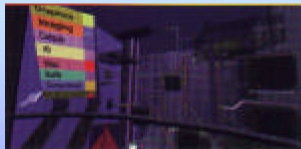
Realtime 3D Computer Graphics & Virtual Reality



Introduction

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Acknowledgement: Partly based on work by Angel/Bowman/B. Fröhlich and others

3D Computer Graphics is about

- Representation and modeling of three-dimensional objects
- Creation of 3D scenes including lighting
- Rendering of 3D scenes
- Computer Animation

Virtual Reality is about

- 3D Computer graphics
- Real-time simulation & rendering
- Interaction & feedback
- Immersion
- Creation & design of virtual environments

3D Computer Graphics vs. Virtual Reality

- VR can be seen as subfield of CG
- also instructive to contrast VR with conventional CG:

3D Computer Graphics	Virtual Reality
Purely visual presentation	Multimedia presentation visual, acoustic, haptic
Presentation can be rendered off-line, time is uncritical	Real-time presentation
Static scenes or predefined animations	Real-time interaction and simulation
2D interaction mouse, keyboard	3D interaction with special input devices + speech

VR-programming

- To drive advanced virtual reality input devices like
  - 3D mice, spaceball
  - stylus
  - gloves
  - 6DOF trackers (magnetic, gyroscopic, ultrasonic, optical)
  - speech recognition systems
  - haptic devices
  - treadmill-type
  - inertial displays (flight simulators) - full and partial

VR Input devices

- Hardware that allows the user to communicate with the system
- Input device vs. interaction technique
- Same device can be used for various interaction techniques

Input device characteristics

- Discrete / event-based
- Continuous / sampled
- Hybrids
- Miscellaneous input
  - speech
  - locomotion devices

Discrete input devices

- Generate one event at a time
- Event queue
- Examples:
  - buttons
  - keyboards
  - pinch gloves

Continuous input devices

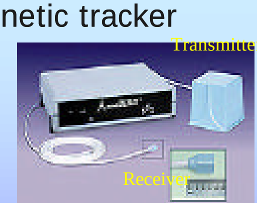
- Produce steady* stream of data
- Sampled at various times by the system for “snapshot” of state
- Examples:
  - trackers
  - data gloves
  - potentiometers

Tracking systems

- Measure position and/or orientation of a sensor
  - 6 degrees of freedom in space
- Most VEs track the head and the hand(s)
- Spatial input devices
- Tracked real objects resembling virtual objects
- Motion capture

Electromagnetic tracker

- Most common (still)
- Transmitter
  - Creates three orthogonal low-frequency magnetic fields
  - Short range version: < 1m
  - Long range version: < 3m
- Receiver(s)
  - Three perpendicular antennas
  - Distance is inferred from the currents induced in the antennas
- Distortions
  - Noisy – requires filtering
  - Affected by metal – requires non-linear calibration
- Wireless versions



6DOF Magnetic tracker & Data*Glove*

Sensors

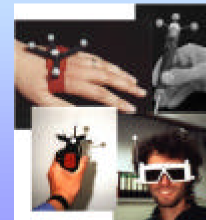
100 updates/sec
3 meters range
from base unit
Resolution<2 mm
and <.2 degrees

Electronic unit
(2 hours battery life)

Wireless suit (Ascension Technology)

Optical tracker

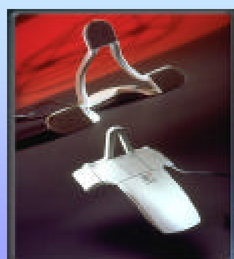
- "marker"
  - reflects IR light
  - Combined to unique spatial configuration per tracked position
- > 3 IR cameras
- Advantages
  - No interference with metal
  - Low latency
  - High resolution
- Disadvantages
  - Line of sight issues (more cameras help)



6DOF optical tracker by ART

Acoustic Trackers

- Uses ultrasound
- Typical setup for 3 DOF
  - 3 microphones
  - 1 speaker
- Distance is inferred from the travel time for the sound
- Advantages
  - No interference with metal
  - Relatively inexpensive
- Disadvantages
  - Line of sight issues
  - Sensitive to air temperature and certain noises



Logitech Fly Mouse

Inertial trackers

- Intersense IS-300
- Less noise, lag
- Only 3 DOFs (orientation)
- Use gyroscopes and accelerometers

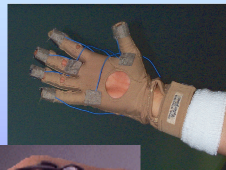
Hybrid Trackers

- For example: Intersense IS-600 / 900
- inertial (orient.)
- acoustic (pos.)

