributions to surgery while at J. Hopkins and a new formal training model

See one, do one, teach one

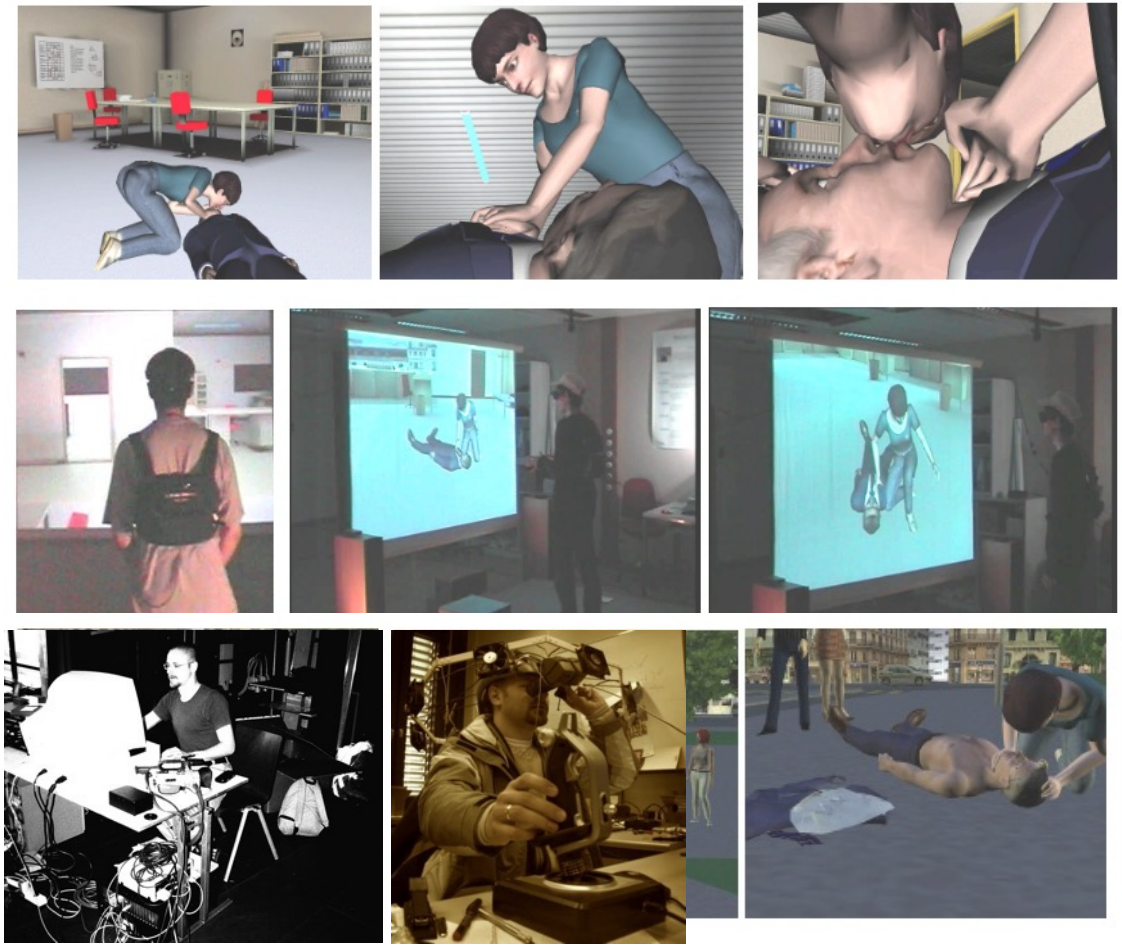
Medical residency model: master – apprentice training program till today

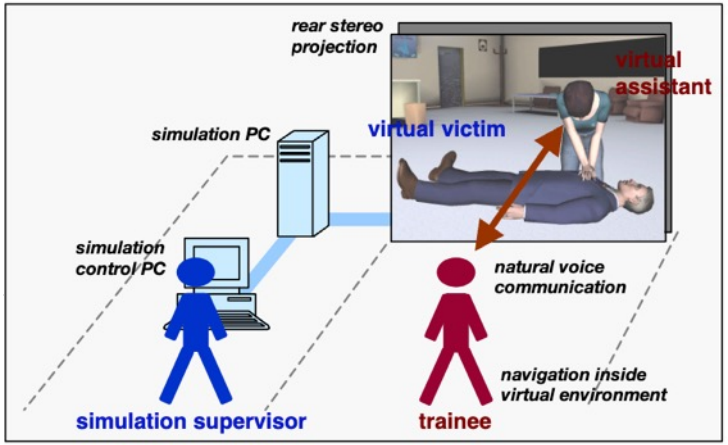
Cameron, john L. William Stewart Halsted. Our Surgical Heritage. *annals of surgery* doi:10.1097/00000658-199705000-00002.

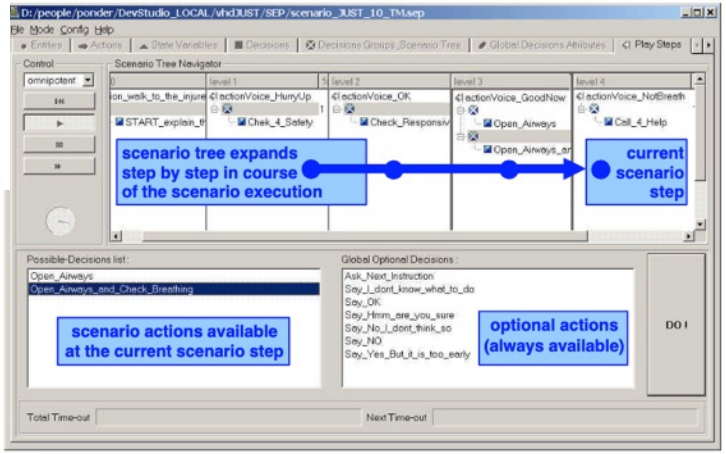
Augmented Reality for education?

Papagiannakis, G. *et al.* Mixing Virtual and Real scenes in the site of ancient Pompeii. *Computer Animation and Virtual Worlds, John Wiley and Sons Ltd* 16, 11–24 (2005)

Virtual Reality for medical training?

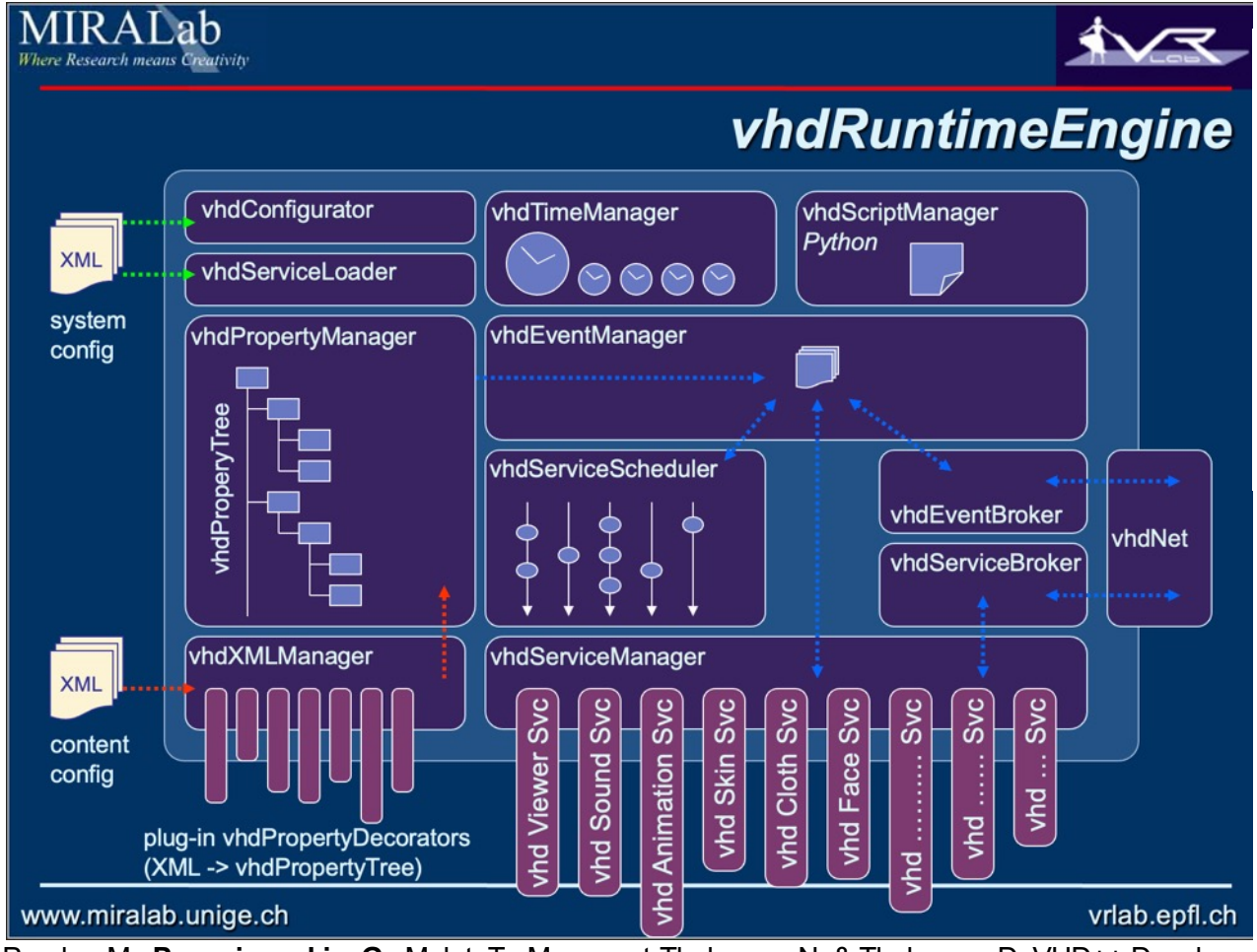


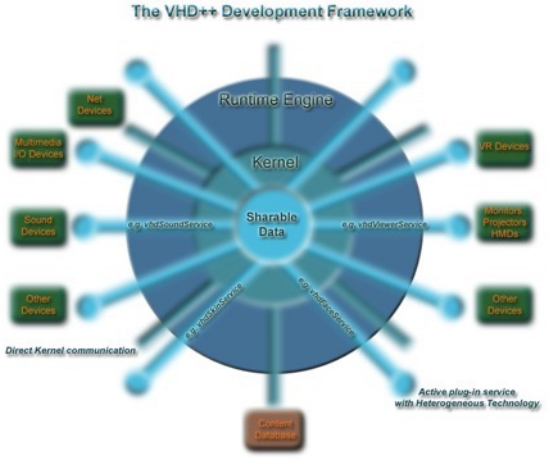




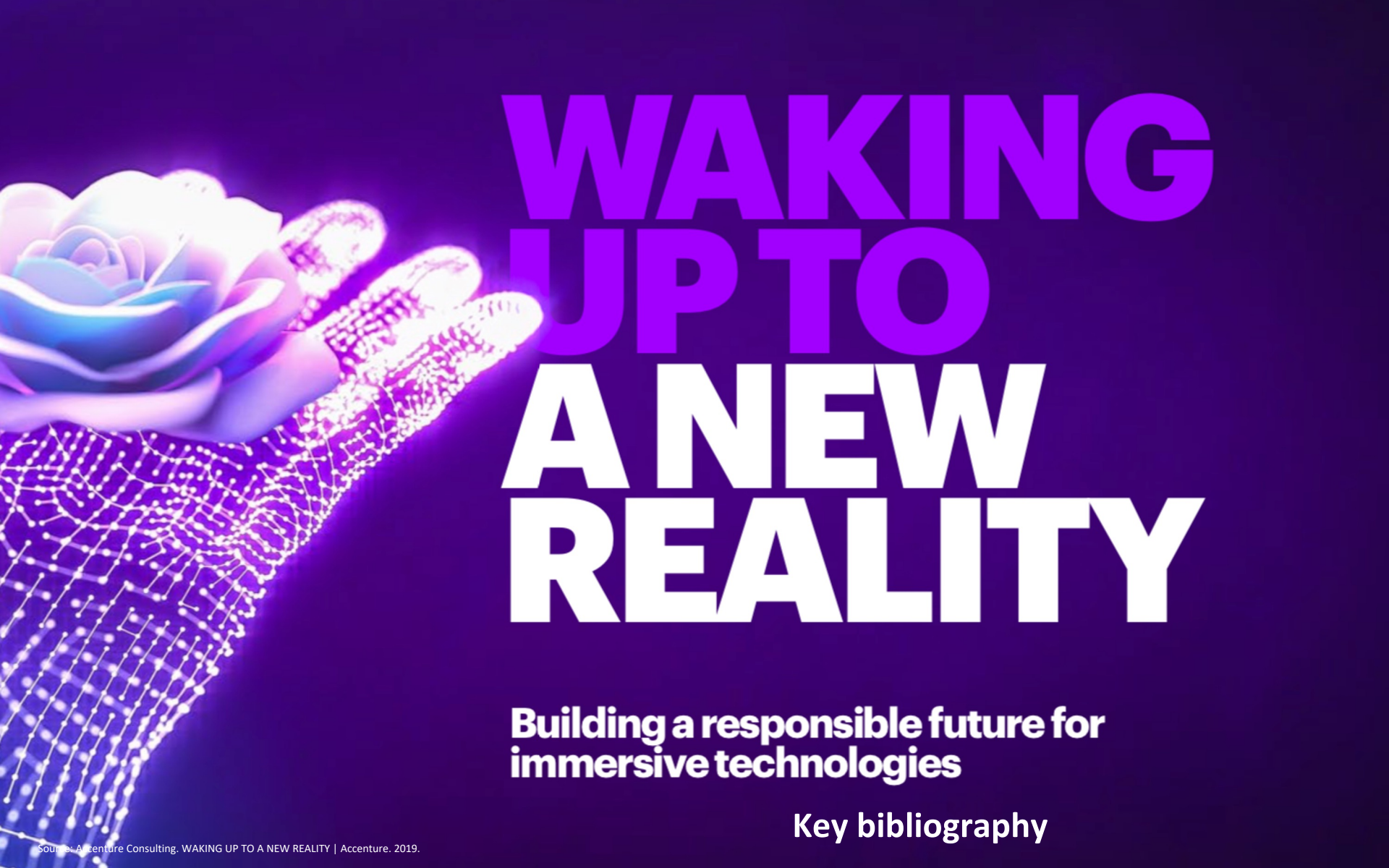
Michal Ponder, Bruno Herbelin, Tom Molet, Sebastien Schertenlieb, Branislav Ulicny, **George Papagiannakis**, Nadia Magnenat-Thalmann, and Daniel Thalmann. 2003. Immersive VR decision training: telling interactive stories featuring advanced virtual human simulation technologies. DOI:https://doi.org/10.1145/769953.769965

Authoring systems for VR/AR virtual human simulations?





