

# VR Application & Developments

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Kyoung Shin Park

Computer Engineering

Dankook University

# Applications

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- ❑ Engineering & Architectural Walkthroughs
- ❑ Education and Training
- ❑ Therapy and Rehabilitation
- ❑ Scientific Visualization
- ❑ Cultural Heritage
- ❑ Art
- ❑ Social VR
- ❑ Fashion & Shopping
- ❑ Entertainment & VR Zone

# Vehicle Design & Manufacturing



- ❑ **Visual Eyes** developed by General Motors Research, Hughes Research Lab & EVL
- ❑ Rapid prototypes for reviewing computer generated 3D CAD models

# Vehicle Design & Manufacturing



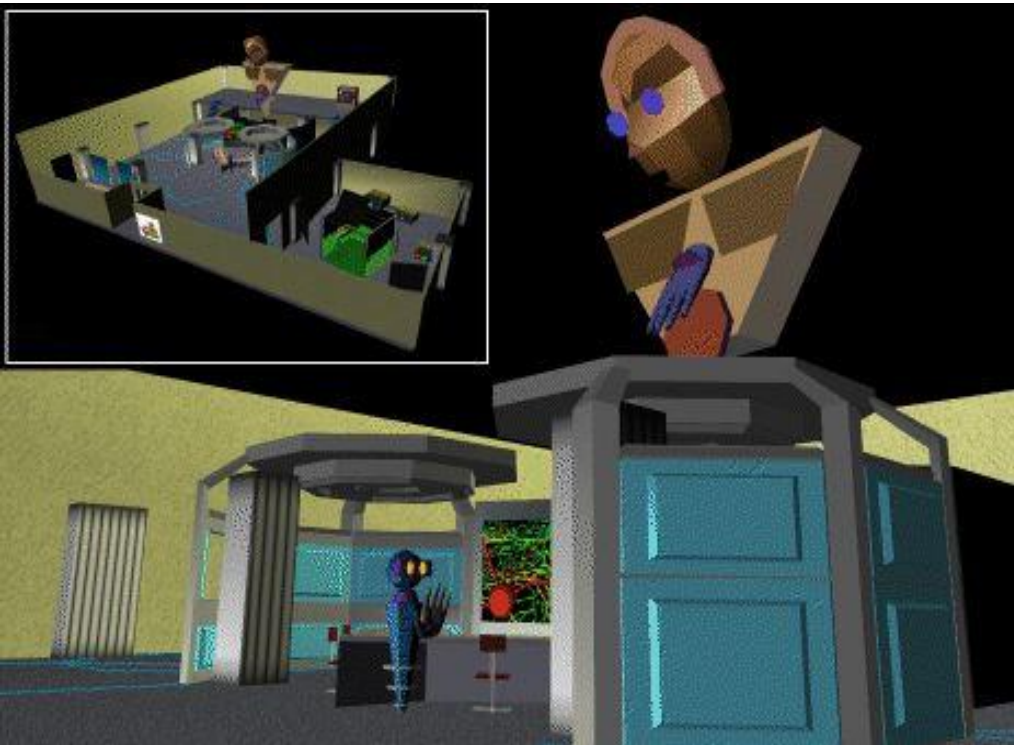
- ❑ **The Virtual Backhoe** project by NCSA & Caterpillar Inc.
- ❑ VR manufacturing system that allows engineers to quickly prototype wheel loader and backhoe loader design
- ❑ Engineers can operate the equipment and evaluate visual obstructions in a natural manner without having to build a physical prototype.

# Architectural Walkthroughs



- ❑ **Architectural Linked Immersive Environment (ALIVE)** by SARA, The Netherlands & EVL
- ❑ Dutch architect Rem Koolhaas' design of the new Campus Center at the Illinois Institute of Technology in Chicago
- ❑ ALIVE lets viewers navigate through 3D CAD models

# Architectural Walkthroughs



- ❑ **CALVIN (Collaborative Architectural Layout Via Immersive Navigation)**
- ❑ Persistent networked virtual environment
- ❑ Multi-perspective (Mortals and Deities) collaborative design

# Architectural Walkthroughs



- ❑ Using Web3D
- ❑ VRML cyber exhibition floor, model house, simulation, interior, etc.

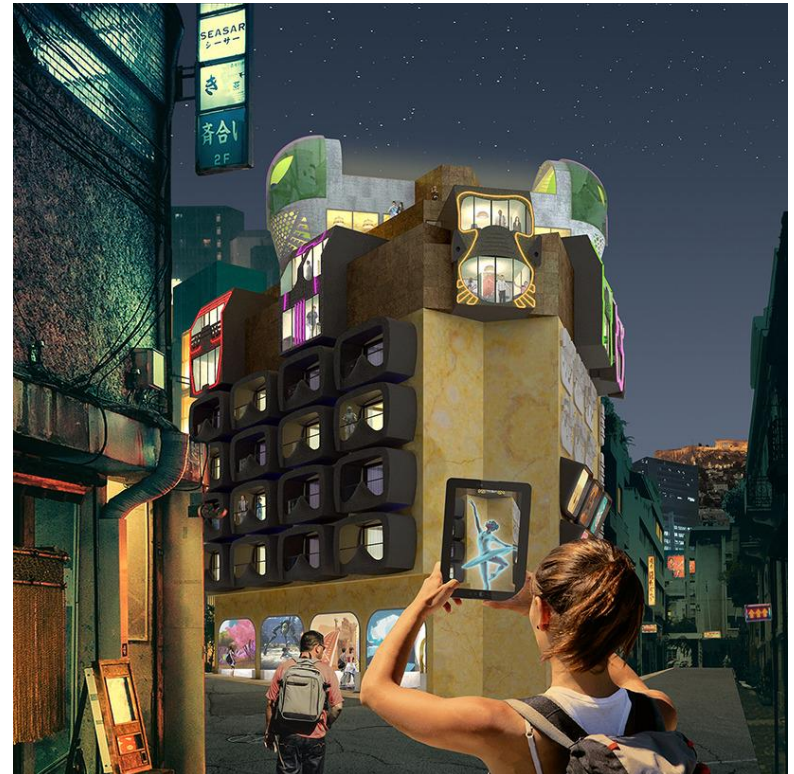


# Architectural Walkthroughs



<https://www.designboom.com/architecture/stathis-stylidis-virtual-augmented-reality-experimental-space-athens-10-10-2017/>

- Greece Stathis Stylidis proposes a virtual and augmented reality experience in Athens





# Architectural Walkthroughs

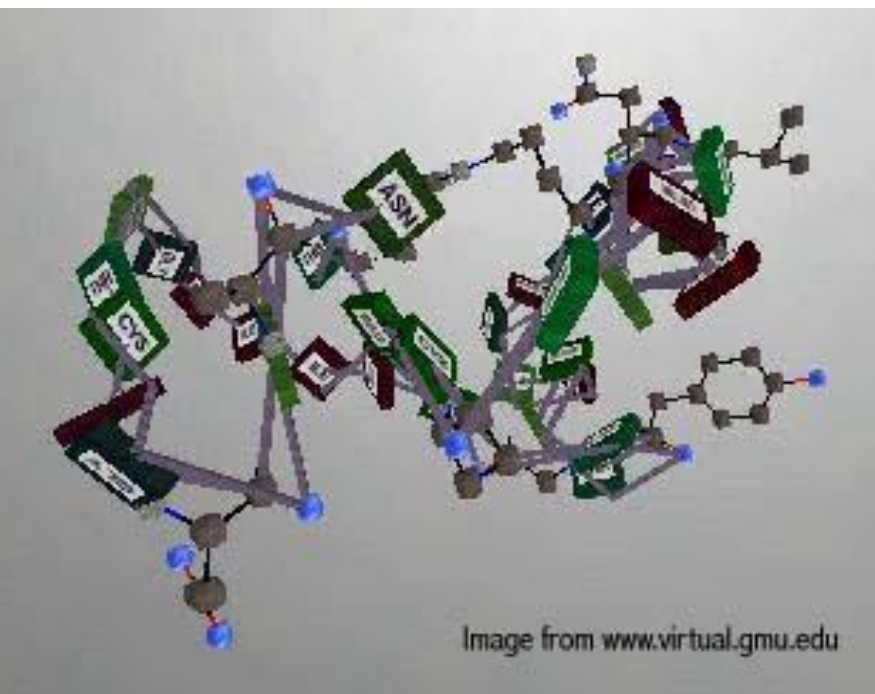


- ❑ Seattle Hawk Tower developed by American Life.
- ❑ With augmented and virtual reality, tour your office before it's built.



<https://www.seattletimes.com/business/real-estate/with-augmented-and-virtual-reality-tour-your-office-before-its-built/> (December 16, 2018)

# Education



- ❑ **Science Space** for high school or college students, using HMD by George Mason University & University of Houston
- ❑ Newton World allows students to experience Newton's three laws where they control the environment
- ❑ Maxell World examines Gauss's Law by examining the nature of electrostatic forces and fields
- ❑ Pauling World studies chemical structure of molecules

# Education



- For middle school students, by GVU, Georgia Tech
- **The Virtual Gorilla Exhibit project** which is based on actual data from the Zoo Atlanta gorilla exhibit (gorilla behavior data & terrain data)
- Children can “**be a gorilla**” and experience first-hand what it is like to join a gorilla family group

# Education



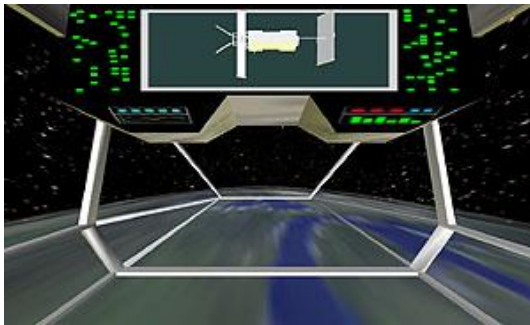
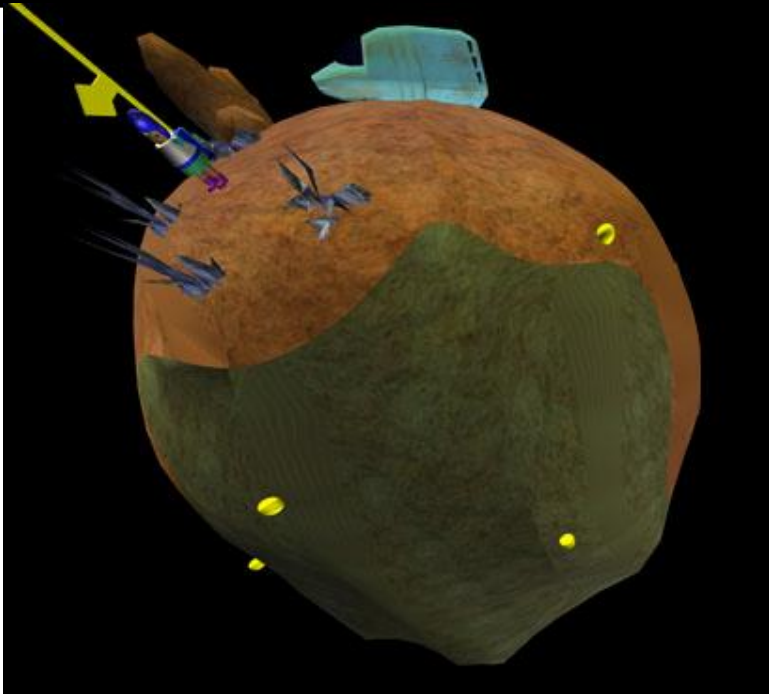
- For elementary students, by EVL
- NICE (Narrative Immersive Constructionist Environments) Persistent garden
- Round Earth Project is intended to teach young children the concept of a spherical Earth
- Virtual Ambients is designed to help students improve early stages of students' scientific inquiry skills

# Education



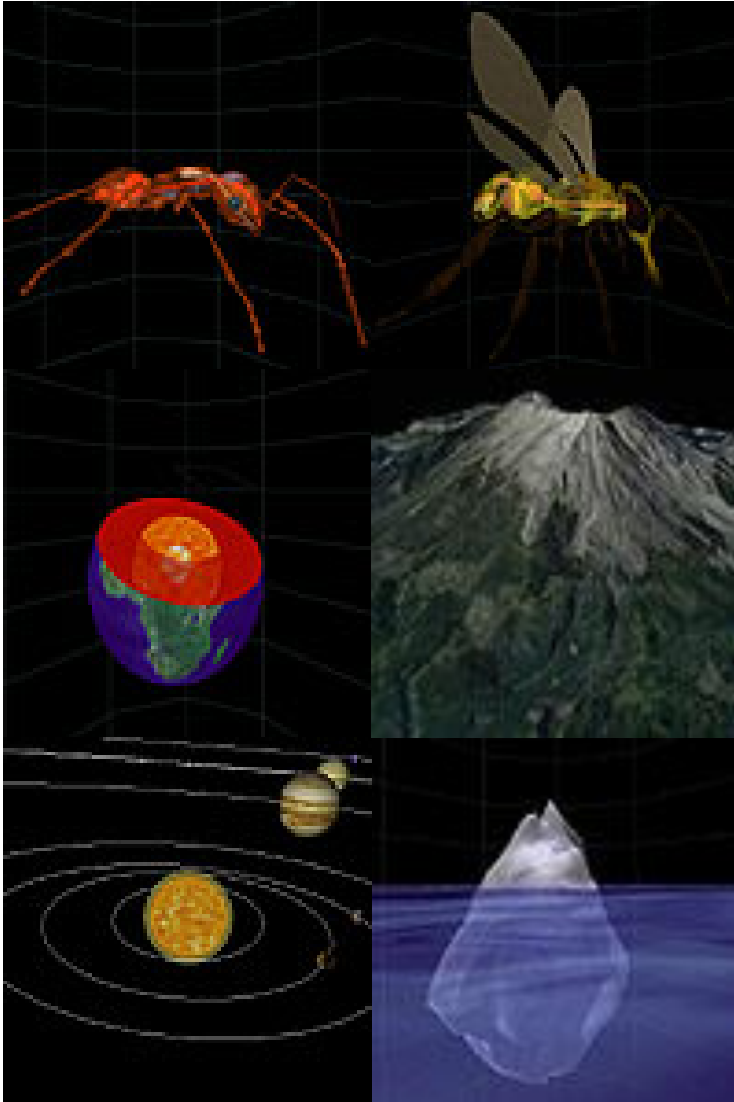
- ❑ **NICE (Narrative Immersive Constructionist Environments) Persistent garden**
- ❑ Encourage learners to actively construct and interrelate knowledge and ideas
- ❑ Persistent garden
- ❑ Collaborative learning and narrative space
- ❑ 6-8 year old users