Data Gloves

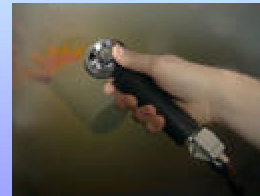
- Used to track the user's finger movements
  - for gesture and posture communication
- Almost always used with a tracker sensor mounted on the wrist
- Common types
  - CyberGlove
    - 18 sensors
    - 22 sensors
  - 5DT Glove
    - 5 sensors
    - 16 sensors

Hybrid devices



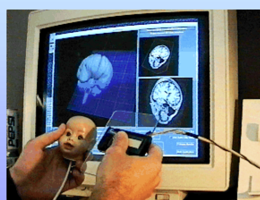
- Continuous and discrete input
- Examples
  - Button device + tracker
  - Flex & Pinch
  - ring mouse
  - LCD tablet
  - Shape Tape
  - Cubic Mouse
  - Spaceball

Tracked Wands



Props

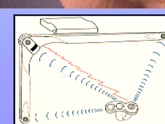
- Head prop
- Car prop
- ...



Courtesy Hinkley et al.

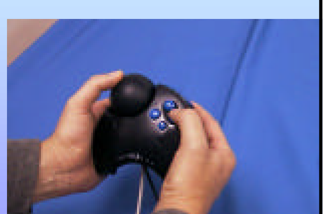
Mouse Type Devices

- Space Mouse
- Ring Mouse (pictured)
- Fly Mouse

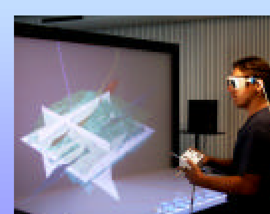


Isometric Devices

- Spaceball
- SpaceOrb (pictured)
  - Potentially tracked



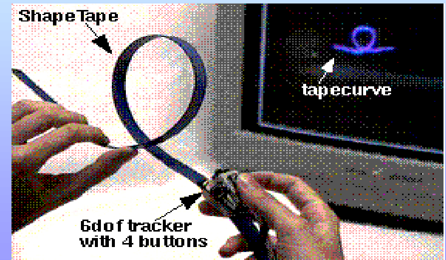
The Cubic Mouse



Cubic Mouse

- First 12 DOF input device
- Tracks position and rotation of rods using potentiometers
- Other shapes and implementations possible
  - Mini Cubic Mouse
  - ...

Shape Tape



Courtesy Balakrishnan et al

More input devices

Cyberglove with haptics

Treadmill types
(e.g. bicycles)

Speech Input

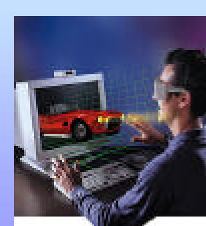
- Can complement other modes of interaction
  ☞multi-modal interaction
- Issues to consider
  - continuous vs. one-time recognition
  - choice and placement of microphone
  - training vs. no training
  - handling of false positive recognition
  - surrounding noise interference

VR-programming

- To drive enhanced virtual reality display setups like
  - responsive workbenches
  - walls
  - head-mounted displays
  - boomes
  - domes
  - caves

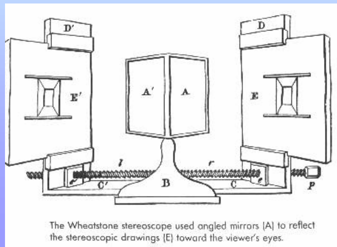
Fish Tank VR

- Monitor-based systems
- Use i.e. shutter glasses



3D (stereo) viewing

- 1838 – Wheatstone stereoscope



1968: Sutherland

"A head-mounted three-dimensional display"

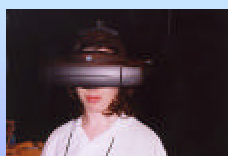
- Hidden-line graphics
- Mechanical tracking

