

# Introduction to Virtual Environment Technology

10<sup>th</sup> Anniversary of  
“What Is VR? A Homebrew Introduction”

*IEEE VR2003*  
*March 23, 2003*

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## VE Technology Review Outline

1. *Introduction*
2. *Interface Technology*
3. *Processing Technology*
4. *Network Virtual Environments*
5. *Project Development*
6. *VR Systems & Applications*
7. *Resources*



## Part 1: Introduction

Virtual Reality is a fairly complex technology with few complete off the shelf solution bundles.

Creating a working application often requires a systems approach with fairly broad range of knowledge and talent.

- *What Is VR? (Definition, Taxonomy)*
- *Why Use VR? Why Not?*
- *When: Early History of VR*
- *How? - VE Technology*
- *Where next? Research Issues of VR*

## Many Names of VR

*Virtual Reality*

*Virtual Environment*

*Artificial Reality*

*Computer Generated  
Environment*

*Computer Simulated  
Environment*

*Synthetic Environment*

*Spatial Immersion*

*Cyberspace*

*Virtual Worlds*

*Virtual Presence*

*Metaverse*

## A Definition of VR

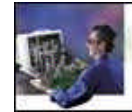
**“A Computer-Generated, 3D Spatial Environment in Which Users Can Participate in Real-time.”**

- Michael Capps, Naval Postgraduate School



**Virtual Environments Can Be:**

- Fully Immersive, Encompassing Worlds
- Augmentations (Overlay) to the Real World
- “Through the Window” Worlds (Non-immersive)



## Some Related Technologies

- **Vehicle/Flight Simulators**
- **“Interactive 3D Computer Graphics” (I3D)**
- **CAD**
- **Computer animation/special effects**
- **PC/Video Games**
- **Interactive Images (QuickTime VR)**
- **Augmented Reality**
  - Combined real world and computer generated environment
  - Video AR: Real world video with generated overlay
  - See Through AR: Generated display is semi-transparent
- **Tele-Presence**
  - Teleconferencing
  - Remote robotic control
- **Collaborative Systems**

## VR as special case of I3D

**I3D = Interactive 3D Computer Graphics**

**Both based on:**

- Modeling,
- Interaction,
- Simulation,
- Rendering

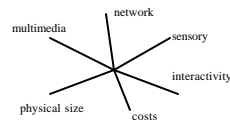
**VR is special case based on**

- Interface devices & techniques
- Immersion & Presence
- Free range navigation
- Manipulation of world entities
- Other senses (audio, haptics, etc)

## Dimensions of VR Taxonomy

- **Technologies**

- Display
- Tracking
- Networking
- Input devices



- **Interactivity Continuum**

- purely passive experience – full control and authorship

- **Immersive Continuum**

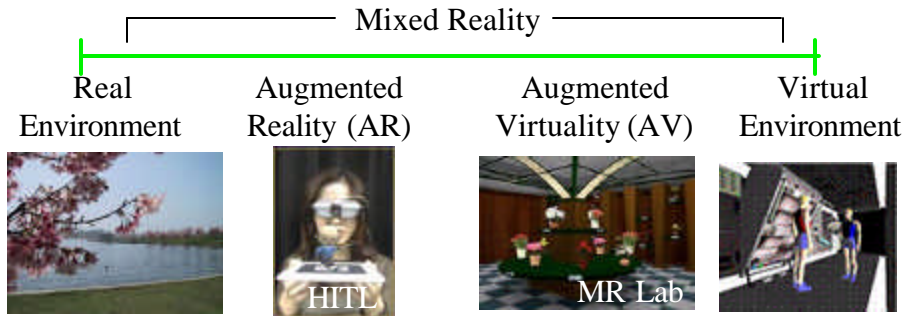
- Immersion: Senses Supported (visual, auditory, haptic, etc)
- Presence (being “there”)

- **Population (single – many)**

- **Milgram et al: Reality-Virtuality Continuum of Mixed Reality**

- **Stapleton et al: Mixed Fantasy Framework**

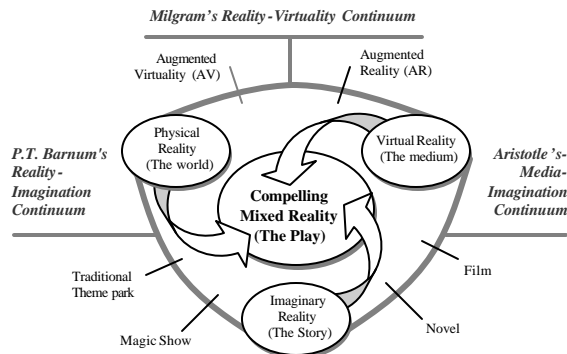
# Milgram's Reality-Virtuality Continuum



Adapted by Ron Azuma from Milgram, Takemura, Utsumi, Kishino. "Augmented Reality: A class of displays on the reality-virtuality continuum" 1994

# Stapleton's Mixed Fantasy Framework

From Stapleton, et al, "Applying Mixed Reality to Entertainment" IEEE Computer, Dec 2002