# Education



- ❑ **Round Earth**
- ❑ Conceptual change: flat to spherical Earth
- ❑ Learning paradox: prior knowledge
- ❑ Displacement theory
- ❑ First-person experience + bridging
- ❑ Tele-immersive application

# Education



- ❑ QuickWorlds
- ❑ Teacher-initiated
- ❑ Rapid turnaround
- ❑ Minimal teacher time investment
- ❑ Extend traditional practice
- ❑ Gradual transfer of control

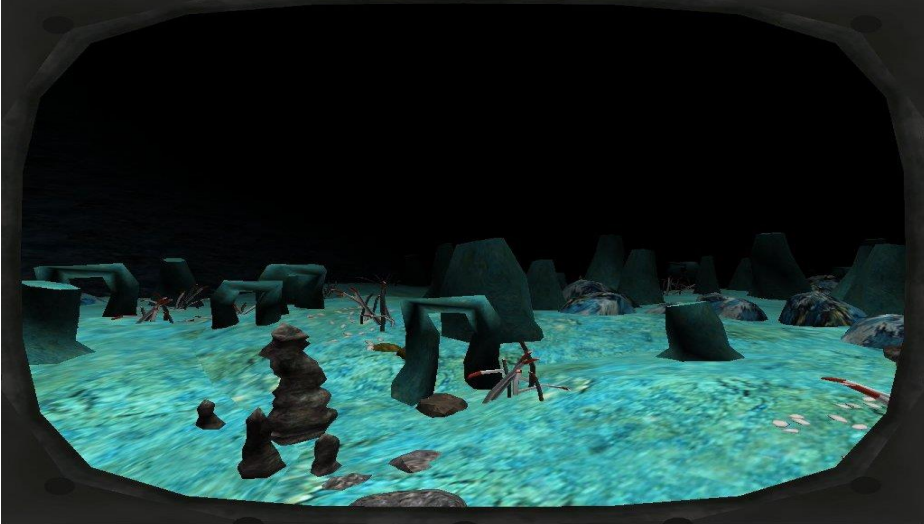
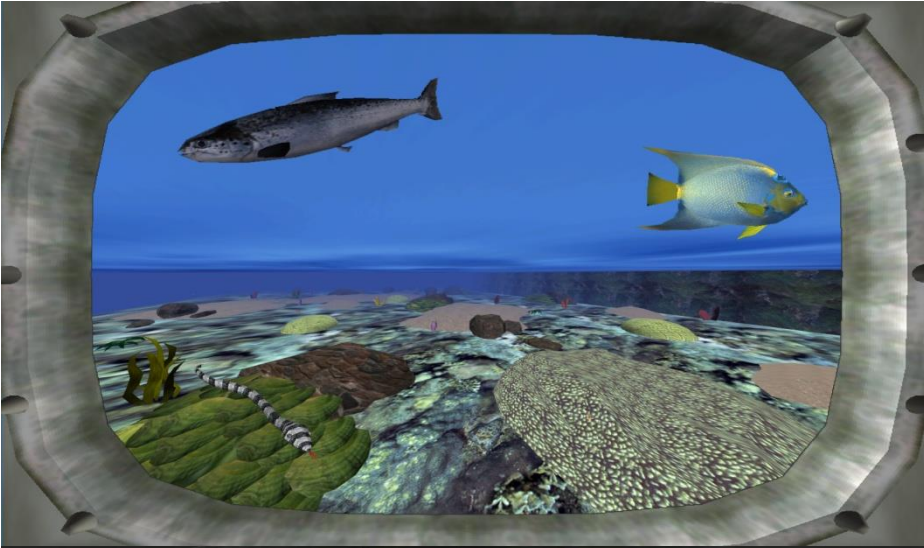
# Education



- ❑ **Virtual Ambients - The Field**
- ❑ Populated with plants and moving objects such as turtles
- ❑ Similarity and difference lesson for the 2nd grade
- ❑ Interpolation and extrapolation for the 4th grade
- ❑ Co-occurrence rules; Beehive, salinity, moisture, and plants; Herbicides and plants for the 6th grade



# Education



- ❑ **Virtual Ambient – The Big Gulp**
- ❑ Populated with fishes, corals, rocks, vents
- ❑ 12000 feet deep ocean
- ❑ Study of graphing environmental factors
- ❑ Study of learning in observation skills by gender

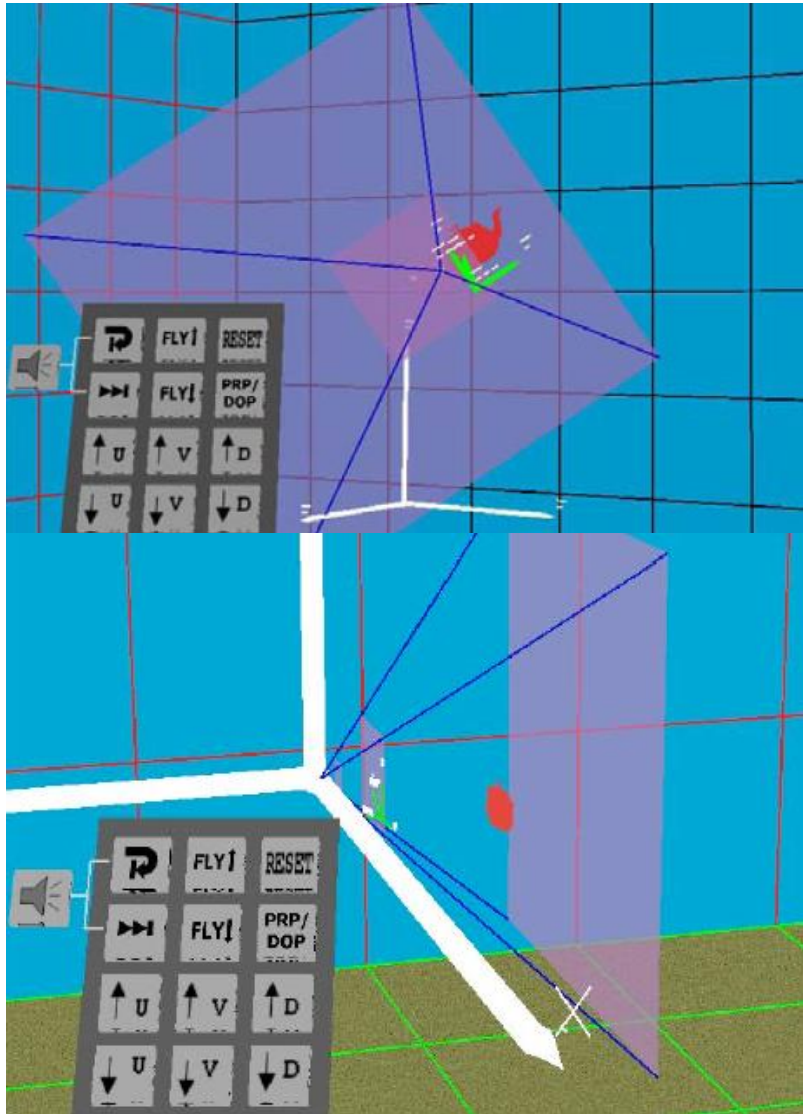
# Education



- ❑ Visualization of the effects of earthquakes on building structures
- ❑ The response of the structure to an earthquake is simulated with **structural analysis program (SAP)**
- ❑ Interactively construct building or load predefined structures
- ❑ Integrated into architecture classes at Virginia Tech

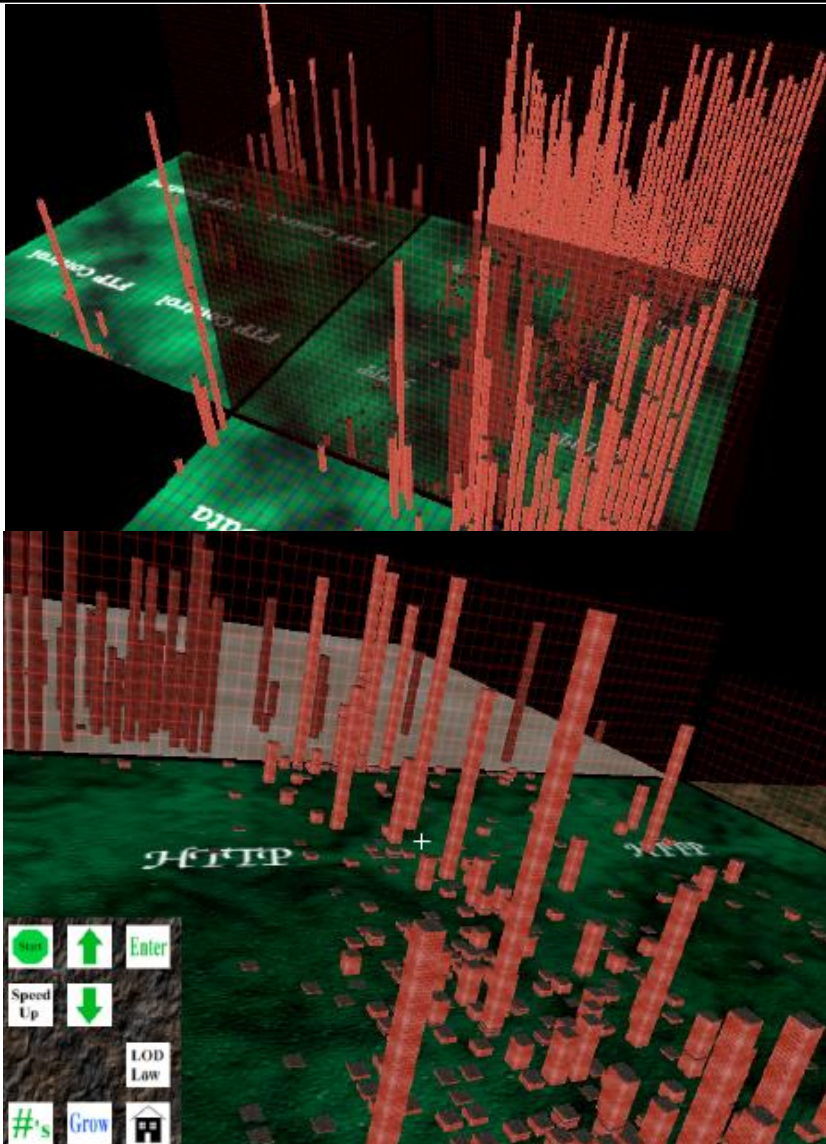


# Education



- ❑ **VENTS** demonstrates multi-step normalizing transformation for perspective views
- ❑ Visualization of view frustum, coordinate systems and rendered object
- ❑ Initial parameters can be modified to display effects of changes
- ❑ Transformation may be viewed from different points
- ❑ Integrated into a computer graphics class

# Education



- **NetViz** provides visualization of large-scale network traffic data
- Enter buildings to view connection-specific data
- Based on “city” metaphor
  - Buildings are connections
  - Building dimensions represent bandwidth, packet-size and lifetime
  - Districts are protocols
- Integrated into computer network classes

# Education



- Stanford Woods Institute for the Environment, **Ocean Acidification**



# Education

- ❑ Harvard Graduate School of Education, **EcoLearn** Group
- ❑ EcoMUVE, EcoXPT, EcoMOD, EcoMobile virtual ecosystem



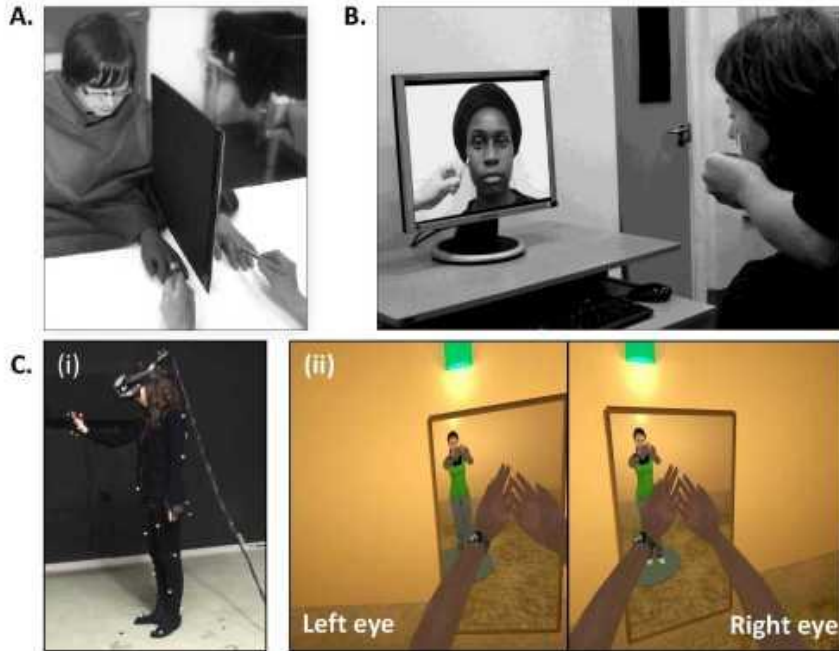
# Education



- ❑ **In the Eyes of the Animal**
- ❑ Explore the food chain through cinematic sonic experience
- ❑ Woodland species ( Mosquito, Dragonfly, Frog, Owl) with their visions and their worlds
- ❑ <http://iteota.com/>



# Education



Trends in Cognitive Sciences, Maister et al.

