Professors d’IDI - UPC

IDI – Introduction to VR & AR

Outline

- **Virtual Reality**
  - **General Concepts**
  - VR Systems
  - Stereo Synthesis
  - Interaction
- Augmented Reality

Augmented vs Virtual Reality

- **Augmented Reality**
  - System augments the real world scene
  - User maintains a sense of presence in real world
  - Needs a mechanism to combine virtual and real worlds
- **Virtual Reality**
  - Totally immersive environment
  - Visual senses are under control of system (sometimes aural and proprioceptive senses too)

Virtual Reality

- Definition given by A. Rowell:

"The Virtual Reality is the computer interactive simulation from the point of view of the participant, in which the sensory information he/she perceives is substituted or augmented".

Virtual Reality

- Fundamental elements:
  - *Digital 3D model*
  - **Interactive Visualization/Navigation**
  - **Implicit Interaction**
  - **3D sensorial immersion**

Concept of Virtual Reality

Interactive Visualization/ Navigation

3D Geometric Model

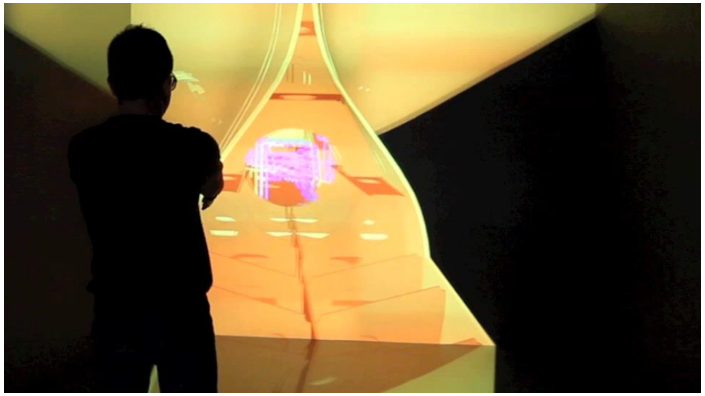
Digital Representations

3D Immersion

Implicit interaction

Virtual Reality

- **Interactive Visualization**
- Implicit interaction
- Immersion



Reproduces a virtual world which only exists as a digital model inside the computer

- **Interactive simulation vs animation**
  - passivity, previously decided
  - improvisation**, active**, **real time response**
- **3D geometric** and appearance representation
- Realistic visualization algorithms
- Memory management algorithms
- Multiresolution models
- "Zoom" capacity
- Visibility pre-process

Concept of Virtual Reality

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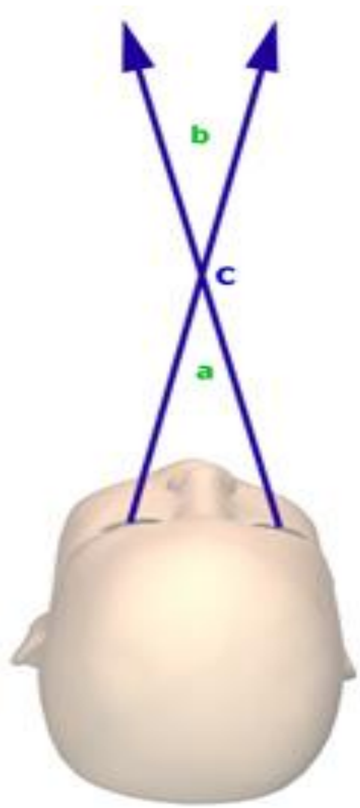
Virtual Reality

- Interactive Visualization
- Implicit interaction
- **Immersion**

Disconnecting senses from the real world, and connecting them to the virtual environment

- Visual immersion: objects exist independently of the visualization device
  - **Stereoscopic vision.** Presence feeling into the space
- Acoustics immersion
- Touch immersion
- Movement immersion: acceleration
- Smelling, tasting…

Retinal disparity



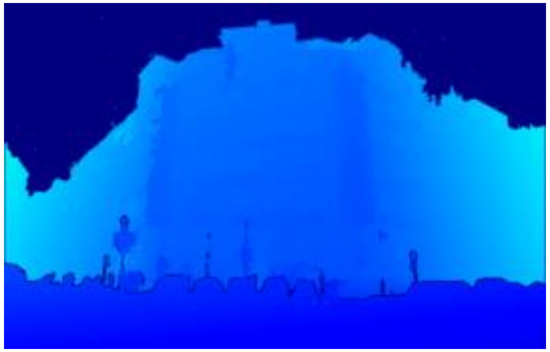
Retinal disparity

- Difference in the L/R images of an object due to the eyes' horizontal separation

Fusion and stereopsis

- The human brain is able to **combine two images with disparity into a single image with depth.**
- This ability is called **fusion** and the resulting sense is called **stereopsis.**





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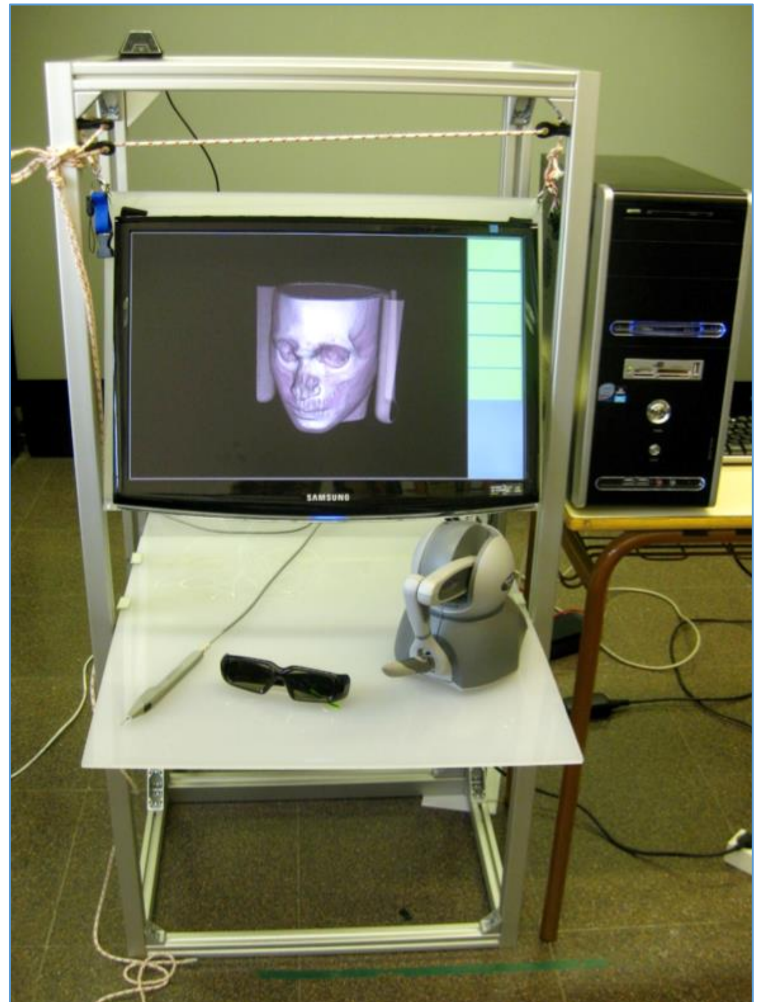
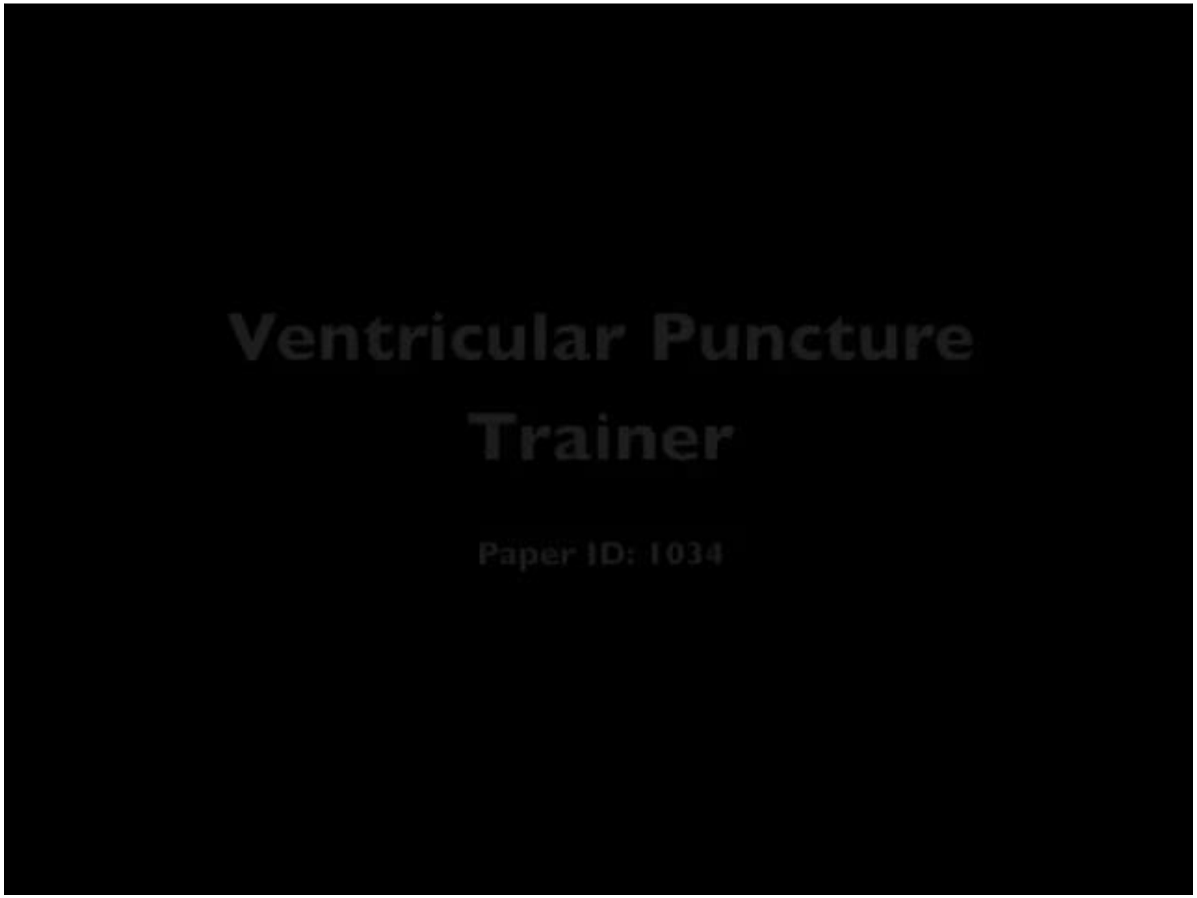
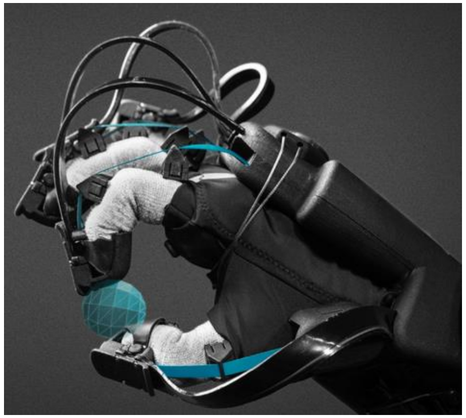
Virtual Reality: Haptic Devices