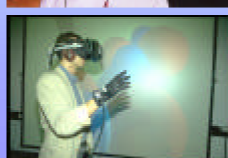
- See-through HMD

Head-mounted display

- Scene completely surrounds user
- Graphics are sharp and bright

- FOV is narrow
- Devices are heavy, cumbersome
- Can't see other people



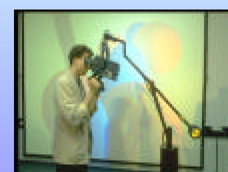


BOOM

(Binoccular Omni Orientation Monitor)

- High resolution 1280x1024
- Wide Field of View
- User must not carry heavy weight
- Electromechanical tracking with minimal lag

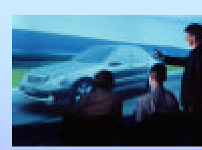
- Limited user movement
- Requires the user to hold onto the BOOM for control



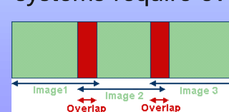
Projection-based VR

- Use video projectors
- Rear or front projection
- Active or passive stereo
- Commonly used

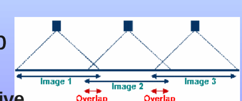
Projection Walls



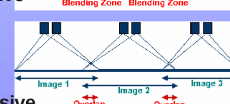
- Active or passive stereo
- Multi-projector systems require overlap



active

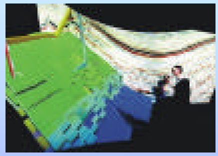


passive

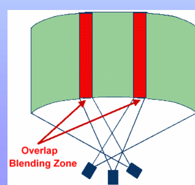


Pictures courtesy TAN

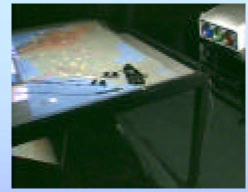
Cylindrical Screen Configurations



- Common in industry
- Head tracking difficult
  - Curved screen requires distortion correction in software

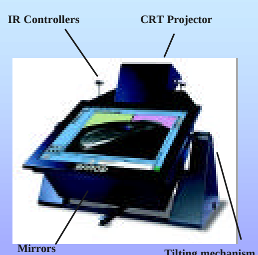


Workbench



- Table-top metaphor
- Change display orientation
- Integrate real & virtual

- Less immersion
- Occlusion/cancellation
- $$$



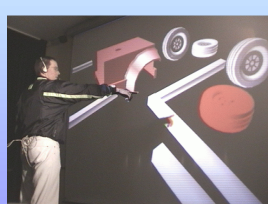
Baron workbench (courtesy of BARCO Co.)

Two-Sided Workbench

- View volume
- Telepresence

Wall

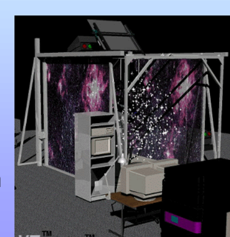
- Wall/door metaphor
- Allows 1:1 real object sizes
- High resolution



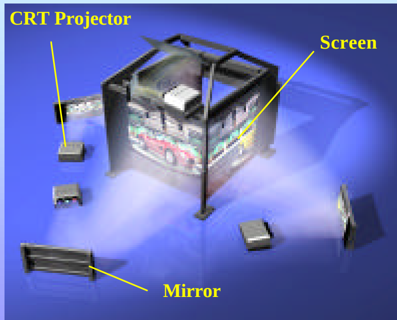
- Screen size limit
- Immersion breaks at the display borders

CAVE

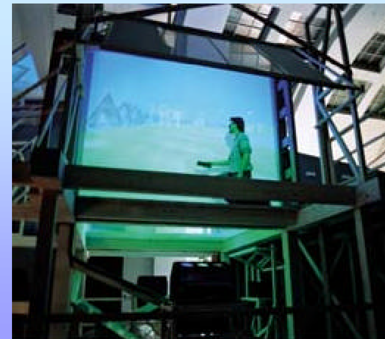
- Multi-wall (usually 4) provides wide FOV
- Can see other people
- Stereo more realistic

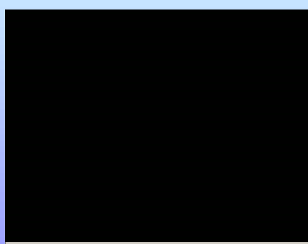


- Missing walls break illusion
- (Less bright with CRT)
- $$$



CAVE 3-D large volume display (courtesy of Fakespace Co.)