- T Peck, S Seinfeld, M Aglioti, M Slater (2013) **Putting Yourself in the Skin of a Black Avatar Reduces Implicit Racial Bias, Consciousness and Cognition** Volume 22, Issue 3, September 2013, Pages 779--787 22
- <https://youtu.be/HliN3iOX090>



# Education



- ❑ Autism Simulator, a game about autism, lets you experience the horror of sensory overload
- ❑ <https://www.youtube.com/watch?v=DwS-qm8hUxc>

# Education



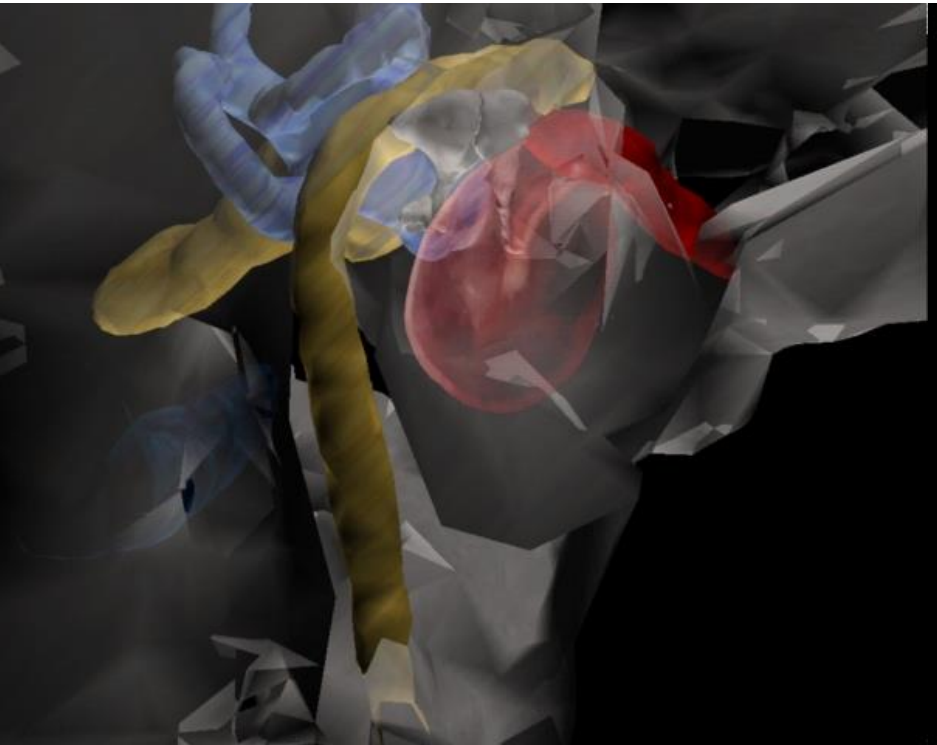
- ❑ Jongam Middle School in Seoul
- ❑ Principles and understanding of wind power generators was conducted using VR.

# Military Training



- ❑ NPSNET – Large Scale Virtual Environment Technology Testbed
- ❑ NPSNet is a real-time, interactive distribution simulation system, developed by Naval Postgraduate School
- ❑ To implement a large-scale networked virtual environment
- ❑ IEEE 1278 Distributed Interactive Simulation (DIS) application protocol

# Medical Training



- ❑ **Virtual Temporal Bone**, developed by UIC's VR Medicine Lab lets physician teach medical students about 3D structure and function of the inner ear
- ❑ External view of the human ear
- ❑ Human temporal bone to reveal the delicate anatomic structures imbedded within bone
- ❑ Close-up view of the structure within the bone

# Medical Training



- ▣ **Virtual Reality Dental Training System (VRDTS)**, developed by School of Dental Medicine at Harvard University, to train medical students

# Medical Training



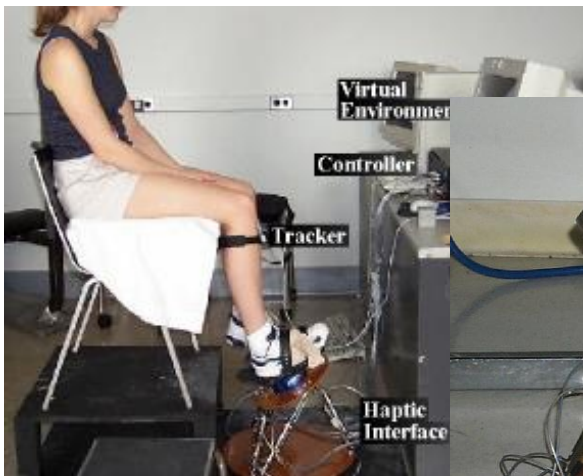
- ❑ Ewha Women's University, Computer Graphics and Virtual Reality Research Center
- ❑ Medical image visualization
- ❑ VR table, front-wall projection display

# Medical Training



- ❑ **FundamentalVR** offers simulator-based training programs for surgeons. <https://onix-systems.com/blog/implementing-virtual-reality-in-medicine-and-medical-training>
- ❑ **VR surgery training** platform 'Osso VR' <https://www.roadtovr.com/osso-vr-training-surgeons/>

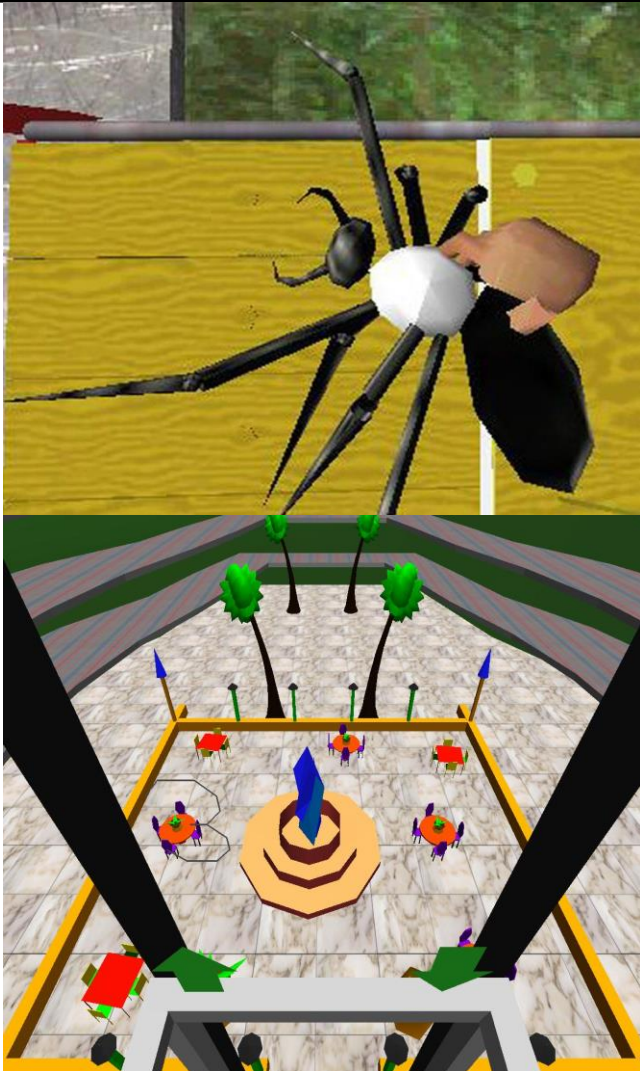
# VR Therapy



- **'Rutgers Ankle' Rehabilitation Interface**, developed by Rutgers University
- Pilot the virtual plane
- The "Rutgers Ankle" Rehabilitation Interface is a robotic ankle rehabilitation device designed for at-home use and Internet-based remote monitoring by therapists



# VR Therapy – phobia treatment



- ❑ **Spider phobia**, developed by HIT lab at University of Washington – VR exposure therapy for treating spider phobia
- ❑ **Acrophobia** (the fear of heights), developed by GVI at Georgia Tech – VR exposure therapy that involves exposing the subject to anxiety producing stimuli while allowing the anxiety to attenuate

# VR Therapy



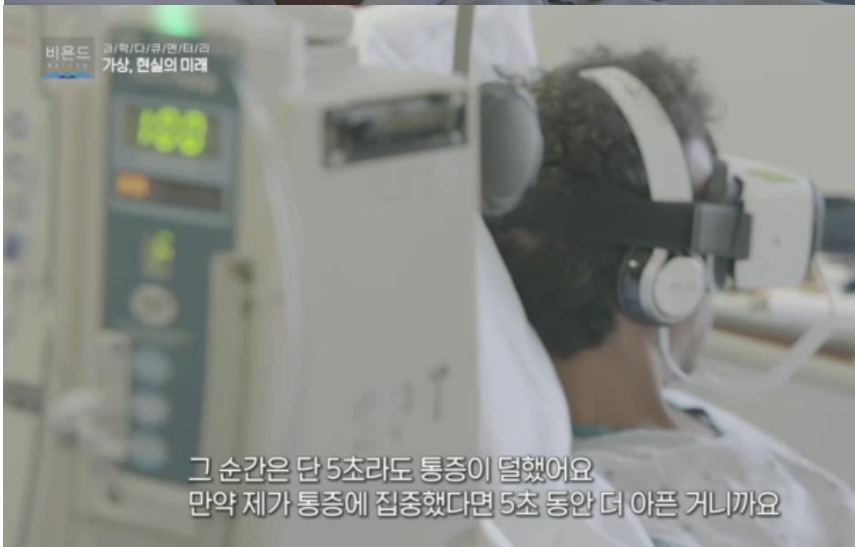
- ❑ Seoul Baik Hospital, VR therapy clinic
- ❑ Severance Hospital



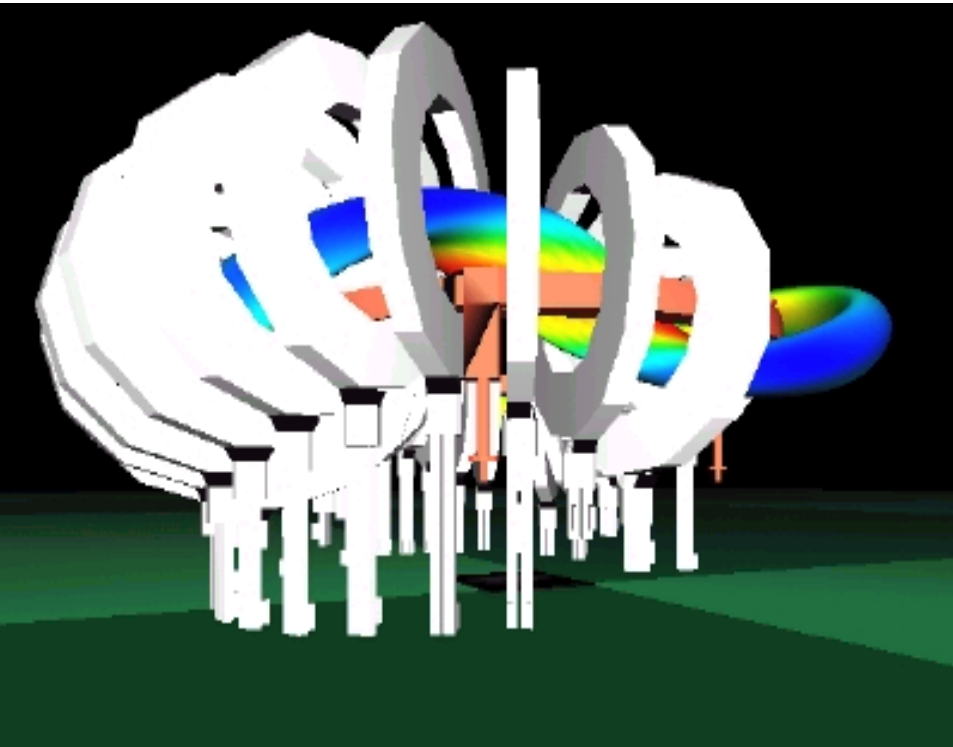
# VR Therapy



- **Applied VR** provides therapeutic VR therapy to enhance patient's experience, helping with anxiety and pain
- <https://appliedvr.io/appliedvr-content/>

