Augmented Reality

Part 1 – Technologies & Applications

Vortrag von: Daniel Rauch

Betreuer: Marc Langheinrich

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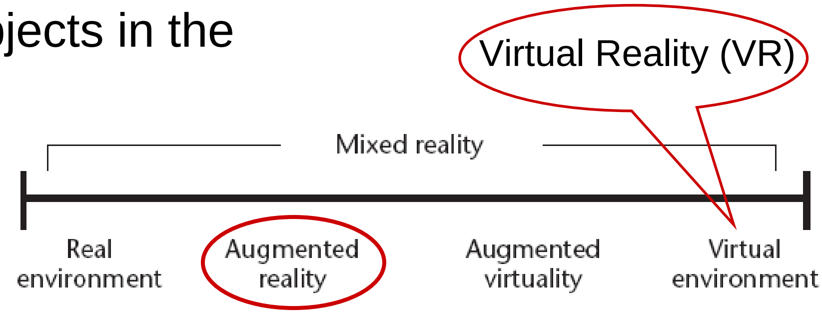
Definition

Augmented Reality (AR):

- Supplementation of the real world with virtual objects
- Coexistence of real and virtual objects in the *same* real space

- Relatively new research field (~1993)



Milgram's reality-virtuality continuum (1994)

3 characteristics of AR-Systems:

1. Combines real and virtual objects in a real (3-D) environment
2. Runs interactively and in real time
3. Registers (aligns) real and virtual objects with each other

Ronald T. Azuma

Augmentation

- Adding virtual objects to the real world
- Removing or hiding objects from the real world (*mediated / diminished reality*)

- **Output** of an AR-System:
  - might apply to *all* human senses (ability not only to *see* but also to *hear*, *touch* and *smell* the virtual world)
- **Input** of an AR-System:
  - everything a sensor can detect (also *ultrasound*, *infrared*, *ultraviolet* frequencies)

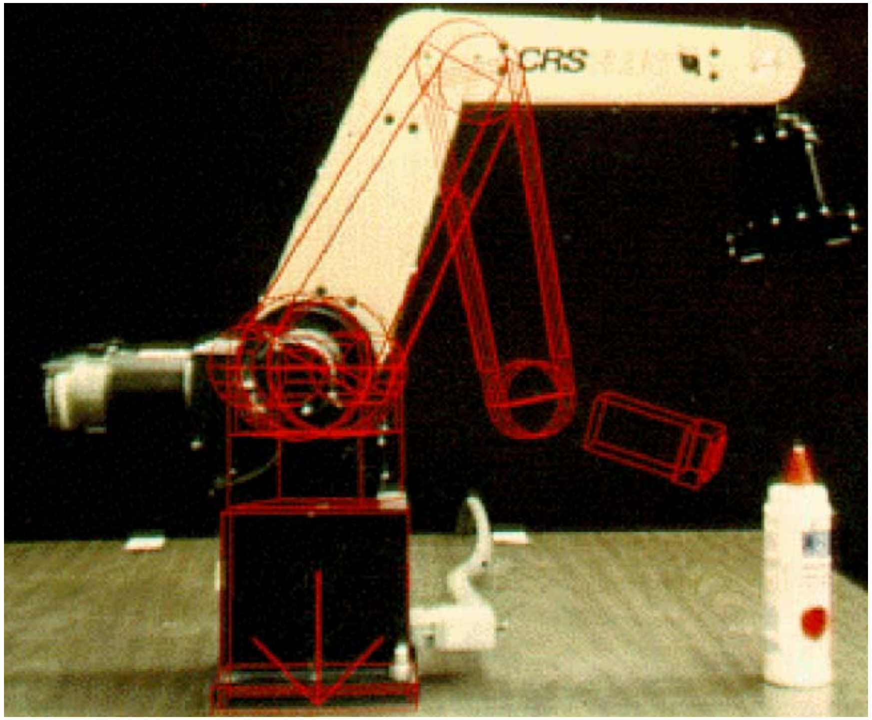
- Not a trivial task!
  - Identify *what* information should be provided
  - Appropriate representation of that data
  - User interaction with the AR-System

Why is AR useful?