Ponder, M., **Papagiannakis, G.,** Molet, T., Magnenat-Thalmann, N. & Thalmann, D. VHD++ Development Framework: Towards Extendible, Component Based VR/AR Simulation Engine Featuring Advanced Virtual Character Technologies. (Computer Graphics International 2003). doi:10.1109/cgi.2003.1214453.



Key bibliography

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

"A deeply human, highly personal, and beautifully told story."
—DAVE EGGERS

JARON LANIER

Author of the *New York Times* bestseller *You Are Not a Gadget*

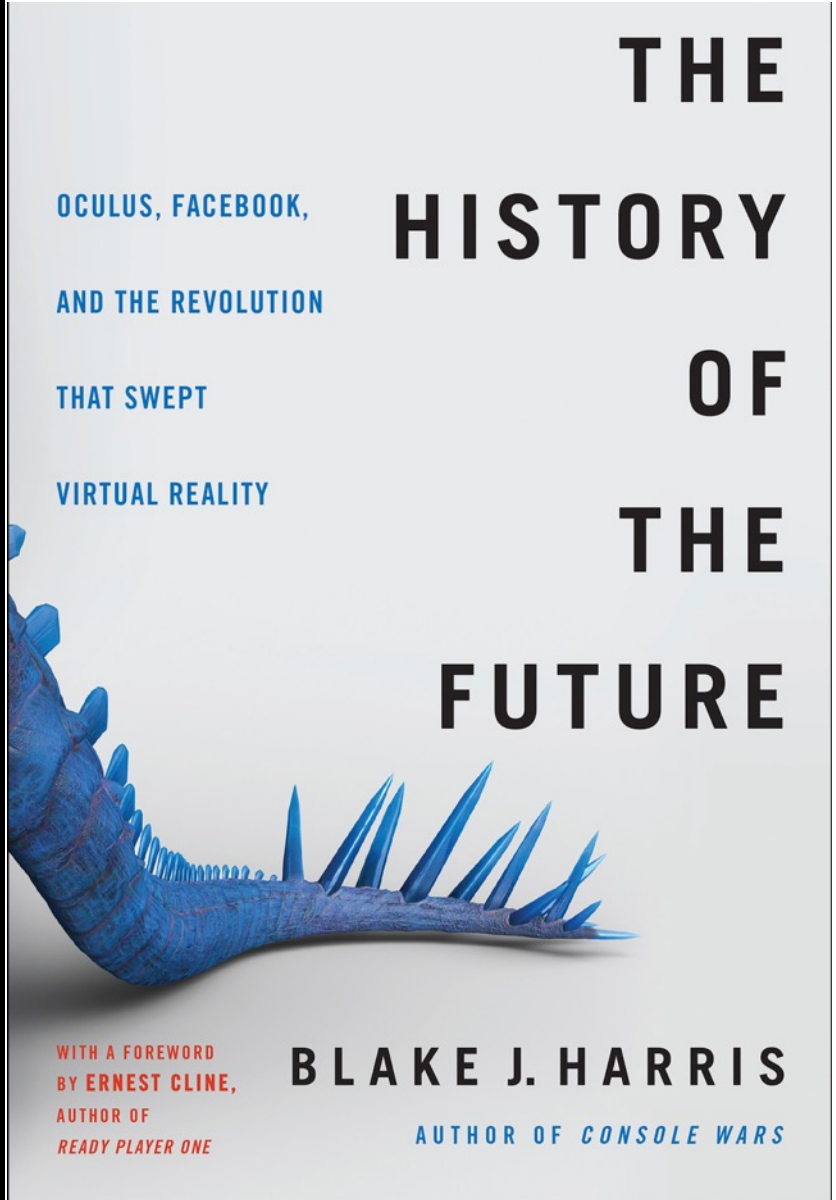
Dawn of the New Everything

ENCOUNTERS with REALITY and VIRTUAL REALITY

PICADOR

THE HISTORY OF THE FUTURE

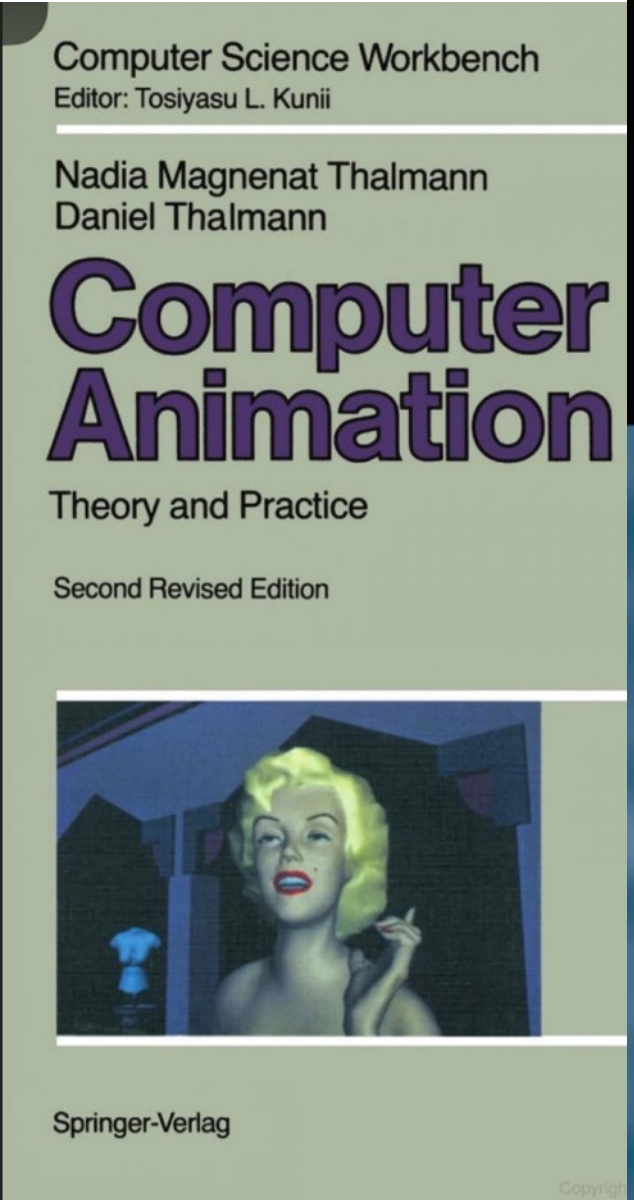
OCULUS, FACEBOOK, AND THE REVOLUTION THAT SWEPT VIRTUAL REALITY

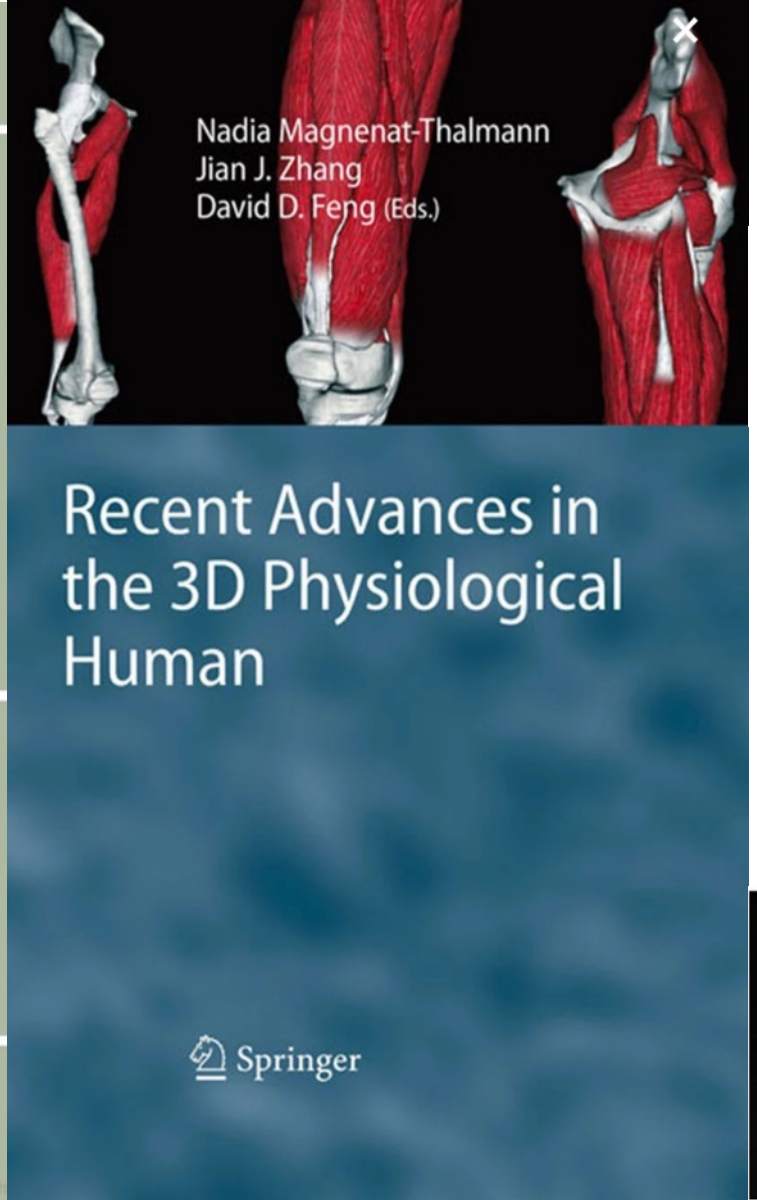


WITH A FOREWORD BY ERNEST CLINE, AUTHOR OF *READY PLAYER ONE*

BLAKE J. HARRIS

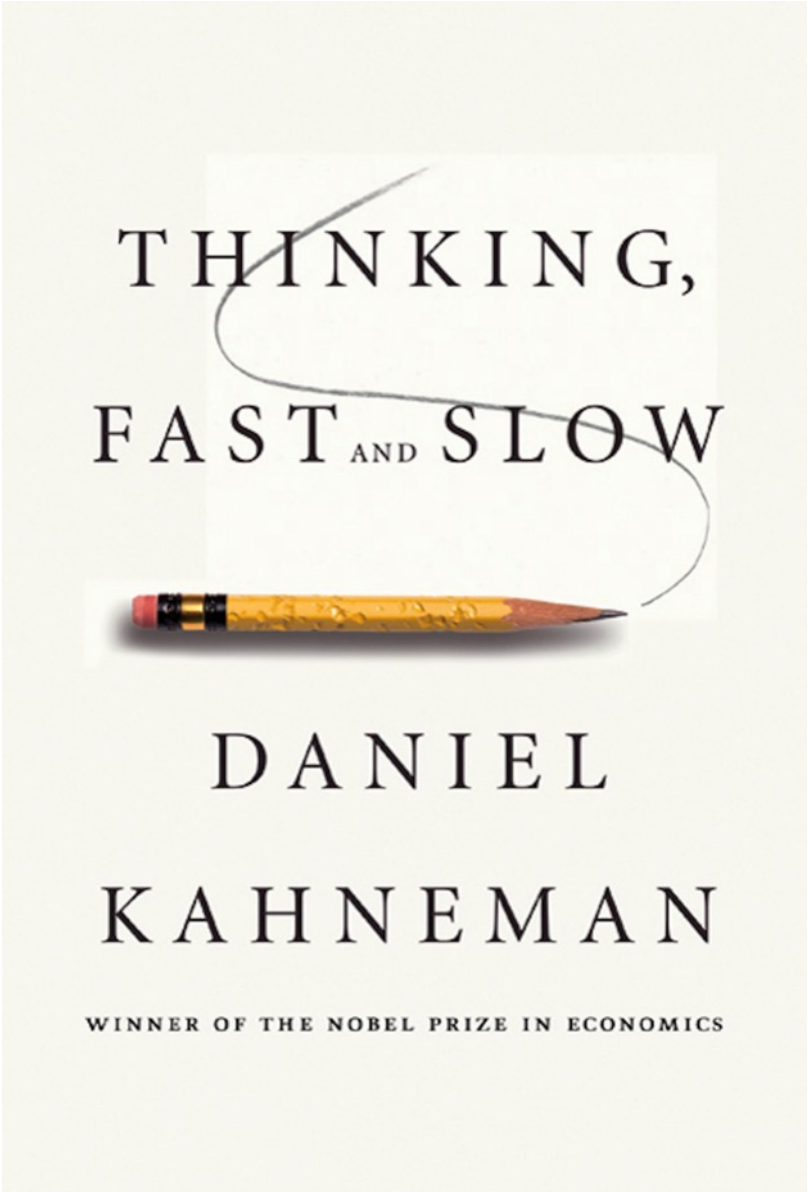
AUTHOR OF *CONSOLE WARS*





Virtual Human Research

Prof. Nadia Magnenat-Thalmann established the field of virtual human research in 1977