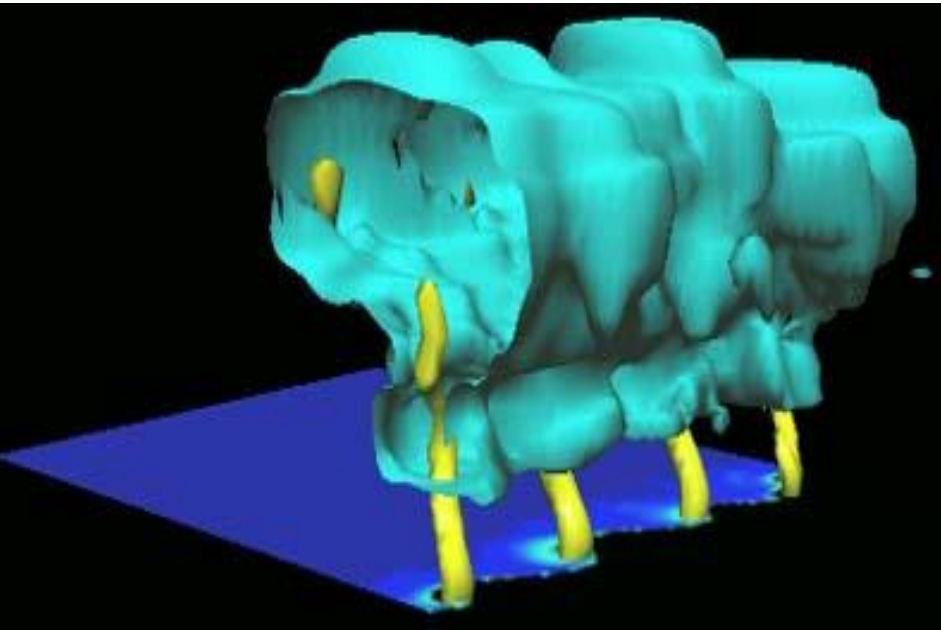


# Scientific Visualization



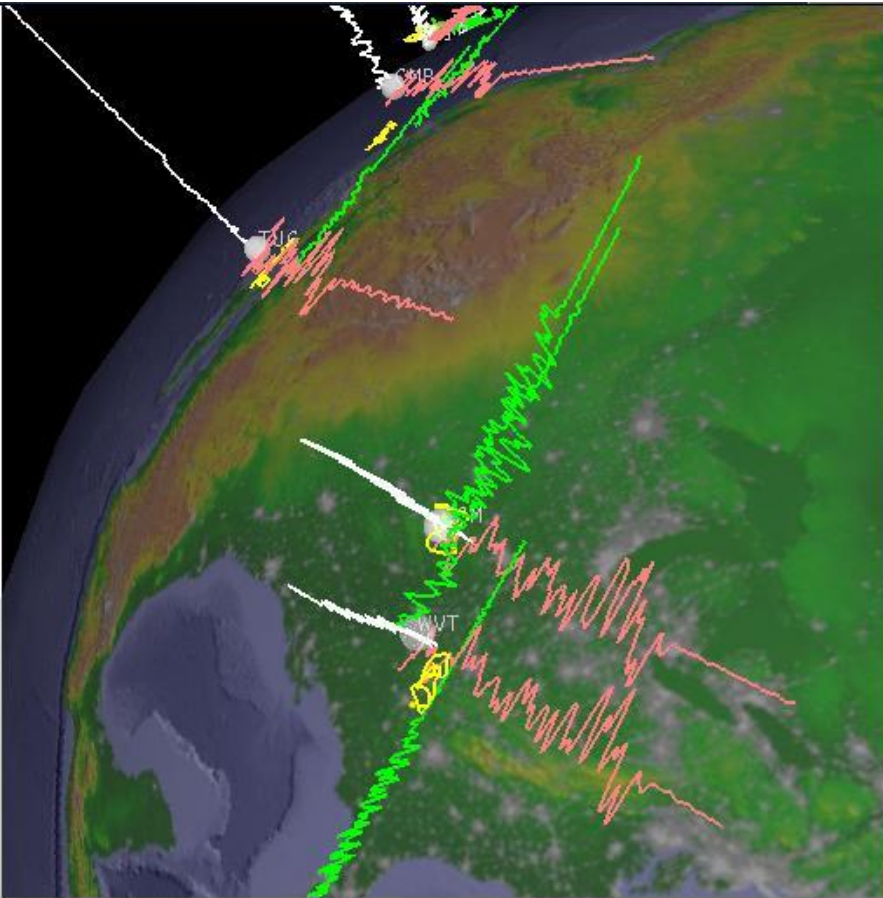
- **Helic Plasma Coil**, developed by Cooperative Research Center for Advanced Computational Systems at Australian National University
- Main magnetic coil set and a magnetic “flux surface” of the H-1HF Helic fusion plasma physics experiment

# Scientific Visualization



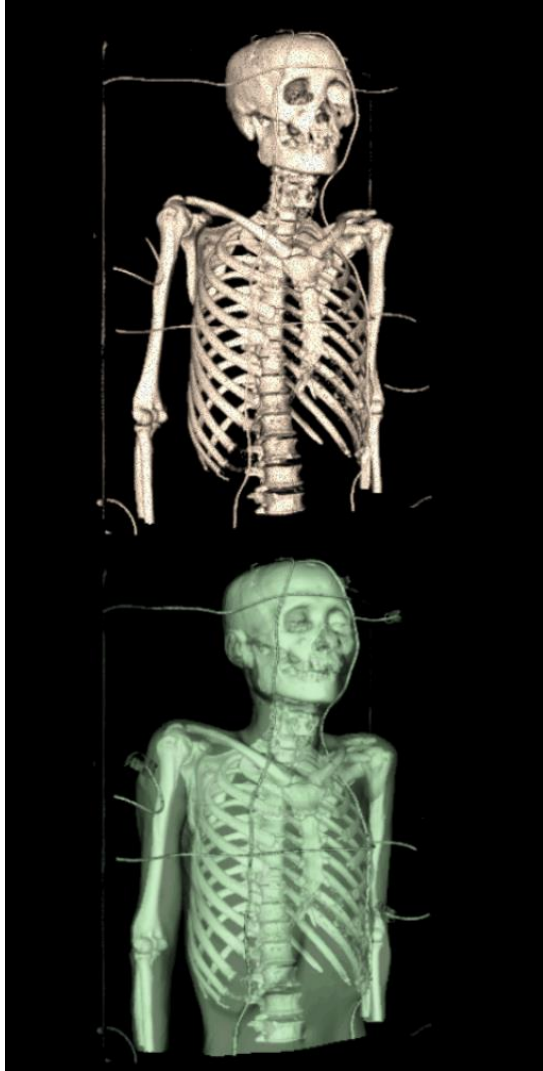
- ❑ **Non-Supercell Tornado Simulation** developed by UIUC Dept. of Atmospheric Sciences & NCSA
- ❑ Viewers can immerse themselves with the digital storm and understand how they form and develop

# Scientific Visualization



- ❑ **Wiggleview**, developed by EVL
- ❑ Traditionally seismologists look at 2D X-Y plots of a time-series of the displacement of a seismometer in the North-South, East-West, and Up-Down directions
- ❑ Wiggleview allows to visualize the simultaneous recording of three channels of seismic data in response to an event

# Scientific Visualization



- ❑ **Visible Korean Human**, developed by Computer Graphics Lab at Sogang U. & KISTI
- ❑ Volume visualization using image-based rendering technique
- ❑ CT, MRI, RGB datasets of a Korean senior, created by KISTI and Ajou Univ.
- ❑ allows users to investigate skin and bone of the human

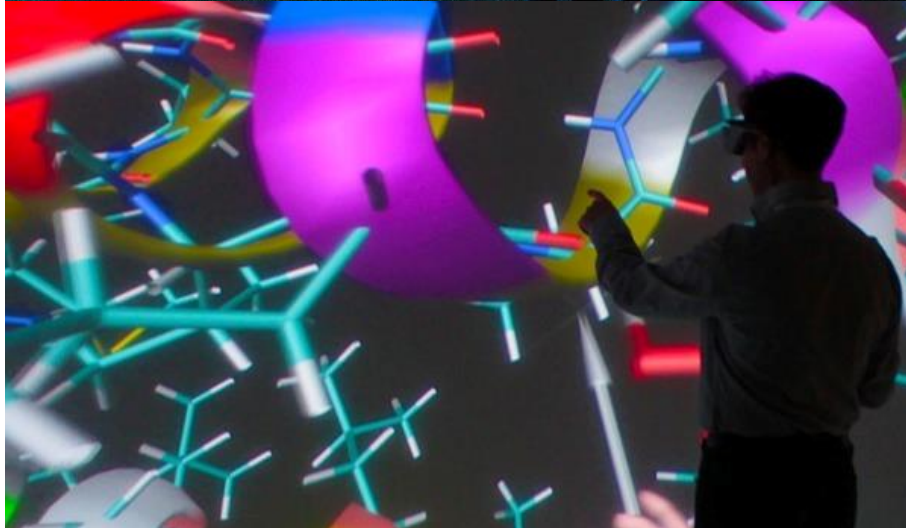
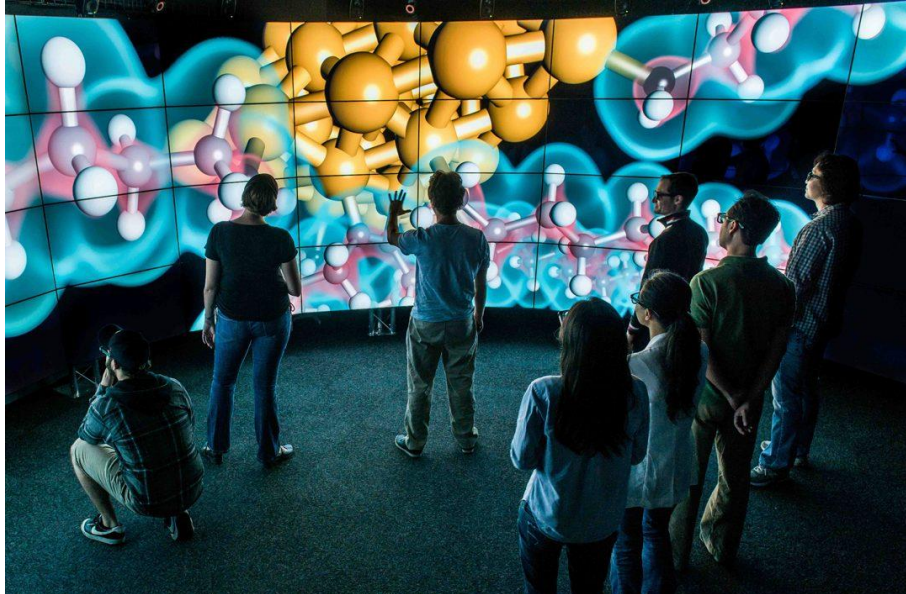
# Scientific Visualization



- ❑ Development of **Typhoon Maemi** landed on the southern coastal area of Korea during Sep 2003, developed by Digital Ocean & Virtual Environment Center at Korea Ocean Research and Development Institute
- ❑ Low-saline water in Yellow Sea due to spreading of Changjiang Diluted water toward Jeju Island, developed by DOVE at KORDI
- ❑ Scientific visualization to display multi-dimensional numerical data (e.g. atmospheric, oceanographic),



# Scientific Visualization



- Visualization of a balls-and-sticks model of a molecular chemistry dataset in EVL's CAVE2 virtual reality environment.
- Use of Virtual Reality in the Pharmaceutical industry.  
<https://blog.techviz.net/7-use-case-of-virtual-reality-in-the-pharmaceutical-industry>

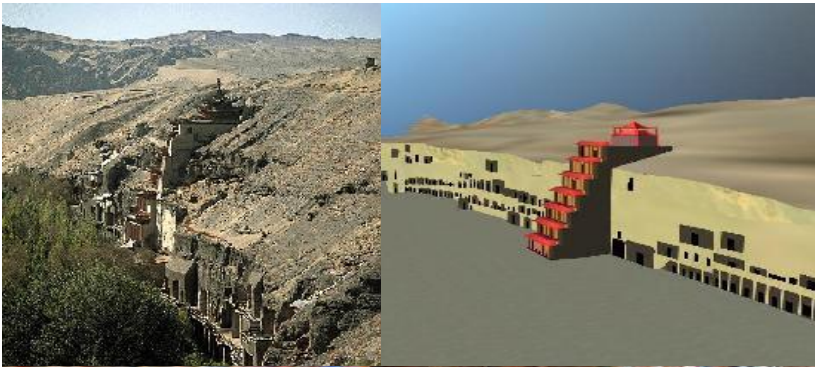
# Cultural Heritage



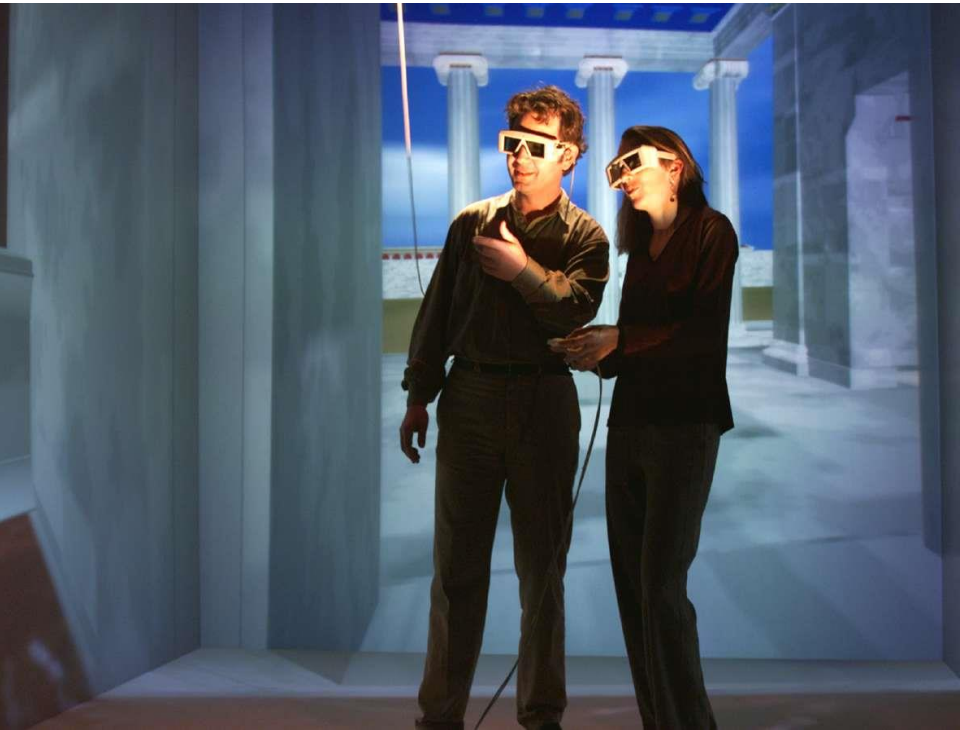
- ❑ **Virtual Harlem** allows people at remotely located CAVEs to tour 1920-40 Harlem, and listen to African American artists, writers and intellectuals of that time - notably Langston Hughes, Marcus Garvey and others.
- ❑ Collaborative effort between Central Missouri State University, Advanced Technology Center at University of Missouri, and EVL at UIC.