- AR enhances *user interactions* with the real world
  - Intelligence Amplification (IA)
    - „*using the computer as a tool to make a task easier for human to perform*“ [Brooks96]

- Virtual objects can make information not directly detectable by human senses visible
  - this information helps a user perform real-world tasks

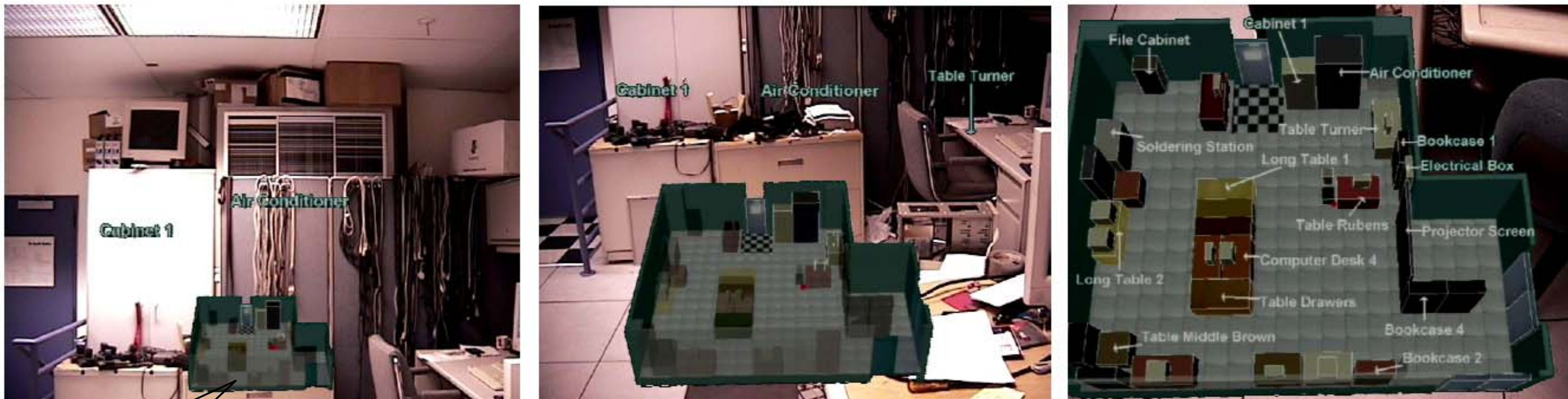
Example 1 – Robot path planning



[Drascic93 and Milgram93]

- control a *virtual version* of the robot
- plan the robot's actions on the virtual counterpart in real time
- test & determine the plan
- virtual overlay predicts the effects of the manipulation
- real robot executes the specified plan

Example 2
Annotated Situation-Awareness Aid



„WIM“

[B.Bell, T.Höllerer, S.Feiner – CS Dep. Columbia University 2002]

- Overlaid graphics annotate the surrounding world
  - label objects
  - detailed information about the objects
- Aid is based on a world in miniature (WIM)
- Controlling the *position*, *scale* and *orientation* of the WIM only through head orientation

  -> *hands-free interface*
- Looking down to access the aid

Application Domains

1. Medical visualization
   - e.g. Visualization and training aid for surgery
2. Manufacturing and repair
   - e.g. Superimposed 3-D (animated) drawings instead of numerous complicated manuals
3. Annotation and visualization
   - e.g. show where the pipes and electric lines are inside the walls
4. Robot path planning
   - *example on slide 5*
5. Entertainment
   - e.g. in sports broadcasting (*real time* annotations on race cars)
6. Military aircraft navigation and targeting
   - e.g. aim the aircraft's weapons by looking at the target

