VR Application & Developments

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Applications

- Vehicle Design
- Architectural Walkthroughs
- Education and Training
- Therapy and Rehabilitation
- Scientific Visualization
- Cultural Heritage
- Art and Entertainment

Vehicle Design & Manufacturing

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

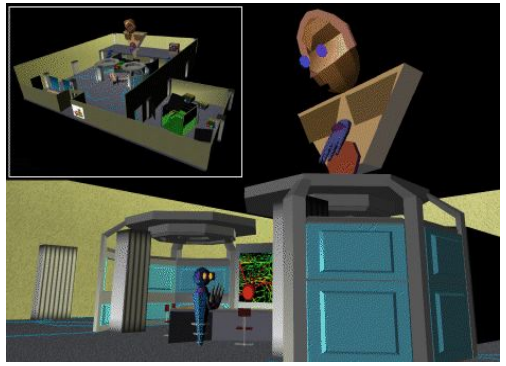
Vehicle Design & Manufacturing

- 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

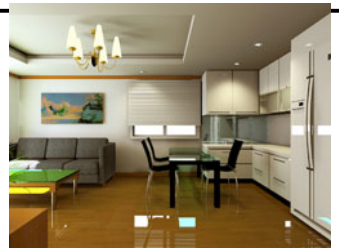
- Architectural Linked Immersive Environment (ALIVE) by SARA, The Netherlands & EVL
- Dutch architect Rem Koolhaas' design of the new Campus Center at the Illinois Institute of Technology in Chicago
- ALIVE lets viewers navigate through 3D CAD models

Architectural Walkthroughs



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

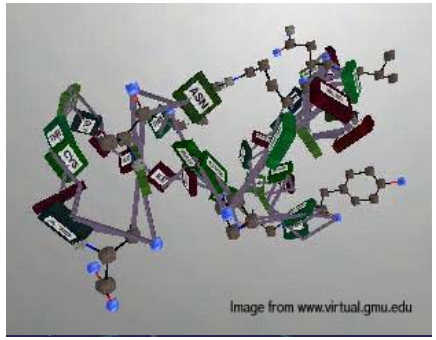
Architectural Walkthroughs



http://www.freeform.kr/

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

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, Geogia 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

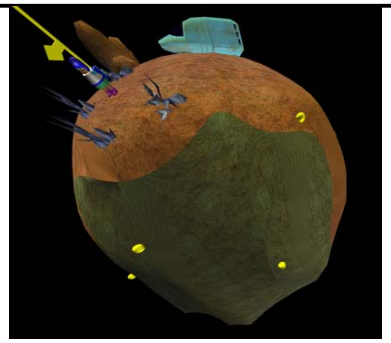
Education

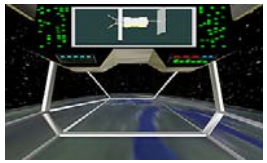
- For elementary students, by EVL
- NICE (Narrative Immersive Constructionist Environments) Persistent garden
- Round Earth Project is intended to teach young children the concept of a spherical Earth
- Virtual Ambients is designed to help students improve early stages of students' scientific inquiry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