# Cultural Heritage

- A virtual cultural and artistic exhibit of the Mogao Grottoes of Dunhuang. Dunhuang, one of western China's ancient cultural sites, is considered the gateway to the well-known Silk Road- the East-West trade route between Asia & Europe.



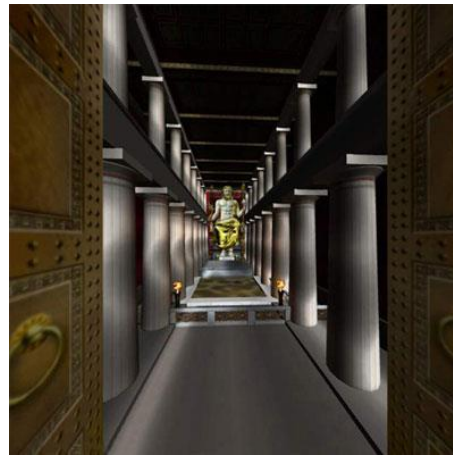
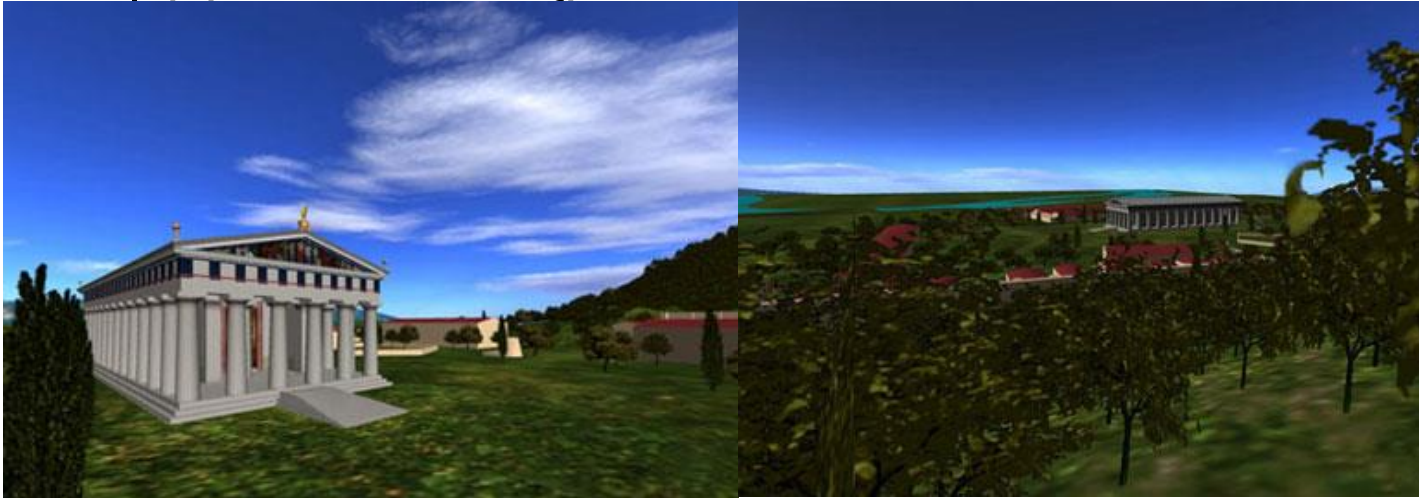
# Cultural Heritage



- ▣ **Hellenistic Miletus**, by Foundation of Hellenic World (FHW) & EVL
- ▣ A cultural heritage demonstration which takes visitors on a shared virtual voyage through the ancient Greek city of Miletus as it existed 2000 years ago

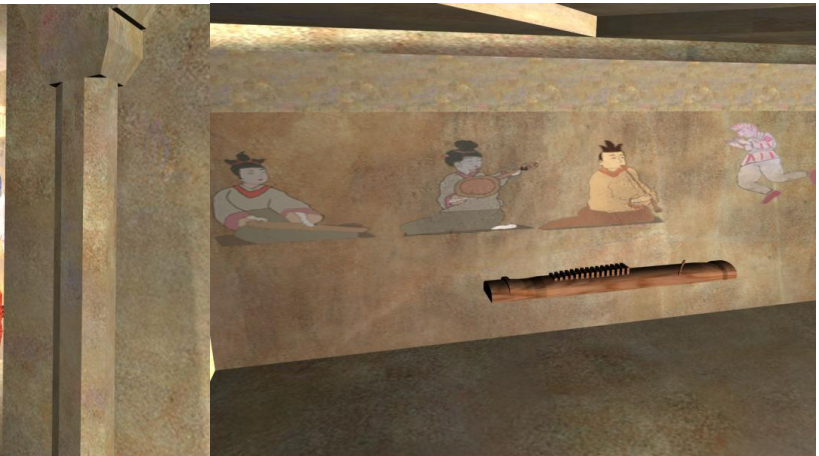
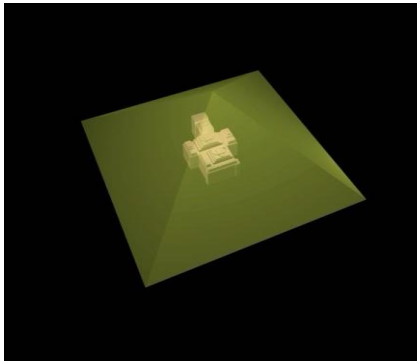
# Cultural Heritage

- **Temple of Zeus at Olympia**, Foundation of the Hellenic



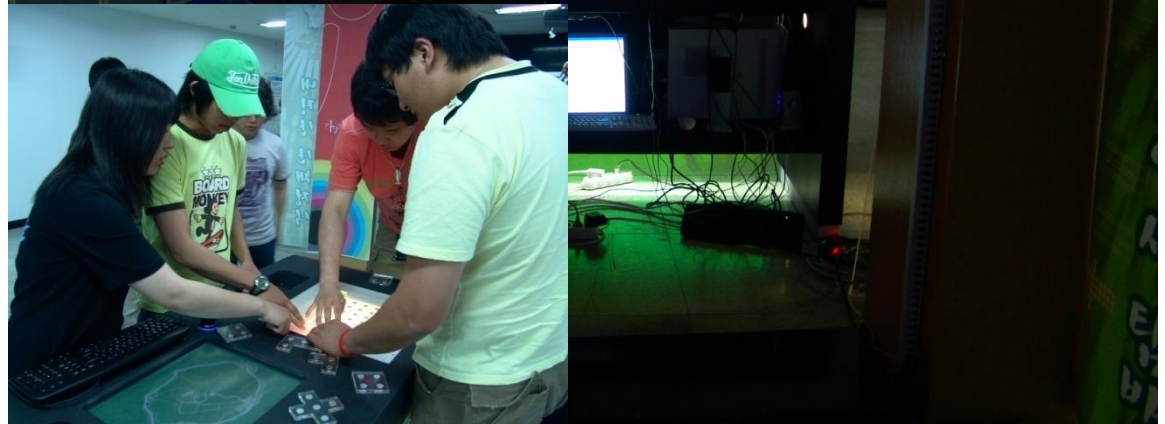
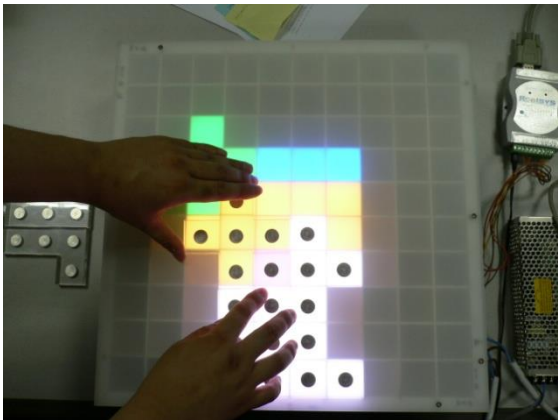
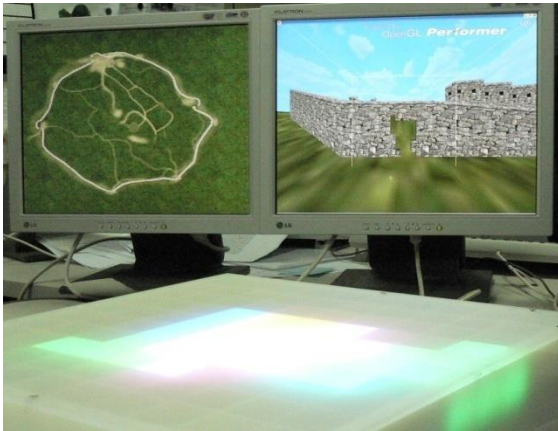
# Cultural Heritage

- ▣ **Digital Koguryo**, Digital reconstruction of Anak No. 3 Tumulus in Virtual Reality

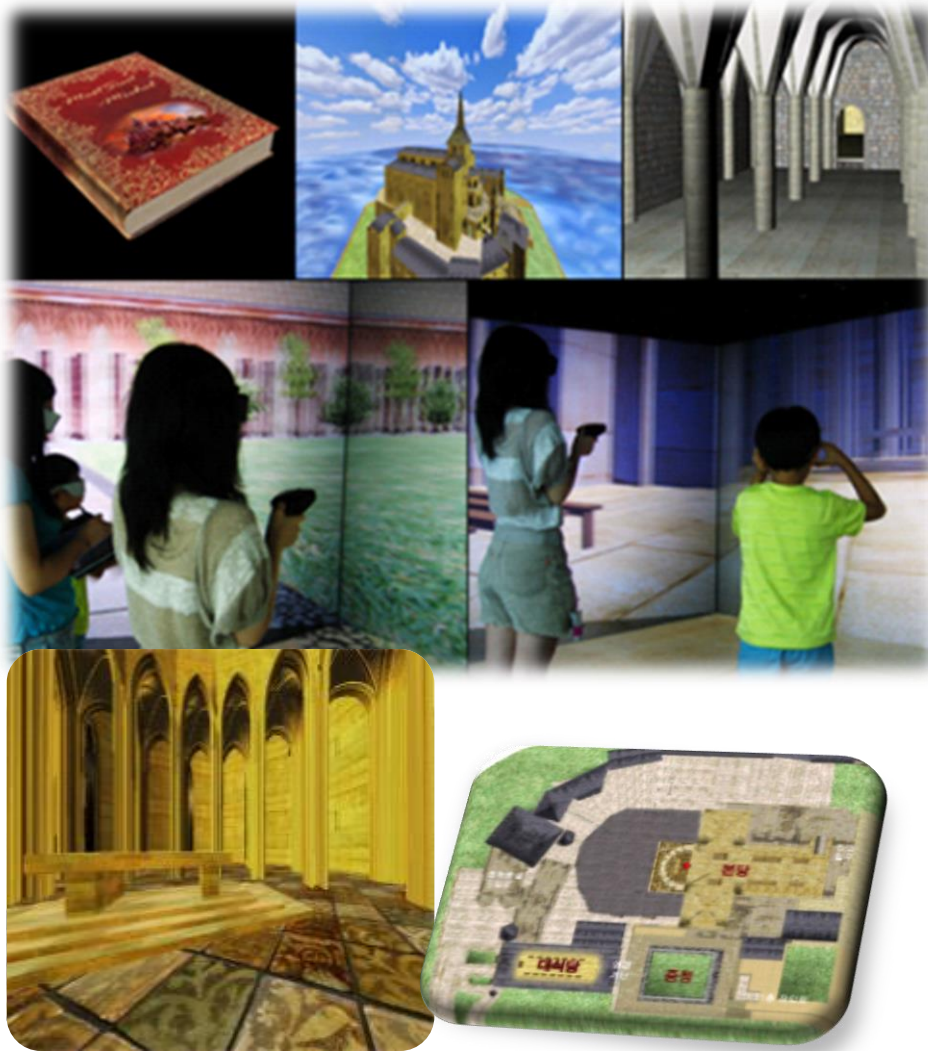


# Cultural Heritage

- ▣ **Tangible Moyangsung**, Use of tangible blocks to interact with the virtual environment