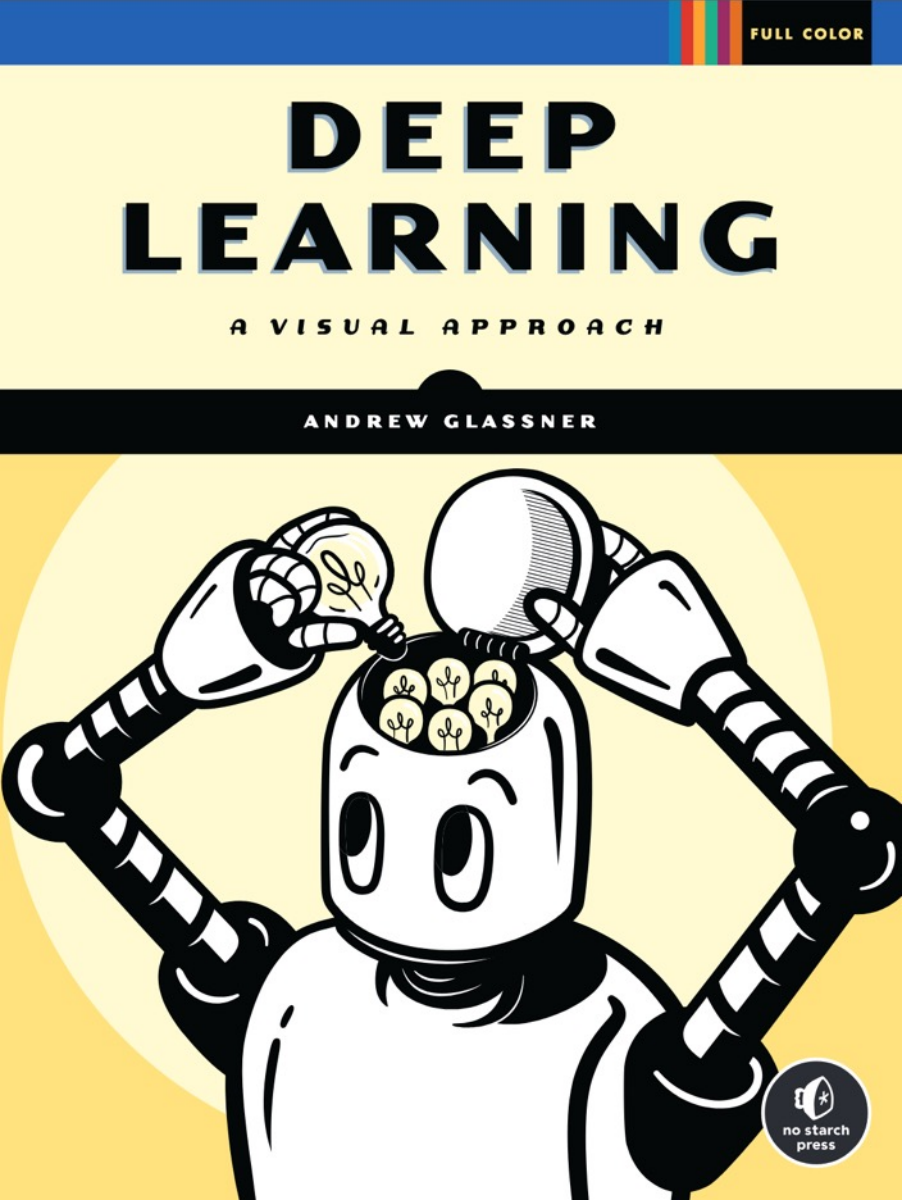


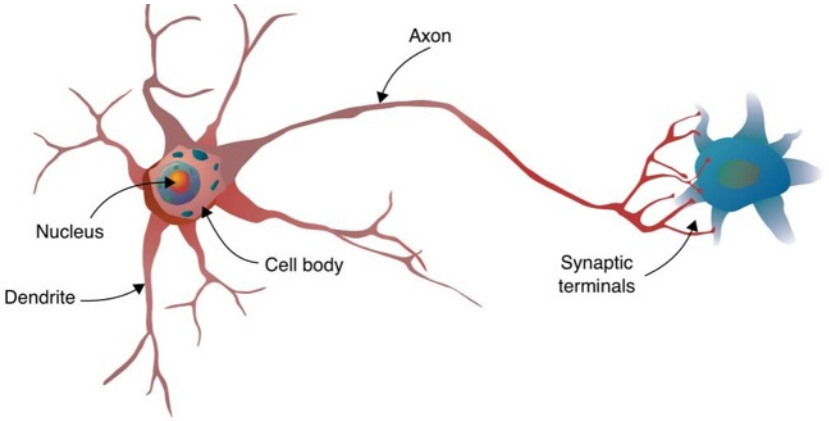
System 1 and System 2

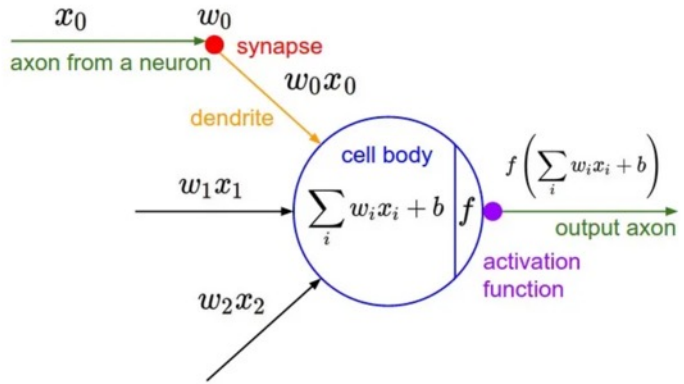
"...as far as I'm concerned, **System 1** certainly knows **language**...
System 2 does involve certain **manipulation** of **symbols**". *D. Kahneman, AAAI-2020*

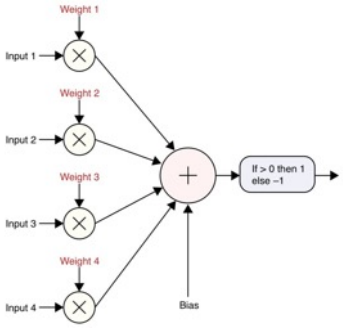
which would in principle be modelled by deep learning and symbolic reasoning, respectively! [Sheth et al 2023]

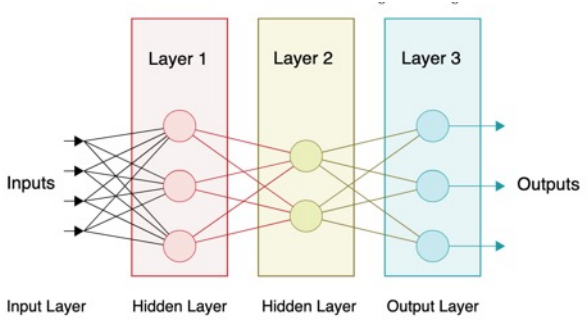
Sheth, A., Roy, K. & Gaur, M.
Neurosymbolic AI - Why, What, and How. *arXiv* (2023) doi:10.48550/arxiv.2305.00813.


FULL COLOR
DEEP
LEARNING
A VISUAL APPROACH
ANDREW GLASSNER
no starch
press

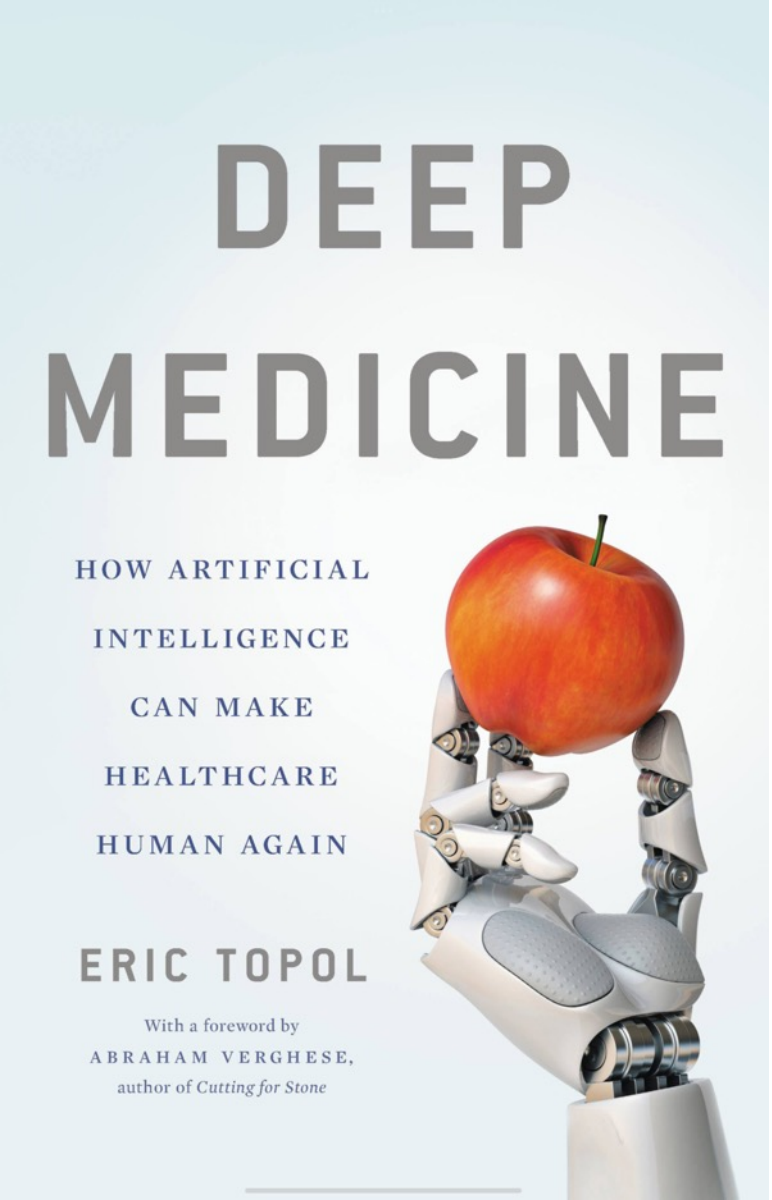

Axon
Nucleus
Cell body
Dendrite
Synaptic
terminals

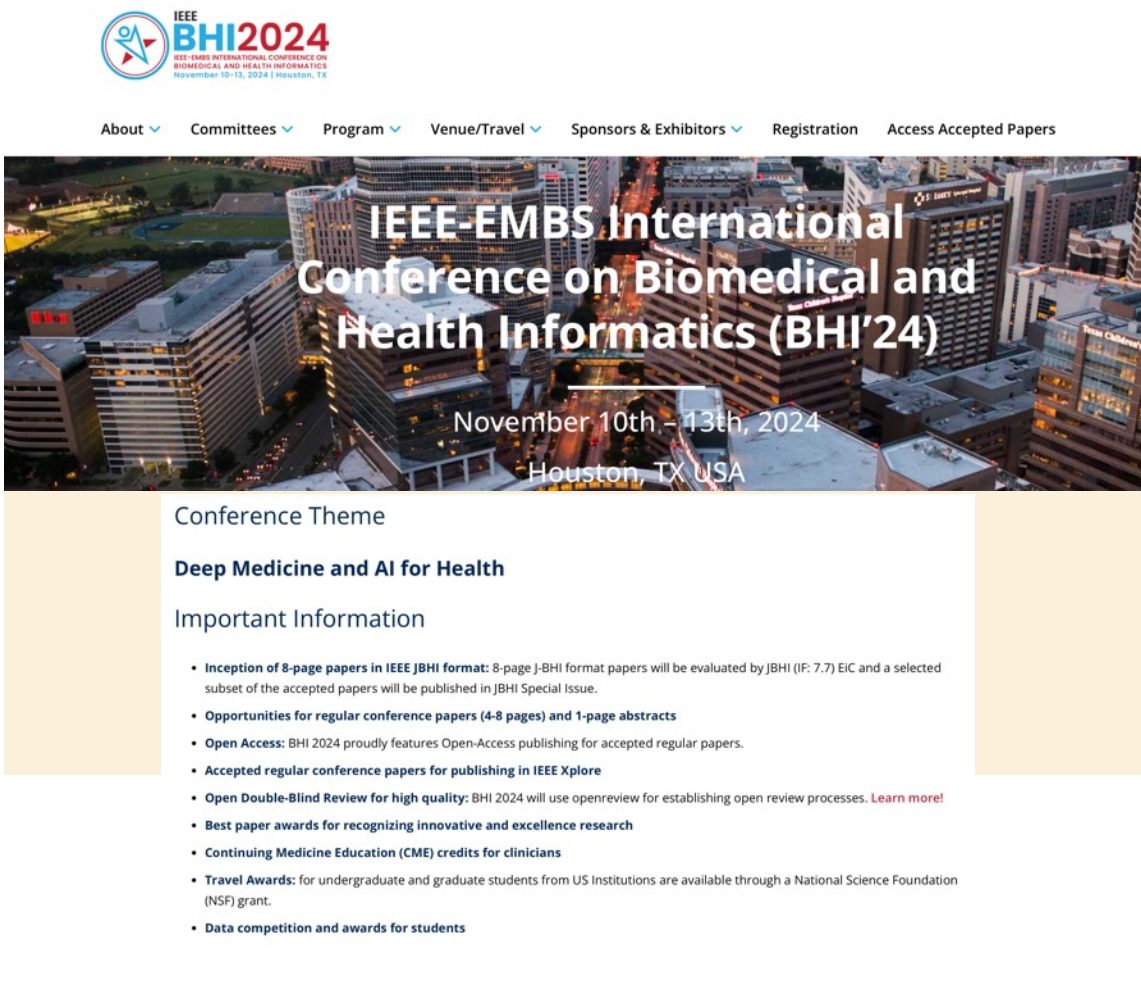

x_0
w_0
axon from a neuron
synapse
$w_0 x_0$
dendrite
cell body
$w_1 x_1$
$\sum_i w_i x_i + b$
f
$f\left(\sum_i w_i x_i + b\right)$
output axon
activation
function
$w_2 x_2$

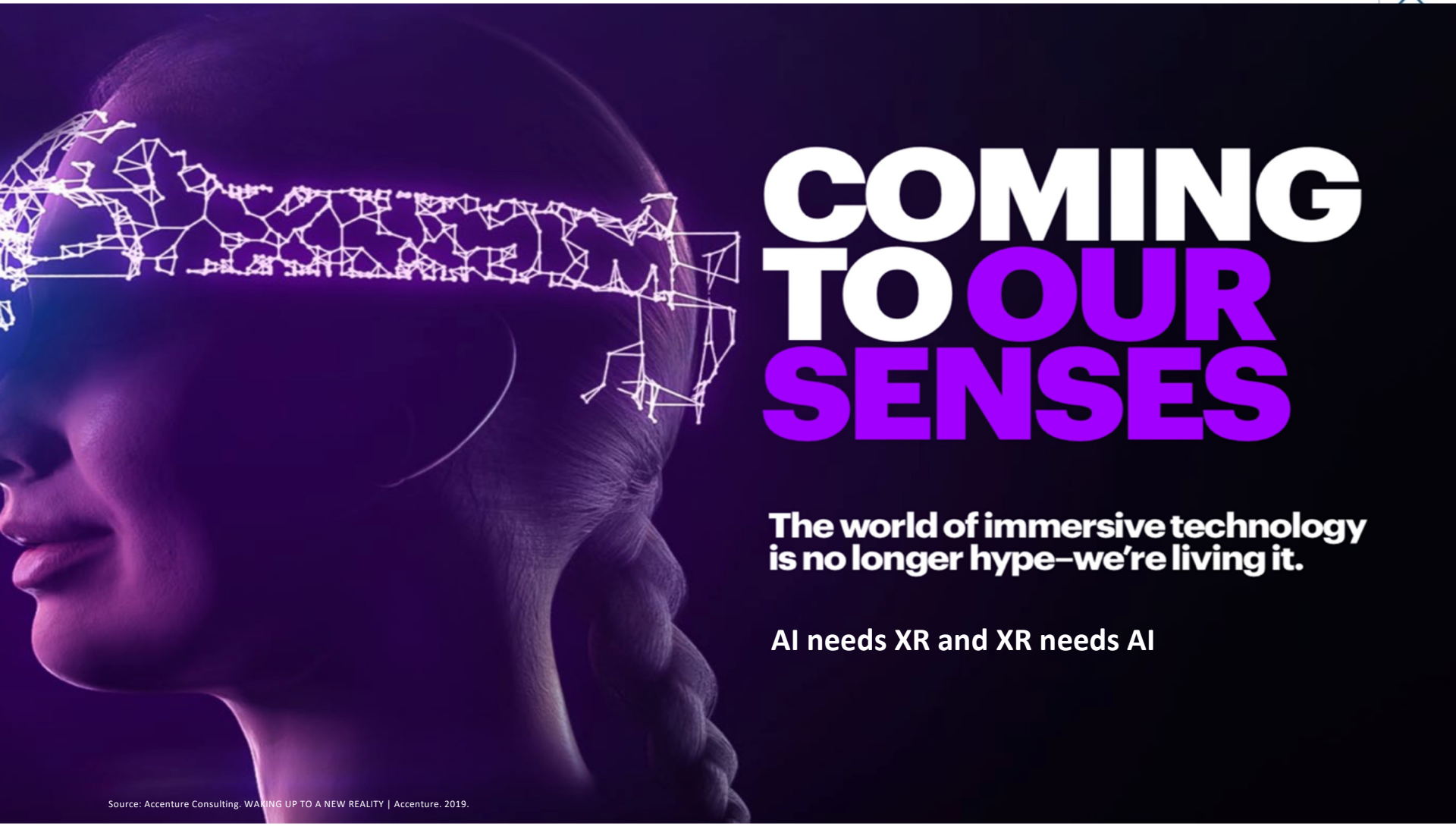

Weight 1
Input 1
Weight 2
Input 2
Weight 3
Input 3
Weight 4
Input 4
If > 0 then 1
else −1
Bias


Layer 1
Layer 2
Layer 3
Inputs
Outputs
Input Layer
Hidden Layer
Hidden Layer
Output Layer

Three components of the deep medicine model







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

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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.