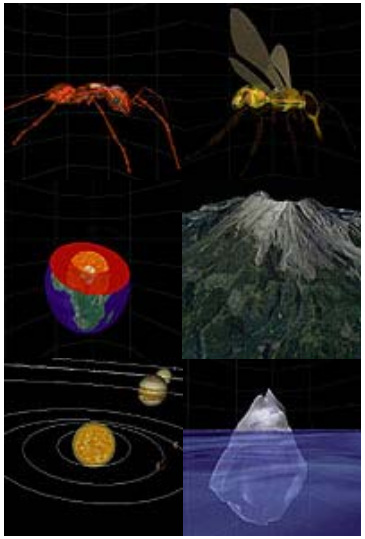
Education





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

Education

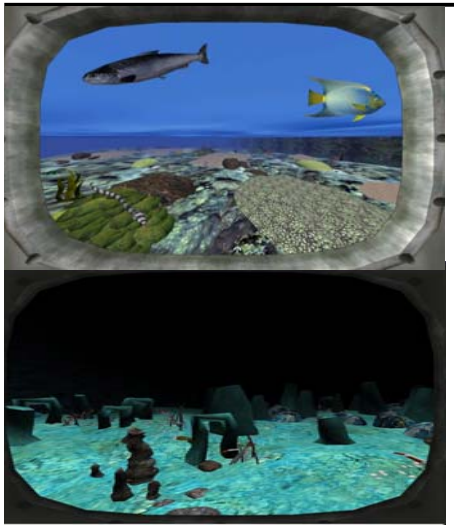


- QuickWorlds
- Teacher-initiated
- Rapid turnaround
- Minimal teacher time investment
- Extend traditional practice
- Gradual transfer of control

Education

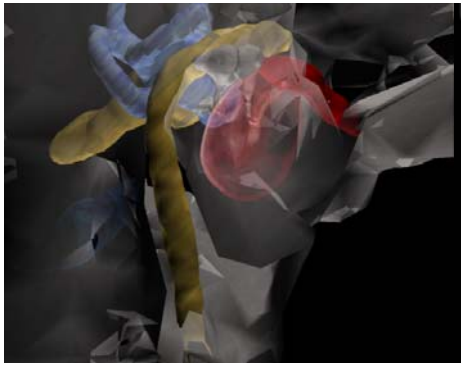
- Virtual Ambients - The Field
- Populated with plants and moving objects such as turtles
- Similarity and difference lesson for the 2nd grade
- Interpolation and extrapolation for the 4th grade
- Co-occurrence rules; Beehive, salinity, moisture, and plants; Herbicides and plants for the 6th grade

Education



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

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

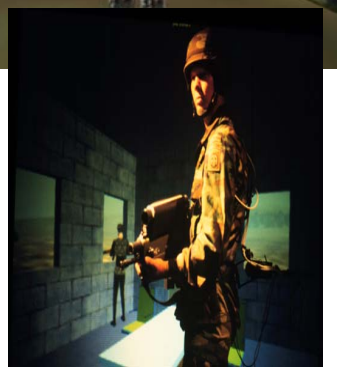
Medical Training

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

Medical Training

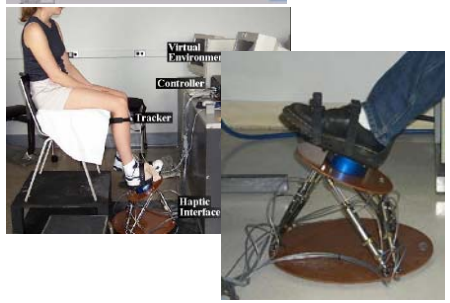
- Ewha Women's University, Computer Graphics and Virtual Reality Research Center
- Medical image visualization
- VR table, front-wall projection display, CAVE-like VR system

Military Training



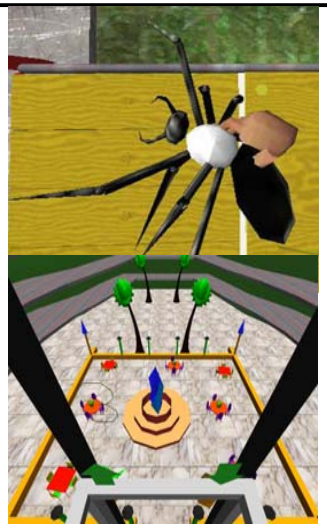
- NPSNET – Large Scale Virtual Environment Technology Testbed
- NPSNet is a real-time, interactive distribution simulation system, developed by Naval Postgraduate School
- To implement a large-scale networked virtual environment
- IEEE 1278 Distributed Interactive Simulation (DIS) application protocol