# Immersion

- **Sensory Immersion**
- **Psychological Immersion**
- **Produced by:**
  - Enveloping environment
  - Natural interaction (view, manip.)
  - Fidelity
  - Update rate

# Presence

(Source: Lombard, et al "Measuring Presence" <http://www.presence-research.org/presence2000.html>)

## **"The Perceptual Illusion Of Non Mediation."**

### **Six different conceptualizations of presence :**

- 1) *Presence as social richness*  
the "warmth" or "intimacy" possible via a medium
- 2) *Realism*  
perceptual and/or social
- 3) *Transportation*  
the sensations of "you are there," "it is here," and/or "we are together"
- 4) *Immersion*  
in a mediated environment
- 5) *Social actor within medium*  
e.g., parasocial interaction
- 6) *Medium as social actor*  
e.g., treating computers as social entities

## Range of VR Systems

images: hmd user, panoram 3 lcd, CAVE, walls, desk

- ***Interactive Images***
- ***World in a Window***
- ***Desktop System***
- ***Game Machine***
- ***HMD Systems***
- ***Rooms***
- ***(Networked) Simulators***
- ***Persistent, Shared Virtual Worlds***



## When: Early VR History

### Fictional Accounts

- Bradbury, *The Veldt*, 1950
- Zelazney, *Dream Master*, 1966
- Vinge *True Names*, 1981
- Gibson *Cyberspace*, 1984, etc

### Systems and Events

- Mort Heilig, *Sensorama*, 1956
- Ivan Sutherland, *The Ultimate Display* (FIPS 1965)
- Visual Simulator Industry (GE 1975, Simnet 1985)
- Myron Kruger, *Video Place*, *Artificial Reality*, 1983
- NASA VIVED, VPL, 1985
- *Scientific America*, 1987
- Meckler VR conferences early 1990s



# Why Use VR

- Why an immersive interface?
- VE Applications
- Why Not Use VR

# Why An Immersive Interface?

- *Real environment is hazardous or costly*
- *Environment encompasses large virtual spaces*
- *Large number of parameters manipulated*
- *Tasks are of a hands-busy nature*
- *Perspective is important*
- *Need presence to understand environment*
- *High Tech is Cool*

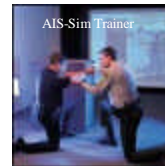
## Why Not Use VR

- ***Cybersickness***
- ***System Costs (equipment, space, people)***
- ***Development Complexity***
- ***Appropriate Content Design***
- ***Cumbersome Equipment***

## VE Applications

*More details later*

- ***Entertainment***
- ***Design and Development***
- ***Training***
- ***Education***
- ***Information / Scientific Visualization***
- ***Collaboration / Community***
- ***Medicine / Mental Health***
- ***Marketing***



## How - VE Technology

- Programmatics
- VR System Components



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## Programmatics in A VR Project

- *Project Management*
- *Technical: Systems Engineering*
- *Artistic: World Design*
- *Business: Marketing, Funding*

# VR System Components

- Hardware:
  - *Input Devices,*
  - *Displays,*
  - *Processors*
- Software:
  - *Simulation Manager*
  - *World Database*
  - *Authoring*
  - *Interaction Techniques*
  - *Application Software*
- Network Connectivity (Optional)

# Input Devices

- **Tracking systems**
  - Position and Orientation (6DOF)
- **Wide variety of interface devices**
  - Gloves
  - Wands
  - Speech Recognition
  - Eye Tracking
  - Keyboards (desktop & handheld)
  - Spaceball
  - Treadmills
  - Etc.



## Displays

- **Visual**
- **Audio**
- **Haptic**
- **Other displays**



Immersion CyberForce®



## Processor Hardware

- **Main processor**
- **Graphics hardware**
  - PC Graphics Adapters
  - Workstation Architectures
- **Multiple processors – Cluster VR**

## VR Software

- Simulation Manager
- Authoring Tools
- Application
- World Database
  - *Geometry*
  - *Textures*
  - *Behaviors*

## Where next? VE Research Issues

- ***Increased Realism And Scene Complexity***
- ***Decreased Lag (Action To Reaction Time)***
- ***3d User Interfaces And Interaction***
- ***Multi-sensory Output***
- ***Seamless Collaboration (Multi-user)***
- ***Behavior Simulation & Storytelling***
- ***Component Frameworks And Tools***
- ***VE Design Theories***

## Part 2: VE Interface Technology

- 1. Interface and Interaction*
- 2. VR Input Technology*
- 3. Rendering and Displays*

## Interface Device vs. Interface Technique

A device can be used in many ways,  
effectively or otherwise

- Device Hardware (device, cabling, interface port)
- Device Driver
- Interaction Technique (Software use of device)

# Universal Interaction Tasks

- **Passive Experience**
  - Not really "interaction", simply experiencing displays
- **Navigation**
  - Locomotion: motor component
  - Way-finding: cognitive component
- **Selection**
  - Choosing one or more objects from a set
- **Manipulation**
  - Specification of object position & orientation
  - Specification of scale, shape, other attributes
- **System control**
  - All other interactions, usually accomplished via commands
  - May be composed of other tasks