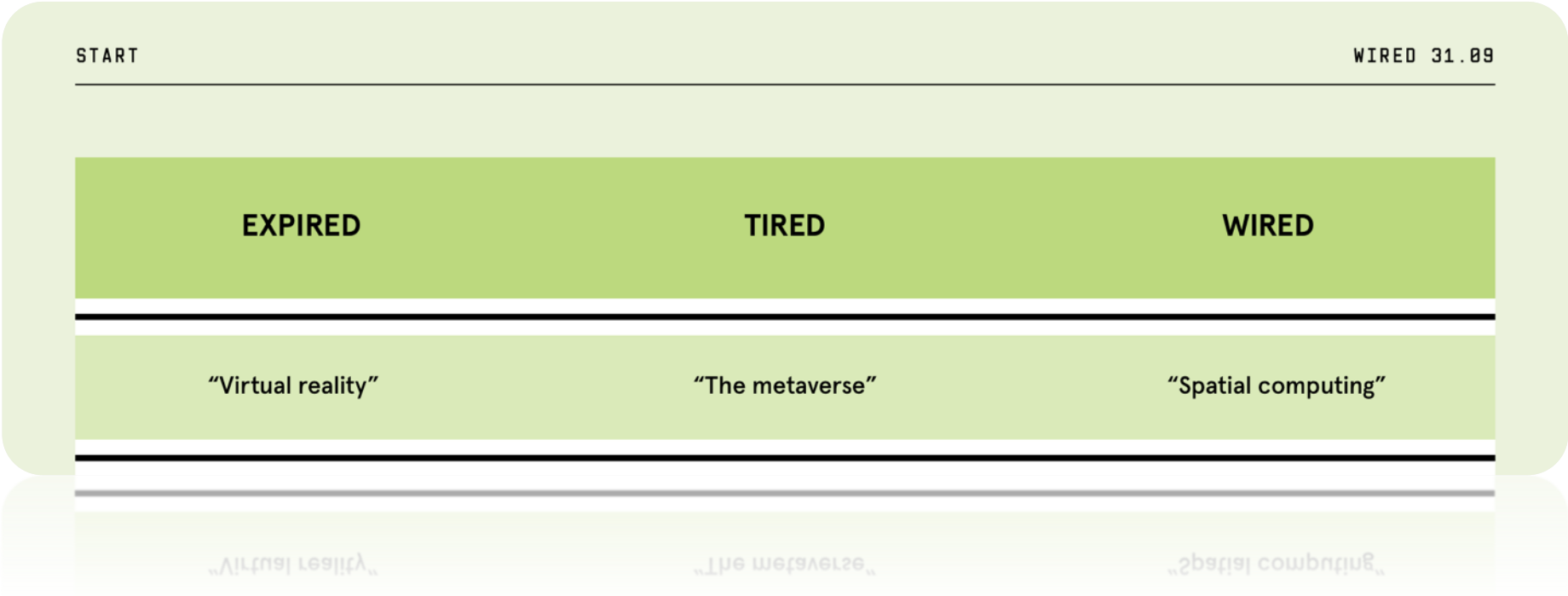
Rule #7: The Metaverse is the Internet.

* A. Graylin, HarvardXR, April 2023

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

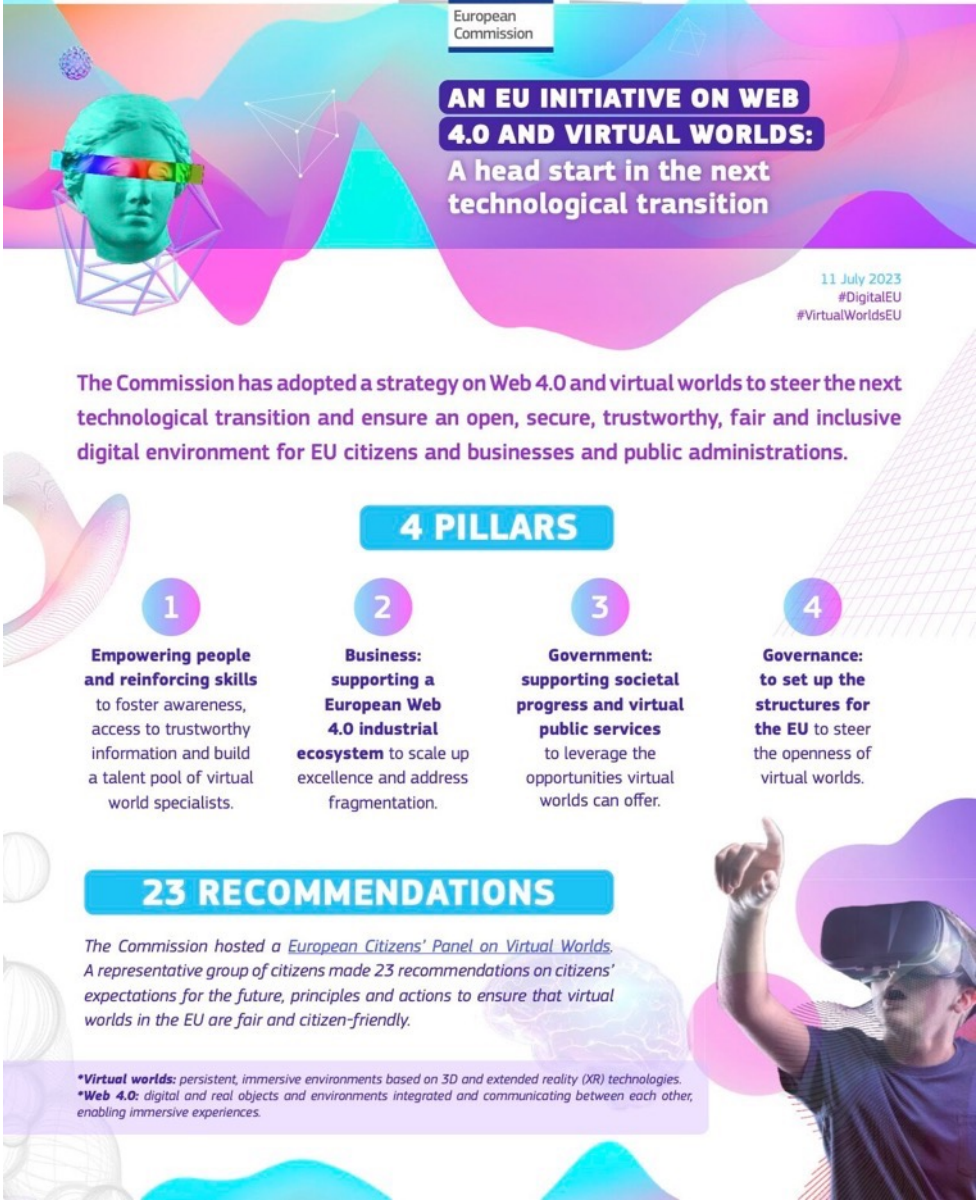
Stable Diffusion prompt:
"a girl in VR glasses experiencing metaverse worlds"

What about ‘Spatial Computing’?



*"human interaction with a machine in which the **machine** retains and manipulates referents to **real** objects and spaces”* [Greenwold 2003]

Greenwold, Simon (June 2003). "Spatial Computing" (PDF). MIT Graduate Thesis. Retrieved 22 December 2019.



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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

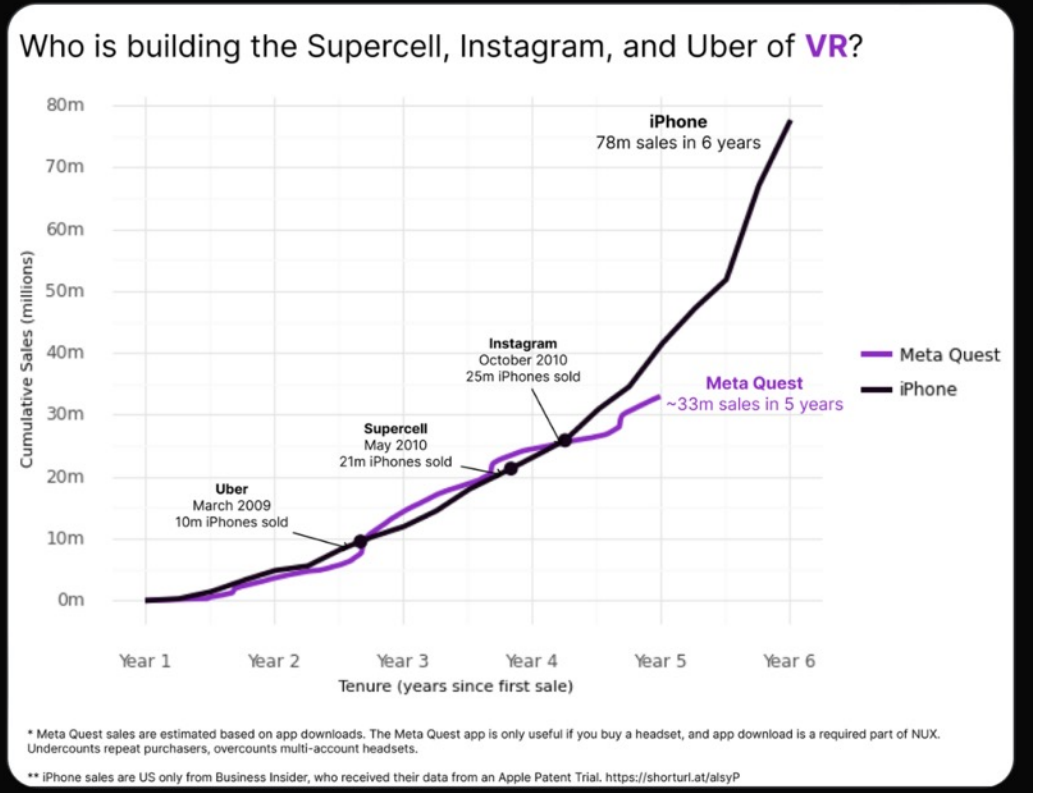
* Source: https://digital-strategy.ec.europa.eu/en/library/virtual-worlds-and-web-40-factsheet

Jack Soslow @JackSoslow · Apr 25

13) We believe the moment is ripe for ARVR apps.

Reflecting on the iPhone's impact, consider:
- Uber launched when 10m iPhones were sold
- Supercell at the 21m mark
- Instagram at 25m

Who will be the equivalent defining companies of ARVR?



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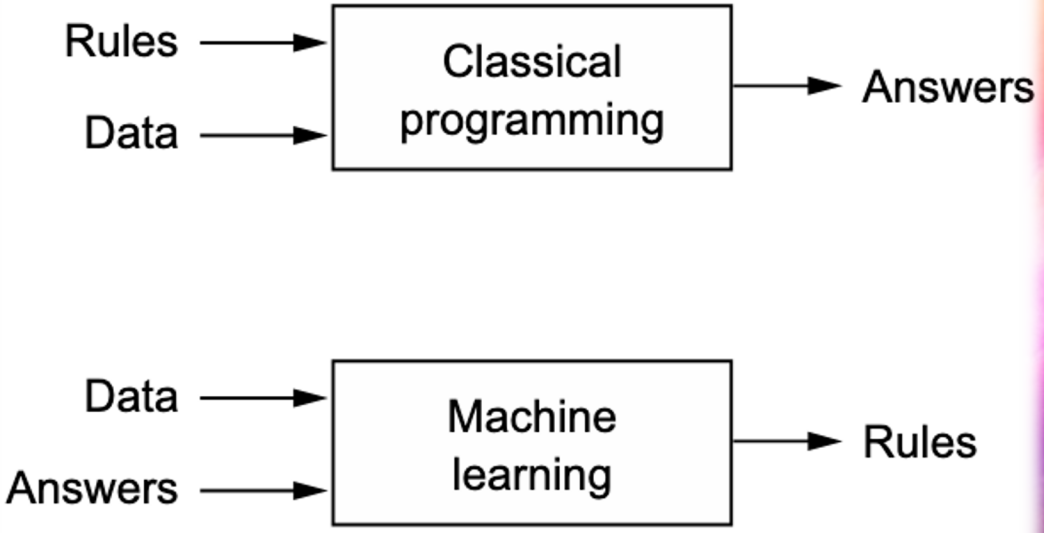
Is now the right moment for VR/AR?

The 3 Stages of XR

2014-2017	2017-2023	2024-Now
Oculus Acquisition HOT	"VR is dead" COLD	Apple Vision ???

https://x.com/jacksoslow/status/1783297751629123860?s=46&t=iEblN9skT-JfsYUDKLznVw

https://analyticsindiamag.com/smartphones-will-be-obsolete-in-10-years-says-metas-ai-chief/



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Machine/Deep learning and intelligence

"Machine/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, Deep learning with Python, Second Edition

Stable Diffusion prompt:
"an explosion of colorful powder"

Stable Diffusion prompt:
"doctors and nurses with 3D VR and AR glasses in digital and real objects and environments integrated and communicating between each other based on immersive experiences"

ORama VR

AI's greatest impact? healthcare

"**Healthcare** as an industry has been slow to **adopt** technology, reluctant to burden **overwhelmed** IT teams, and **train** burned-out staff on **new** systems.

