UNIVERSITÉ PARIS SUD

Comprendre le monde, construire l'avenir®

Groupware and Collaborative Interaction

Collaborative Virtual Environments

Master Interaction / Univ. Paris-Sud / 2019-2020

Cédric Fleury (cedric.fleury@lri.fr)

Outline

Introduction to Mixed Reality (MR)

Overview of Interaction in MR

Collaboration in MR

- Remote Collaboration
- Co-located Collaboration

Awareness and Communication

Collaborative Interaction

- Navigation
- Co-manipulation

Outline

Introduction to Mixed Reality (MR)

Overview of Interaction in MR

Collaboration in MR

- Remote Collaboration
- Co-located Collaboration

Awareness and Communication

Collaborative Interaction

- Navigation
- Co-manipulation

Virtual Reality

Virtual environment (VE)

- 3D virtual world
- Simulated by computers

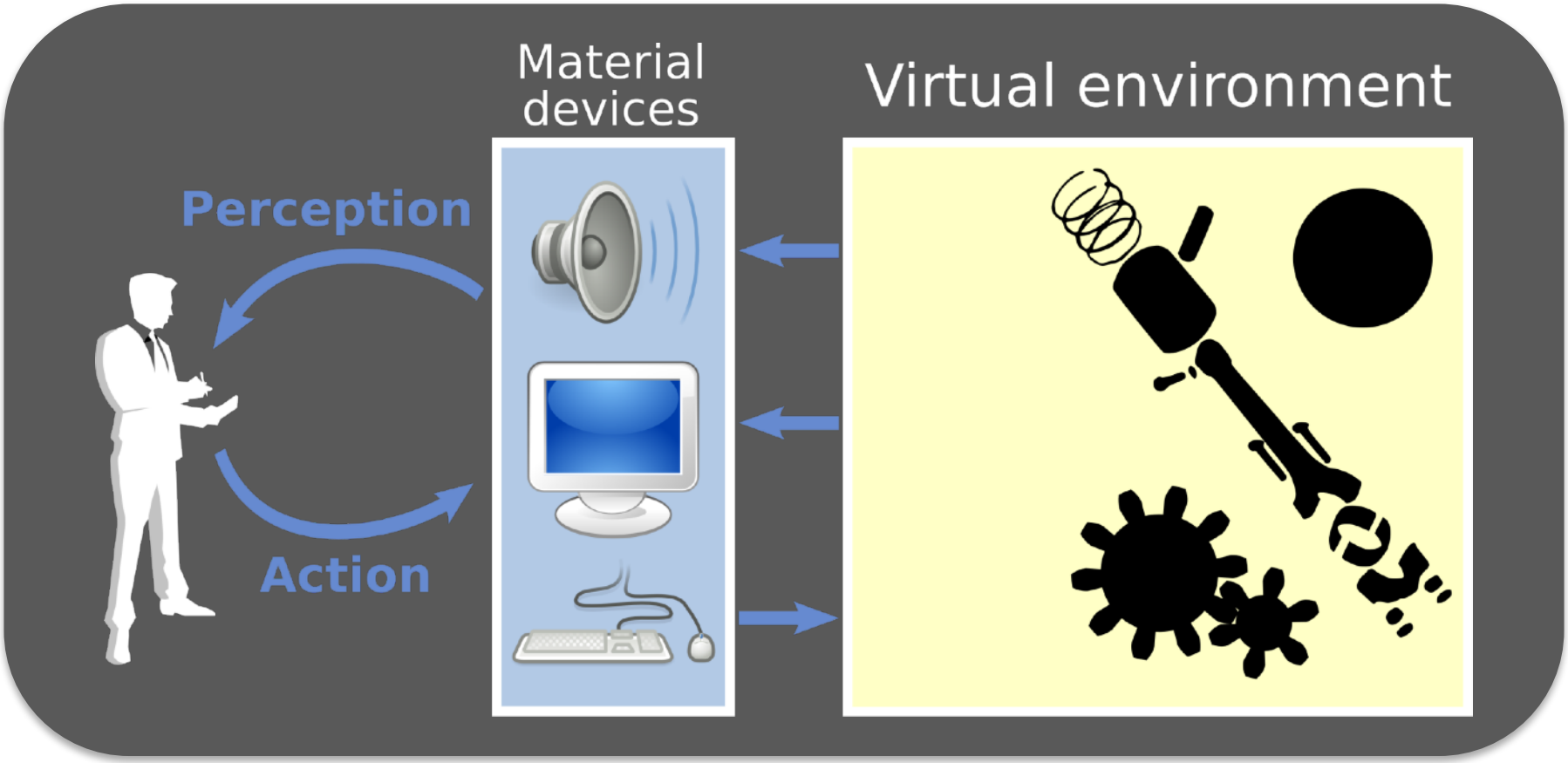
Interaction in real time

- Trough various material devices

Immersion

- Multi-sensorial perception of the VE

Action/perception loop



Augmented Reality

Real environment + Virtual environment

Add virtual information on the real environment

How can we define the boundary between virtual reality and augmented reality
?

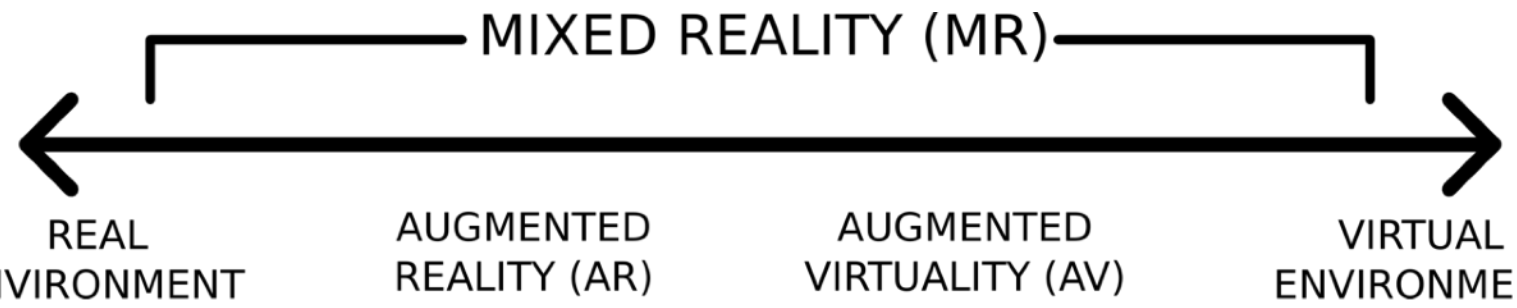
Mixed Reality