# Cultural Heritage

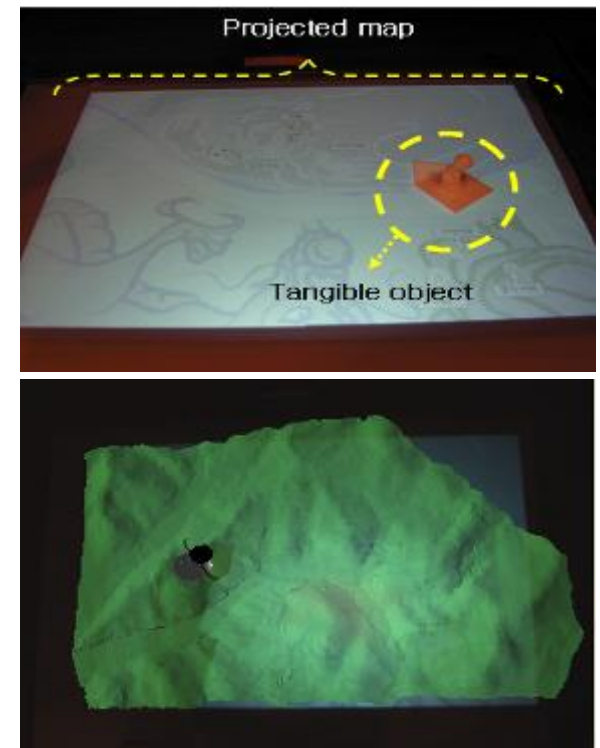


- **Mont-Saint-Michel** interactive virtual heritage tour guide system
- Allows users to travel in the virtual heritage site and get more information about the sites or items of user's interests.
- Also allows users to make their own tour guidebook with the pictures they have taken during the virtual tour and more detail descriptions from the tour guide database



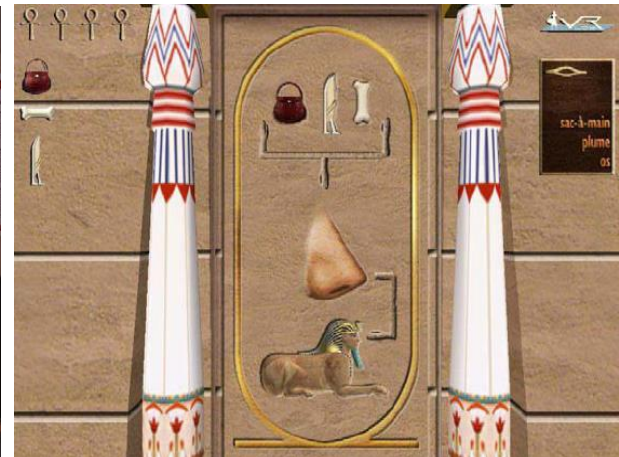
# Cultural Heritage

- **Dream of Mee-luck** @GIST, VR-based immersive cultural heritage system which supports context-aware, personalized human-computer interaction

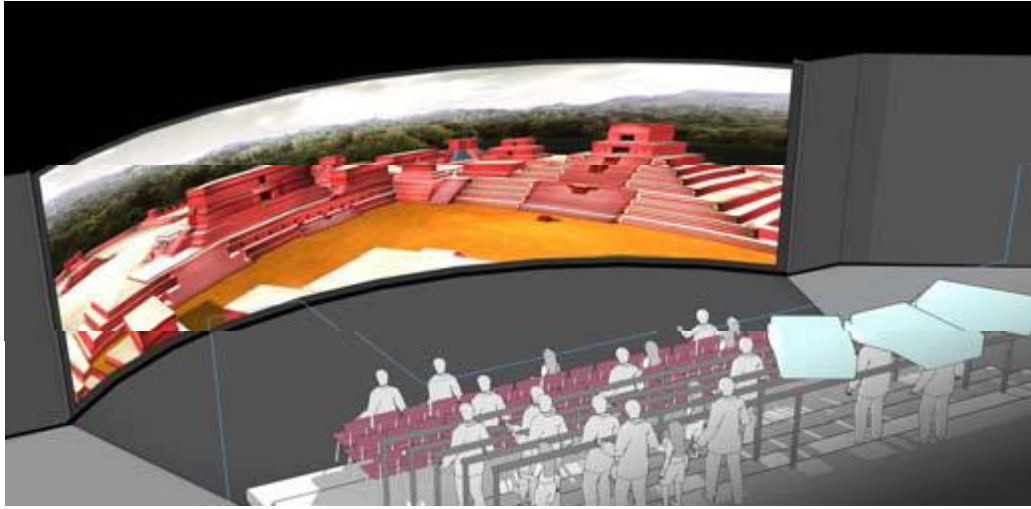


# Cultural Heritage

- Enigma of the Sphinx, Swiss Federal Institute of Technology in Lausanne (EPFL)



# Cultural Heritage



Virtual Reality  
Theater for  
**Mayan Civilization  
Exhibit**, U of Tokyo

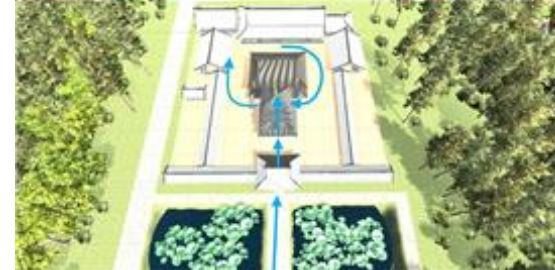
# Cultural Heritage



**A Journey into the Breath of Sorabol**

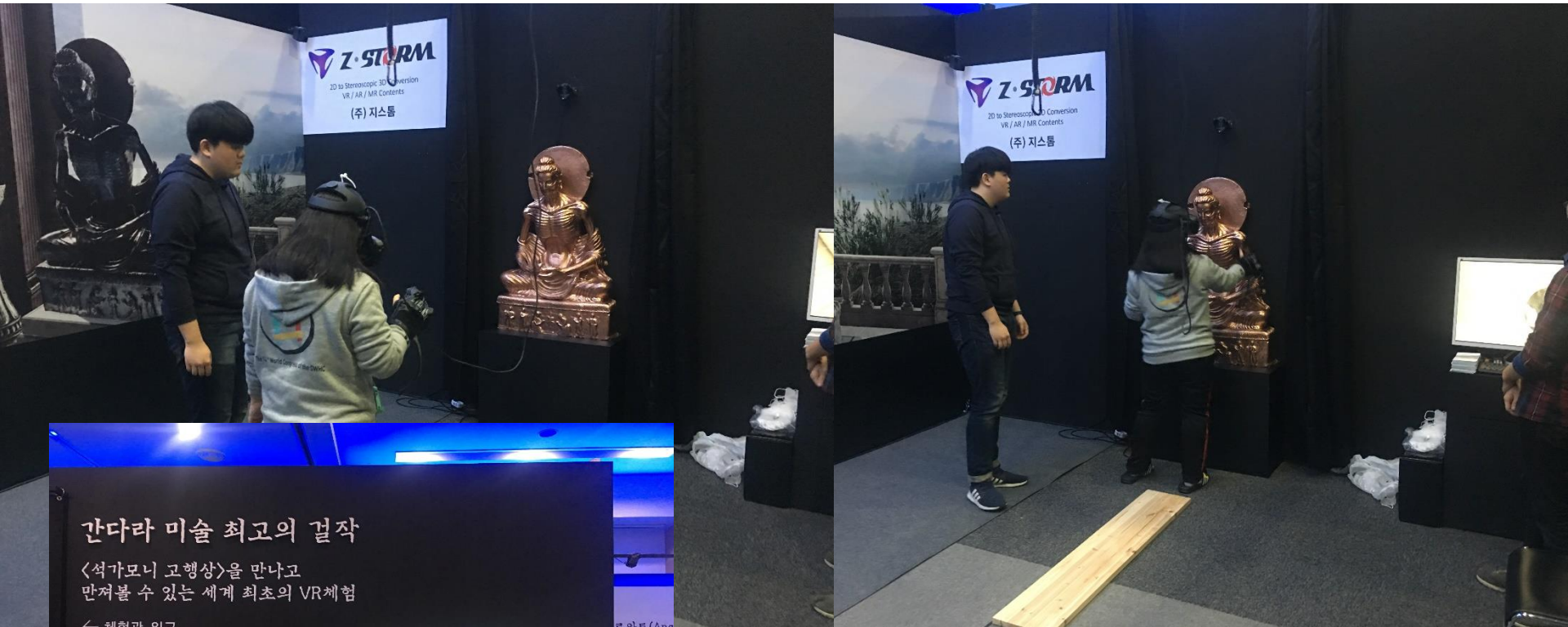
@Gyeongju World Culture Expo 2000, KIST

# Cultural Heritage



Baekje Neungsa

# Cultural Heritage



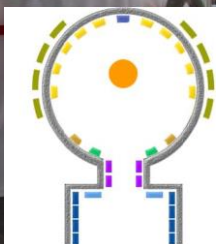
World Digital Heritage Forum 2017

# Cultural Heritage



Seokguram HMD VR  
@ World Digital Heritage Forum 2017

# Cultural Heritage



Walkable Seokguram HMD VR



# Cultural Heritage



Walkable Seokguram VR @COEX 2015/11

# Cultural Heritage



# Cultural Heritage



콘클라베로 유명한 시스티나 예배당 내부  
불멸의 마스터피스 미켈란젤로의 천장화

Michelangelo's famous frescoes :  
The Sistine Chapel VR

The Sistine Chapel is one of the most important religious sites in the world. The ceiling of the chapel is a masterpiece of Renaissance art, created by Michelangelo between 1508 and 1541. This VR experience allows you to explore the chapel and its famous frescoes in a virtual reality environment.

시스티나 예배당

시스티나 예배당은 콘클라베를 치는 장소로, 1508년부터 1541년까지 미켈란젤로가 천장화를 그리는 동안 완성되었습니다. 이 VR 체험을 통해 시스티나 예배당의 내부와 미켈란젤로의 천장화를 가상 현실에서 경험할 수 있습니다.

파라오이

파라오이는 시스티나 예배당의 천장화 중 하나로, 노아와 그의 가족이 홍수에서 구해낸 이야기를 묘사하고 있습니다. 이 VR 체험을 통해 파라오이의 세부적인 묘사와 미켈란젤로의 예술적 기교를 감상할 수 있습니다.

## 시스티나 예배당 VR

VR 기술을 통해 현지 방문과 동일한 체험을 선사한다.  
문화유산 관람에 대한 새로운 해석

시스티나 예배당 VR은 다양한 백화가 그려진 시스티나 예배당 내부와 인류 최고의 문화유산이자 불멸의 마스터피스로 칭송받는 미켈란젤로의 천장화를 VR 기술과 과학적 고증을 통해 재구현된 콘텐츠이다. 직접 로마 바티칸을 방문하지 않더라도 HMD를 통해 예배당 내부와 미켈란젤로의 그림들을 둘러 볼 수 있으며 이를 통해 단순히 건축물과 그림을 보는 것이 아닌 체험으로서의 새로운 감상법을 제안하고자 한다.

천장화가 그려지기 이전의 예배당과 미켈란젤로가 그림을 그리기 위해 만든 비계 등이 논문, 사료 연구자료 등의 분석을 통해 재현되며 관람객이 그림을 감상할 때만 그림에 관한 설명과 재현된 비계 등의 정보를 안내하는 인터랙티브 기능, 현지에서 천장화를 둘러보는 시점과 더불어 현장을 원거리로 관람하는 시점, 절벽에서 파노라마를 바라볼 수 있는 절경을 제공하여 다각도로 천장화를 감상할 수 있도록 의도하였다.

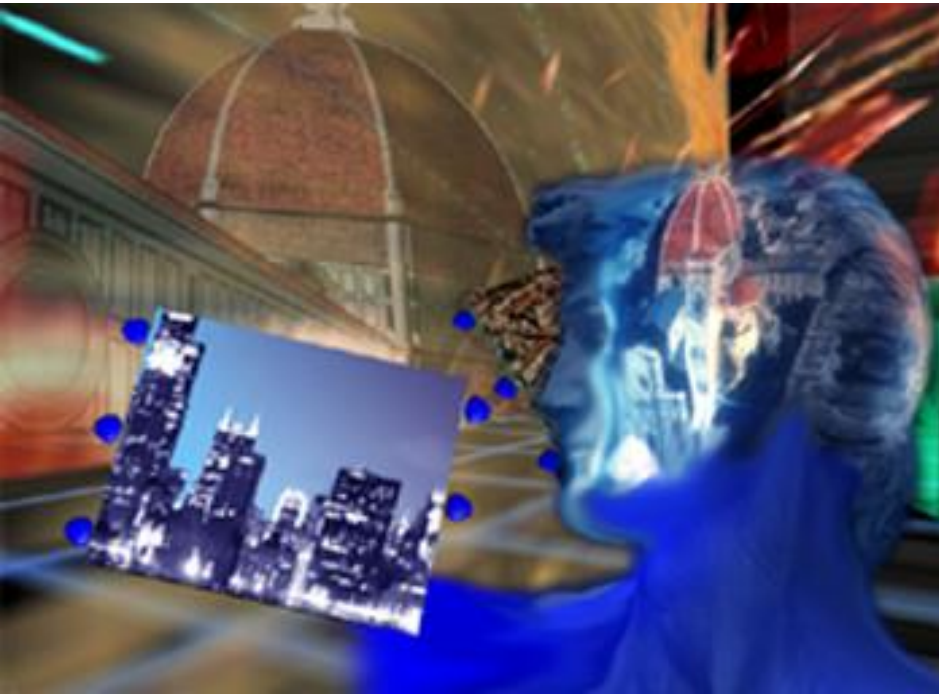
Michelangelo, Ceiling Fresco of the Sistine Chapel @ World Digital Heritage Forum 2017

