Computer Graphics in Virtual Environments

Doug Bowman
Computer Science
Virginia Tech
Definitions

- Virtual Environment (VE): an interactive computer-generated “world” seen from a first-person point of view
- Immersive VE: A real-time 3D synthetic environment that appears to surround the user in space
  - HMD with head tracking, CAVE
  - “Fishtank VR”, MUDs, Multimedia apps
Example VE

Center for Human Computer Interaction
Virginia Polytechnic Institute and State University

Trauma Room Simulation

Computer Science Dept  Carilion Clinic
Virginia Tech  Department of
Surgery

In collaboration with CCTAD
Example immersive VE
Components of a VE system

- Display hardware
- Tracking system
- Input devices
- Environment model(s)
- Rendering / display software
- Interaction software

(C) 2008 Doug Bowman, Virginia Tech
System components overview

Env. model

Simulation loop:
- render
- check for events
- respond to events
- iterate simulation
- get new tracker data

Display(s)

Input device(s)

Tracking system

(C) 2008 Doug Bowman, Virginia Tech
Display requirements for VEs

To create immersion, display should:

- Present high-quality 3D graphics
- Update at a high rate
- Provide wide field of view (FOV)
- Provide wide field of regard (FOR)
- Provide more 3D depth cues

(C) 2008 Doug Bowman, Virginia Tech
3D depth cues

- Pictorial
- Stereopsis
- Motion parallax
- Oculomotor
  - Accommodation
  - Convergence

Accommodation-convergence mismatch

right-eye image

left-eye image

(C) 2008 Doug Bowman, Virginia Tech
Implementing stereoscopy

- Render from two offset eyepoints (IPD)
- 2 images per frame may affect frame rate
  - multiple graphics pipelines
  - each image lower resolution
- HMD: directly send images to 2 eyes
- other displays:
  - Active, time-multiplexed stereo
  - Passive stereo, based on polarization or wavelength shifting

(C) 2008 Doug Bowman, Virginia Tech
Display hardware for VEs

- Technologies: CRT, LCD, Plasma, Projection
- Form factor:
  - Monitor
  - Head-mounted
  - Single large screen
  - Surround-screen
  - Tabletop
VR with a monitor
Head-mounted display

- Scene completely surrounds user
- Simple stereo

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

(C) 2008 Doug Bowman, Virginia Tech
CAVE

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

- Missing walls break illusion
- Less bright
- $$$

(C) 2008 Doug Bowman, Virginia Tech
Six-sided CAVE (Duke U. DiVE)
Workbench

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

- Less immersion
- Occlusion/cancellation
- $$$
Volumetric display

- Pixels displayed in actual 3D space
- Multi-user correct viewing
- Size issues
- Opacity issues
- Can’t move/reach into display

(C) 2008 Doug Bowman, Virginia Tech
Other visual display types
Non-visual displays

- Auditory displays
  - standard
  - spatialized
- Haptic displays
  - collision indication
  - force-feedback
- Olfactory, gustatory displays (!)
Tracking systems

- 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”
Types of trackers

- Electromagnetic
- Acoustic
- Inertial
- Vision-based
- hybrids

Differ in number of degrees of freedom (DOFs)
- 3 DOF: x, y, z
- 6 DOF: x, y, z, roll, pitch, yaw

(C) 2008 Doug Bowman, Virginia Tech
Other uses of trackers

- Track hands, feet, or other body parts
  - “whole body” interaction
  - motion capture application
- Track physical objects that can be used in the virtual world
  - props
  - spatial input devices
Input devices

- Mouse & keyboard not suited for 3D input/interaction
- Tracker is one type of input device
- Combine trackers with:
  - button devices
  - instrumented gloves
Tracked devices
Other types of VE input
Environment model

- A description of the scene to be rendered
- Usually created in a commercial modeling package
- Can also be specified directly in files
- Objects, colors, textures, light sources, hierarchy, properties
- May include behavior specification
Rendering software

- Get current eye point from:
  - tracker information (how old is it?)
  - location of user within environment
- Render 3D view of env. from viewpoint (2 views if stereo, 8 views for stereo CAVE)
- *Must work in real time!* (10 Hz min., >30 Hz preferred)
  - requires low polygon count
  - requires simple lighting model
  - requires optimization (e.g. view culling, LOD)
  - textures (hardware) increase realism
Off-axis rendering for VEs
Interaction software

- Most of the application program is concerned with how the environment reacts to user input
- Basic interaction types:
  - navigation
  - selection / manipulation
  - system control
Applications of VEs

- Entertainment
- Design verification and modification
- Training
- Education
- Information / Scientific Visualization
- Collaboration / Community
- Medicine / Mental Health
VEs in the real world: DisneyQuest

- Disney’s “Interactive Indoor Theme Park”
- 5-story building containing:
  - Major VE attractions
  - Technology-based creative experiences
  - Classic and modern video games
  - Expensive food and gifts :-)

(C) 2008 Doug Bowman, Virginia Tech
VEs at DisneyQuest

- HMD-based attractions:
  - Ride the Comix
  - Aladdin’s Magic Carpet Ride
- Single projection screen VR:
  - Jungle River Rafting
  - Design and ride your own roller coaster
- Multiple projection screen VR: Pirates of the Caribbean

(C) 2008 Doug Bowman, Virginia Tech
Scenes from DisneyQuest

(C) 2008 Doug Bowman, Virginia Tech
Screen shot from Aladdin’s Magic Carpet ride. Entrance into the Sultan’s palace.
How to learn more

- Do a VTURCS project
- Apply to grad school!
- Conferences:
  - IEEE Virtual Reality
  - ACM VRST
- Journals:
  - PRESENCE: Teleoperators and Virtual Environments
  - IEEE Transactions on Visualization and CG

(C) 2008 Doug Bowman, Virginia Tech