# VR Input Technology

## ***Hardware that allows the user to communicate with the system***

- Discreet, event based devices
- Continuous, sampled devices
- Trackers
- Gloves, Wands, Gestures
- Speech
- Locomotion
- Other

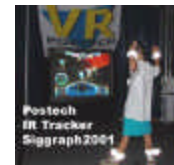
# Trackers

Measure position and/or orientation of a sensor

- Degrees of freedom (DOFs)
  - *Position (3 axis)*
  - *Rotation (3 axis)*
- Mostly used for tracking head and hands
- Some systems provide whole body tracking
- Object Tracking (tablet, controls, etc.)
- Preprocessing system required
- Very common, nearly essential part of VE

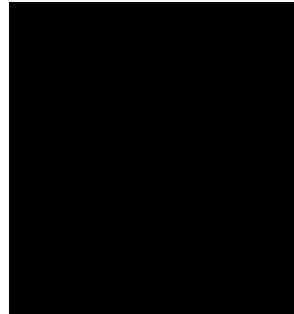
# Types of Trackers

- Mechanical
  - *Armature with position sensors*
- Electromagnetic
  - *AC or DC field emitters/sensors*
  - *Compass*
- Optical
  - *Target tracking (led, ping pong balls)*
  - *Full Vision or simply targets*
- Acoustic
  - *Ultrasonic*
- Inertial
  - *Acceleration and impulse forces*
- GPS
  - *Outdoor Augmented Reality*
- Hybrid (combinations of above)



# Tracker Issues

- Latency and lag
  - *Prediction*
- Interference
- Noise
- Tethering / encumbrance
- Range
- Accuracy
- Orientation/Handedness



Courtesy Flaxon Alternative Interface Technology

# Gloves

- Classic VR device
- Finger position sensing gloves
- Discrete gloves
  - tips touching: Fakespace Pinch
- Armature tracked
- Bend sensors (optical, resistive, other)
- Tracker required for overall position/orientation



## Wands

- Free space joystick
- Buttons plus tracker
- Variety of shapes and configurations



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## Gesture Recognition

- Single posture
- Multiple posture
- Posture plus motion
- Face, hand, arm gestures
- Gloves, video, etc.

# Speech Recognition

- Frees hands for other devices
- Discreet Command vs. Continuous Speech
- Dialog Management
- Ambient Noise
- False positives
- Training

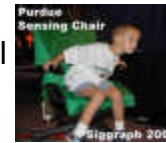
# Locomotion Devices

- Tread mill, Stair Stepper
- Skates, walking in place
- Bicycle, Unicycle
- Tilt platform (skate/snow board)



## Other Devices

- Keyboards (wearable)
- Advanced Mice/Joysticks
- Muscle contraction
- Brain wave
- Eye tracking
- Osmose: Breathing
- PDAs
- Pressure
- Real world sensors (IR, RF, Video, etc.)



## Rendering and Display

- Rendering: computation process
- Display: device which presents perceptual information
- Often 'display' used to mean 'visual display'
- Goal: display devices which accurately represent perceptions in simulated world
  1. Display What?
  2. Visual
  3. Audio
  4. Haptics
  5. Other Displays

# Display What?

- Environment Display
- Control Display
  - *cockpit, buttons, menus, etc.*
- Systems Monitor
  - *behind the scenes details*
  - *man behind the curtain*

# Visual Displays

Stimulus: light of wavelengths ~350-750 nm

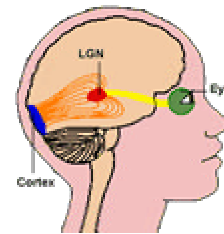
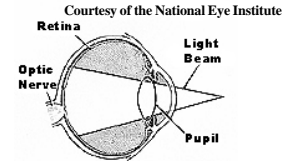
Visual dominance: 50% of brain involved in processing!

Visual Display Topics

1. *Visual Rendering*
2. *Human Visual System*
3. *Desktop Displays*
4. *Head Mounted Displays (HMD)*
5. *Projection Displays*
6. *Other Visual Displays*
7. *Which Visual Display to Use?*

# Human Visual System

- Physiology of Eyes
  - *Fovial/Peripheral Vission*
  - *Rods: periphery, motion, B&W, sensitivity*
  - *Cones: fovea, static, color, acuity*
- Perception & Brain
  - 3D depth cues
  - Issues for Visual Displays



# Depth Cues

***Several different types of cues used by human visual system***

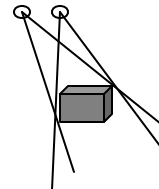
1. *Static monocular cues*
2. *Stereopsis*
3. *Motion parallax*
4. *Oculomotor cues*
5. *Accommodation-convergence mismatch*

## Static Monocular Cues

- Types of Monocular Cues
  - Occlusion
  - Relative Size
  - Relative Height
  - Linear Perspective
  - Aerial Perspective
  - Texture Gradient
  - Shading
- Can lead to depth illusions
  - “man on hand” photo, Ames Room

## Stereopsis

- Static, binocular cue
- Each eye gets a slightly different image
  - *Monocular cues from each image*
- Only effective within a few feet of viewer
- Many implementation schemes
  - *Autostereoscopic (no glasses)*
  - *Active LC shutters*
  - *Passive polarization*
  - *Etc.*