We believe that any new technology has to be **10 times better** to successfully **displace** the last one—marginal improvements aren't worth the effort. Enterprise software struggled to clear that 10x bar in healthcare; **AI clears** it easily.

With AI, healthtech companies no longer need to fight the uphill battle of **training people** on **software**. Instead, they can sell AI that **acts** like a **person** and takes more and more of the work off healthcare professionals' plates, **enabling them** to **work** on more **interesting** problems and **practice** at the **top** of their **licenses**."

Daisy Wolf and Vijay Pande, https://a16z.com/2023/08/02/where-will-ai-have-the-biggest-impact-healthcare/

Virtual Reality Technology For Medicine

- Current technologies and concepts are founded on more than *30 years of research and development*
- Recent changes in cost and access make VR affordable
- VR tech is currently used for prevention, evaluation, treatment and chronic disease management
- After years of validation and use by early adopters - VR technology is poised to move to the mainstream
- On the horizon: enhanced, ubiquitous, informative and integrated

Dr. Walter Greenleaf,
Stanford Health Care & Virtual Human Interaction Lab

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

Science, Computational Science and Computer Science?

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

COMMUNICATIONS OF THE ACM December 1994/Vol.37, No.12 85

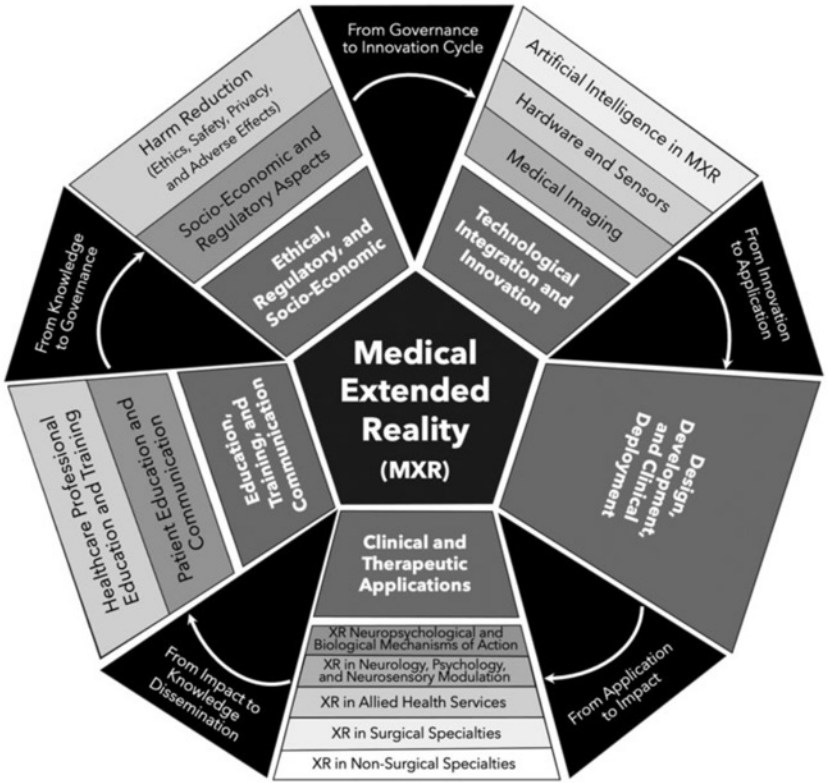
D. E. Stevenson. 1994. Science, computational science, and computer science: at a crossroads. Commun. ACM 37, 12 (Dec. 1994), 85–96. DOI:https://doi.org/10.1145/198366.198386

Why Computational Science?

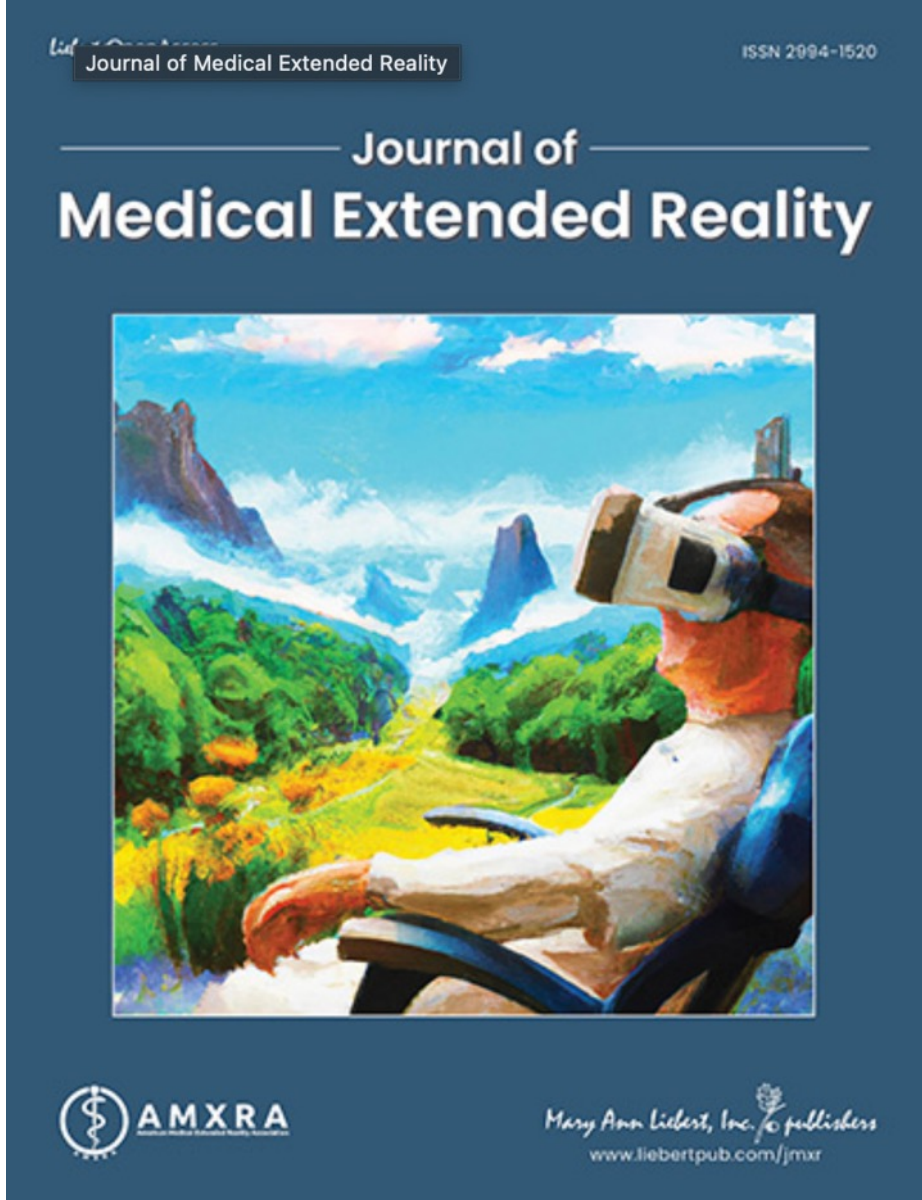
An interdisciplinary field (physical sciences, life sciences, engineering, mathematics, computer science) whose time has come – again:

- Addressing **complex** problems that have **important** implications to **humankind**
- Unlikely to succeed in near term without further **advances** in **software** and **hardware**
- Computer science has been **generally not** participating in science or engineering applications or preparing students to do so – except very recently (Nobel Physics & Chemistry 2024)

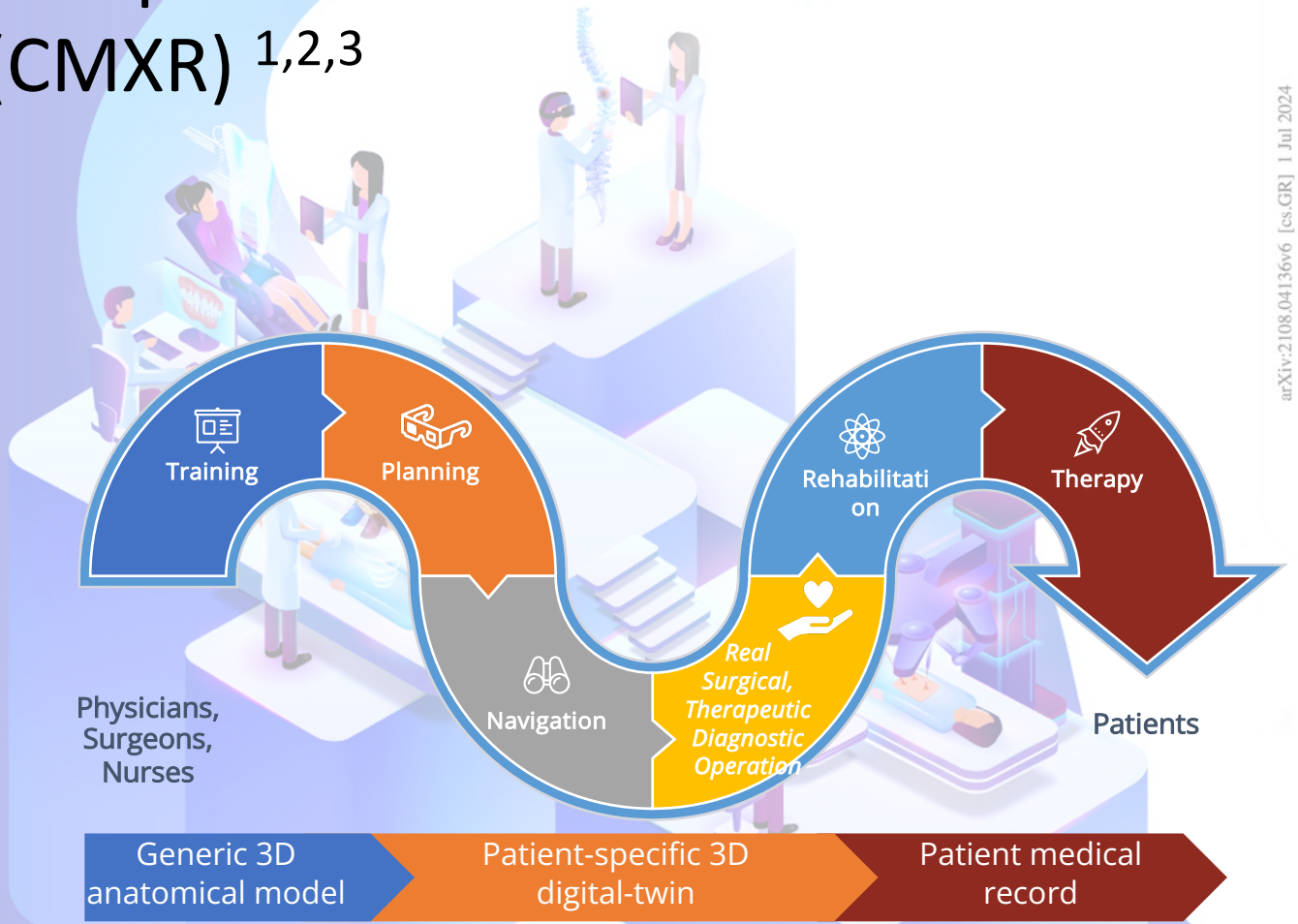
Definition of medical XR?



"What Is Medical Extended Reality? A Taxonomy Defining the Current Breadth and Depth of an Evolving Field ", Spiegel, Brennan M.R.; Rizzo, Albert; Persky, Susan; Liran, Omer; Wiederhold, Brenda; Woods, Susan; Donovan, Kate; Sarkar, Korak; Xiang, Henry; Joo, Sun; Jotwani, Rohan; Lang, Min; Paul, Margot; Senter-Zapata, Mike; Widmeier, Keith; Zhang, Haipeng, Doi: 10.1089/jmxr.2023.0012, https://www.liebertpub.com/doi/10.1089%2Fjmxr.2023.0012



Computational Medical XR (CMXR) [1,2,3]



A Computational *Medical XR* Discipline

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

Walter Greenleaf
Stanford University USA

Michael Cole
University of Michigan Medical School USA

Mark Zhang
Brigham and Women's Hospital Harvard University USA

Rabi Datta
University Hospital of Cologne Germany

Mathias Delahaye
Geneva University Hospitals Switzerland

Eleni Grigoriou
University of Crete Greece, ORamaVR Switzerland

Manos Kamarianakis
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Antonis Protopsaltis
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Eleftherios Tsiridis
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Aristotle University of Thessaloniki Greece

Oliver A Kannape
Geneva University Hospitals & MindMaze S.A. Switzerland

ABSTRACT

Computational Medical Extended Reality (*CMXR*), 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 differs from previous "Clinical XR" and "Medical XR" terms, as it is focusing on how to integrate computational methods from neural simulation to computational geometry, computational vision and computer graphics with deep learning models to solve hard problems in medicine and neuroscience: from low-code/no-code/genAI authoring platforms to deep learning XR systems for training, planning, real-time operative navigation, therapeutics, and rehabilitation.

1 INTRODUCTION

Today, 5 billion people lack access to surgical and anesthesia care, as traditional medical training methods struggle to keep up. According to OECD, over 1 billion jobs worldwide, nearly 30% of all jobs, are likely to be transformed by technology within the next decade. In that respect, the World Health Organization predicts a shortage of 10 million healthcare professionals by 2030. Evidently, this growing need for training and continuous upskilling and reskilling of medical personnel, has become more crucial in the post pandemic era. Extended Reality (XR) coupled with spatial computing technologies emerges as a frontier in medical training, education, and empowerment, offering innovative solutions for psychomotor and cognitive skill development. In this position-survey paper, we present some of the most recent advances in the computational medical XR field, based on its definition (see figure 1), using state-of-the-art examples of research on simulation protocols, immersive and embodied research approaches, and steps towards more effective, user-tailored empowerment, therapy, rehabilitation, planning, navigation, upskilling and reskilling in the post-pandemic world.

2 CMXR MOTIVATION AND PROGRESS BEYOND THE STATE OF THE ART

Recent CMXR related articles [31] [33] and case study review articles [32] in industry [11] as well as dedicated academic special journal issues [26] highlight the facilitation of Virtual, Augmented, Mixed reality (VR / AR / MR) technologies (grouped by the industry as XR) to transform and modernize the medical training model. An increasing number of published clinical trials [17] [34] [6] [9] measured and testified the efficacy of medical XR training and skills transfer from virtual to real. In that frame, another recent policy report [29] highlights that XR technologies can offer significant boost in experiential and collaborative learning of healthcare professionals.