VR Rehabilitation



- '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

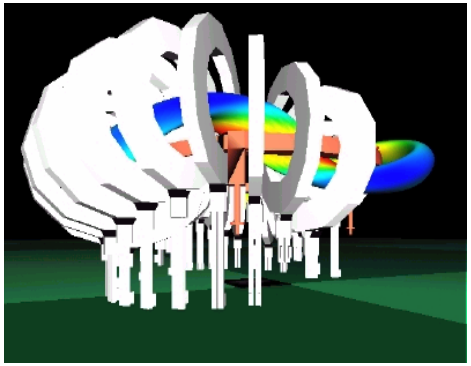


- Spider phobia, developed by HIT lab at University of Washington – VR exposure therapy for treating spider phobia
- Acrophobia (the fear of heights), developed by GVU at Georgia Tech – VR exposure therapy that involves exposing the subject to anxiety producing stimuli while allowing the anxiety to attenuate

VR Therapy

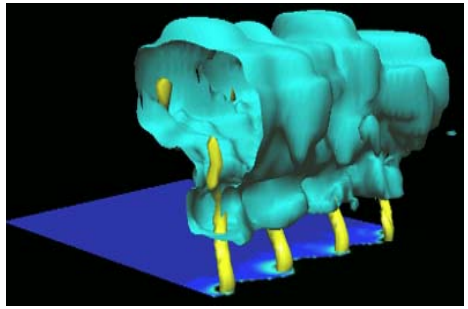
- Seoul Baik Hospital, VR therapy clinic
- Severance Hospital

Scientific Visualization



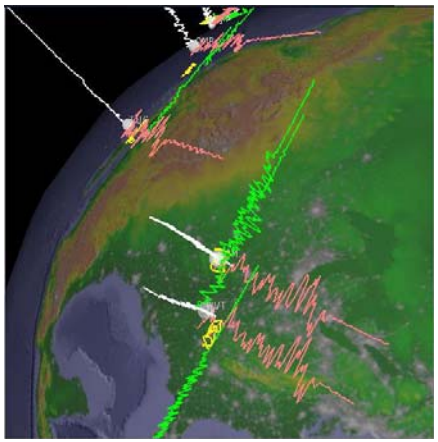
- Heliac Plasma Coil, developed by Cooperative Research Center for Advanced Computational Systems at Australian National University
- Main magnetic coil set and a magnetic "flux surface" of the H-1HF Heliac fusion plasma physics experiment

Scientific Visualization



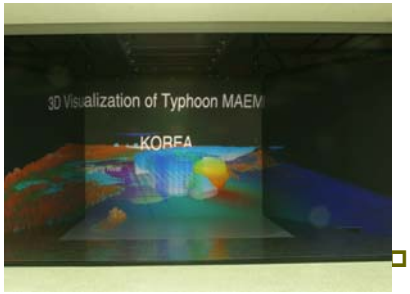
- Non-Supercell Tornado Simulation developed by UIUC Dept. of Atmospheric Sciences & NCSA
- Viewers can immerse themselves with the digital storm and understand how they form and develop

Scientific Visualization



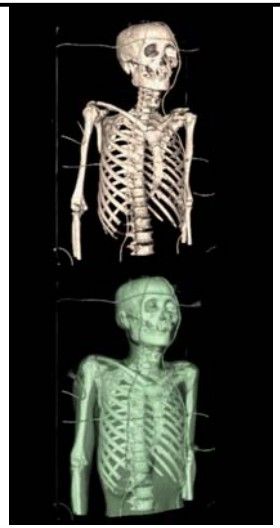
- Wiggleview, developed by EVL
- Traditionally seismologists look at 2D X-Y plots of a time-series of the displacement of a seismometer in the North-South, East-West, and Up-Down directions
- Wiggleview allows to visualize the simultaneous recording of three channels of seismic data in response to an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

Scientific Visualization



- 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



- Visible Korean Human, developed by Computer Graphics Lab at Sogang U. & KISTI
- Volume visualization using image-based rending 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

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 Mogoa 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