# Motion Parallax

- Dynamic, monocular cue
- Near objects move faster than far objects

***Generally more important than stereo!***

# Oculomotor Cues

- Based on information from muscles in the eye
- Accommodation: lens shape
- Convergence: gaze direction

## Accommodation- Convergence Mismatch

- Standard Stereo displays confuse the brain based on oculomotor cues
  - *Accommodation focuses eye at one distance*
  - *Convergence says objects are at different distance*
- Only “true 3d” displays can provide these correctly

## Issues for Visual Displays

- Resolution (angular range of pixel)
- Field of View (angular range of display)
- Image Update Rate

# Desktop Displays

- Standard Monitor
- Multiple-Monitors
- Autostereoscopic
- Volumetric



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# Stereo Techniques

- Active Stereo
  - *Single source, time division*
  - *LC Shutters – glasses or source*
- Passive Stereo
  - *two polarized sources*
- 3-D Monitors (Autostereoscopic)
- Head Tracking for motion cues and eye position



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# Head Mounted Displays (HMD)

- *Symbol of VR to most people*
- *Display and Optics mounted on Head*
- *May or may not fully occlude real world*

HMD Description  
HMD Issues



**Olympus Eye-Trek**

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**MicroOptical SV-9**

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**ProView XL40**

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# HMD Description

- Support System
- Display (pixels vs triads)
- Optics
- Binocular/Monocular/Biocular
- Tracker strongly recommended



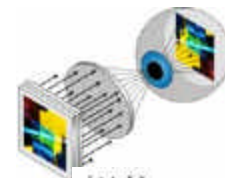
**NVIS Inc NVISOR**

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**Daeyang Cy-Visor**

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**LightView™**  
Personal View Modification



**Displaytech Inc**



**Cybermind HiRes900**

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## HMD Issues

- Cumbersome to wear
- Single user
- Small Field Of View
- Adjustable Field of View
- Exit Pupil Size
- Inter-pupil distance
- Resolution
- Costs (US\$999 - \$25,000+)

## Projection Displays

- *One or more projectors and screens*
- *Front or Rear projected*
- *Larger size than monitors*
- *Don't occlude reality*
- *Viewed by many people at a time*



## Example Projection Displays

- Table ( 1 or more surfaces)
- Wall (curved, flat)
- Room (3 to 6 sides)
- Dome (desk to Planetarium))



## Projection Display Issues

- Projector, screen and space are main \$\$
- Seam blending, and Sync issues
- Brightness (front/rear projection)
- Visibility Angles
- Stereo support (Active, Passive issues)



## Other Visual Displays

- Push BOOM - Fakespace Labs
- WindowVR - Virtual Research
- Tablets - Wacom
- Cybersphere - VR Systems



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## Which Visual Display to Use?

- **Research & Product Design Topic**
- **Cost: Monitor, HMD, Projection**
- **HMD for 360, close up, block reality, single user**
- **Group display: projection variety**

# Audio

2<sup>nd</sup> most studied sense

Adds tremendously to experience, if well executed

Stimulus: disturbance of molecules in a medium (air)

Perceptions: pitch, loudness, location

Audio Subtopics:

1. Sonification
2. Sound Effects
3. Spatialized Audio
4. Environmental Audio
5. Speech Generation
6. Audio Display Devices

# Sonification

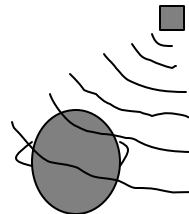
- Use of non-speech audio to convey information
  - *Gieger Counter, Sonar, etc.*
- Alerts and Interaction Feedback
- Ambient Sound
- Modern systems are too quiet, lack operating noise
- NSF Sonification Report (1997)  
(<http://www.icad.org/websiteV2.0/References/nsf.html>)
- Kevin Meinert:  
*IEEE VR2002 course notes for "Open Source VR"*  
(<http://www.vrjuggler.org/events/ieevr2002/course.php>)

## Sound Effects

- Classic Multimedia, game tool
- Intensity fall-off ( $1/d^2$ )
- Headphones also block out real-world noises
- Ambient sound (e.g. stream, crowd)
- MIDI in devices & pc audio cards

## Spatialized Audio

- 2 ears allow localization
- Works well in plane of ears
- Interaural intensity differences
- Interaural time differences
- Pinna shape effects
- Head Related Transfer Function (HRTF)



## Environmental Audio

- Air Absorbtion
- Sound occlusions
- Reverberation from surfaces
- Room acoustics
- Spatialized Audio
- Microsoft Direct X API
- Creative Labs EAX® (<http://eax.creative.com>)

## Speech Generation

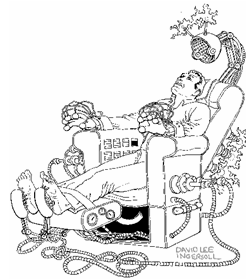
- Avoids text display which breaks illusion
- Extra processing required
- Vocal Tract simulation
- Prerecorded words, phonemes and diphones
- Intelligibility may require practice
- Lacks tonality, rhythm, emphasis, general expressiveness