Virtual Reality: Haptic Devices



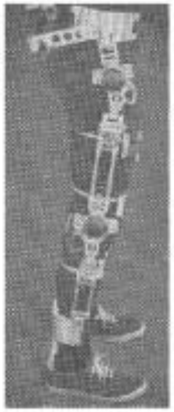
Virtual Reality: Haptic Devices



Intuitive Surgical, Inc.
Mountain View, CA

rehabilitation

Durfee & Goldfarb,
MIT Biomechanics Lab:
controllable brake aids
paraplegics in walking



Hogan & Krebs, MIT Biomechanics Lab:
retraining stroke patients while measuring
their progress.

Concept of Virtual Reality

Interactive Visualization/ Navigation

3D Geometric Model

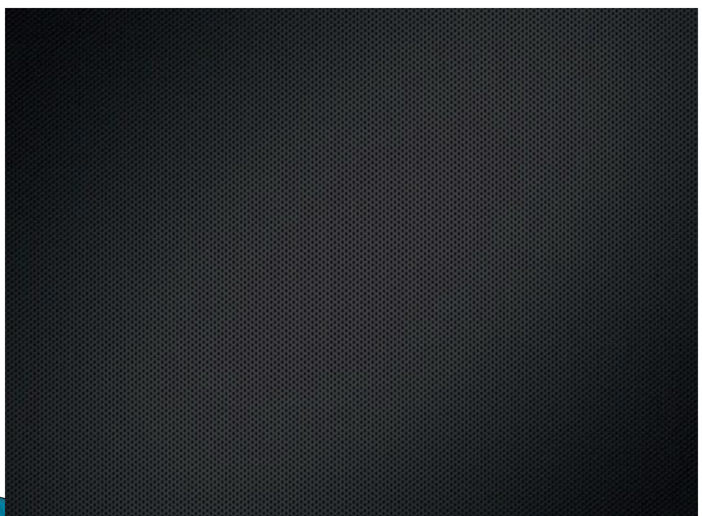
Digital Representations

3D Immersion

Implicit interaction

Virtual Reality

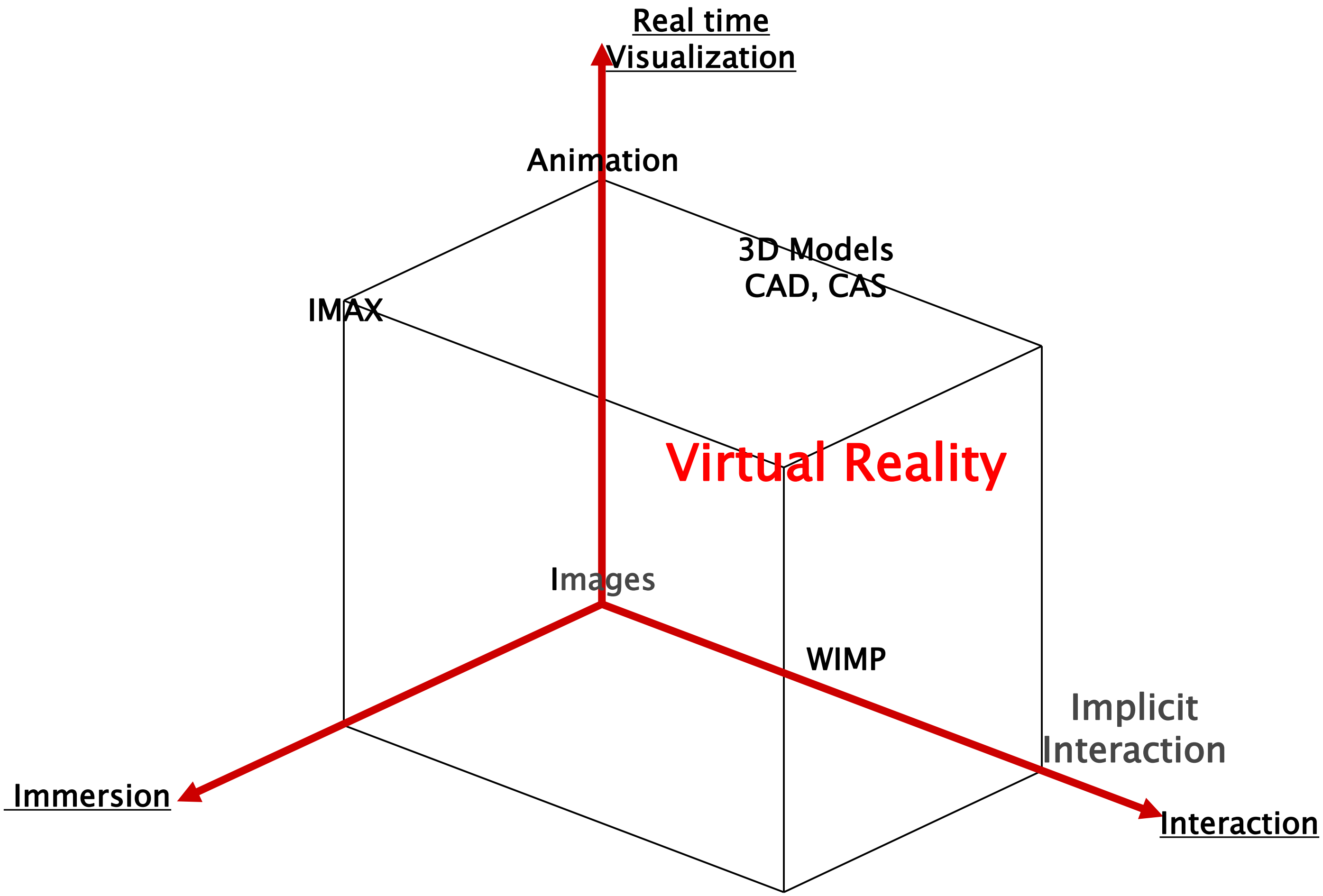
- Interactive Visualization
- **Implicit interaction**
- Immersion



The system decides what the user wants from his ***natural movements***

- Gestures, head movements vs interaction with the mouse
- Interaction, selection: movements of grab with hand or finger, etc.
- Transparency of the devices and the computer
- Perception of the direct interaction with objects
- **Window to the model vs immersion to the virtual environment**