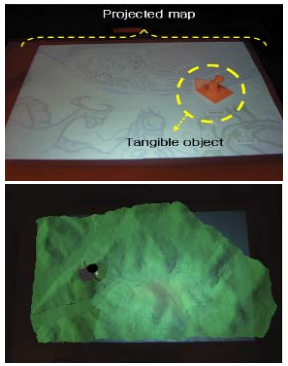
- Tangible Moyangsung, Use of tangible blocks to interact with the virtual environment

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

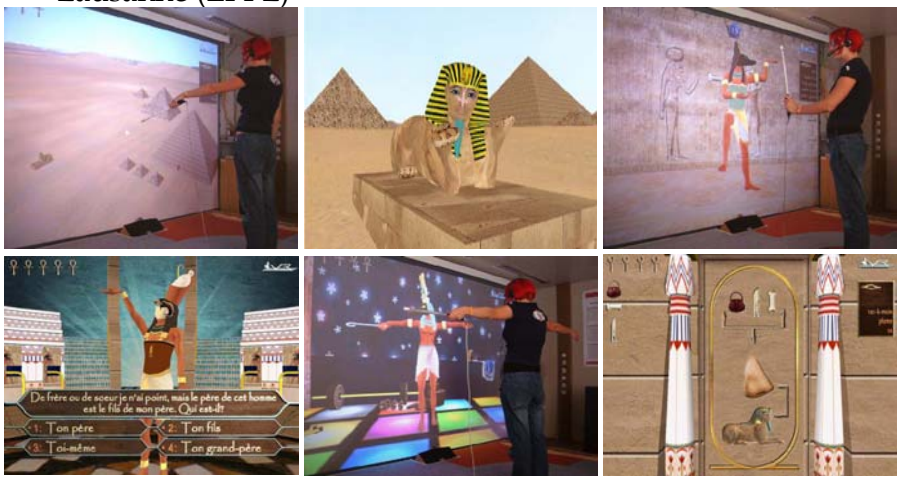
Cultural Heritage

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

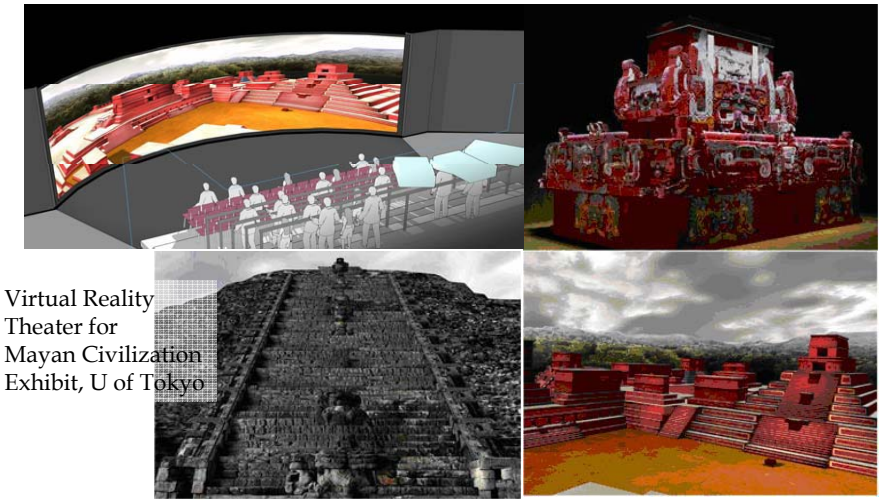


Cultural Heritage

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



Cultural Heritage



Virtual Reality Theater for Mayan Civilization Exhibit, U of Tokyo

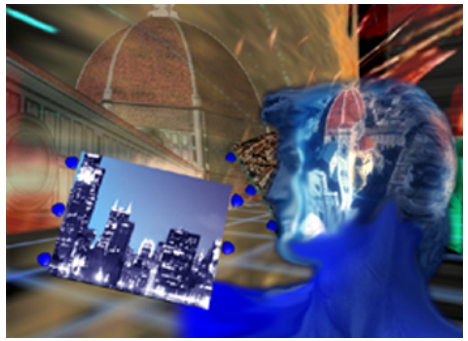
Cultural Heritage

A Journey into the Breath of Sorabol @Gyeongju World Culture Expo, KIST

Interactive Art

- Crayoland created by Dave Pape, EVL – 2D crayon drawings placed in a 3D world
- Synesthesia by Rita Addison & Marcus Thiebaux, 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

