Advanced Topics in Virtual Reality

Calibration and Registration

To produce a working 3D viewing and interaction experience, one has to calibrate all devices and register them to reality.

**Calibration:**
- mapping tracker to real world position
- mapping HMD to real world view

**Registration:**
- for the set-up to work, all devices have to be „registered“ to each other in the same coordinate system
**Calibration**

Determine & correct non-linearities and scale factors, e.g.:

- distortions of optics in a HMD:
- distortions of magnetic tracker:

**Calibration**

mapping of image to projection screen::
**Registration**

registration parameters for a projection set-up


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**Correct Stereoscopy**

The stereoscopic effect depends heavily on the correct projection of left and right image.

Example: rendering for stereoscopic projection

Wrong:
offset or tilt

Correct:
off-axis projection
Correct Stereoscopy

A general camera model is necessary, where view plane and eye-point with viewing direction can be defined independently.
This is NOT generally possible in most render packages and OpenGL cameras!
VR setups

Categories:
- Immersive / Augmented (Mixed)
- Single / Multi user
- Local / Distributed
Immersive vs. Augmented setups

Immersive setup
- user sees only simulation
- pro:
  - whole visible world can be manipulated
  - less registration problems
- contra:
  - possible: disorientation & claustrophobia
  - collisions w/reality
  - whole environment must be generated
    (real objects too \(\Rightarrow\) real collisions!)

Augmented (Mixed) setup
- user sees real & virtual environment
- pro:
  - only virtual objects have to be displayed
  - social interaction possible
  - objects outside the simulation are visible
    (cars, other people, doors, etc.)
- contra:
  - registration between real & virtual world tricky
    (misregistration very visible)
  - navigation metaphors reduced
The CAVE
(“CAVE Automatic Virtual Environment”)

The “CAVE” consists of 3 to 6 back-projection screens. These screens form (parts of) a cubical room in which the user has a large view of the VE.

A CAVE user
- wears Shutter- or Pol-glasses
- has to be head-tracked
- uses a tracked input device
The CAVE – back projection

mirrors

projectors

screens
(semi-transparent)

Illustration by Minh Phuong
Electronics Visualization Laboratory University of Illinois at Chicago

The CAVE – front projection
The CAVE – front vs. back projection

<table>
<thead>
<tr>
<th></th>
<th>Back</th>
<th>front</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space requirements</td>
<td>Larger than working volume</td>
<td>Working volume</td>
</tr>
<tr>
<td>Screen</td>
<td>Expensive, special corners</td>
<td>White wall</td>
</tr>
<tr>
<td>Vignetting</td>
<td>Extensive</td>
<td>Not noticeable</td>
</tr>
<tr>
<td>Shadows</td>
<td>None</td>
<td>When standing close</td>
</tr>
<tr>
<td>Polarization</td>
<td>Possible, but mediocre</td>
<td>Not really possible</td>
</tr>
<tr>
<td>Top &amp; bottom projection</td>
<td>Possible</td>
<td>Not possible</td>
</tr>
</tbody>
</table>

The CAVE

Images for the CAVE have to be calculated depending on the users and screens position.
From the wrong position, the images look like this:
The CAVE

The FLYCAVE
The FLYCAVE - display
The FLYCAVE – rendering

- Virtual world
  - arbitrary scene rendered with OpenSceneGraph
  - user input (e.g., movement and interaction)
  - orthographic projection
- Calenmap
  - six degrees of freedom
  - view direction
  - defined in local frame
- Geometry texture
  - generated by projecting calenmap onto
  - 3D model of display rather than local frame
- Display view
  - created by binding tapl frame geometry
  - view direction
  - defined in local frame

3D pose of observer
- defined in local frame

The FLYCAVE – tethered version

Three images are projected via mirrors on a small, translucent ball

Inside the ball, a fly is anchored

The amplitudes of the fly's wings give its intended direction
The FLYCAVE – tethered version

The FLYCAVE – confinement results
Studierstube

“Studierstube” is a multi-user local VE. It uses see-through HMDs to let users share a common augmented workspace.

The main interface is the “Personal Interaction Panel” a pad and pen combination. The pad is augmented with 2D and 3D widgets, which can be manipulated by the pen.
**Studierstube (video)**

Using sliders on the PIP to parameterize the AVS network

**Studierstube (video)**

Two-User Interaction
Studierstube (video)

Select your viewpoint by simply moving your head around....