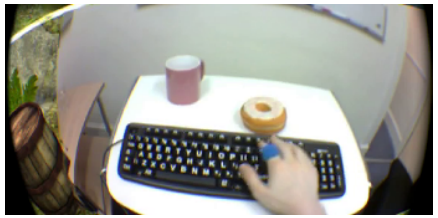
Boundary between real and virtual can be fuzzy

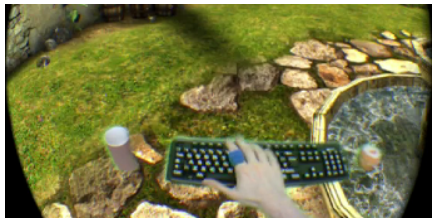
Augmented virtuality

- Integrated elements from the real world in the virtual environment
- Ex: video feed, tangible interaction, user's real position, …

Milgram Continuum







Virtual Reality

Applications of Mixed Reality

Scientific data analysis

Industrial applications

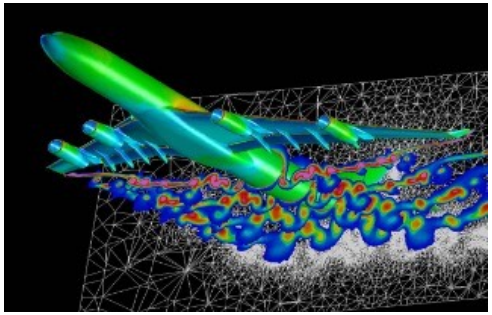
- Design, conception
- Fabrication process

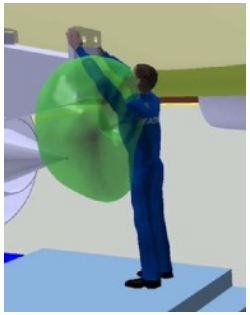
Training, education

Phobia therapy, rehabilitation

Entertainments

- Video games
- Virtual visits of museums
- Social communication (telepresence)





Outline

Introduction to Mixed Reality (MR)

Overview of Interaction in MR

Collaboration in MR

- Remote Collaboration
- Co-located Collaboration

Awareness and Communication

Collaborative Interaction

- Navigation
- Co-manipulation

Interaction

3 kinds of interaction techniques [Hand, 1997]

- Object manipulation (interaction)
- Viewpoint manipulation (navigation)
- Application Control

[Bowman et al., 2004]
Bowman D. A., Kruijff E., LaViola J. J. et Poupyrev I. (2004). 3D User Interfaces : Theory and Practice. Addison Wesley.

