Implementing additional depth cues

- Stereoscopy:
  - Render from two offset eye points (IPD) or center of projections (CPs).
  - Off-axis projection α and β in 3D: α ≠ 0, β ≠ 0.
  - Linear polarization.
  - Motion parallax:
    - Track head (and hence eye movements).
    - Calculate dynamic view frustum in case of image plane fixed w.r.t. world.

- Filters can block certain directions of polarization.

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

Stereoscopy

- Features of binocular parallax:
  - Negative: object in front of screen.
  - Zero: object on the screen.
  - Positive: object behind the screen.
  - Focus vs. convergence.
  - Convergence is 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).

Stereoscopy methods

- Feed each channel and its rendered picture to one specific eye by:
  - Using one screen per eye (HMD).
  - Time-multiplexing generated images (shutter glasses).
  - Filter images through polarization filters.
  - Filter images using color filters (anaglyph).
  - Using auto-stereoscopic displays.

Stereoscopy

- Polarization:
  - Light: wave length and direction of polarization. Two components orthogonal to each other.
  - Filters can block certain directions of polarization.
  - See through linear polarization (see two projectors):
    - Left view: vertical filter in front of the lens.
    - Right view: horizontal filter in front of the lens.
    - Wear glasses with polarizing filters.
    - Left eye: vertical.
    - Right eye: horizontal.

- Circular polarization:
  - Combine each channel's R, G, B values by two complementing transformations to calculate an integrated channel.
  - Several anaglyph version exist. Usually black/white images, color possible but filter and image colors may interfere.
  - Example for a red/blue transformation:
    - Left view: clockwise filter.
    - Right view: counter clockwise filter.
    - Allows arbitrary head orientations.
    - In general more ghosting than linear polarization.

Realtime 3D Computer Graphics Virtual Reality

Virtual Reality Display Systems
VR display systems

- Morton Heilig began designing the first multisensory virtual experiences in 1956 (patented in 1961): Sensorama
- 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.
- 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.

VR visual display systems

- A head-mounted three-dimensional display (Sutherland, 1968) by Ivan E. Sutherland:
  - Hidden-line graphics
  - Mechanical tracking
  - see through HMD

VR visual display systems

- Head-mounted display (HMD)
  - Scene completely surrounds user
  - Graphics are sharp and bright
  - FOV is narrow
  - Devices are heavy, cumbersome
  - Can’t see other people (nowadays see-through with some devices)

- Boom (Binocular 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

VR visual display systems

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

VR visual display systems

- Cylindrical Screen Configurations, e.g., Cone
  - Common in industry
  - Projection difficult, curved screen requires distortion correction in hardware or software

VR visual display systems

- (Responsive) Workbench
  - Table-top metaphor
  - Change display orientation
  - Integrates real & virtual
  - Less immersion
  - Occlusion/cancellation
  - expensive
VR visual display systems

- Two-Sided Workbench, holoscreen
  - Enlarged view volume (w.r.t. workbench)
  - Enhanced immersion
  - High resolution possible
  - Telepresence

- Wall (door/window metaphor)
  - Allows 1:1 real object sizes
  - High resolution possible
  - Relative cheap
  - Screen size limit
  - Immersion breaks at the display borders

VR display systems

- Several more specialized visual display systems exist (see images on bottom/right).
- The term display system is not restricted to visual display systems.
- Each sense for which stimuli has to be simulated requires its own display.
- Many VR systems (including the introduced ones) already include more than one display type, e.g., many visual displays include an auditory display (CAVEs, HMDs with earphones, etc.).

VR input devices

Special input devices are required for interaction, navigation and motion tracking (e.g., for depth cue calculation):

1. **Motion Trackers**: Position and orientation of a reference system in 3D requires to measure 6 Degrees of Freedom (DOFs).
2. **3D Mice/Wands etc.**: Specialized devices for point and click WIMP-style metaphors have to account for additional DOFs.
3. **Joint sensors**: Sensors which measure movement of user's joints (Also possible with trackers and inverse kinematics).
4. **Props**: Real placeholders for virtual objects.
5. **Movement effect sensors**: Measure the effect user movement has to the surrounding (no kinematics involved).
6. **Skin sensors, neural interfaces, bio-sensors**: Measure skin resistance, brain activity and other body related data.

…and hybrid devices.
VR input devices

Input is measured by a multitude of physical and biological principles, e.g.,
- electro-magnetism
- optics (marker/marker less, visible spectrum/infrared)
- electrics (voltage, impedance, electrical flow, ...)
- acoustics (ultrasound, ...)
- inertia

Input devices produce data
- discrete event based (buttons, state changers).
- continuously (discrete but continuously sampled).

Electromagnetic tracker & Data Glove
- Electromagnetic tracker
  - used to be most common see: “put-there”
  - Transmitter
    - Creates three orthogonal low-frequency magnetic fields
    - Short range version: < 1 m
    - Long range version: < 3 m
  - Receiver(s)
    - Three perpendicular antennas.
    - Distance is inferred from the currents induced in the antennas.
  - Affected by metal – requires non-linear calibration.
  - Wireless versions expensive.

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

Acoustic trackers
- Uses ultrasound
- Typical setup for 3 DOF
  - 3 microphones and 1 speaker
- Distance is inferred from the travel time of the sound
- No interference with metal
- Relatively inexpensive
- Line of sight issues
  - Sensitive to air temperature and certain noises
  - Inertial trackers (Intersense IS-300)
    - Less noise, lag
    - Only 3 DOFs (orientation)
    - Use gyroscopes and accelerometers

Optical marker based tracker
- marker reflects IR light
- Combined to unique spatial configuration per tracked position
- No interference with metal
- Low latency
- High resolution
- Line of sight issues (more cameras help)

3D mice/wands
- Several buttons and sensors for selection of binary states and/or continuous state changes (e.g., potentiometers).
- Often hybrid devices for additional position/orientation.

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

- **Data Gloves**
  - Used to track the user’s finger movements.
  - For posture and gesture detection.
  - Almost always used with a tracker sensor mounted on the wrist.
- **Common types**:
  - SDT Glove (left) 5/16 sensors
  - CyberGlove (right) 16/22 sensors
  - New hybrid modification for flexion and pinch

Electronic unit
10 updates per second
3 meters range from base unit
Resolution < 2 mm
and < 0.2 degrees

Electronic unit
Head-prop
Courtesy of Hinkley et al

Cyberglove with haptics
Shape-replication
courtesy of Balakrishnan et al.

VR input devices

- **Speech Input**
  - Continuous vs. one-time recognition
  - Choice and placement of microphone
  - Training vs. no training
  - Handling of false positive recognition
  - Surrounding noise interference
- Can complement other modes of interaction
- Multi-modal interaction (by, e.g., additionally including gesture processing which benefits from the VR sensory equipment)

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 a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.“

(Sutherland 1965)

References

- Gibson, William (1964): Neuromancer (first print)