Virtual Reality: Summary



Outline

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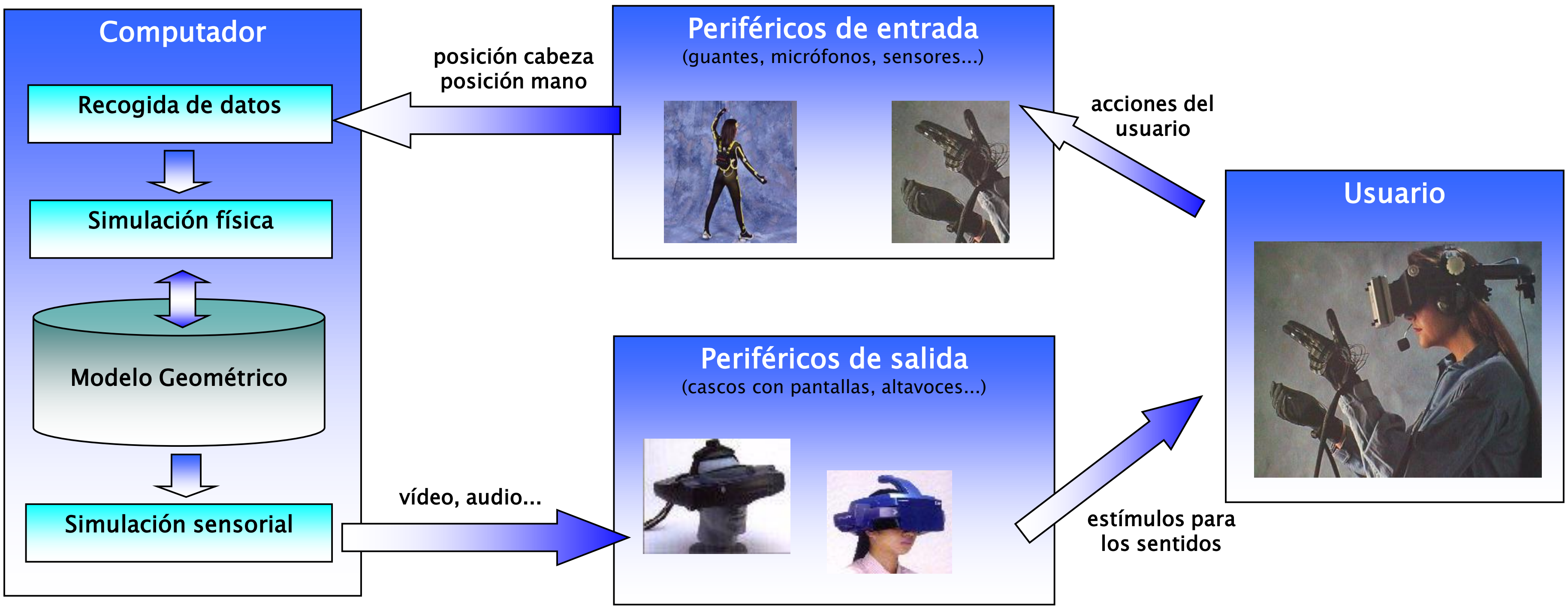
Virtual Reality Systems: Arquitecture

- Actualization frequency
- Latency time

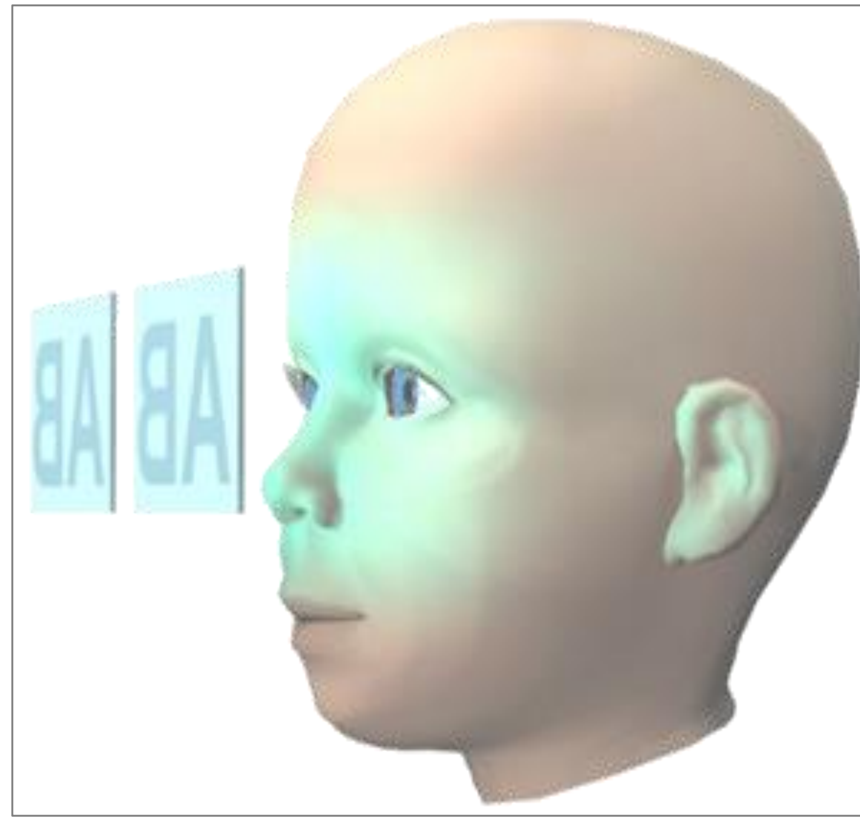


Virtual Reality Systems

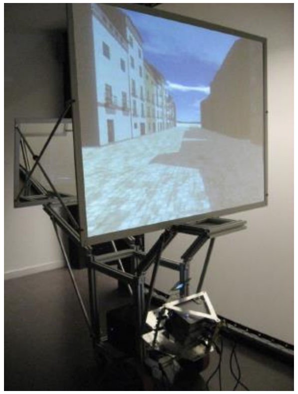
- Immersive

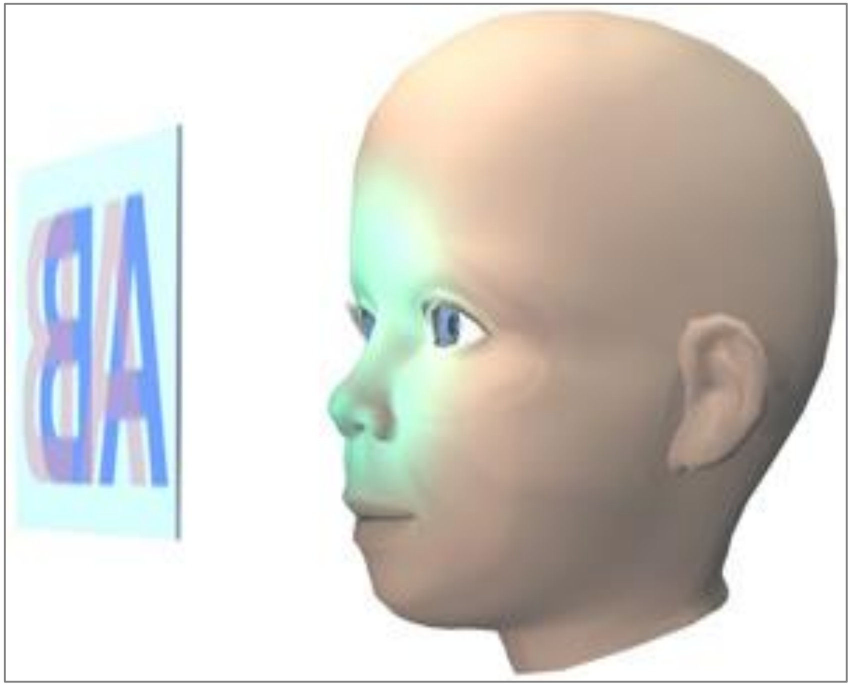
- Semi-Immersive

VR: Immersive systems



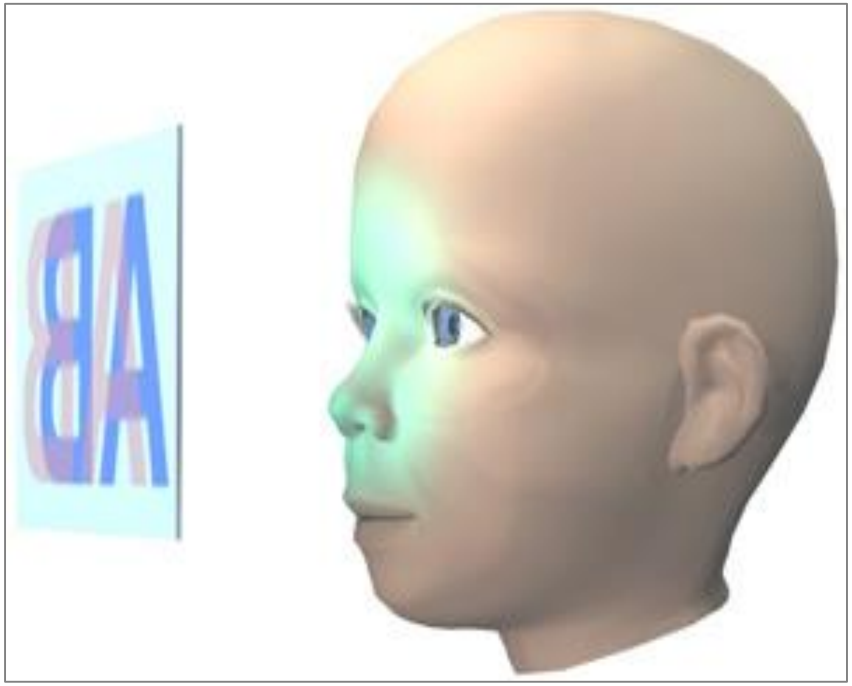
VR: Semi-immersive systems

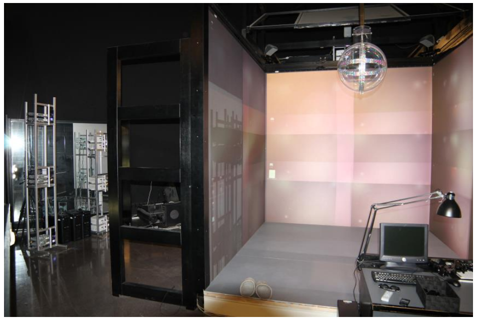




VR: Semi-immersive systems

- Both eyes can see the screen
- Requires some **image separation technique** (eg. polarization glasses, anaglyph…)
- Used in most projection-based equipment (CAVEs…)





