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

The Wheatstone stereoscope used angled mirrors (A) to reflect the stereoscopic drawings (I) toward the viewer’s eyes.

The term „Virtual Reality“

- The actual term "Virtual Reality" is attributed to Jaron Lanier of VPL in 1986 in a conversation regarding the work of Scott Fisher.
- Fisher, of NASA Ames, had been referring to the field as "Virtual Environments".
1961: Morton Heilig Sensorama

- Morton Heilig began designing the first multisensory virtual experiences in 1956 (patented in 1961).
- The Sensorama combined projected film, audio, vibration, wind, and odors.
- The five "experiences" included
  - a motorcycle ride through New York
  - a bicycle ride
  - a ride on a dune buggy
  - a helicopter ride over Century city in 1960
  - a dance by a belly dancer.

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1961: Morton Heilig Sensorama

- Heilig also patented an idea for a device that some consider the first Head-Mounted Display (HMD) (proposed 1960 and applied for patent in 1962).
  - Wide field of view optics to view 3D photographic slides.
  - Stereo sound.
  - Odor generator.
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

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
- $$$
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.
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

The Ultimate Display

The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked. (Sutherland 1965)
Some first gfx steps
- Spacewar, tennis for two and pong

Some intermediate gfx steps
- Unreal3 engine
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

![Diagram showing the relationship between Application Model, Application Program, Graphics System, and the computer.]