XR can provide the means for remote qualitative education (knowledge) and training (skills), using affordable technology with personalized, on-demand and smooth learning curves. Based on recent major advances in the fields of 5G edge computing [28], neuroscience [30], MR [36] and spatial computing:

"VR/AR shares with our brain the same basic mechanism: embodied simulations" [30]

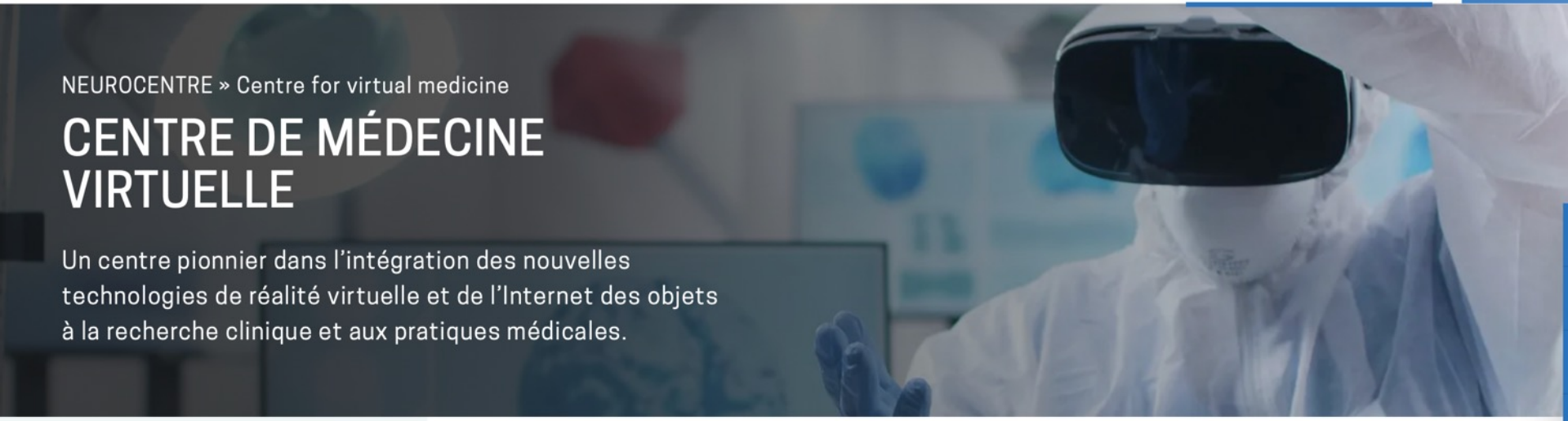
Such immersive technologies can facilitate continuous learning, provide curriculum programs and self-improvement opportunitie

[1] https://s2023.siggraph.org/presentation/?id=ftalk_101&sess=sess408
[2] https://s2023.siggraph.org/presentation/?id=fwork_109&sess=sess287, 2023
[3] Papagiannakis, G., et al "A computational medical XR discipline", 2024, https://arxiv.org/abs/2108.04136, CGI2024, Springer LNCS

Who are the leading hospitals in this field?

HUG Hôpitaux Universitaires Genève | NEUROCENTRE

HOMEPAGE THE CENTRE RESEARCH & INNOVATION CENTRE FOR VIRTUAL MEDICINE



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CONTACT

Dr. Oliver Kannape, Mindmaze & University Hospital of Geneva


Neurosymbolic AI:
The Future of AI
Reasoning?

What is Neurosymbolic AI?

- Neurosymbolic AI combines neural networks (perception) with symbolic reasoning (cognition).
- What is the role of symbols and programs?
- Build them or let them emerge?
- What's the best way to integrate them with DL?

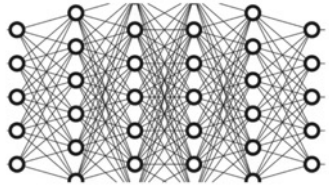
Kautz, H. A. The third AI summer: AAAI Robert S. Engelmore Memorial Lecture. *AI Mag.* **43**, 105–125 (2022).

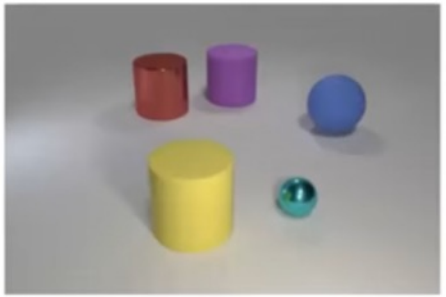
What is the shape of the red object left of the sphere?

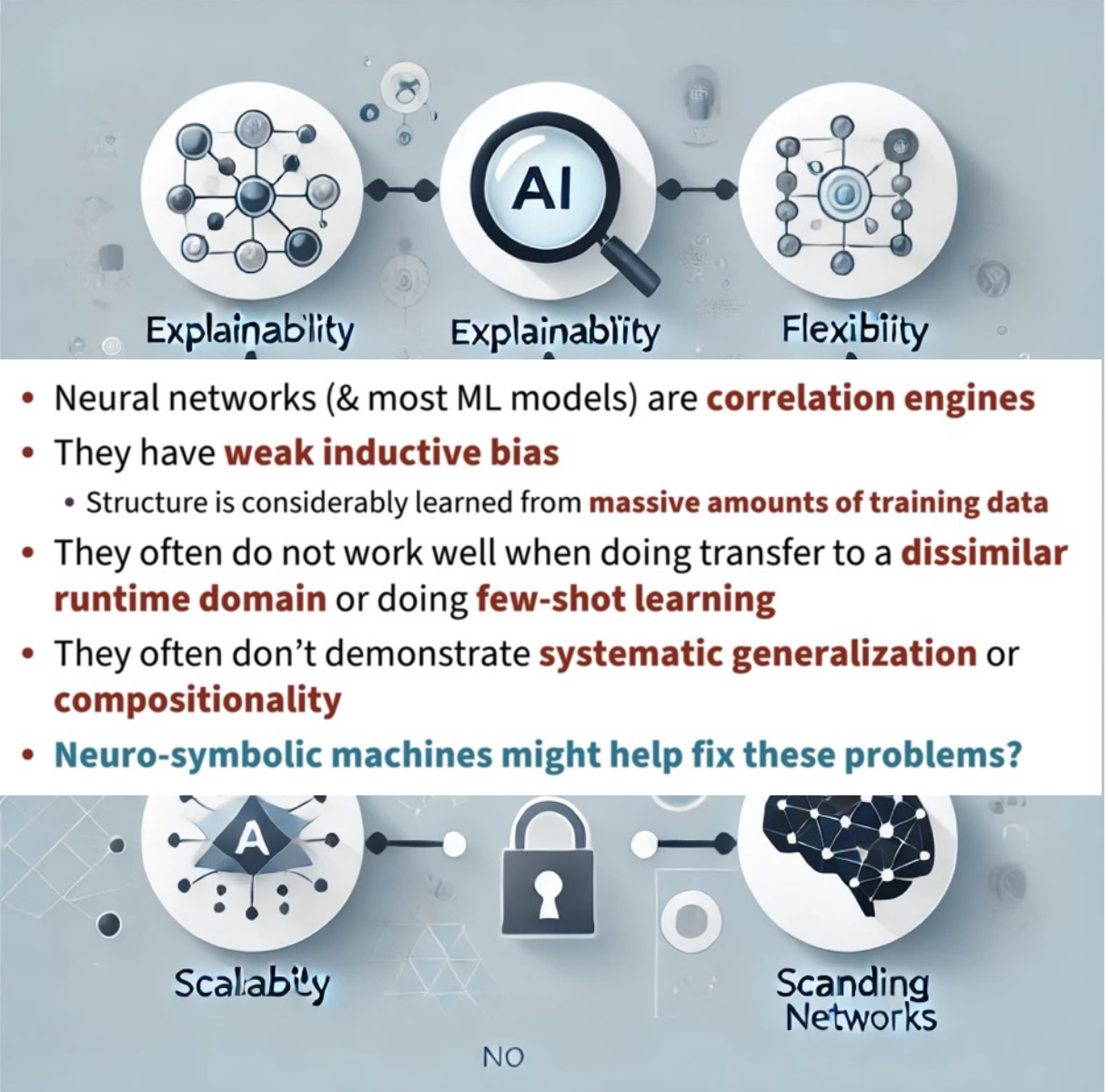
$$[\![\lambda z.\, \exists x \exists y.\, \text{shape}(y, z) \wedge \text{color}(y, \text{red}) \wedge \text{leftOf}(y, x) \wedge \text{sphere}(x)]\!]$$

Query(Shape, Filter(Red, Relate(Left, Filter(Sphere))))

Artificial Neural Networks







- Neural networks (& most ML models) are **correlation engines**
- They have **weak inductive bias**
  - Structure is considerably learned from **massive amounts of training data**
- They often do not work well when doing transfer to a **dissimilar runtime domain** or doing **few-shot learning**
- They often don't demonstrate **systematic generalization** or **compositionality**
- **Neuro-symbolic machines might help fix these problems?**

Why Neurosymbolic AI Matters

- **Explainability**: Provides clear decision-making steps.
- **Flexibility**: Adapts to various tasks and improves learning.
- **Scalability**: Large-scale data processing and reasoning.

Sheth, A., Roy, K. & Gaur, M. Neurosymbolic AI - Why, What, and How. *arXiv* (2023) doi:10.48550/arxiv.2305.00813.

State-of-the-art in medical XR training

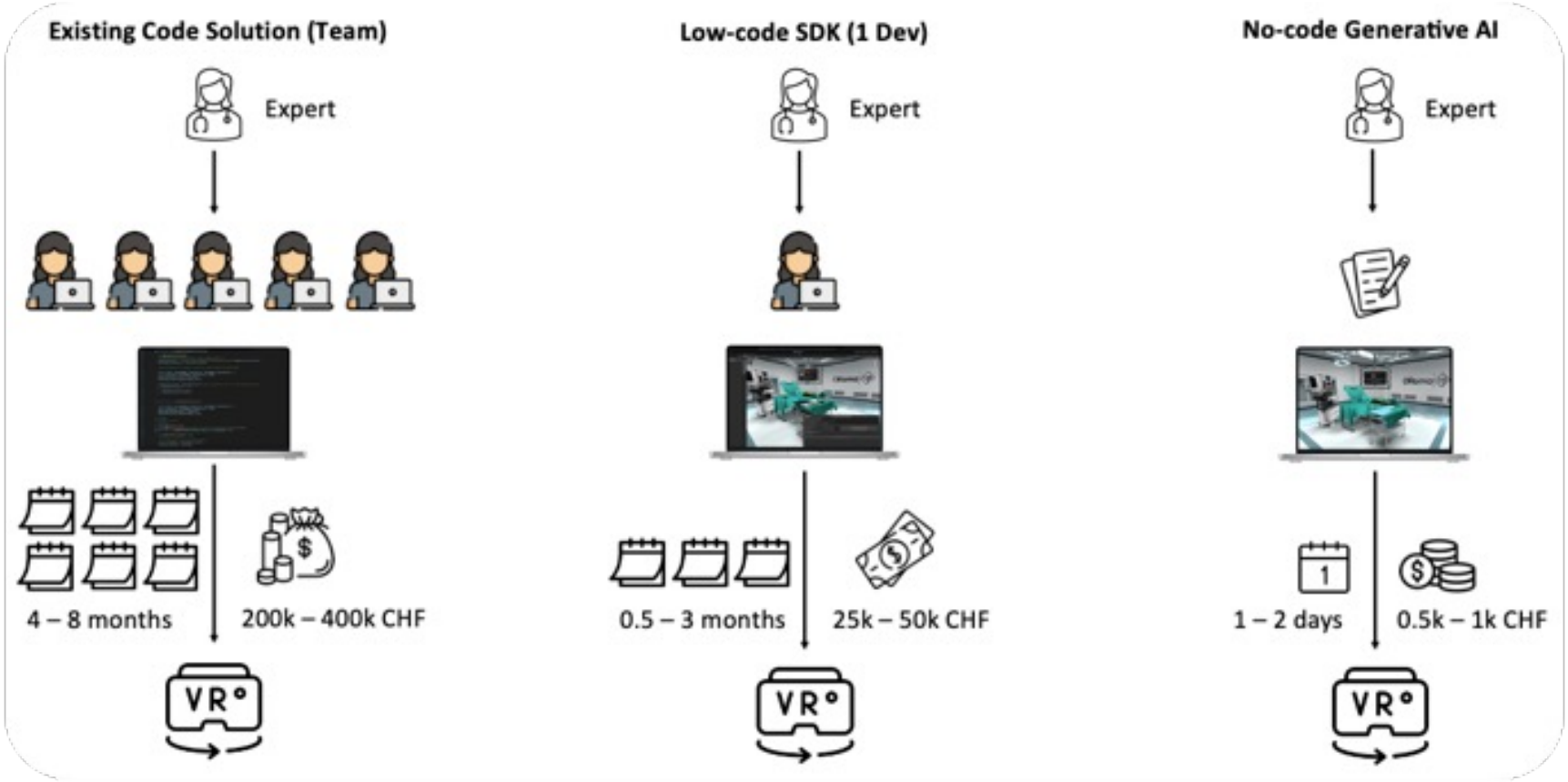
Source: Accenture Consulting. WAKING UP TO A NEW REALITY | Accenture. 2019.

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

ORama VR

"For most of the technology's history, however, virtual experiences have been hard to build and maintain. This has been one of V.R.'s biggest problems."

Jaron Lanier, https://www.newyorker.com/tech/annals-of-technology/where-will-virtual-reality-take-us, Feb, 2024



State-of-the-art in computational medical XR training: Applications*

- Surgical/ Diagnostic/ Therapeutic training
- Anatomy education
- Disaster Preparedness
- Patient Education
- Patient Counselling

* Bashir, A. K. *et al.* A Survey on Federated Learning for the Healthcare Metaverse: Concepts, Applications, Challenges, and Future Directions. *Arxiv* (2023).