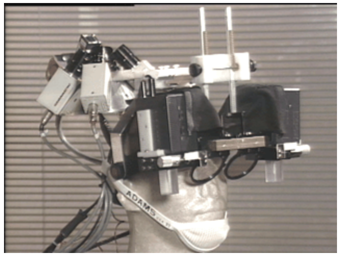
Overview

1. **Introduction**
   - *Definition AR*
   - *Augmentation*
   - *Why is AR useful?*
   - *Examples & Application Domains*
2. **Design of AR-Systems**
   - *Display Types & Technologies*
   - *Advantages*
   - *AR vs. Virtual Reality*

Design of AR-Systems

Types of displays used in AR:

1. Head-Mounted-Displays (HMD)
   - LCD-based, head-worn
   - virtual retinal displays

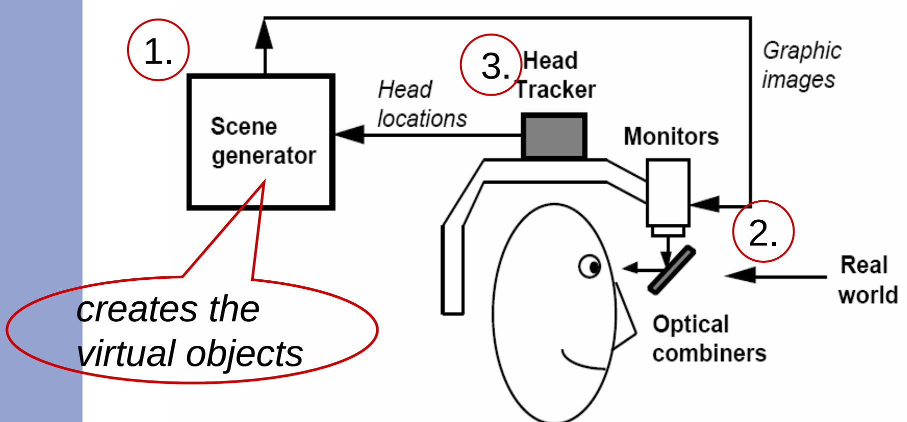


2. Handheld displays
   - flat panel LCD displays with an attached camera

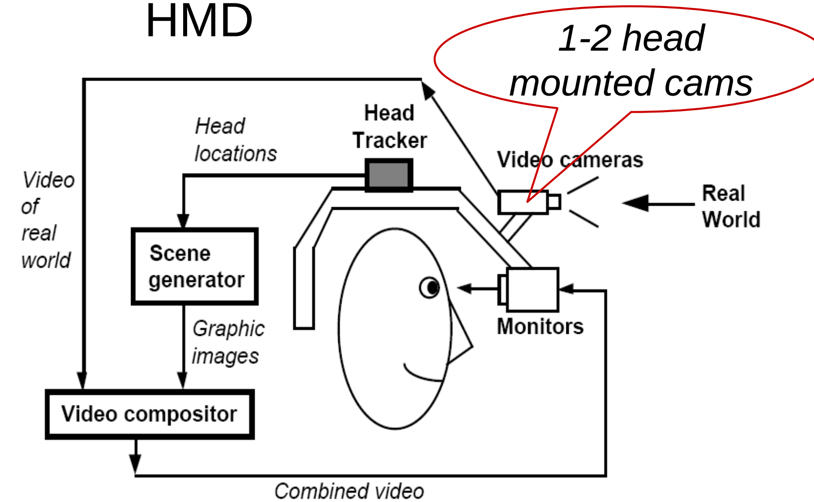
3. Projection displays
   - project the virtual information *directly* on the physical objects
   - head-worn or fixed projector in the room
   - objects with *special surface* reflecting the light
   - projected images only visible along the *line of projection*

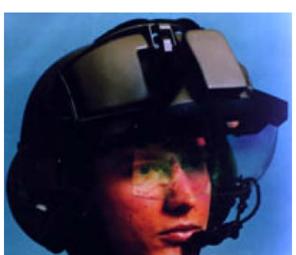
Design of AR-Systems (2)