# Interactive Art



- ❑ **Crayoland** created by Dave Pape, EVL – 2D crayon drawings placed in a 3D world
- ❑ **Synesthesia** by Rita Addison & Marcus Thieboux, EVL – a sensory input (e.g. music) is perceived as a different sensory mode
- ❑ **CAVE Quake** by Paul Rajlich, NCSA

# Interactive Art



- **CITYCLUSTER** "From the Renaissance to the Gigabits Networking Age", EVL & Fabricat
- Florence representing "Renaissance Age" & Chicago representing the "Gigabits Age" are interconnected by high speed network, enabling remote participants to interact and collaborate in shared environments

# Interactive Art



- **ID Illusion**
- Exploration into the artist's subconscious as a metaphorical journey: maze, topiary garden, family photograph, falling away of the floorboards, ultimately dropping into a space fills with memories, abstract world, magic mirror reflecting identity, liberate from the bird cage, hanging butterfly, tree growing out of the ground

# Interactive Art

- ▣ **Dreams of Dali** - Florida Salvador Dali Museum using Oculus VR, <https://thedali.org>



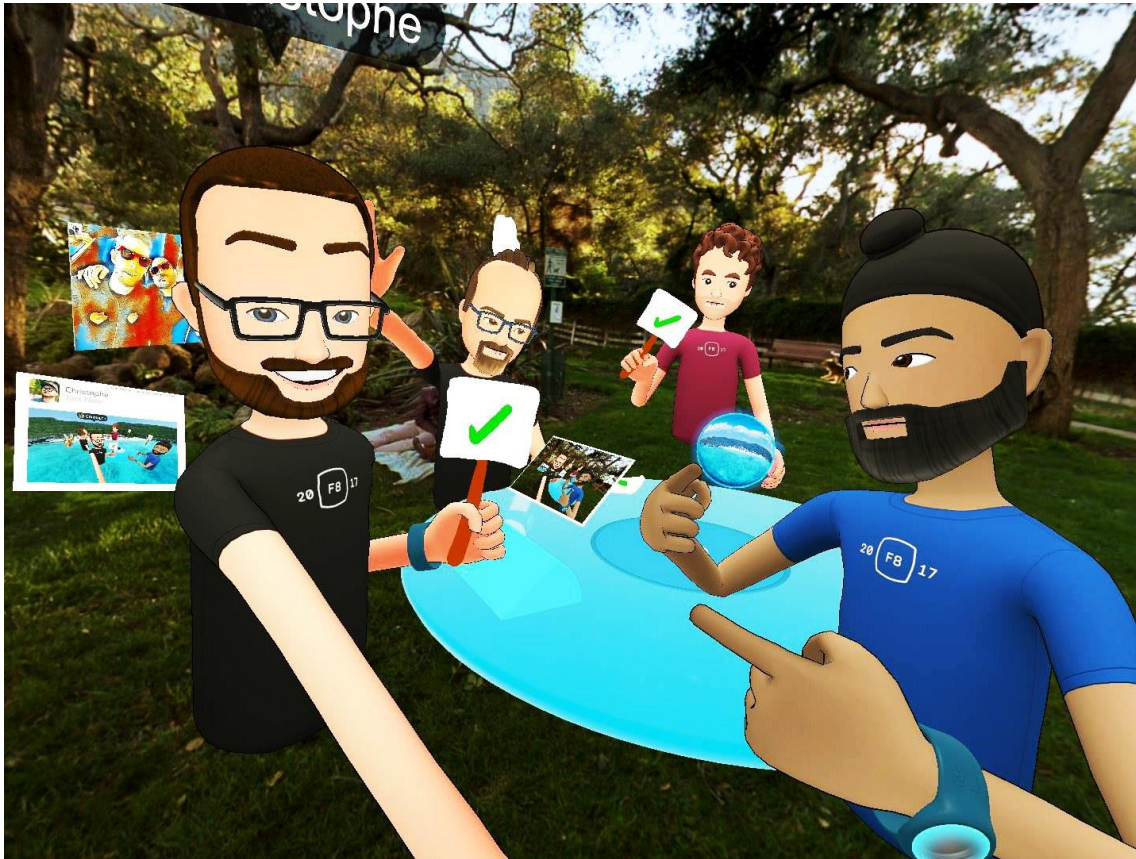
# Social VR



- ❑ SecondLife
- ❑ <https://www.youtube.com/watch?v=XQkYBbM9YyM>



# Social VR



- ❑ Facebook Spaces – sharing experiences with friends in VR
- ❑ <https://www.youtube.com/watch?v=iUHu3VT94p0>

# VR in Fashion Industry



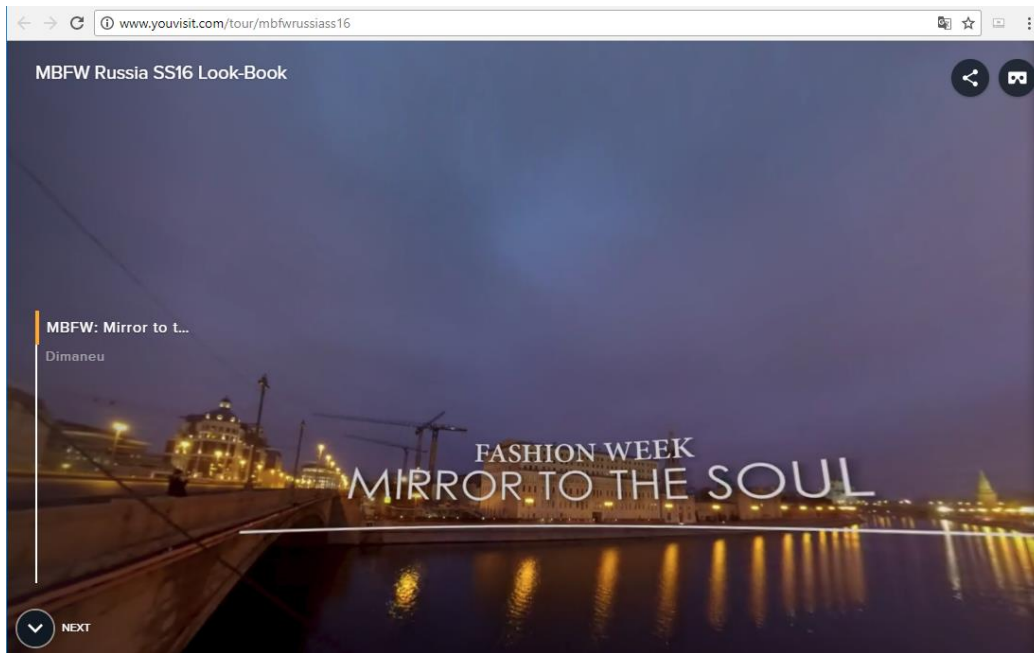
- ❑ Virtual Reality shopping experience for the Vera Bradley Home collection, on the Google Daydream View headset. Powered by Obsess. Shop in 360 here: <https://www.youtube.com/watch?v=iCtw6olfeMw>
- ❑ Rebecca Minkoff virtual store, powered by Obsess for the Innov8 showcase <https://www.youtube.com/watch?v=iTLjTcfdFxE>

# VR in Fashion Industry



- ❑ Samsung Gear VR headset of the VR experience developed by Obsess for The Shows at FTL Moda, in partnership with Samsung, for New York Fashion Week. Release on February 14, 2017.
- ❑ <https://www.youtube.com/watch?v=9iyFPyTNYfU&feature=youtu.be>

# VR in Fashion Industry



■ Mirror to the Sour - YouVisit (a platform that creates 360 degree interactive virtual tours) aligned with Mercedes-Benz Fashion Week Russia

<http://www.youvisit.com/tour/mbfwrussiass16>

■ <https://www.vogue.com/article/virtual-reality-future-fashion-week>

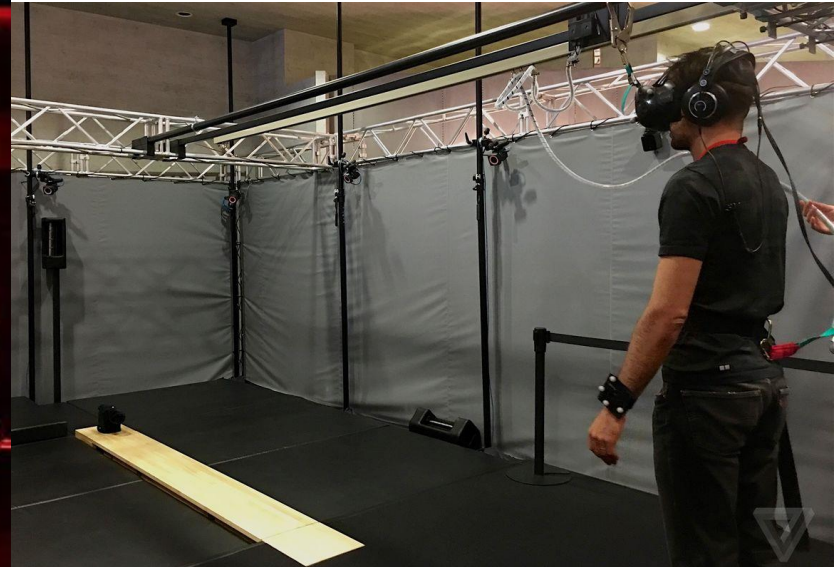


# Entertainment



- Disney Quest - Aladdin

# Japan VR Zone



① スキ ロデオ	700 円
② リアル ドライブ	700 円
③ 高所  공포 SHOW	1,000 円
④ 脱出 病棟 Ω	800 円
⑤ トレイン マイスター	700 円
⑥ アガイル イ동	700 円

営業時間 Opening Time	入室 Entrance	体験時間 Experience Time	退室 Exit
10:00 ~ 11:30	5 分	80 分	5 分
11:30 ~ 13:00	5 分	80 分	5 分
閉鎖時間 15 分			
13:15 ~ 14:45	5 分	80 分	5 分
14:45 ~ 16:15	5 分	80 分	5 分
閉鎖時間 15 分			
16:30 ~ 18:00	5 分	80 分	5 分
18:00 ~ 19:30	5 分	80 分	5 分
19:30 ~ 21:00	5 分	80 分	5 分

# Shanghai VR Zone



# Best VR Applications (2023)

□ <https://www.creativebloq.com/features/best-vr-apps>

1. Space Explorers: The ISS Experience
2. YouTube VR channel
3. Within VR
4. The Guardian VR
5. Provata VR
6. Dreams (for PSVR)
7. Quill by Smoothstep
8. Gravity sketch
9. Tilt Brush
10. Kingspray Graffiti
11. Tвори
12. AnimVR
13. Substance 3D Modeller





# 10 Top-Selling VR Games

□ <https://gamerant.com/top-selling-vr-games-according-steam/>

1. Half-Life: Alyx
2. Beat Saber
3. Boneworks
4. Pavlov VR
5. Blade And Sorcery
6. The Elder Scrolls V: Skyrim VR
7. Hot Dogs, Horseshoes & Hand Grenades
8. The Walking Dead: Saints & Sinners
9. Gorn
10. Job Simulator



# The problem of VR applications

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- Are there any real world problems that
  - Benefit from VEs?
  - Requires VEs?
- Why few applications?
  - Hardware issues
  - Software issues
  - Public acceptance
  - Interaction

# Hardware Issues

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- ❑ High cost/benefit ratio
- ❑ Overall system latency
- ❑ Expensive cost to get high resolution, wide FOV, bright stereoscopic display
- ❑ Rendering very large models
- ❑ Realistic haptics

# Software Issues

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- ❑ Lack of standards
  - Recent SDKs, such as OpenVR (first released in 2015) developed by Valve, support more VR headsets.
- ❑ Vastly different & too many toolkits
- ❑ Interoperability & portability
- ❑ Graphics file formats
- ❑ Difficult to build models

# Public Acceptance

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- ❑ Simulator sickness
- ❑ Fatigue
- ❑ Isolate from real world

# Interaction

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- ❑ Interaction simple and infrequent
- ❑ Need 3D interface for complex interaction
- ❑ Domain experts (scientists, architects, engineers, etc) want to use virtual environments, but their projects die in the research lab because the prototypes are not usable

# VR Software

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- CAVElib (EVL/VRCO) <http://www.vrco.com/>
  - software toolkit for developing VR applications, such as CAVE, ImmersaDesks, HMDs
  - The major tasks are to read data from the input devices (trackers and wand or other controller), configure the graphics output, and manage the multiple, parallel processes in an application
  - support simulator mode
- VR Juggler (Iowa State) <http://www.vrjuggler.org/>
  - open source, object-oriented, virtual platform for VR application developments
- FreeVR (NCSA) <http://www.freevr.org/>
  - open source VR toolkit
- Diverse (Virginia Tech) <http://diverse.sourceforge.net/>
  - cross-platform, open source APIs for VR application developments
- Vega (Multigen) <http://www.multigen.com/>
  - provides cross-platform scene graph APIs

# VR Software

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- Alice (CMU) <http://www.alice.org/>
  - programming environment for interactive virtual environments
  - provide an easy-to-user rapid prototyping environment for 3D application
  - use Python for programming object behaviors
- WorldToolKit (Sense8/ EAI) <http://www.sense8.com/>
  - WorldToolKit, WorldUp, World2World
  - WTK is a collection of C functions for driving VR input and output devices and manipulating the world database
  - Behaviors are programmed as VisualBasic scripts
- dVise (Division)
  - commercial VR development packages
  - allows one to create applications without direct programming
  - uses the script file that contains the world object hierarchy and behaviors



# VR Software

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## □ VSS (NCSA)