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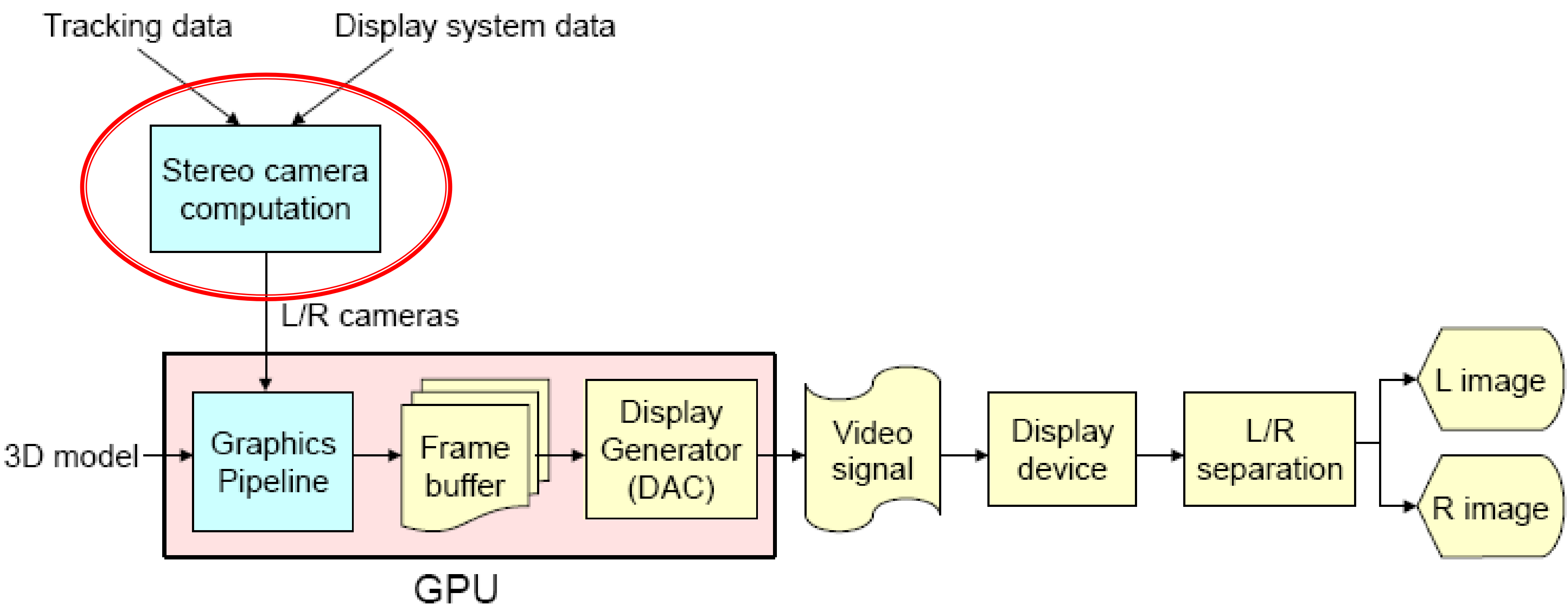
VR: Synthesis of stereo images

- Input: 3D model, tracking data, display system data
- Output: images with retinal disparity

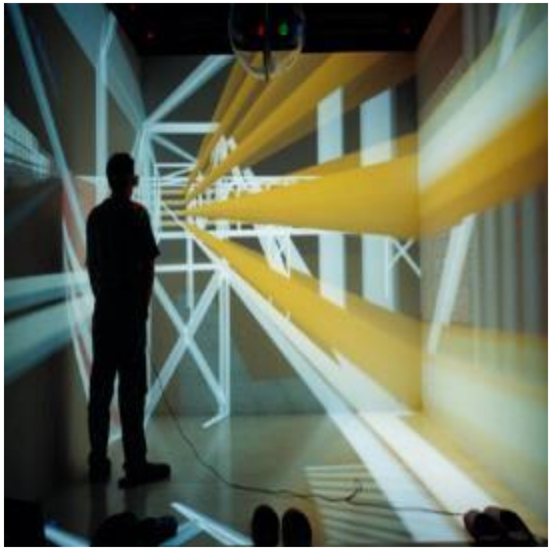


VR: Stereo camera computation

- Output: **Left** and **Right** cameras:
  - Position and orientation parameters:
    - Eye (OBS), target (VRP), up (VUV)
    - lookAt (eye.x, eye.y, eye.z, target.x, target.y, target.z, up.x, up.y, up.z);
  - Intrinsic parameters:
    - view frustum geometry
    - frustum (left, right, bottom, top, near, far);

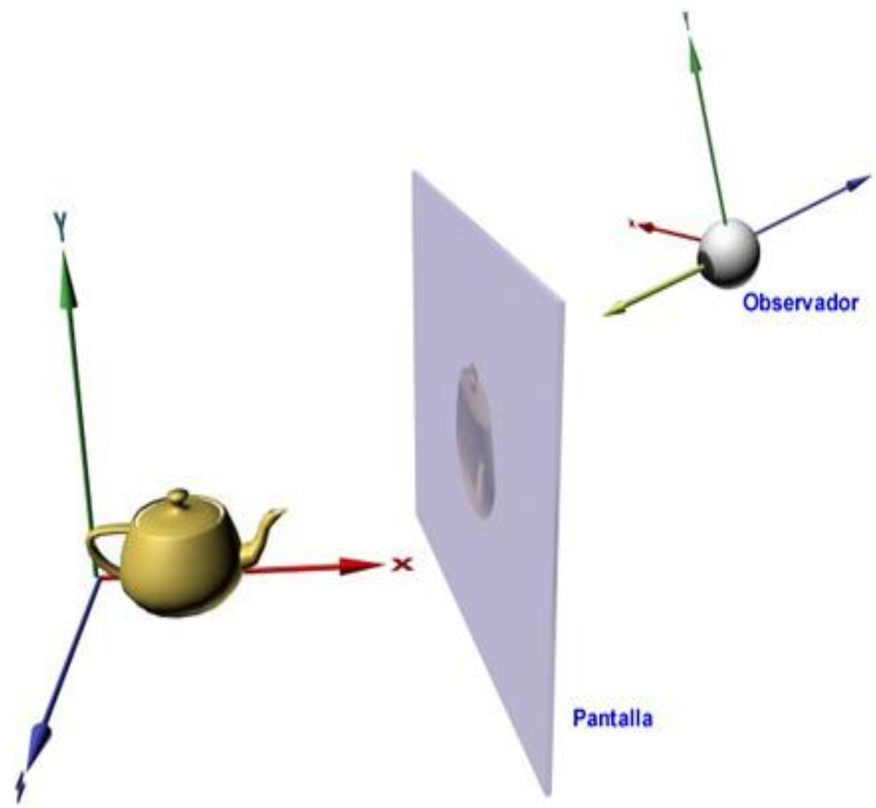
VR: System Configurations

- Static screen + head-tracking (projection-based)
- Dynamic screen + head-tracking (HMDs)



VR: Stereo camera computation

- The scene should be centered in the viewing path from user to screen
- The virtual camera must be computed taking into account:
  - Screen geometry (size, position, orientation)
  - The eye position with respect to the screen.