## Audio Display Devices

- PC sound boards
- External 3D Processor
- External synthesizer, mixer
- Stereo Headset (with or w/o HRTF)
- Stereo speakers (HRTF with cancellation)
- Multiple Speakers
- Bass Shaker Speaker
- Amplifiers, wiring issues

## Haptics

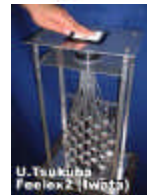
- Adds greatly to VE when you interact with objects
- Tactile vs Kinematic
  1. Tactile
  2. Force
  3. Motion Platform
  4. Issues for Haptics



Images Courtesy Flaxon Alternative Interface Technology

# Tactile Display

- Temperature, skin curvature and stretch, velocity, vibration, slip, pressure and local force
- Vibration fairly easy and cheap
  - pager parts
- Texture is harder to reproduce
  - pin arrays
- Gross vs local temperature



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# Force Display

- Force feedback, Force reflection
- Exoskeleton (CyberGrasp)
- Armature (Sensible Phantom)
- PC Joysticks & Steering wheels
- Mice (vibration or forces)



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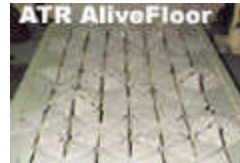
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## Motion Platform

- Vestibular and Proprioception
- Impulse Force and Onset Cues
- Washout
- Degrees and Range of Motion (1, 3, 6)
- Stewart Platform (aka Hexapod)
- Walking Simulators
- Virtual Motion Headset
  - *Electrostimulation - defunct*

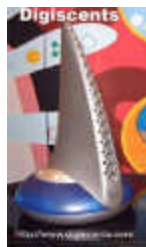


## Issues for Haptics

- Detailed Geometric Modeling
- Complex Force Calculations
- Input Coupling
- Often requires separate processor

## Other Displays

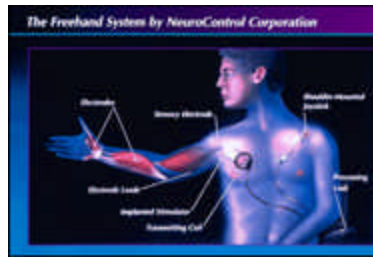
- Wind
- Heat
- Smell
- Muscle Control



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## Part 3: VE Processing Technology

- Basic VR Processing Loop
- Processing Layers
- I3D Math
- Modeling
- Simulation
- The Graphics Pipeline
- PCs vs Workstations
- Non-Visual Rendering

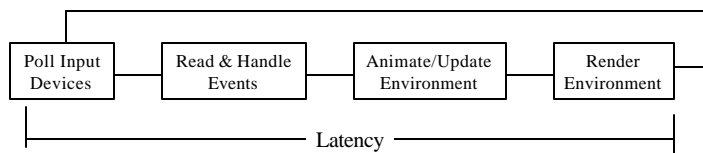
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## Basic VR Processing Loop

- Input Processing
- Simulation Update
- Rendering (to displays and network)
- Processing Latency between input sensing and display
- Multi-threaded processing



## Processing Layers

- *Application*
- *VR interaction and process managers*
- *Object Management: Scene Graph API*
- *Rendering Software: DirectX, OpenGL, Shader Languages*
- *Hardware rendering/driver*

## I3D Math: Coordinates & Transforms

6 degrees of Euclidean Space:

- Position: X,Y,Z
- Orientation: Roll, Pitch, Yaw

Trig, Vectors, Matrices, Quaternions

Transformations ,

*Rotation, Translation, Scale*

*Spaces: Model, World, View (Camera or Eye),  
Screen*

## Modeling 1: Levels of Detail

- Different model descriptions for same object
- Switch to lower complexity models
  - *Distance*
  - *Scene complexity*
  - *Viewpoing motion*
- Switching objects can cause artifacts
- Particular to Simulator and VE systems

## Modeling 2: Geometry Types

- Polygon Models
- 3D Curve Surfaces
- Solid Modeling (voxels, solid geometry)
- Procedural (Fractals, etc.)
- Articulated Objects
- Landscape (height field)

## Modeling 3: 3D Object Scanning

Quickly produce models of real objects

- Point Clouds and Post Processing
- Volume (small, medium, large)
- Laser Digitizers
- White Light Digitizers
- Tracker-based Wand
- Photogrammetry (from photograph)

## Modeling 4: Texturing

- Substitute image for geometric detail
- Highly effective
- Texture to Object Mapping (uv coords)
- Many techniques for texturing
  - *MIP maps (multi-level of detail)*
  - *Reflectance Maps*
  - *Bump Maps*
  - *Solid Textures*

## Modeling 5: Virtual Human Avatars

- Represents user and others in virtual world
- May or may not be humanoid
- Some standardization efforts
  - *MPEG-4,*
  - *H-Anim*
- Nat. Lib. Medicine Virtual Human Project
  - *not really avatar*
  - *detailed human model from sliced cadavers*
  - *extending to provide animation, behaviors*