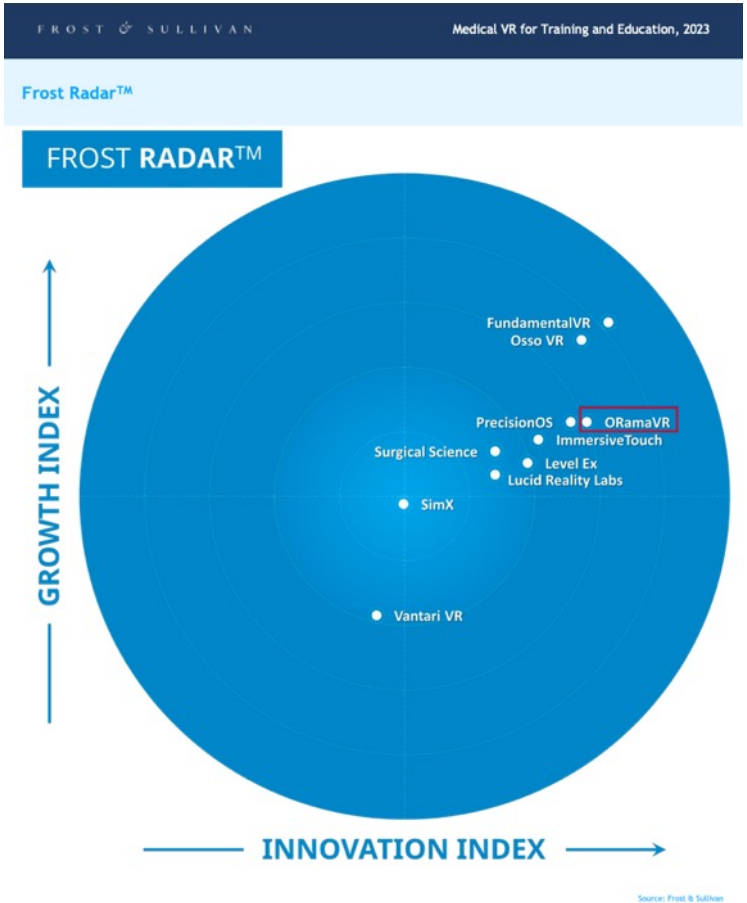
From VR training simulators to XR simulations: 5 Generations of training

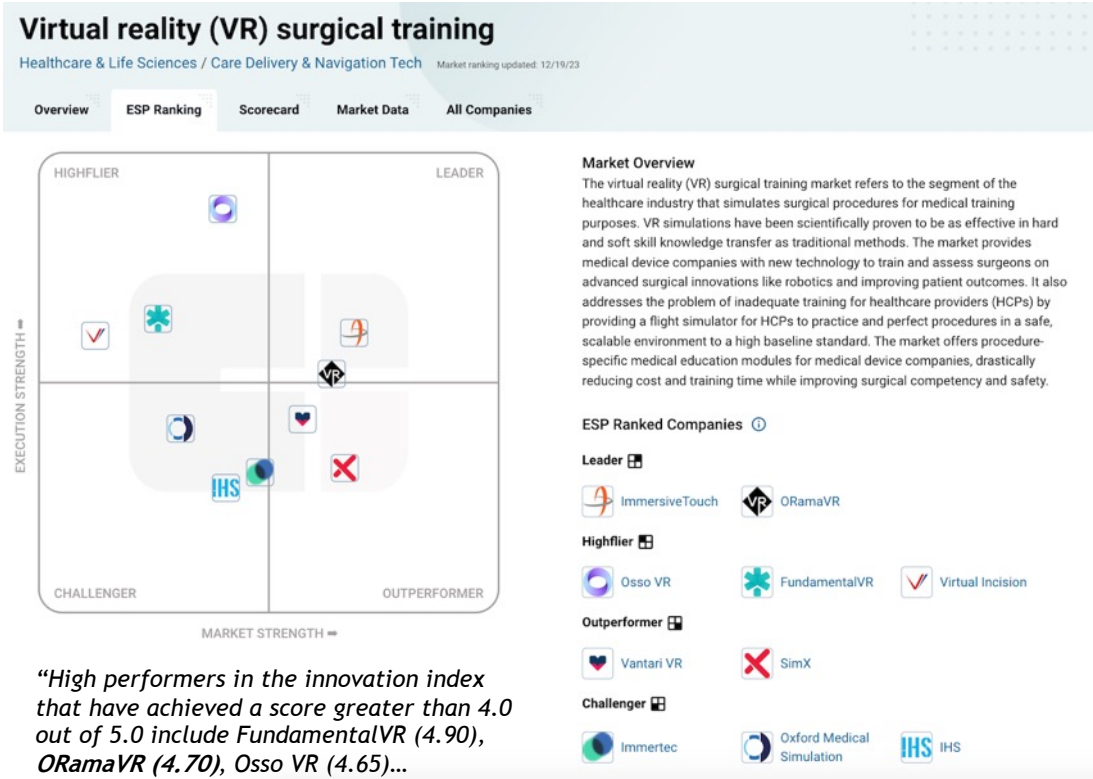
ORama VR

- **1.0** high-fidelity, haptic-based 3D and (VR) simulators *(non true-VR)*
- **2.0** 360-VR simulations or mobile-3D interactive *(non true-VR)*
- **3.0** true-VR simulators *(APIE: agency, presence, immersion, embodiment)* + off-the-shelf haptics
- **4.0** CMXR, Low/no-code SDK-based, fully customizable and extensible simulations *(today)*
- **5.0** CMXR genAI-based with human-in-the-loop simulations *(forthcoming)*

- Bansal, G., Rajgopal, K., Chamola, V., Xiong, Z. & Niyato, D. Healthcare in Metaverse: A Survey On Current Metaverse Applications in Healthcare. IEEE Access PP, 1–1 (2022)
- Cerasa, A., Gaggioli, A., Marino, F., Riva, G. & Pioggia, G. The promise of the metaverse in mental health: the new era of MEDverse. Heliyon e11762 (2022) doi:10.1016/j.heliyon.2022.e11762
- Yang, D. et al. Expert consensus on the metaverse in medicine. Clin Ehealth 5, 1–9 (2022).

MEDICAL XR FIELD IS GROWING!





*"High performers in the innovation index that have achieved a score greater than 4.0 out of 5.0 include FundamentalVR (4.90), **ORamaVR (4.70)**, Osso VR (4.65)…*

..Growth Leaders—include FundamentalVR (4.55) and Osso VR (4.40), ORamaVR (3.70)…"

Frost & Sullivan Medical VR for Training and Education report 2023

CBINSIGHTS

- https://www.linkedin.com/posts/fundamentalvr_frost-radar-leader-in-medical-vr-training-activity-7141463504510750720-7uRX?utm_source=share&utm_medium=member_desktop
- https://www.cbinsights.com/esp/healthcare-&-life-sciences/care-delivery-&-navigation-tech/virtual-reality-(vr)-surgical-training
- https://metaverseinsider.tech/2024/02/19/top-7-vr-training-companies-in-2024-revolutionizing-learning/ , https://tryspecter.com/report/fastest-growing-vr-ar-companies

ORama VR

From no-code to neurosymbolicAI

for CMXR training simulations

The solution

Neurosymbolic AI-powered medical XR platform that automates training reducing costs, time 10X

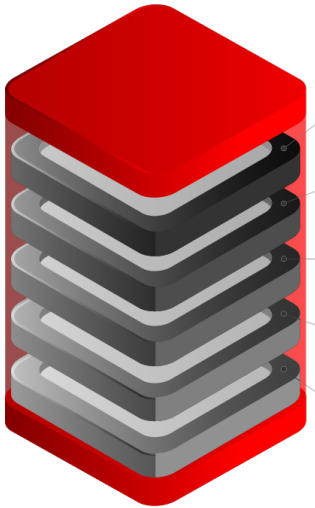
Clear Benefits in 9+ published high-impact peer-reviewed journal studies by our partners

80%
error reduction

32%
skill improvement

MAGES SUITE

MAGES SDK - Software Development Kit- SaaS, proprietary deep-tech *(patent pending)*
(USP: no-code AI-based CMXR simulation creation/authoring platform, *available today*)



M **Multiplayer with GA Interpolation**
Networking
Hardware Agnostic Device Manager

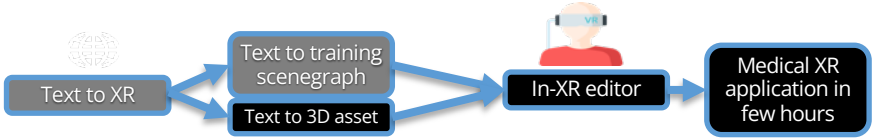
A **Analytics**
Competency and Performance Analytics
Session and User Data Container

G **GA Deformable Animation, Cutting, and Tearing**
Realistic User Interaction System

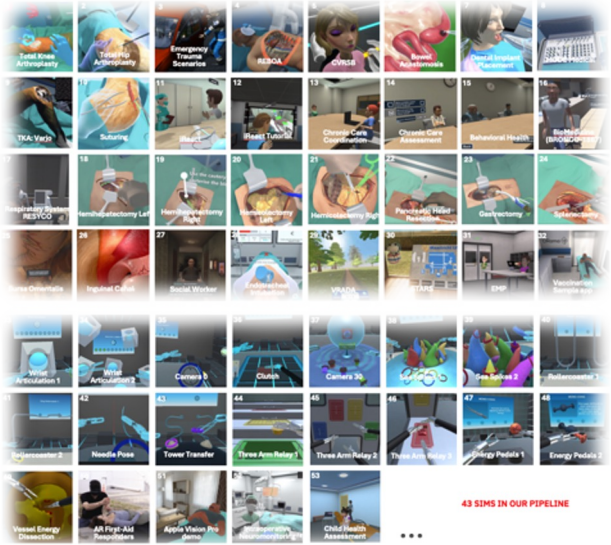
E **Editor With Action Prototypes**
No-code SceneGraph Editor
JARIA, Just Another ARtificial Intelligent Assistant

S **Semantically Annotated Deformable, Soft, and Rigid Bodies**

MAGES OMEN-E text2XR SaaS, (Proprietary Gen-AI based, *'ChatGPT for CMXR', forthcoming*)



MAGES SIM Service, 66 fully customizable, open medical XR training simulations authored so far



Unique proprietary dataset used to train OMEN-E & future CMXR app-store for revenue share with partners

DOES IT WORK?

We have proven that medical XR training facilitates
a) skills transfer from the virtual world to the real
b) reduction of medical errors

- **9+** published medical XR clinical trials & pilot studies:
- https://oramavr.com/case-studies-testimonials/

- **60+** scientific publications on computational medical XR:
- https://oramavr.com/publications/

International Orthopaedics
https://doi.org/10.1007/s00264-023-06038-8

ORIGINAL PAPER

Effectiveness of virtual reality compared to video training on acetabular cup and femoral stem implantation accuracy in total hip arthroplasty among medical students: a randomised controlled trial

Eustathios Kenanidis[1,2] · Panagiotis Boutos[2] · Grigorios Voulgaris[2] · Aikaterini Zgouridou[2] · Eleni Gkoura[2] · Zakareya Gamie[2] · George Papagiannakis[3,4] · Eleftherios Tsiridis[1,2]

Received: 3 October 2023 / Accepted: 10 November 2023
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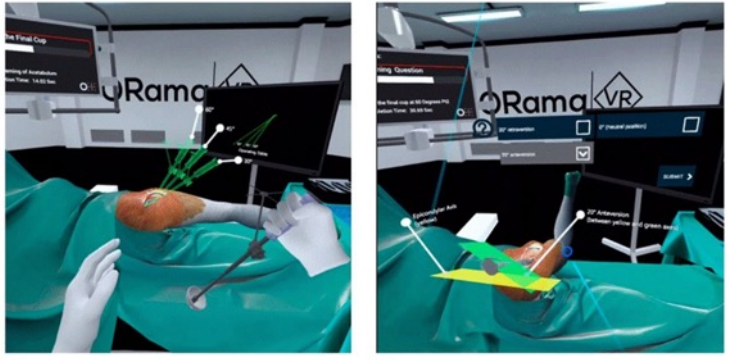
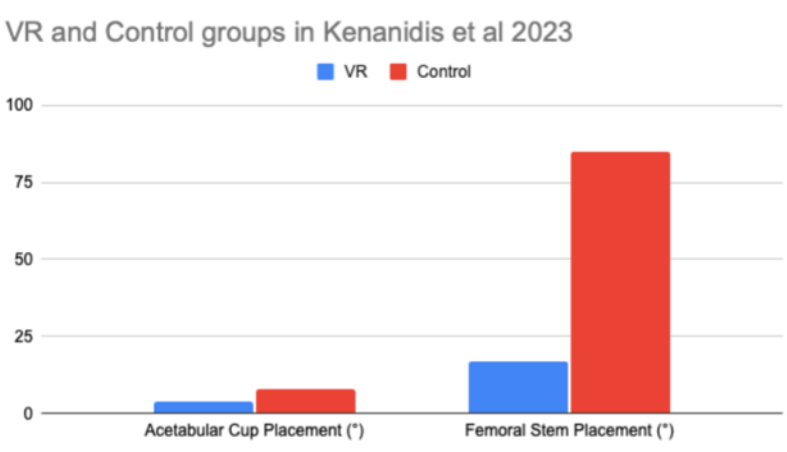




e.g. Kenanidis et al 2023, Aristotle University, (N=101), Journal of International Orthopedics, 80% reduction on errors for Femoral Stem Placement and 50% for Acetabular Cup Placement after VR training

DOES IT WORK II?