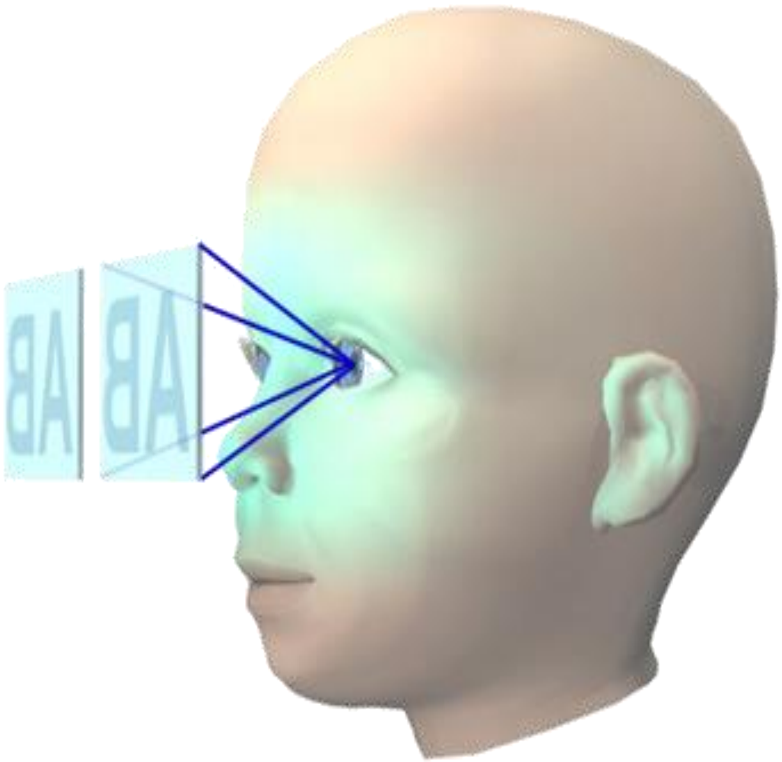


Dynamic screen: Stereo Camera Computation

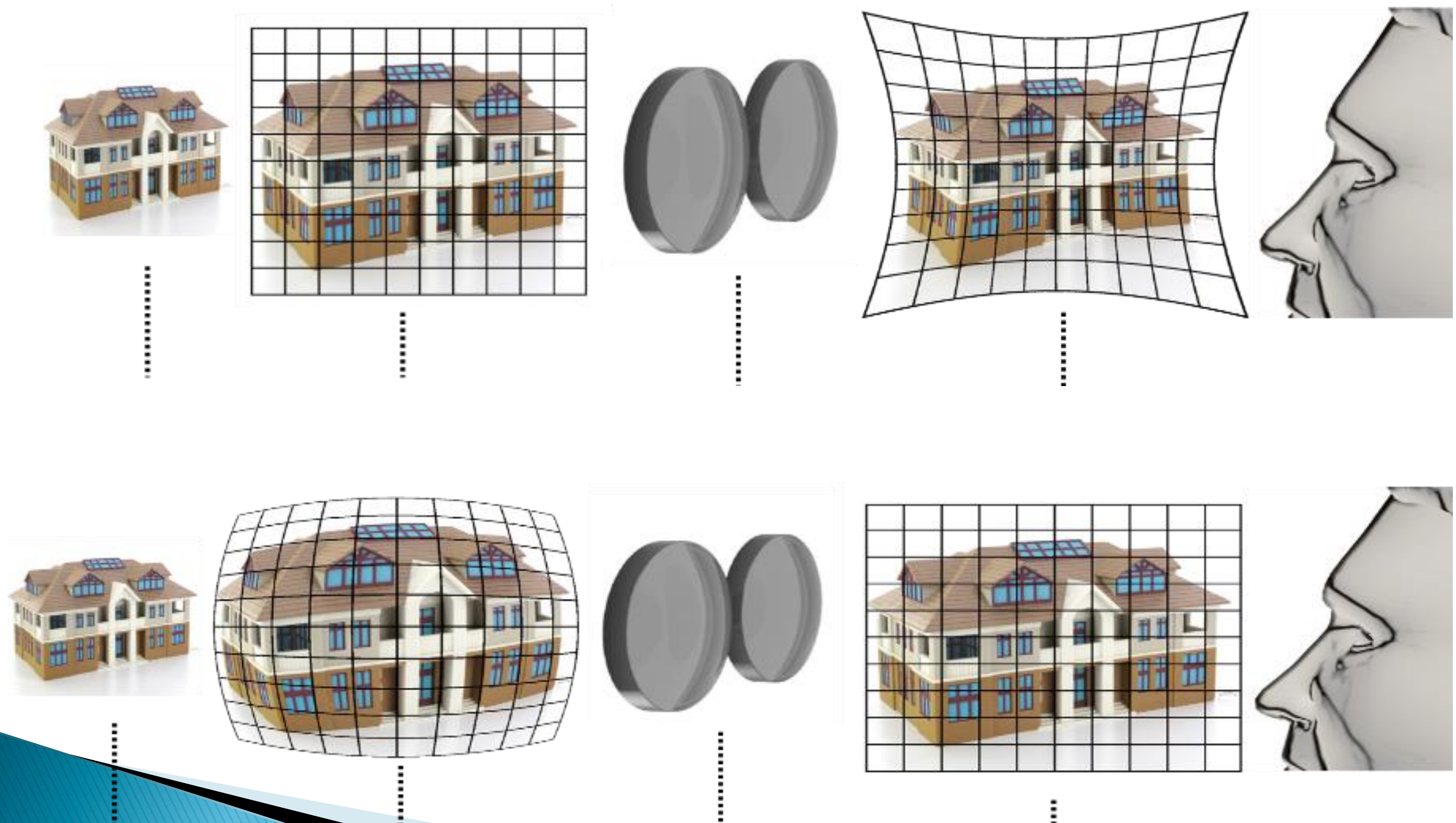
- Used in HMDs
- The screens follow the head movements, so they are fixed with respect to the eyes.
- Parameters:
  - Head orientation
  - Head position (optional)
  - HMD frustum

Dynamic screen:
Stereo Camera Computation

```
// View Matrix

VM = lookAt (eye.x, eye.y, eye.z, center.x, center.y, center.z,
                  up.x, up.y, up.z);

sendViewMatrix (VM);

// Projection Matrix

PM = frustum (left, right, bottom, top,
                  near, far);

sendProjectionMatrix (PM);
```



Distortion



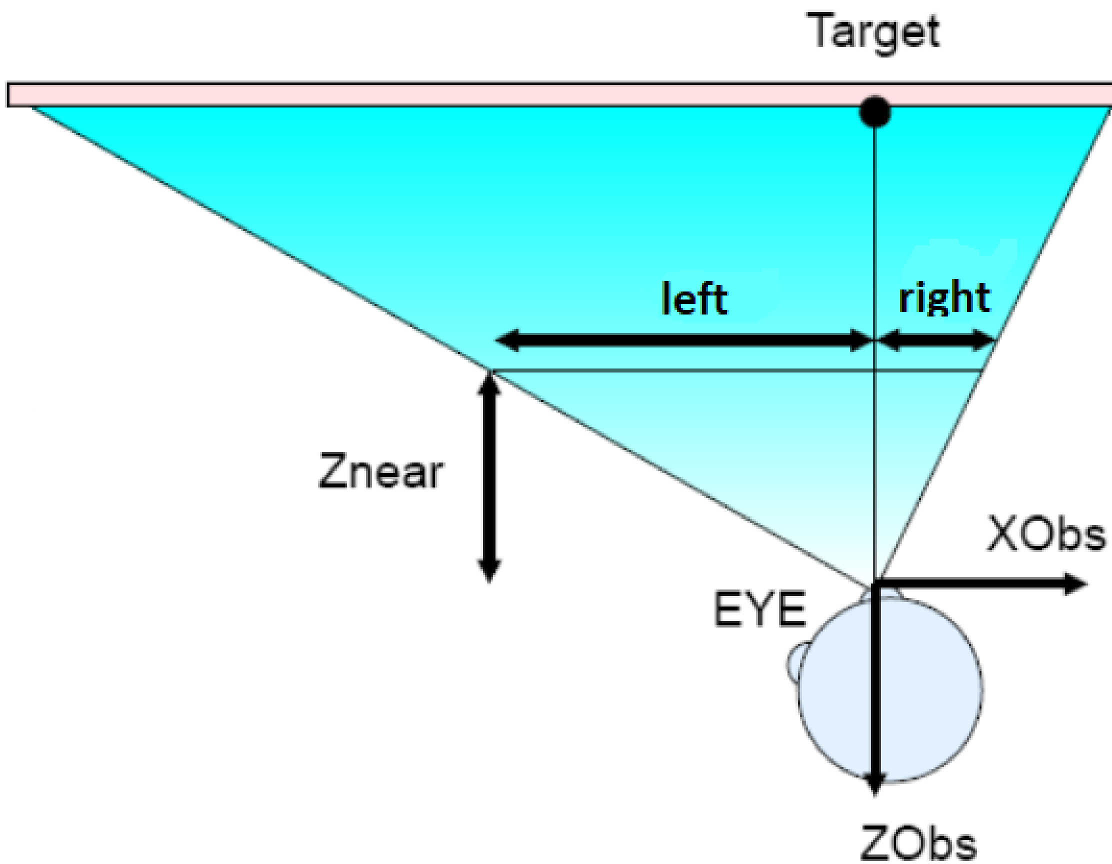
Distortion


The images are distorted and appear as misshapen ovals.
More data is presented on the left of the image for the left eye.
There's an image per eye.
More data is presented on the right for the right eye.

Static screen: Stereo Camera Computation

- This is the configuration of projection-based systems (CAVEs, Videowalls, workbenches…)
- Parameters:
  - Tracking data: L/R eye position
    - Two position trackers (3DOF each)
    - One 6DOF tracker (head, glasses,…)
  - Display system data
    - Screen geometry