Entertainment

- Disney Quest - Aladdin

The problem of VR applications

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

Hardware Issues

- 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

- Lack of standards
- Vastly different & too many toolkits
- Interoperability & portability
- Graphics file formats
- Difficult to build models

Public acceptance

- Simulator sickness
- Fatigue
- Isolate from real world

Interaction

- 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

- 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://ww.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

- 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

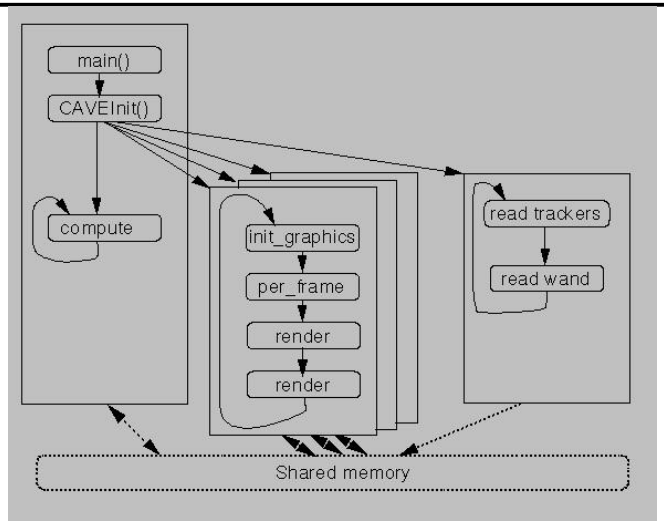
- VSS (NCSA)
  - http://cage.ncsa.uiuc.edu/adg/VSS/
  - Networked client/server
  - Sample playback & advanced synthesis algorithms
  - Real-time manipulation
  - Localization
- bergen (Dave Pape)
  - http://www.evl.uic.edu/pape/sw/bergen/
  - Networked client/server
  - Sample playback
  - Free, Simple, C++ interface

CAVElib Components

- Tracking – support Flock of Birds, Spacepad, Motionstar, Polhemus, Intersense IS-600, IS-900, tracker daemon
- Control device (wand)
- Multiprocessing – should be multiprocessing (separate processes for calculation, tracking, and display)
- Stereo perspective projection – must provide off-axis perspective projection for correct stereo in the CAVE
- Configuration files
- Simulator
- Miscellaneous utilities

- CAVEUser's Guide at http://www.evl.uic.edu/pape/CAVE/prog/CAVEGuide.html

CAVElib Components



CAVElib Configuration

- Evolved for new systems
  - Tracking
  - Input
  - Graphics display
  - Physical display

CAVElib Configuration Files for CAVE

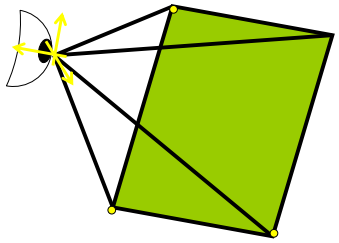
```
WallDisplay front :0.0 1024x768+1+1
WallDisplay left :0.0 1024x768+1024+0
WallDisplay floor :0.1 1024x768+0+0
WallDisplay right :0.1 1024x768+1024+0

DisplayMode     stereo
StereoBuffer    y
TrackerType     birds
TransmitterOffset –0.1 7.04 1.65 feet

HeadSensorRotation 0 0 1 –90
HeadSensorOffset 3.5 0 –2.5 inches
WandSensorRotation 1 0 0 –30
WandSensorOffset 0 0 –4 inches
```