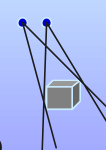
Other visual display types

Immersion and stereoscopy

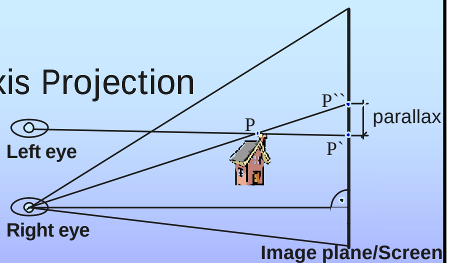
- Standard 3D rendering gives depth cues:
  - perspective
  - relative size
  - texture gradient, etc.
- To enhance 3D depth, use stereo imagery
- Slightly different images for each eye

Implementing stereoscopy

- Render from two offset eyepoints (IPD)
- 2 images per frame may affect fr. rate
  - multiple graphics pipelines
  - each image lower resolution
- HMD: directly send images to 2 eyes
- other displays:
  - time-multiplexed stereo (shutter glasses)
  - using phase filters
  - using color filters
  - autostereoscopic displays



Off-Axis Projection



- Parallax
  - Negative: object in front of screen
  - Zero: object on the screen
  - Positive: object behind the screen
- Focus vs. convergence
  - Focus on image plane
  - Convergence on virtual object
  - Large parallax puts strain on the eye

Shutter Technology

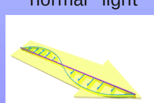
- Close left eye when right eye image is displayed and vice versa
- Controlled through infrared or wired up
- Usually connects to V-sync signal (vertical retrace of CRT)

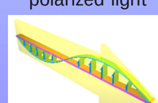
Polarization

- Light: wave length and direction of polarization. Two components orthogonal to each other.

"normal" light

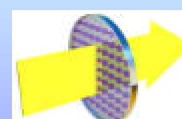
polarized light

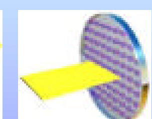




Polarization

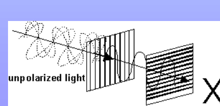
- Filters can block certain directions of polarization





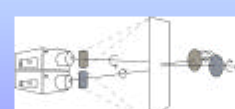
Stereo Through Polarization

- Use two projectors
  - Proj. 1/left view: vertical filter in front of the lens
  - Proj. 2/right view: horizontal filter in front of the lens
- Wear glasses with polarization filters
  - Left eye: vertical
  - Right eye: horizontal



Stereo Through Polarization

- Linear polarization
  - Can't tilt head
  - Little ghosting



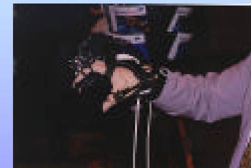
- Circular polarization
  - Proj. 1/left view: clockwise filter
  - Proj. 2/right view: counter clockwise filter
  - Allows arbitrary head orientations
  - In general more ghosting than linear polarization

Immersion needs more

- The most important depth cue is not stereo, it's *motion parallax*
  - far objects move more slowly across the visual field as our viewpoint moves
- Can achieve motion parallax with head tracking
- Tracking also allows us to view the scene "naturally"

Immersion needs more

- Auditory displays
  - standard
  - spatialized
- Haptic displays
  - collision indication
  - force-feedback
- Olfactory displays (!)
- Natural interaction and believable object behaviour



VR-programming

- Input and display devices are the main hardware interface to users
- Immersion embeds users through the generation of rich sensory experiences
- *But how is the programmers/designers view?*

VR-programming tools

- Direct rendering and gfx packages
  - OpenGL, Direct3D, GKS (3D)
- Scene graph based tools
  - VRML, OpenGL Performer, OpenGL Optimizer, Open Inventor, PHIGS+
- VR modeling toolkits
  - AVANGO, World toolkit, Massive1-3, Dive, Lightning, game engines

What is a gfx package?

- software
  - that takes user input and passes it to applications
  - that displays graphical output for applications