Static screen:
Stereo Camera Computation



Static screen:
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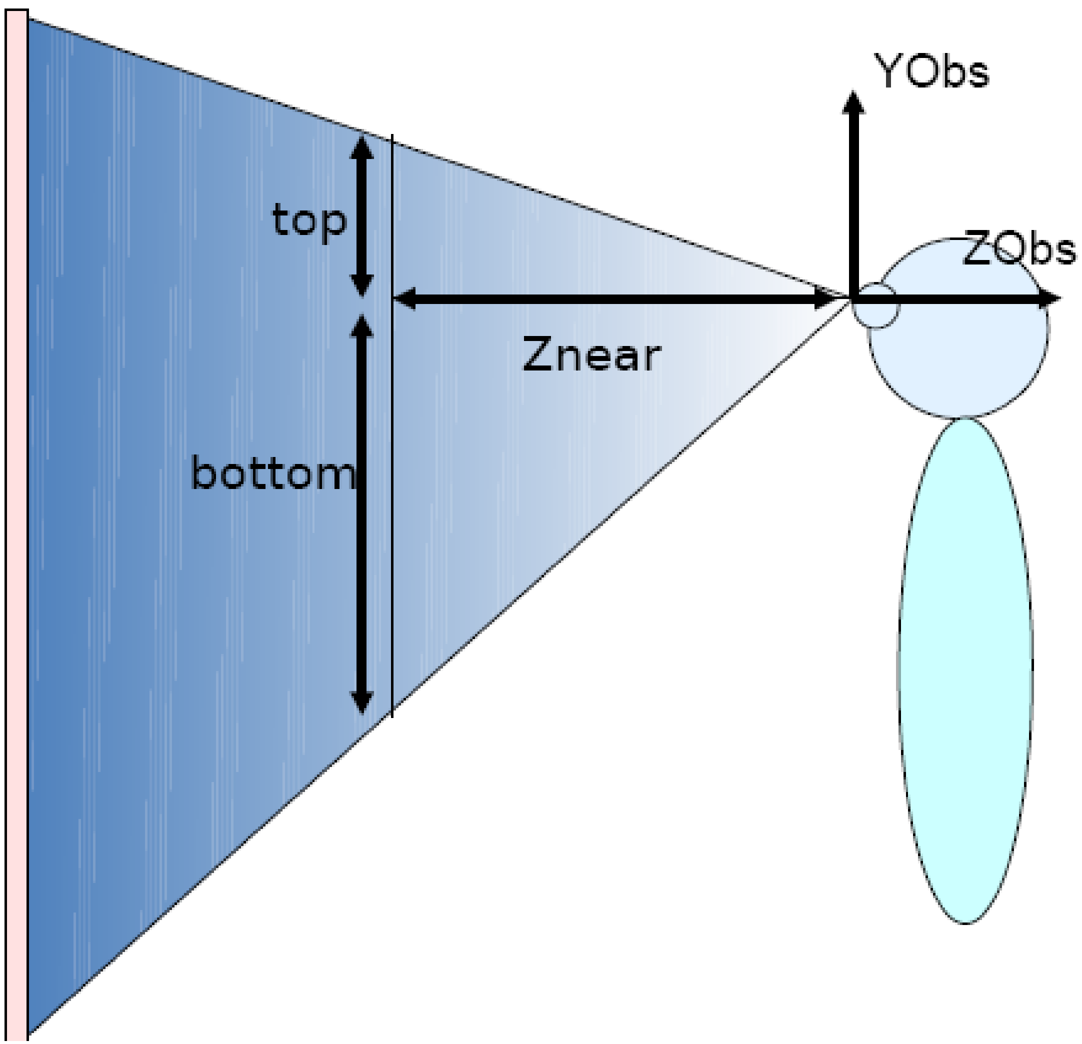

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VR Interaction

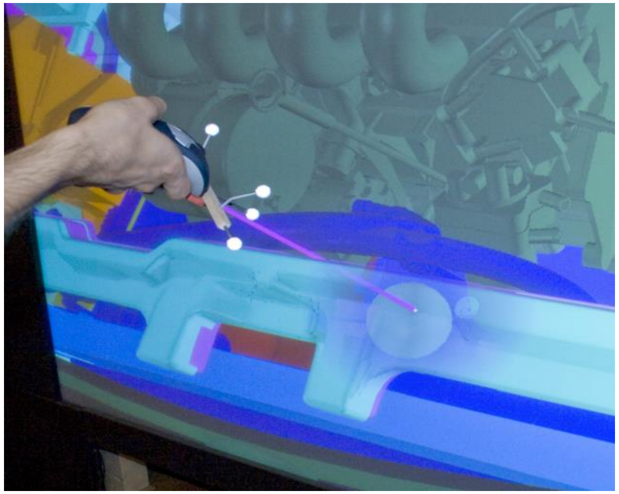
- Definitions
  - **3D interaction**
    - HC Interaction where user's tasks are carried out in a 3D spatial context
    - Using 3D or 2D input devices with direct mappings to 3D
  - **3D user interface**
    - A User Interface that involves 3D interaction.
  - **3D interaction technique**
    - Technique designed for solving a task
      - Involves the use of hardware and software

3D Selection

- 3D interfaces can make several tasks easier than classical 2D systems
  - Even better than reality?
- **3D selection:** selection task in a 3D immersive environment

VR Interaction & 3D Selection

- Hand extension techniques or 3D point cursors
  - A 3D point in space is represented as a mapping of the user's hand position.
- Ray-based techniques
  - Use the hand position and some element to indicate orientation
  - A ray is generated a ray in space and is used as a pointer
    - Also called aperture-based selection techniques or ray cursors

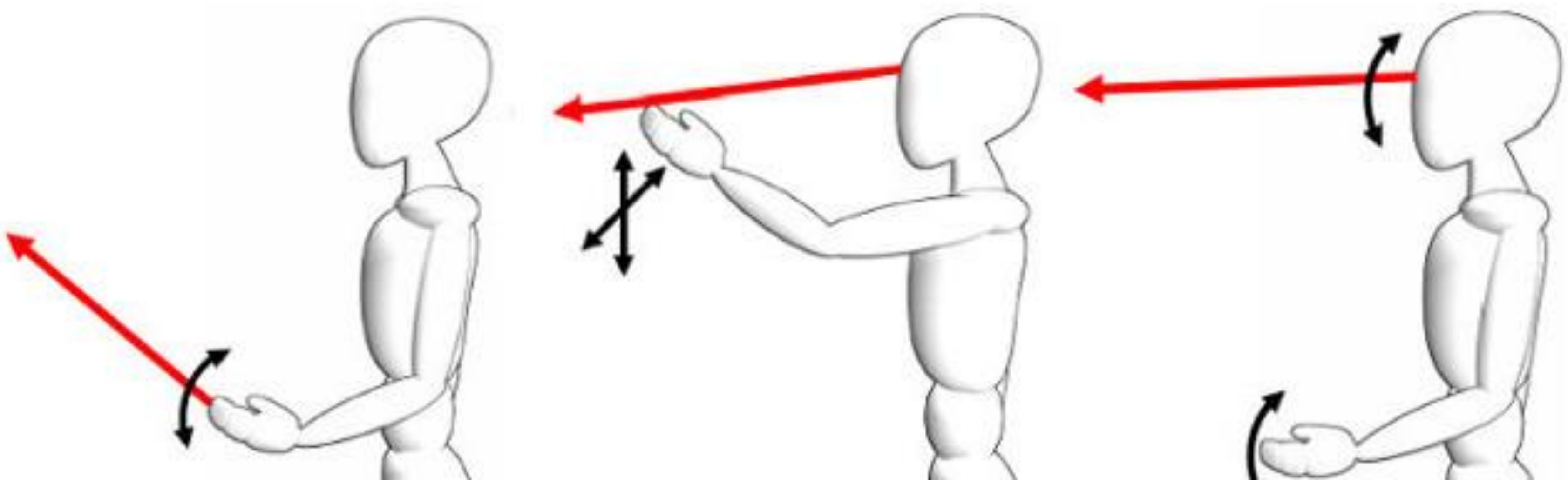


VR Interaction & 3D Selection

- Hand extension:
  - May require ample movements due to the direct mapping with 3D world
  - Sometimes elements are difficult to reach
  - May be more intuitive if virtual world represents some real world

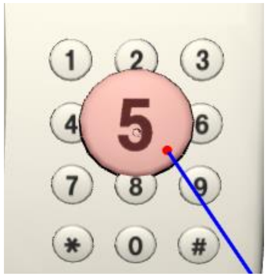
VR Interaction & 3D Selection

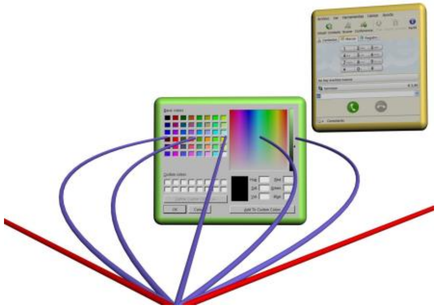
- Ray-based techniques



VR Interaction & 3D Selection

- Ray-based techniques:
  - Hand position + wrist orientation
  - Head position and hand direction
- Problems:
  - Visible objects may be occluded to the ray
    - Difficult to reach
    - Selection of objects needs to visit all of them
  - Region selection not easy
- Some solutions
  - Sticky targets, enlarging objects, flatten regions…





VR Interaction & Navigation

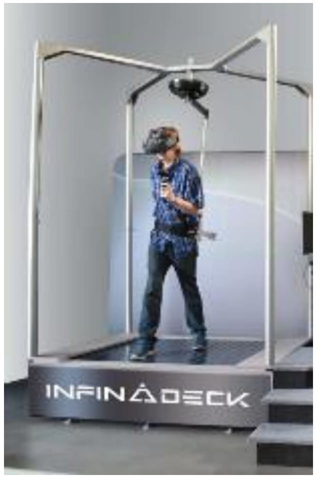
- Types of travel tasks according to user’s goal:
  - Exploration
    - No explicit goal.
    - Typically used at the beginning of the interaction with a VE.
  - Search
    - The user knows the final location.
    - Naive search: the user doesn’t know where the target is or how to get there.
    - Primer search: the user has knowledge about target location.

VR Interaction & Navigation

- How interaction techniques should be for:
  - Exploration
    - The user must be able to change the target at any moment (continuous control of the viewpoint).
    - Little cognitive load → user can focus on information gathering.
  - Search
    - Techniques can be goal-oriented (e.g. specify the final location on a map) provided that the target is explicitly represented in the map.