ARAS – augmented reality aided surgery

Polygons, vessel tree, vessel tree transformation, Anotation markers

Radiologist's Workstation

Surgeon's video camera

Surgeon's Workstation

Ultrasound Device

Tracker Server

Position and Orientation of all tracked devices:
- Surgeon’s head tracker
- Patient tracker
- US-probe tracker

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[Fuhrmann2002]
ARAS – augmented reality aided surgery

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**Spherical Projection Setups**

Non-planar screens – mostly spherical – screens used when large FoV is important.

E.g. architectural walkthroughs or car- or flight-simulators:

**Motion Simulators**

(hemi-)spherical projection in combination with a motion platform delivers an extremely immersive experience:

e.g.: military helicopter simulation
Blue-C

Developed @ ETH Zürich (Markus Gross & Oliver Staadt)
The blue-c system combines the CAVE with real-time image capture and 3D video

http://blue-c.ethz.ch/
The blue-c system includes:

- a fully immersive three-dimensional stereo projection theatre
- real-time acquisition of multiple video streams
- three-dimensional human inlays reconstructed from video images
- voice and spatial sound rendering
- distributed computing architectures for real-time image processing and rendering
- a flexible communication layer adapting to network performance
- a scalable hard- and software architecture for both fixed and mobile installations
Blue-C

Back-projection screens can be switched to transparent → cameras from outside CAVE can grab images → 3D reconstruction of user possible

Blue-C

Capturing the user from a lot of cameras surrounding the system allows to reconstruct a 3D model, which can be rendered from different angles
Blue-C

By using an additional phase, where both shutters of the glasses are opaque, the capturing can be performed invisible to the user:

<table>
<thead>
<tr>
<th></th>
<th>stereo right</th>
<th>picture acquisition</th>
<th>stereo left</th>
<th>picture acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td>active projection screen</td>
<td>trans.</td>
<td>0 ms</td>
<td>trans.</td>
<td>0 ms</td>
</tr>
<tr>
<td>LED illumination</td>
<td>on</td>
<td>4 ms</td>
<td>on</td>
<td>4 ms</td>
</tr>
<tr>
<td>camera</td>
<td>on</td>
<td>8 ms</td>
<td>on</td>
<td>8 ms</td>
</tr>
<tr>
<td>right eye shutter glass</td>
<td>opaque</td>
<td>12 ms</td>
<td>opaque</td>
<td>12 ms</td>
</tr>
<tr>
<td>left eye shutter glass</td>
<td>opaque</td>
<td>16 ms</td>
<td>opaque</td>
<td>16 ms</td>
</tr>
<tr>
<td>right projector shutter</td>
<td>opaque</td>
<td>20 ms</td>
<td>opaque</td>
<td>20 ms</td>
</tr>
<tr>
<td>left projector shutter</td>
<td>opaque</td>
<td>24 ms</td>
<td>opaque</td>
<td>24 ms</td>
</tr>
</tbody>
</table>

Background subtraction segments the image into user and background:

![Background subtraction example](image1.png)
Blue-C

Many images & silhouettes from different viewpoint deliver 3D point stream:

Blue-C

3D holographic telephony, system setup:
Motion Simulators

Motion platforms can be used to simulate acceleration. Because humans do not recognize slow changes in acceleration, and because the gravity-vector can be used as substitute for ongoing accelerations (e.g. tilting), a relatively small range of motions is sufficient.
VirtuSphere

- Implements „walking“ in VR
- gigantic „Trackball“
- user inside
- moves in all direction
- ultrasound sensors deliver XY

Advantages
- no physical constraints of (planar) movement

Disadvantages
- high inertia → movement difficult
- accident prone setup
- tracking & display has to be wireless or self-contained (mobile VR)
Virtuix Omni

Low-friction shoes!

Virtuix Omni

Socks!
CyberCarpet

- Implements „walking“ in VR
- omni-directional treadmill
- conveyor belt built from conveyor belts turned 90°

CyberCarpet (movie)
Infinadeck

End of Lecture

Evaluation:

- DO NOT FORGET TO EVALUATE!
- Den verwendeten Fragebogen können Sie über TUWIS++ [http://tuwis.tuwien.ac.at/](http://tuwis.tuwien.ac.at/) (Benutzername: Ihr Nachname; Passwort: Ihr persönliches TU-Passwort) abrufen.

LVA-NR. Typ Fragebogen Modus Bewertungszeitraum

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186.156 VU VO e SS 2012
End of Lecture

Lab-Project:
- 1-2 students per group
- max. 3 months
- work@home or VRVis
- own or given themes

Examn
- this semester (as early as possible)