## Scene Graphs

- “Retained Mode” vs “Immediate Mode”
- Data structures holding elements of scene
- Simplifies processing and modification
- Trees and Directed Acyclic Graphs (DAG)
- Transforms, objects, effects, etc
- Hierarchy of objects and spaces (geometry and lighting) with position & orientation linkages
- Extended to include input devices (trackers, etc), sounds, behaviors, links to other worlds, etc.
- Visibility Culling, etc

## Simulation: Behaviors

1. *Object Motion*
2. *Collision Detection and Response*
3. *Physical Simulation*
4. *Scripting*
5. *World Linking*
6. *Artificial Life*
7. *Area of Interest Culling*

# Simulation: Behaviors 1

## **Object Motion**

- *Animation*
- *Constraints*
- *Motion Capture*
- *Simulation*

## **Collision Detection and Response**

- *Very important for realism*
- *Many fast detection algorithms emerging*
- *Reactions may require force simulation*

# Simulation: Behaviors 2

## **Physical Simulation**

- *$F=MA$*
- *Modeling Newtonian Forces*
- *Kinematics and other forces*
- *Fake physics for expediency*
- *Physics Engines*

## **Scripting**

- *Data flow programming*
- *Java and other scripting in VRML/X3d*
- *Web based links to other worlds*

## Simulation: Behaviors 3

### **Artificial Life**

- *Simulated life with goals, plans, etc.*
- *"Natural" selection and evolution*
- *Neural Net driven life forms*
- *Virtual Characters*

### **AI for Narrative Control**

- *Storytelling in a virtual world*

## The Graphics Pipeline

Source: D. Slator ExtremeTech 3D Pipeline Tutorial

- **Application/Scene**
  - Simulation
  - Level of Detail
  - Visibility Culling
- **Geometry Transforms** (own slide)
- **Triangle Setup**
  - Backface Culling
  - Slope/Delta Calculation
  - Vertex Shaders
  - Scan-Line Conversion
- **Rendering & Rasterization** (own slide)

## Pipeline 2: Geometry Transforms

Source: D. Slator ExtremeTech 3D Pipeline Tutorial

1. ***Model Xforms: Rotation, Translation, Scale***
2. ***Model Space to World Space Xform***
3. ***World Space to View Space (eye)***
4. ***View Projection***
5. ***Trivial Culling***
6. ***Backface Culling***
7. ***Lighting***
8. ***Perspective Divide***
9. ***Clipping***
10. ***Eye to Screen Space Transform***

## Pipeline 3: Rendering & Rasterization

Source: D. Slator ExtremeTech 3D Pipeline Tutorial

1. ***Shading***
2. ***Texturing***
3. ***Fog***
4. ***Alpha Translucency***
5. ***Pixel Shaders***
6. ***Depth Buffering***
7. ***Antialiasing (optional)***
8. ***Display***

## PC vs Workstation

- Workstations
  - *better bandwidth to memory*
    - More and larger textures
    - More object data,
    - Dynamic surfaces
  - *More rendering pipes*
  - *SGI, Sun Microsystems primary vendors*
- PCs
  - *Graphics capability ~2x 6 months during 1990s, slowing now*
  - *Clusters of PC*
    - more pixels – tiling
    - More surfaces
    - Commercial Products
    - Open Source Solutions

## Simulator Image Generator

- *Scene simulation often limited by culling and clipping*
- *Fixed frame rate - dynamic scene complexity*
- *OpenGL/DirectX don't support this well so PC's suffer*

## Non Visual Rendering

- Audio
  - *Generic PC audio fairly sophisticated*
    - DirectSound, EAX, OpenAL
    - Creative Labs Audigy2, Sensura, nVidia nForce2 APU
  - *Dedicated Audio PC w/LAN connection*
  - *Specialty Processors available*
    - Lake Technology “Huron”
    - Tucker Davis Tech RP2.1 & Stingray
- Haptic Processing
  - *Computationally intense*
  - *Highly sensitive to latency*
  - *Separate processor suggested*

## Part 4: Networked Virtual Environments

- 1. *Types of Networked VE***
- 2. *Challenges***
- 3. *Centralized Model***
- 4. *Distributed Model***

## Types of Net VE

- Collaborative Design Worlds
- Distributed Training Environments
- Web3d:
  - *I3D Catalogs*
  - *Streamed Browser Worlds (single user)*
  - *Community Chat Worlds*
  - *Internet-based Gaming (MMPG)*

## NetVE: Exchange Standards

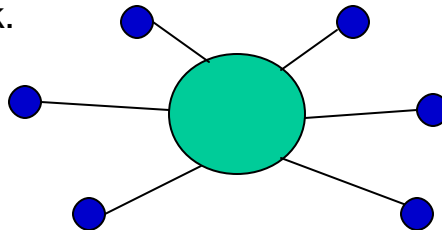
- **VRML97**
- **X3D**
- **MPEG4**
- **Java3D**
- **Proprietary**
  - Quicktime 3D
  - Macromedia Flash
  - Catalog 3D formats

## Net VE Challenges

- Network Bandwidth
- Heterogeneity
- Distributed Interaction
- Real-Time System Design and Resource Management
- Failure Management
- Scalability (geography of scene, net distance, population, etc)
- Deployment and Configuration

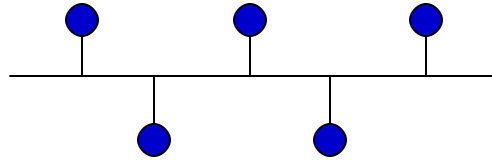
## NetVE: Centralized Model

- One computer (database) collects all data and sends updates to the users.
- Simple structure.
- Not scalable, the database is the bottleneck.