VR Interaction & Navigation

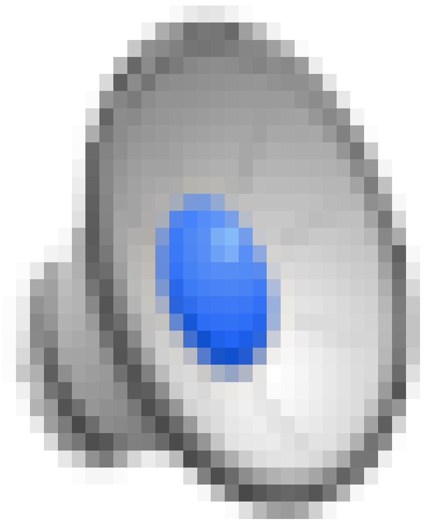
- Some Techniques:



VR Interaction & Navigation

- Some Techniques:

VR Interaction & Navigation



VR & Presence

- Suppose you are in a place that you know to be fictitious.
- You know events you see, hear and feel are not real events in the physical meaning of the word
- You find yourself thinking, feeling and behaving as if the place were real, and as if the events were happening.
- This paradox is at the root of the concept of ***presence.***

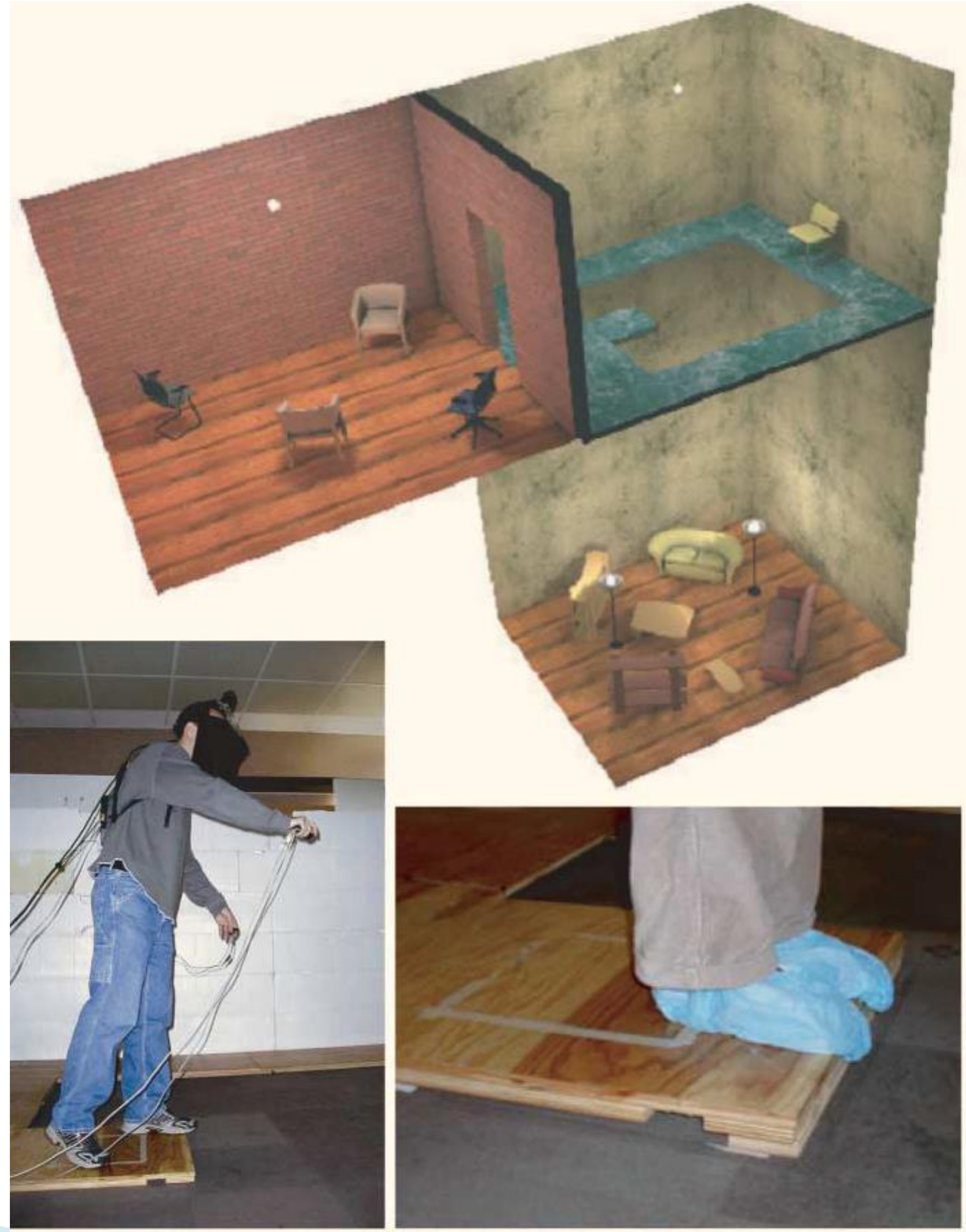
VR & Presence


PoolNationVR (64-bit, PCD3D_SM5)
Menu
Teleport
Cue Off
Reposition
Ready
Pool Nation VR
I'm Cortana. Ask me anything.
6:40 PM
7/22/2016

VR & Presence

VR & Presence

- Presence is common across applications and has been used as an overall measure of the effectiveness of VR.



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Augmented Reality

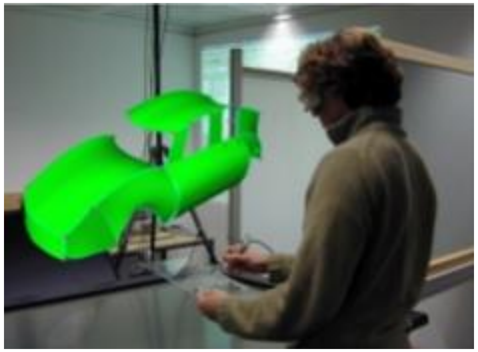
- Augmented Reality is a combination of a **real scene** viewed by a user and a synthetic **virtual scene** that augments the scene with additional information.
- AR environments differ from VEs in that we have access to both real and virtual objects at the same time.

Augmented Reality

- Goal: enhance user **performance** and **perception** of the world.
- Challenge: keep users from **perceiving the difference** between the real world and the virtual augmentation of it.

Augmented Reality

- Archeology
- Entertainment
- Engineering design
- Consumer design



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AR: Registration

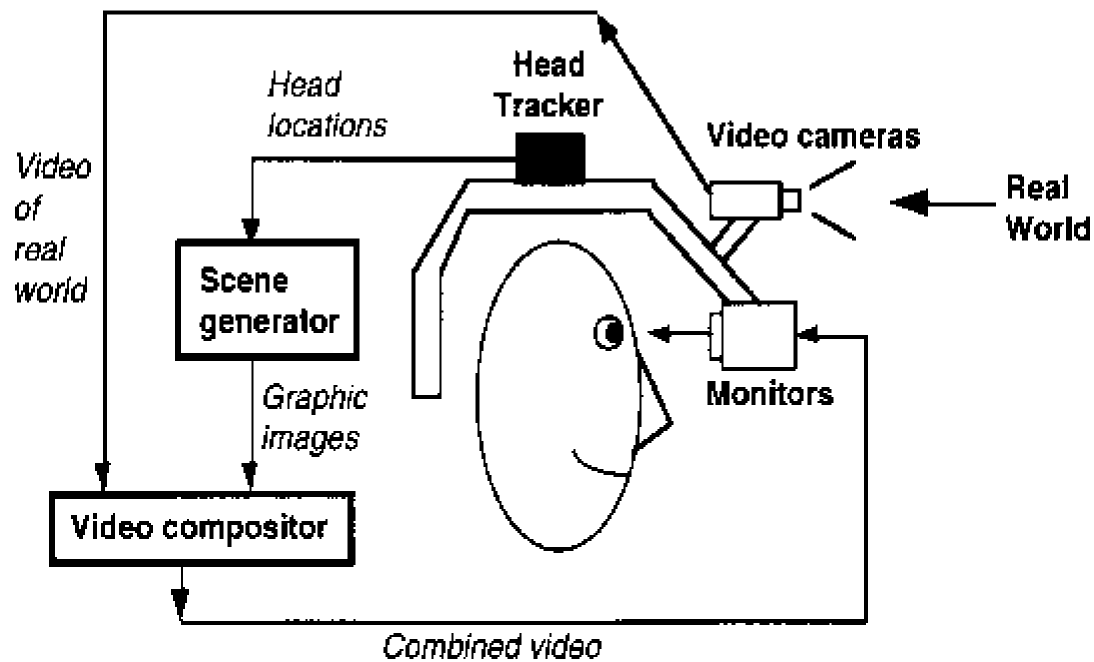
- The importance of **object registration**:
  - The computer generated virtual objects must be **accurately registered** with the real world in all dimensions.
  - Errors in this registration will prevent the user from seeing the real and virtual images as fused.
  - The **correct registration** must be maintained while the user moves about within the real environment.
  - Discrepancies or changes in the apparent registration will range from distracting (difficult to work with), to physically disturbing (unusable system).

AR: Systems

- There are basically three ways to visually present Augmented Reality:
  - **Video see-through**: the virtual environment is replaced by a video feed of reality and the AR is overlaid upon the digitised images
  - **Optical see-through**: Leaves the real-world perception alone but displays only the AR overlay by means of transparent mirrors and lenses.
  - **AR projection** onto real objects.