CAVElib Configuration Files for ImmersaDesk

```
Walls screen0
WallDisplay screen0 :0.0 1280x1024+0+0
ProjectionData screen0 * wall -3 3 0  -3 6 -2  3 3 0
TransmitterOffset 0 7 1.5
```

CAVElib Configuration Files for HMD

```
Walls left_eye right_eye
WallDisplay left_eye :0
WallDisplay right_eye :1
ProjectionCorners left_eye -1 -1 -2  -1 1 -2  1 -1 -2 inches
ProjectionCorners right_eye -1 -1 -2  -1 1 -2  1 -1 -2 inches
```

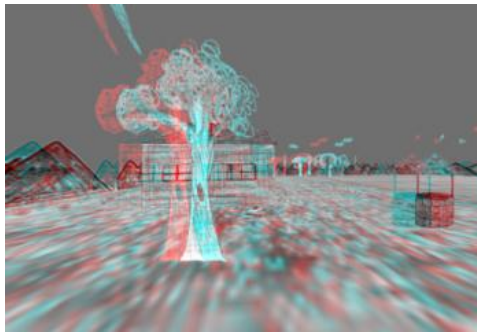


CAVElib Configuration Files for Geowall

```
Walls screen0 screen1
WallDisplay screen0 :0.0 1280x1024+0+0
WallDisplay screen1 :0.0 1280x1024+1280+0
WallEyes screen0 left
WallEyes screen1 right
ProjectionData screen0 * wall -5 0 -5  -5 10 -5  5 0 -5
ProjectionData screen1 * wall -5 0 -5  -5 10 -5  5 0 -5
```

CAVElib Configuration Files for Anaglyph

```
Walls screen0
ColorMask screen0 left R
ColorMask screen0 right GB
```

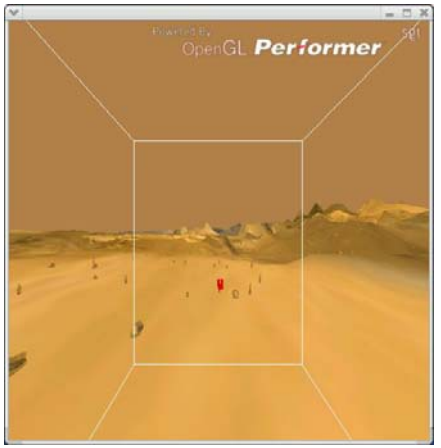


CAVE Tracker Daemon

- Separates tracking & controller details from CAVE library
- Allows addition of new devices not directly supported by CAVElib
- Can be used with non-CAVElib applications
- Data is stored in SysV-style shared memory segments
- Structures are meant to be forward-compatible for future changes

CAVE Simulator

- Provides simulated alternatives to CAVE components



Creating Objects for the Virtual World

- Four classes of Virtual World substance
  - Geography (world terrain)
  - Agents
  - Artifacts (normal objects)
  - User interface objects
- Static vs. Dynamic Objects
  - Static objects created "pre-participation"
  - Static objects are created by the use of modeling package such as Maya, SoftImage, 3D Studio Max, AC3D
  - Dynamic objects "rendered" in code pre-participation or rendered by code during participation
- Static vs. Dynamic Behavior
  - Static behaviors are fixed, articulated, parameterized
  - Dynamic behaviors are simulated by code during participation

VR Application Development Tasks

- 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

- What needs to be configured?
  - What input devices to use & where to fine 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

- 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

- 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

- 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

- 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

- 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

- 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

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

Haptic Rendering

- 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

- 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

- 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

Reference

- Lots of VR toolkit tutorial sessions at Advanced CAVERNUS Workshop Series http://calder.ncsa.uiuc.edu/CAVERNUS_Workshop/workshop.html
- http://www.evl.uic.edu/pape/CAVE/ConfigTricks.html
- http://www.evl.uic.edu/pape/CAVE/prog/CAVEGuide.html