## NetVE: Distributed Model

- Each user maintains its own copy of the database.
- Updates are send to other users.
- Not scalable, the network is the bottleneck.



## Part 5: VE Project Development

- 1. Systems Engineering**
- 2. World Authoring**
- 3. Design Concepts**
  1. Usability & Human Factors
  2. VE Design Theory

## Systems Engineering

- Creating a VE system requires integration of hardware, software and artistic creations
- Many interrelated issues between these domains
- Systems Engineering approach needed to manage these issues.
- Basic Project Management
- Software Engineering

## World Authoring

- Much of the authoring tools and techniques are shared with other 3D graphics domains
- VR demands more speed from models
  - *trade-offs and special techniques for the world database*

# VE Design Concepts

- *Usability & Human Factors*
  - Goals of Interaction Design
    - » *Performance*
    - » *Usability*
    - » *Usefulness*
  - Philosophies Of 3D Interaction Design
- *VE Design Theory*
  - Styles of World Building
  - Church/Murray Aesthetics
  - Perceptual Opportunities

# Usability & Human Factors

- *Usability as measure of quality*
- *VE Usability Research (U. Va, UK, etc.)*
- *3D UI Web*  
(<http://www.mic.atr.co.jp/~poup/3dui.html>)
  - Excellent detailed tutorials

Goals of Interaction Design

Philosophies Of 3D Interaction Design

# Goals of Interaction Design

(courtesy Doug Bowman, Virginia Tech.)

- Performance
  - Efficiency
  - Accuracy
  - Productivity
- Usability
  - Ease of use
  - Ease of learning
  - User comfort
  - Usefulness
- Interaction helps meet system goals
- Interface relatively transparent so users can focus on tasks

# Philosophies Of 3D Interaction Design

(courtesy Doug Bowman, Virginia Tech.)

## **Artistic Approach:**

- *Base design decisions on Intuition about users, tasks, and environments, Heuristics, Metaphors, Common Sense, Aesthetics*
- *Adaptation/Inversion of existing interfaces (e.g. using 2D interface elements in a 3D environment)*

## **Scientific Approach:**

- *Base design decisions on Formal characterization of users, tasks, and environments, Quantitative evaluation results, Performance requirements,*
- *Examples: taxonomies, formal experimentation*

***Both approaches can lead to guidelines & principles***

# VE Design Theory

**Virtual Environment Design is a relatively new field, open to experimentation.**

**Draws from many areas of design including Architectural Theory, Animation, Storytelling, Theme Parks**

**Benedikt's 1992 Cyberspace: First Steps**

**Gamasutra Designer's Notebook Columns**

**AI for VR/Game Story Telling**

**Chapter in "Handbook of Virtual Environments"**

- Styles of World Building
- Church/Murray Aesthetics
- Perceptual Opportunities

# Styles of World Building

Mike Heim, Art Center College of Design, Pasadena CA

- Additive
  - *Draw from pre-built libraries*
- Authoring
  - *Create new objects and spaces*
- Realistic Construction
  - *Reflects real world environments*
- Fantastical Construction
  - *Capitalize on unique nature of VR*

## Church/Murray Aesthetics

Forged by Clive Fencott from Janet Murray's aesthetics for interactive media, Doug Church's 'Formal Abstract Design Tools', Mel Slater on co-presence, and Mike Heim's Transmogrification

- Agency
  - *Pleasure of being, or appearing to be in control*
- Narrative Potential
  - *Ability to impart knowledge or tell story*
- Presence and Co-presence:
  - *Being there*
- Transformation/ Transmogrification
  - *Ability to do or be the unusual*

## Perceptual Opportunities

Characterization of the roles objects are intended to play in establishing purposive experience

- Sureties
  - *Denotative meaning and acceptance of environment*
- Shocks
  - *Perceptual bugs, break illusion of environment*
- Surprises
  - *Deliver connotative meaning & purpose*
  - *Attractors: draw attention to areas of interest or situations*
  - *Connectors: support planning to achieve goals*
  - *Retainers: deliver specific objectives and rewards of world*
- Perceptual Maps
  - *document relations between perceptual opportunities*

## Part 6: VR Systems & Applications

- **VR Software Features**
- **Complete vs Toolkits**
  - Few Off the Shelf Systems,
  - Lots of Toolkits
  - Toolkits for Various Levels
- **System Styles**
- **Example Systems**
- **Applications**

## VR Software Features

- Importing models
- Model Libraries
- Level of detail (LOD)
- Object Position and Orientation
- Constraints
- Articulated features
- Animation
- Collision detection
- Physics
- “Parallel worlds”
- Light sources
- Event handling
- Audio
- Control language
- Sensors/Tracking Device Support
- Stereo viewing