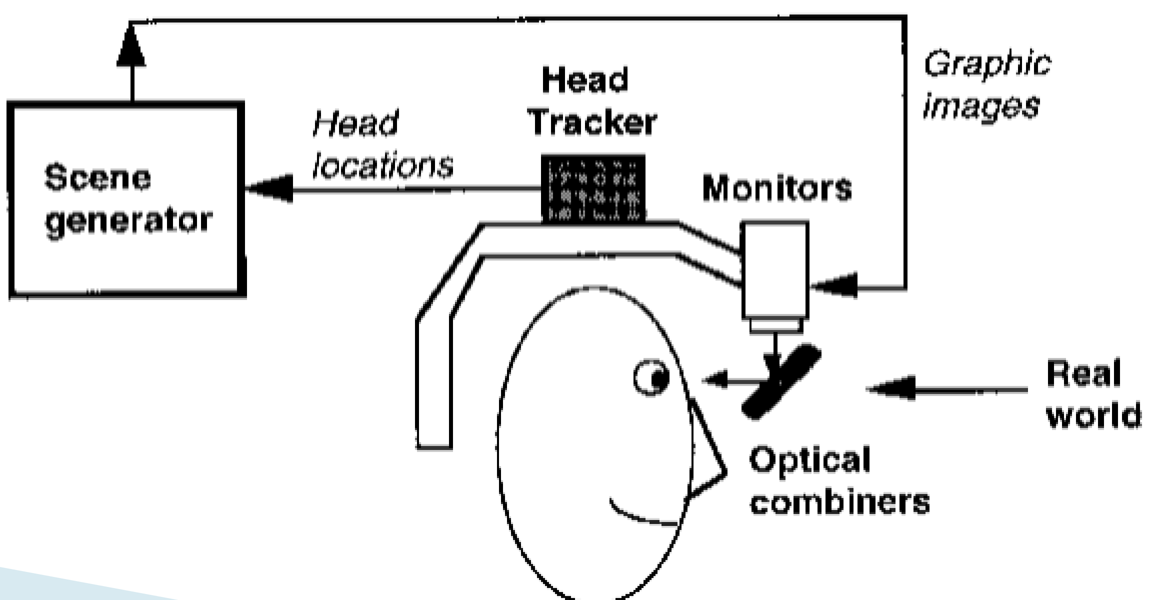
AR: Systems

- Video see-through
  - Use closed-view HMDs.
  - Combine real-time video from head-mounted cameras with virtual imagery.

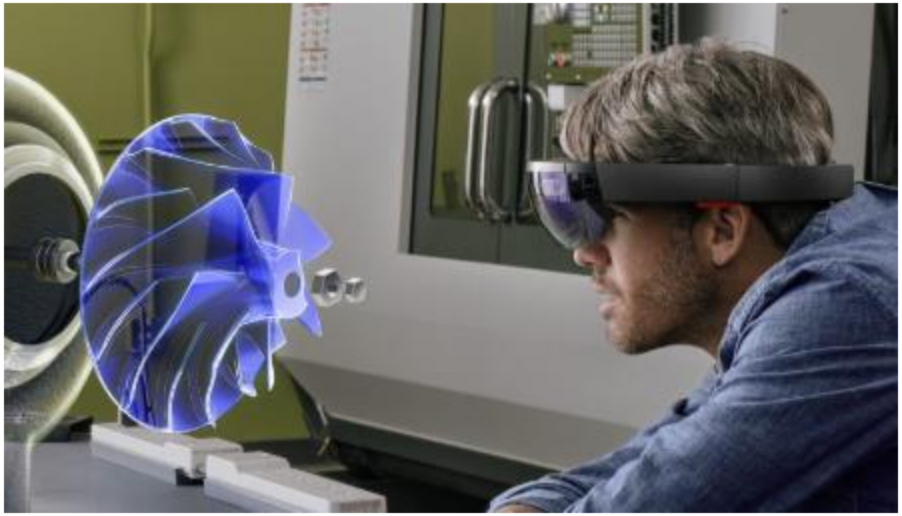


AR: Systems

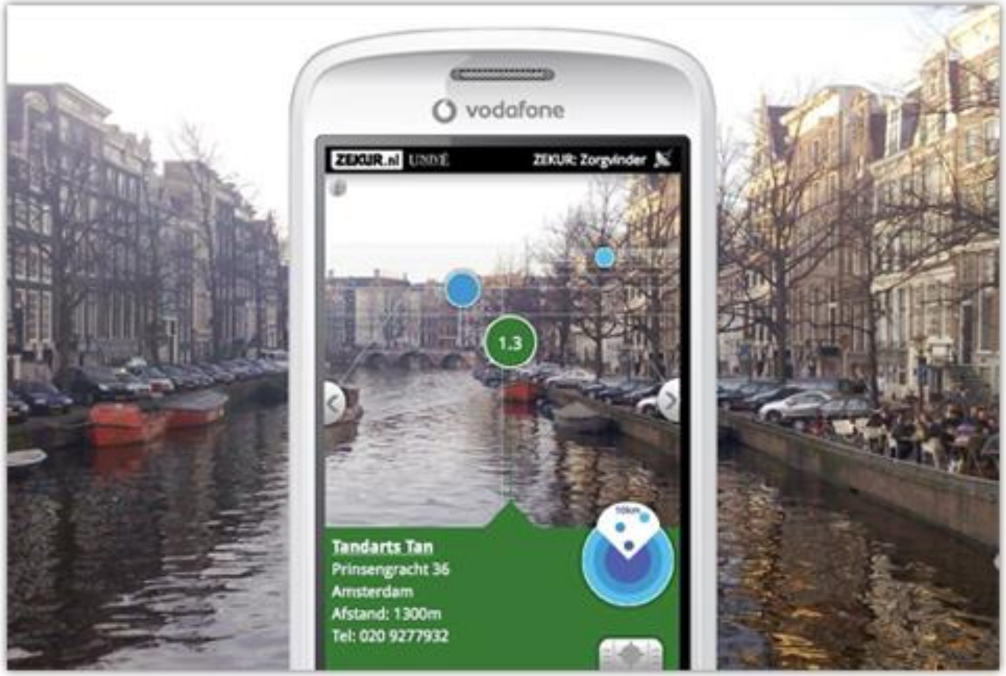
- Optical see-through
  - The user sees the real world **directly**
  - Make use of optical combiners:
    - Half-silvered mirrors (partially transparent, partially reflective)
    - Transparent LCD



AR: Systems

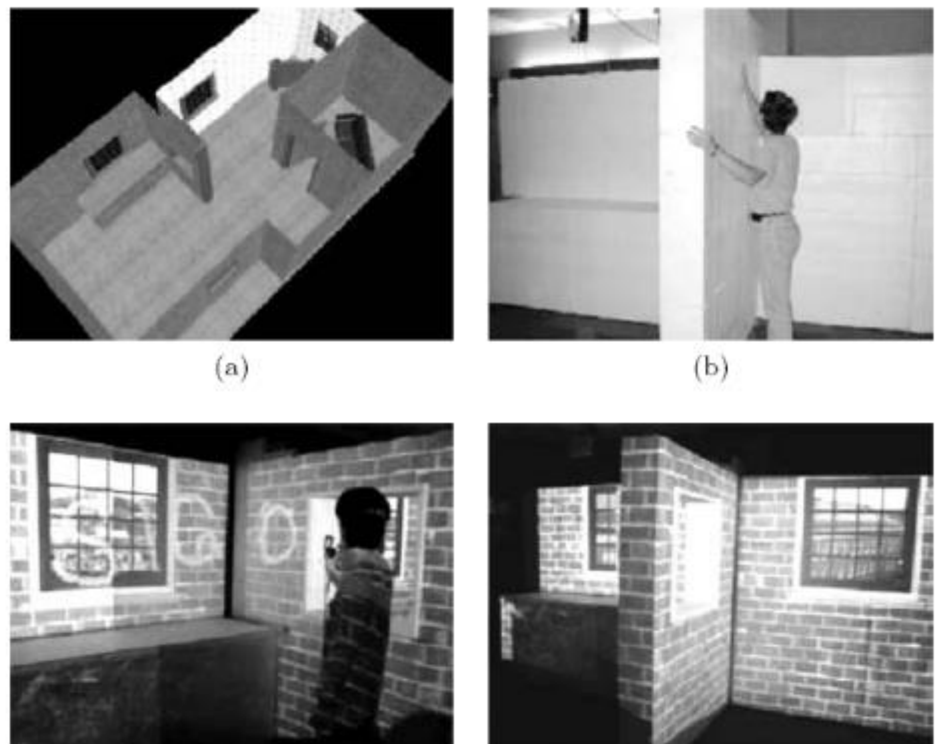


AR: Systems


vodafone
ZEKUR.nl
ZEKUR: Zorgvinder
1.3
Tandarts Tan
Prinsengracht 36
Amsterdam
Afstand: 1300m
Tel: 020 9277932

AR: Systems

- Projection-based spatial displays
  - Images are projected directly into physical objects.
  - Single static, single steerable or multiple projectors.



AR: Systems

- Projective displays. Advantages:
  - They do not require special eye-wear
    - Eye accomodation not required
  - They can cover large surfaces for a wide field-of-view

AR: Systems

- Projective displays. Disadvantages:
  - Projectors need to be calibrated each time the environment or the distance to the projection surface changes (crucial in mobile setups).
    - Fortunately, calibration may be automated
  - Limited to indoor use only due to low brightness and contrast of the projected images.
  - Occlusion or mediation of objects is also quite poor.

AR: Examples

- Pepsi max Bus Stop:
  https://www.youtube.com/watch?v=GB_qT6rAPyY
- Quiver:
  https://www.youtube.com/watch?v=tBYm53L79YY
- Toyota AR demo video:
  https://www.youtube.com/watch?v=xBnyWWECHac

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