- Optical technologies:
  - e.g. an optical see-through HMD



- Video technologies:
  - e.g. a video see-through HMD





3 basic subsystems:

1. *Scene generator*
2. *Display device*
3. *Tracking and Sensing*

Design of AR-Systems (3)

- Optical:

+ optical blending simpler

+ safety (power failure)

+ no reduction of resolution (of the real world)

+ no eye offset

- Video based:

+ easier to match the brightness

+ wide field-of-view displays are easier to build

+ real and virtual view delays can be matched

AR vs. Virtual Reality (VR)

- Rendering is easier! (in AR)
  - VR-Systems completely *replace* the real world
  - AR-Systems „only“ *supplement* the real world

  - only few applications require photorealism
    - text and 3-D wireframe drawings might suffice

- Monitor resolution less crucial! (in AR)
  - no reduction of resolution (of the real environment)
  - smaller field-of-view acceptable

  } optical HMDs

⇒ *Lower* requirements in AR than VR?

- Tracking and sensing much more crucial (in AR)
  - Registration Problem in AR -> limits the applications of AR

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3. **Registration Problem**
   - *Definition*
   - *Dynamic Errors & System Delays*
   - *Wider use of AR?*

Registration Problem

Definition:

AR-Registration: Proper alignment of real objects and virtual objects
(-> perfect illusion that the two worlds coexist)

- Accurate registration required for many applications
  - e.g. in *medical visualization*

- Accurate registration requires:
  1. Accurate tracking of the user‘s head (viewpoint)
  2. Sensing the locations of the other objects in the environment

- Registration errors result in *visual-visual conflicts*
  - easy detectable -> very high resolution of the human eye!

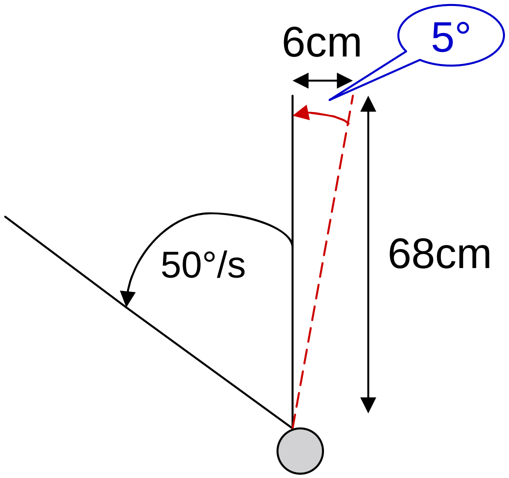
Registration Problem (2)

- AR is an interactive medium
  - User looks where he wants, the system must respond within milliseconds
  - Dynamic errors occur when the *viewpoint* or the real objects begin moving
  - Dynamic errors are the *largest* contributors to *registration errors*
- Main source for dynamic errors:
  - System delays

Registration Problem (3)

- End-to-end system delay (~100 ms)
  - Seriously hurt the illusion that the real and virtual worlds coexist!
  - Only problematic when motion occurs
  - Angular accuracy of a small fraction of a degree required!

- Example:
  - user wearing a see-through HMD
  - given a system lag of 100 ms
  - head rotation of 50°/s
  - -> angular dynamic error of 5°
  - -> 6 cm (at an arm length of 68 cm)



Reducing dynamic errors

1. Reduce / eliminate system delays
   - minimize scene generator latency

2. Reduce apparent lag
   - use feed-forward techniques
     - e.g. render a much larger image than needed

3. Match temporal streams
   - only in video based AR-Systems
   - delay the *video stream* from the real world

4. Prediction
   - predict the future viewpoint and object locations

Obstacles in a wider use of AR

- Technological limitations
  - more accurate, lighter, cheaper and less power consuming displays, trackers and sensors
- User interface limitaions
  - suitable UIs
- Social acceptance
  - Fashion?
  - Privacy

Questions

- Questions?

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