Real clinical-trial based evidence published in high-impact medical journals in our field

Hooper et al 2019, NYU, USA (N=14),
Journal of Arthroplasty*1,
32% improvement in procedural skills

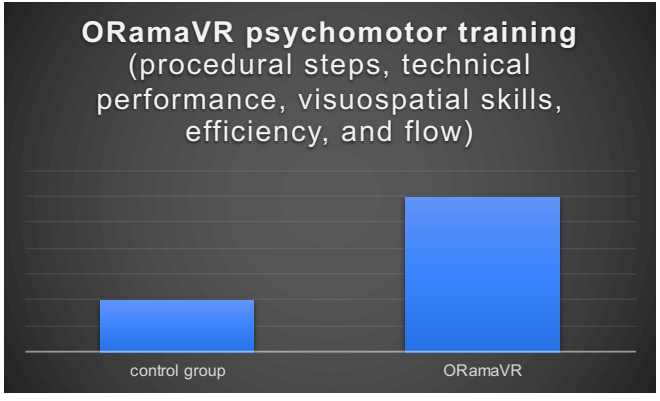

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Virtual Reality Simulation Facilitates Resident Training in Total Hip Arthroplasty: A Randomized Controlled Trial

Jessica Hooper, MD [a, *], Eleftherios Tsiridis, MD, PhD [b, c], James E. Feng, MD [a], Ran Schwarzkopf, MD, MSc [a], Daniel Waren, MS [a], William J. Long, MD, FRCSC [a], Lazaros Poultsides, MD, PhD [a], William Macaulay, MD [a], the NYU Virtual Reality Consortium [a]



Birrenbach et al 2021, Inselspital, Switzerland (N=29),
Journal of Medical Internet Research *2,
16% increased user satisfaction


JMIR SERIOUS GAMES

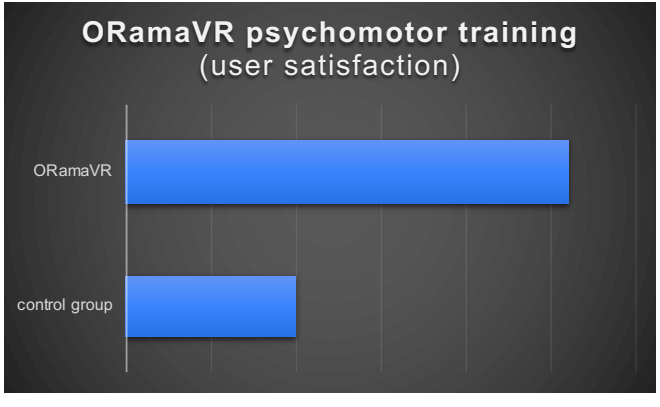
Birrenbach et al

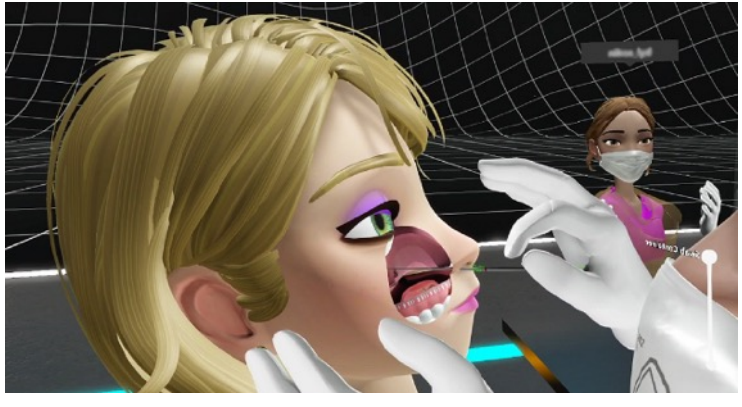
Original Paper

Effectiveness and Utility of Virtual Reality Simulation as an Educational Tool for Safe Performance of COVID-19 Diagnostics: Prospective, Randomized Pilot Trial

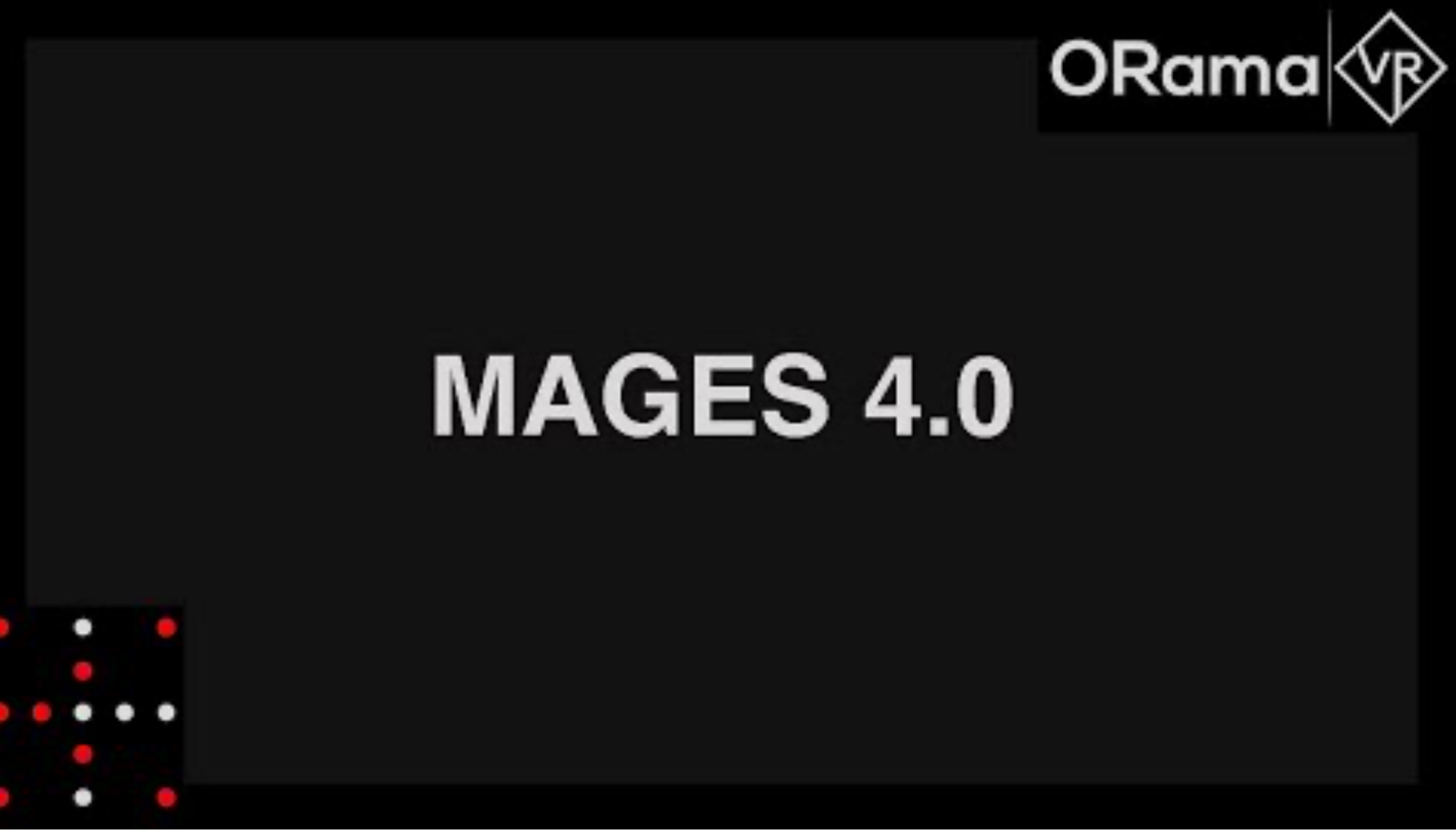
Tanja Birrenbach[1,2], MME, MD; Josua Zbinden[1]; George Papagiannakis[3,4,5], PhD; Aristomenis K Exadaktylos[1], MD, PhD; Martin Müller[1], MD, PhD; Wolf E Hautz[1], MME, MD; Thomas Christian Sauter[1], MME, MD

[1]Department of Emergency Medicine, Inselspital, University Hospital Bern, Bern, Switzerland
[2]Centre for Health Sciences Education, Faculty of Medicine, University of Oslo, Oslo, Norway
[3]ORamaVR SA, Geneva, Switzerland
[4]Institute of Computer Science, Foundation for Research and Technology, Hellas, Heraklion, Greece
[5]Department of Computer Science, University of Crete, Heraklion, Greece





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



VIDEO → MAGES SDK 4.0

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.

MAGES SDK NXT

MAGES No-Code NXT 5.0 Software Development Kit

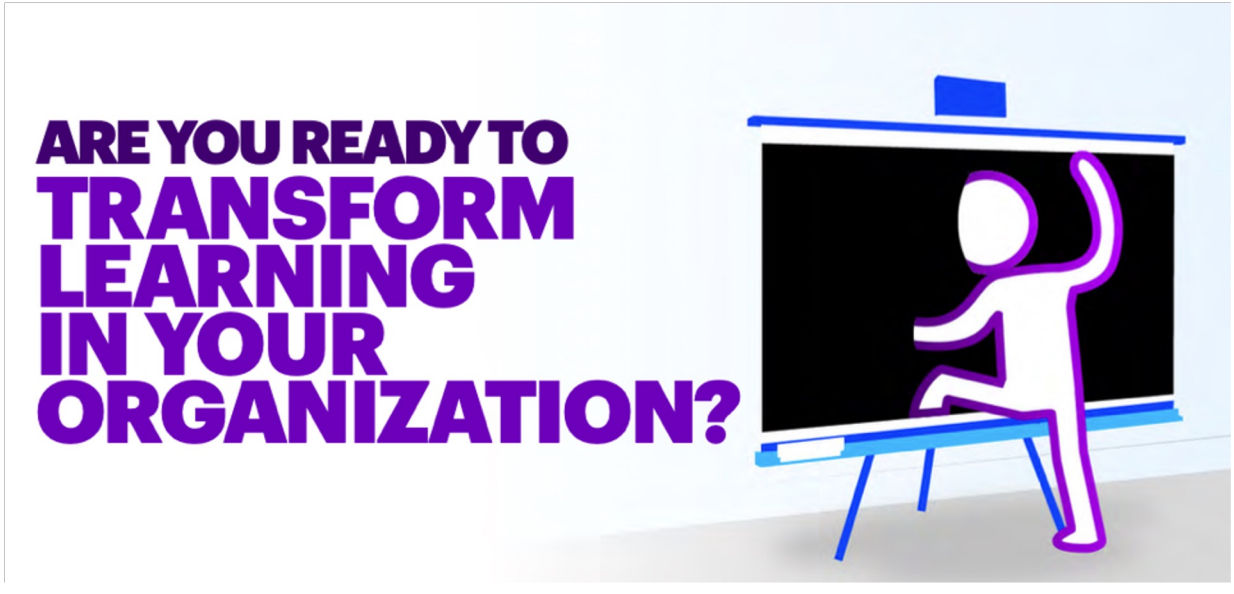
VIDEO → MAGES SDK NXT

Papagiannakis, G., *et al*., ”**A computational medical XR discipline**,"
https://doi.org/10.48550/arXiv.2108.04136 .

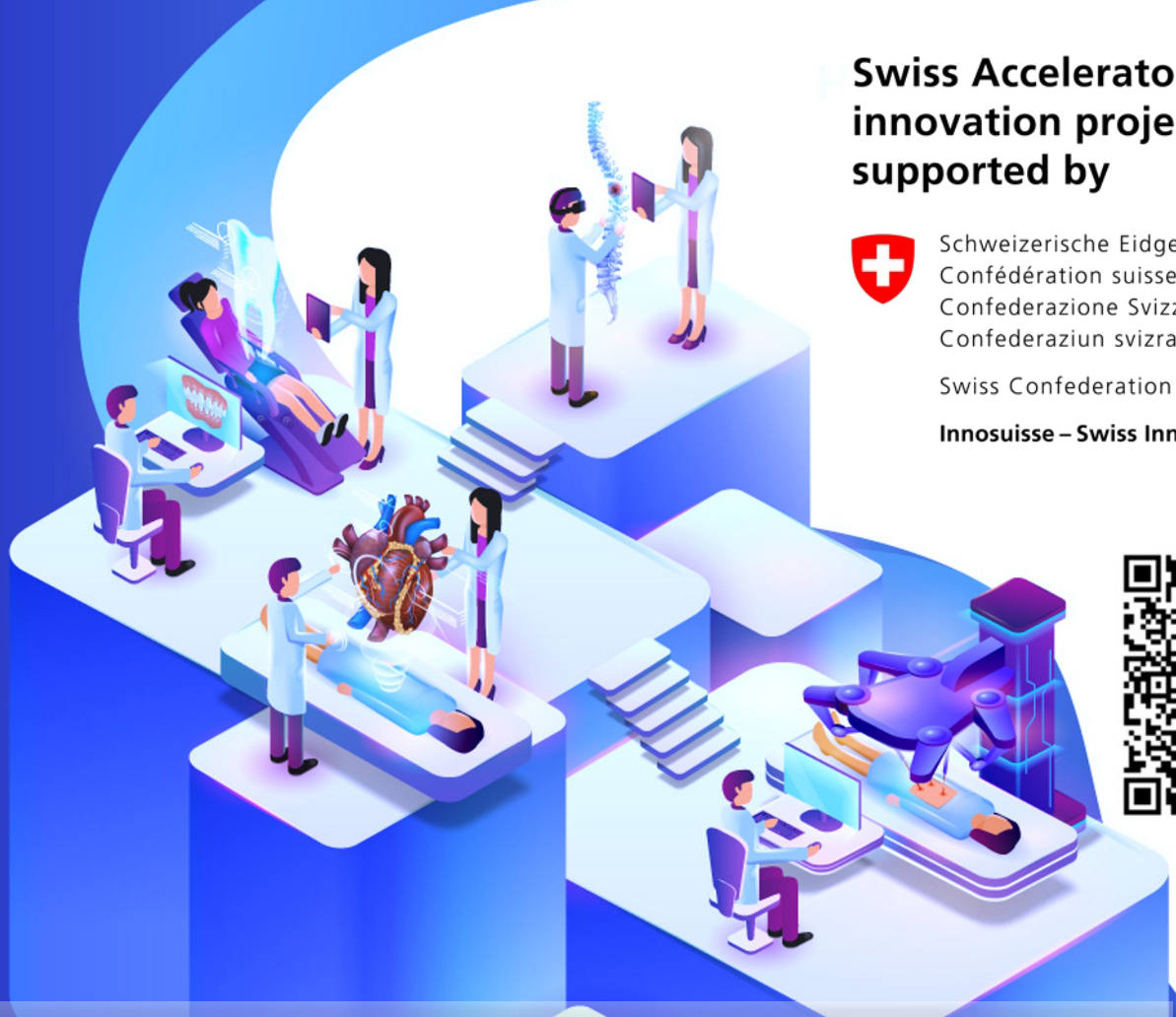
VIDEO → MAGES SDK OMEN-E

D. Angelis, P. Kolyvakis, M. Kamarianakis, G. Papagiannakis, Geometric Algebra Meets Large Language Models: Instruction-Based Transformations of Separate Meshes in 3D, Interactive and Controllable Scenes, https://doi.org/10.48550/arXiv.2408.02275, 2024

Conclusions



- Neurosymbolic AI and computational XR tools have arrived and are transforming medicine and healthcare – CMXR
- Questions on how to scale creation, adoption, deployment remain
- AI and XR technologies will not replace humans in healthcare!



Swiss Accelerator innovation project supported by

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Confédération suisse
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Confederaziun svizra

Swiss Confederation

Innosuisse – Swiss Innovation Agency

Funded by the European Union
NextGenerationEU

Greece 2.0
NATIONAL RECOVERY AND RESILIENCE PLAN

fidal field trials beyond 5G

INDUX-R

Dr. George Papagiannakis
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Affiliated Researcher at FORTH
Visiting Prof. University of Geneva
&
ORamaVR co-founder, CEO
george@oramavr.com

FORTH Foundation for Research & Technology - Hellas

Stanford University

ORama VR

UNIVERSITÉ DE GENÈVE

Let's accelerate world's transition to Deep Medicine & CMXR!