## Off the Shelf Systems

Targeted at specific application markets

- *Psychological testing and rehabilitation*
- *Medical Training Simulators*
- *Product Design (integrated with CAD/CAM)*
- *Web3D graphics*

## Toolkits

- ***Benefits of Toolkits***
  - Flexibility of Device Interfaces
  - Complexity of Application
- ***Toolkits for Various Levels***
  - 3d Graphics (Scene Graph, etc)
  - Physics & Behaviors
  - Audio (VSS, Bergen, OpenAL, EAX)
  - Haptics (GHOST, ReachIn, e-Touch)
  - Device Interface and Interaction (VRPN)
- ***Integration of different kits is an issue***

# System Styles

- Open Source
- Proprietary
- Web targeted
  - *Marketing Worlds (VRML, etc)*
  - *E-Commerce Objects*
  - *Community Worlds*
- High End Systems
- Systems Integrators

# Example Systems

Alice	Meme	VRJuggler
CDS	MR Toolkit	VOS
Centric Software	Multigen-Paradigm	VESS
Crystal Space	Open GL	Syzygy
CyberToolbox	Blaxxun	Java3D
DirectX	Open Performer	X3D
DIVE	R3Vis	CAVELib™
Sense 8 WTK, WorldsUp	Renderware	GHOST
Eon Reality	SVE	PeopleShop
MetaVR	VisKit	OpenSceneGraph
Gismo3d	Vivids	OpenSG
Massive	VRML tools	
	Vtree	

Many, many more commercial and open source

See <http://vr.isdale.com/AuthoringTools.html>

# VE Applications

1. *Entertainment*
2. *Education/Training*
3. *Research*
4. *Design/Development*
5. *Medical*
6. *Marketing*
7. *Visualization*

# Applications: Entertainment

- Location Based Systems
- Arcade Games
- PC and Gamebox

## Applications: Education/Training

- Vehicle Training
- Maintenance Training
- Medical Training
- Patient Education
- Situational Training
- Mission Rehearsal
- Virtual Heritage - History
- Hazardous Operations
- Science & Math Education

## Applications: Research

- Geoscience
- Psychology
- Perception
- VR research

## Applications: Design/Development

- Prototyping
- Product Design reviews
- Architectural review/presentation

## Applications: Medical

- Training
- Psychological Assessment
- Perceptual Assessment
- Rehabilitation (psychological and physical)

## Applications: Marketing

- Loss Leader Attractions
- Product Awareness
- Interactive Catalog

## Applications: Visualization

- Scientific Visualization
  - *Display of scientific or engineering data for exploration and comprehension*
  - *Geological exploration (oil, gas, minerals)*
- Information Visualization
  - *Abstract data displayed geometrically for exploration and comprehension*

## Part 7: Resources

See web site for more details and live links

<http://vr.isdale.com>

1. *Books*
2. *Magazines*
3. *Societies*
4. *Conferences*
5. *Web Sites*

## Books

Most written in early 1990s are out of date. Some still good for background reference. Here are some recent good ones:

- "Handbook of Virtual Environments", Stanney ed., 2002
- "Understanding Virtual Reality: Interface, Applications, and Design", Sherman & Craig, 2002
- "Virtual Reality Technologies for Future Telecommunications Systems", Pakstas ed, 2002
- "Computer Graphic and VE", Slater et al, (2001)
- "Essential Virtual Reality Fast", John Vince, 1998
- "Networked Virtual Environments", Singhal and Zyda, 1999
- "VE Technology" (2<sup>nd</sup> edition), Burdea (June 2003)
- "Digital Space: Designing Virtual Environments", Weishar, 1998
- Distributed Virtual Worlds, Diehl

## Magazines & Newsletters

- *Print:*
  - Game Developer
  - IEEE CG&A
  - Computer Graphics World
  - Real Time Graphic News
  - Advanced Imaging
  - Presence Journal, Presence Lite
  - VR Psychology
- *Email:*
  - WAVE Report <http://www.wave-report.com>
  - VREfresh: <http://www.vrefresh.com>
  - E3D: <http://e3dNews.com/>

## Societies

- ACM SIGGRAPH <http://www.siggraph.org>
- ACM SIGCHI
- ACM SIGMM
- IEEE Computer Society  
<http://www.computer.org>
- SPIE
- HFS

## Conferences

- IEEE VR (other?)
- ACM Siggraph, SIGCHI
- ACM: VRST, CVE, Intl Conf on CG
- ISAR/MR
- Web3D Symposiums
- LAVAL VR (France)
- SPIE: Engineering Reality of VR
- Many others workshops, symposiums, etc
  - <http://www.vrefresh.com/Events.htm>

## Web Sites

- Many Tutorials and University Courses
- VR Information Sites
  - <http://www.cybertherapy.info>
  - <http://vr.isdale.com>
  - <http://directory.google.com/Top/Computers/VirtualReality>
- Topic Specific Information Sites
- Shared Worlds
- Vendor Sites