- <http://cage.ncsa.uiuc.edu/adg/VSS/>
- Networked client/server
- Sample playback & advanced synthesis algorithms
- Real-time manipulation
- Localization

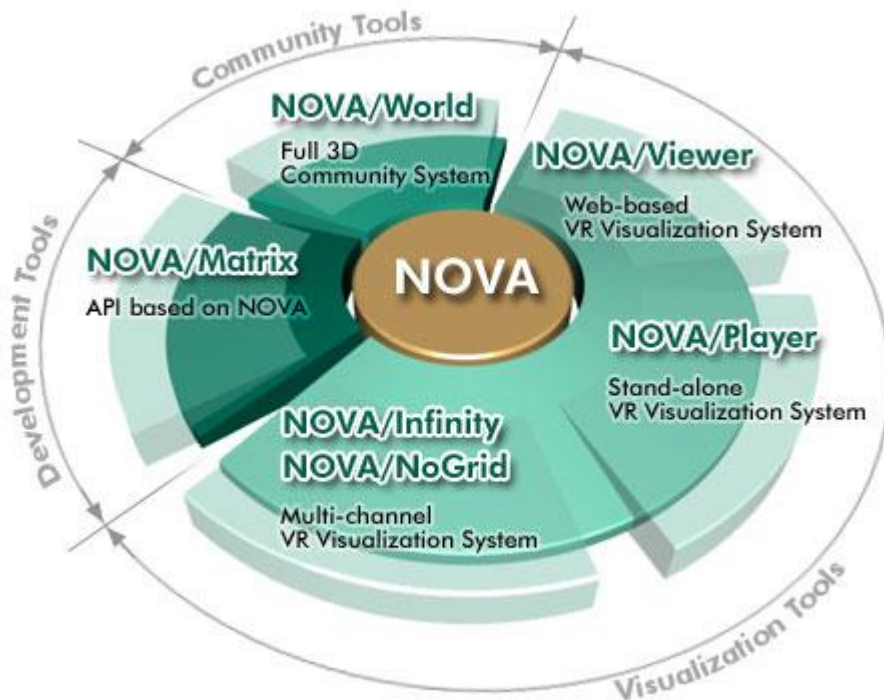
## □ bergen (Dave Pape)

- <http://www.evl.uic.edu/pape/sw/bergen/>
- Networked client/server
- Sample playback
- Free, Simple, C++ interface

# VR Software

## □ 3DIGM

- <http://www.3digm.com/>
- NOVA Series, including real-time 3D graphics engine, web-based visualization, VR visualization, multi-channel VR, etc

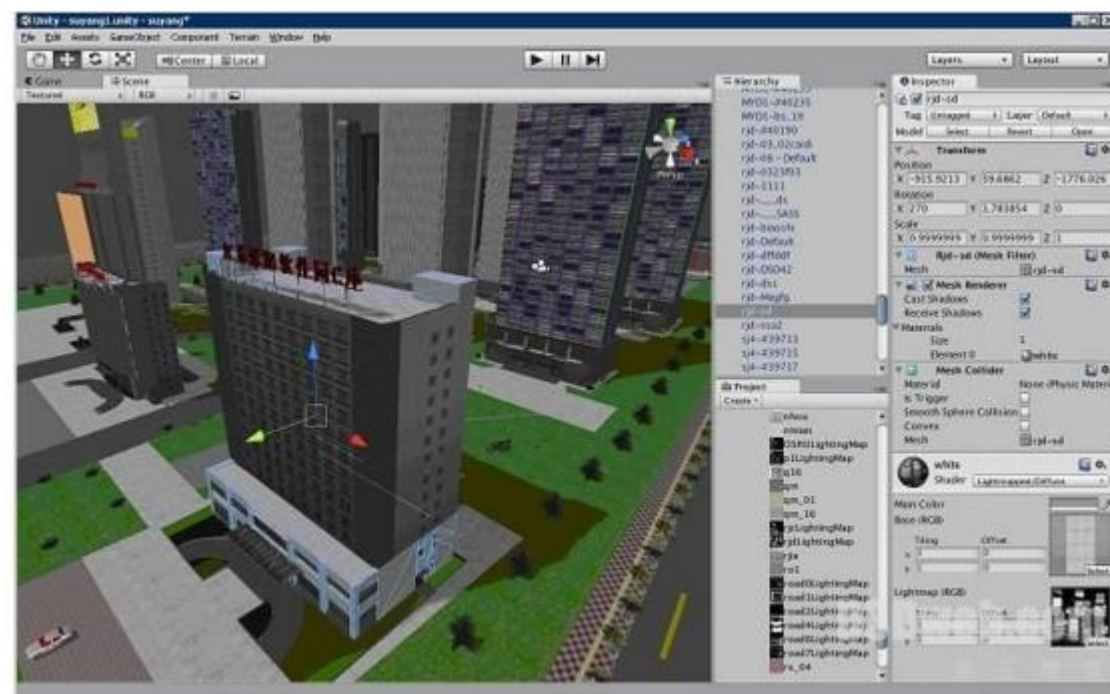


# VR Software



## □ Unity3D

- <https://unity3d.com/>
- Unity is the ultimate game development platform. Use Unity to build high-quality 3D and 2D games, deploy them across mobile, desktop, VR/AR, consoles, etc.



**Developer Day**  
Chile

November 29, 2017

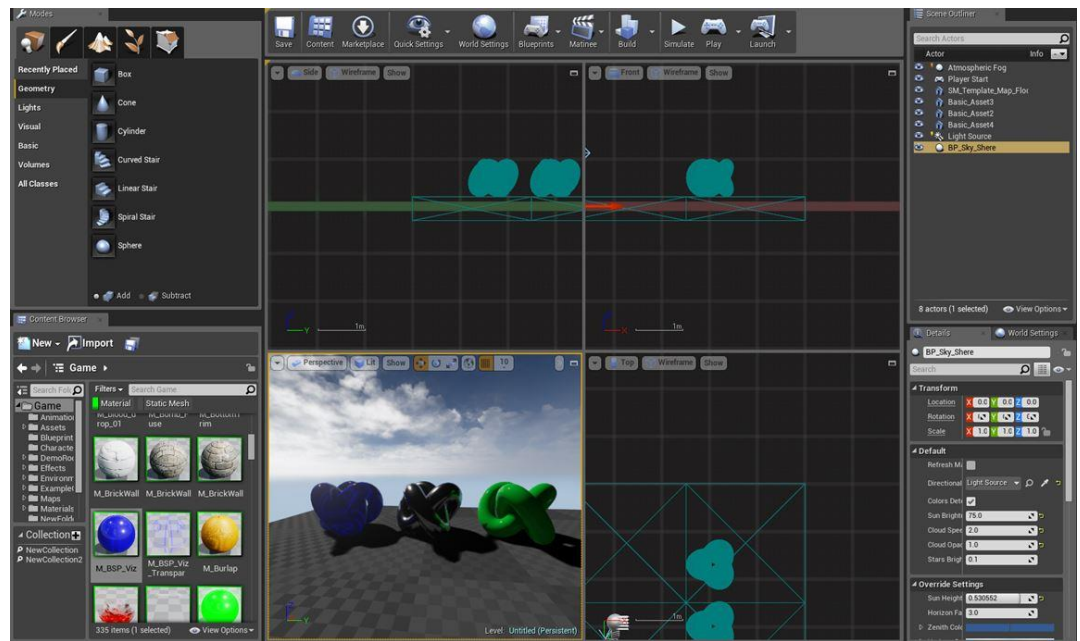
# VR Software

## ❑ Unreal Engine 4

- <https://www.unrealengine.com/>
- Unreal *Engine* 4 is a suite of integrated tools for game developers to design and build games, simulations, and visualizations, etc.







**UNREAL  
ENGINE**



<https://appeal-vr.com/blog/unity-or-unreal-best-vr-gaming-platforms/>

# VR SDK for Interactions for Unity/Unreal

	 VRTK Virtual Reality Toolkit	 MRTK Windows Mixed Reality Toolkit	 XRTK Mixed Reality Toolkit	 Unity XR Interaction Toolkit	 Oculus Interaction SDK
<b>Multiple XR Target devices/ platforms</b>	Oculus Steam VR HP Reverb Windows MR Pico Varjo Vive	Oculus Steam VR AR Core AR Kit Magic Leap Hololens Windows MR	Oculus Steam VR AR Core AR Kit Magic Leap Hololens Windows MR	Oculus Steam VR HP Reverb Pico AR Core AR Kit Magic Leap Varjo Vive	Oculus
<b>Target XR Environment</b>	VR	VR AR	VR AR	VR AR	VR
<b>Game Engine</b>	 				 
<b>Update Frequency</b>					
<b>Open Source</b>					
<b>OpenXR Support</b>					
<b>Physics Interactions</b>	Multiple samples	Multiple samples		Using the Unity editor	Some samples
<b>Hand-Tracking Support</b>					 Including HandTracking API

The best 5 VR SDKs for Interactions for Unity & Unreal (March 18, 2022)  
<https://xrbootcamp.com/the-best-5-vr-sdk-for-interactions/>

# VR Application Development Tasks

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- ❑ Determine Configuration
- ❑ Interface with Input Devices
- ❑ Initiate and Handle Multiprocessing
- ❑ Calculate World Physics Simulation
- ❑ Calculate Perspective Rendering
- ❑ Calculate Primitive Elements
- ❑ Render Primitives
- ❑ Create Object Models

# Configuration

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- What needs to be configured?
  - What input devices to use & where to find them
  - How many displays, and where to find them
  - How to render multiple channels (stereoscopic)
  - Simulated VR hardware
- When is the configuration specified?
  - Fixed in code for local hardware
  - Run-time configuration
  - Dynamic (during run-time) configuration
- How much can be (re)specified during the participation?
  - Stereoscopic view on/off
  - Changes screens
  - Change input devices

# Input Device Interface

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- Interface with the hardware
- Interpreting the Input
  - Mapping Physical inputs to Logical inputs
  - Continuous (e.g. tracking) vs. Discrete (e.g. buttons)
  - Sampled vs. Queued
  - Reading discrete inputs as continuous
  - Reading continuous inputs as discrete
  - Preprocessing (filtering) input
- Some VR software for input only
  - Virtual Reality Peripheral Network (VRPN)
  - AR Toolkit



# Multi-Processing

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- Course-grain parallel processing
  - Reading inputs
  - Simulating world
  - Rendering outputs
  - Networking
- Free running vs. lock-step
- Distributed vs. SMP
- Additional effort
  - Synchronizing
  - Sharing information
  - Distributing information across cluster

# World Physics Simulation

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- Programming the virtual world's "laws of nature"
  - Gravity
  - Object manipulation
  - Particle systems
  - Intelligent agents
  - Collision detection
  - World persistence
  - Transferring information to other shared virtual worlds

# Networking

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- Sharing a world between VR systems
- How much is shared?
  - Avatar
  - Voice
  - State of the world
- How is it implemented?
  - Client/server
  - Peer to peer

# Rendering Parameters

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- Rendering to the senses must respond based on the position of the user in VR
  - Perspective viewing, listening, touching
  - Need to determine the location of each eye
  - Off-axis visual perspective rendering
  - Need to determine the location of each ear
  - Convolution or other processing of sounds
  - Need to determine the location of each finger or other body part
  - Feature of most VR integration libraries

# High-Level Rendering

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- Organized Primitive Elements
  - Organizes the primitives into higher-level concepts to make programming easier
  - A visual “scene graph” uses a directed graph to represent the relationship of visual elements of the rendering
  - Two ways to inherit properties in scene graph: siblings and parents
  - Often allow complex objects to be loaded from a 3D file format, e.g. Inventor/VRML, 3D Studio, Quake format
- Performer, an example high-level visual library:
  - Designed for highly efficient rendering
  - Many file format loaders available
  - Uses parent inheritance
  - Linked many VR integration libraries
  - Uses OpenGL for low-level rendering

# Low-Level Graphics Rendering

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- ❑ Renders the basic primitives
  - Surfaces: Polygons, NURBs surfaces, Constructive Solid Geometry (CSG)
  - Lighting: Solid colors, Shading, Physics of light
  - Effects: Fog, Texture maps
- ❑ For real-time, generally use Polygons & Phong shading
- ❑ OpenGL is (historically) low-level visual rendering library of choice for VR

# Haptic Rendering

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- GHOST is a high-level haptic rendering library
  - It provides a scene graph
  - Has functions such as “vibrate” when contact is made with a node
- ArmLib does more low-level haptic rendering
  - It provides modes such as spring & dashpot, point & plane
  - Applications or high-level haptic library makes use of these primitive models to render the world appropriately

# Stereoscopic Rendering

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- Multiplex two visual images over:
  - Time (shutter glasses)
  - Space (a screen for each eye)
  - Polarity (polarized glasses)
  - Color Spectrum (red/blue anaglyphic, TAN infinitec)
- Time is easy and good quality given sufficient hardware
  - Extra interlace divides top and bottom in time
  - Quad-buffer stereo requires more frame buffer memory
- Space requires specialized hardware
- Polarity requires special filters (easy) and two perfectly aligned projectors (hard)
- Anaglyphic is cheapest, easy to implement, but hard on the eyes



# Real-Time Rendering

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- Real-time rendering rates:
  - Minimally 12 Hz
  - Preferably 30 Hz
- Rendering techniques to decrease render time and enhance realism
  - Culling: Frustum, Backface, Level-Of-Detail (LOD)
  - Texture maps: Image on a polygon
  - Tracks to hide cardboard cutout look:
    - Rotate to viewer
    - Multi-view textures
    - Stereoscopic texture
    - Animated textures