Navigation

Move the viewpoint + Modify the scale [Hand, 1997]

Manipulate its own viewpoint

or

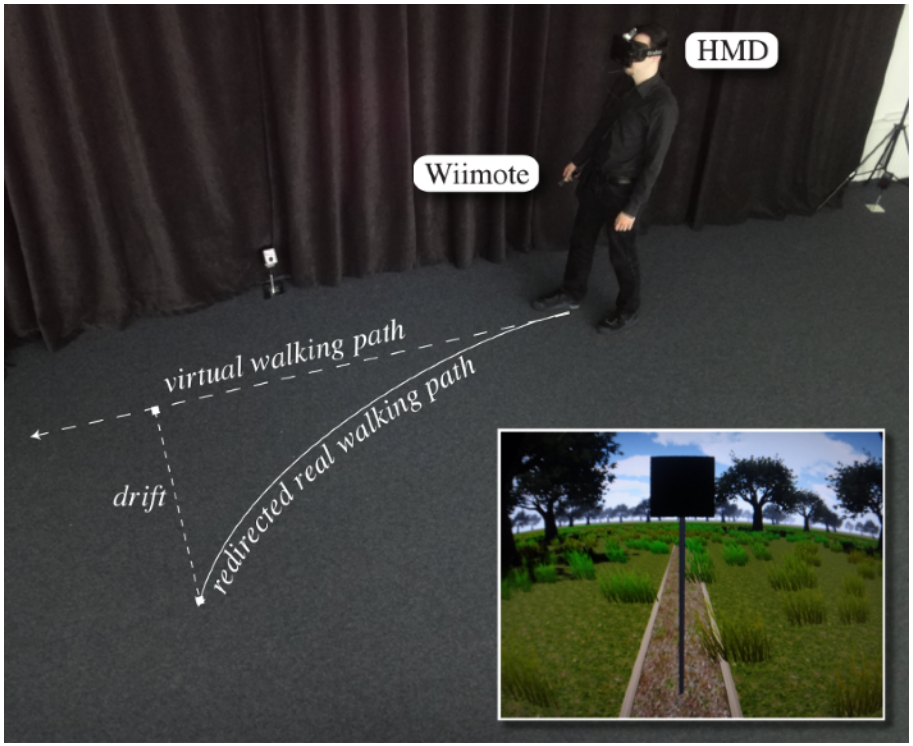
Manipulate the viewpoint of the others

Include path finding [Bowman et al., 2004]

Navigation

Egocentric techniques

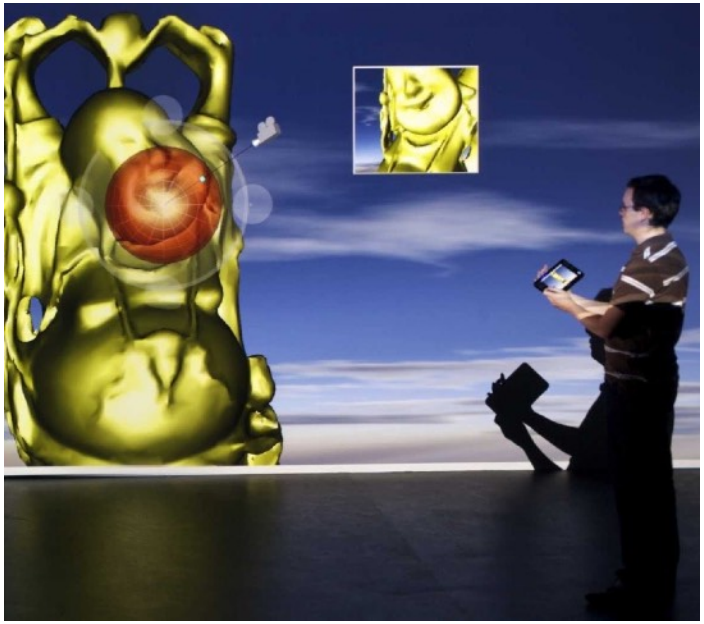
- Walking metaphor
- Flying metaphor
- Driving metaphor



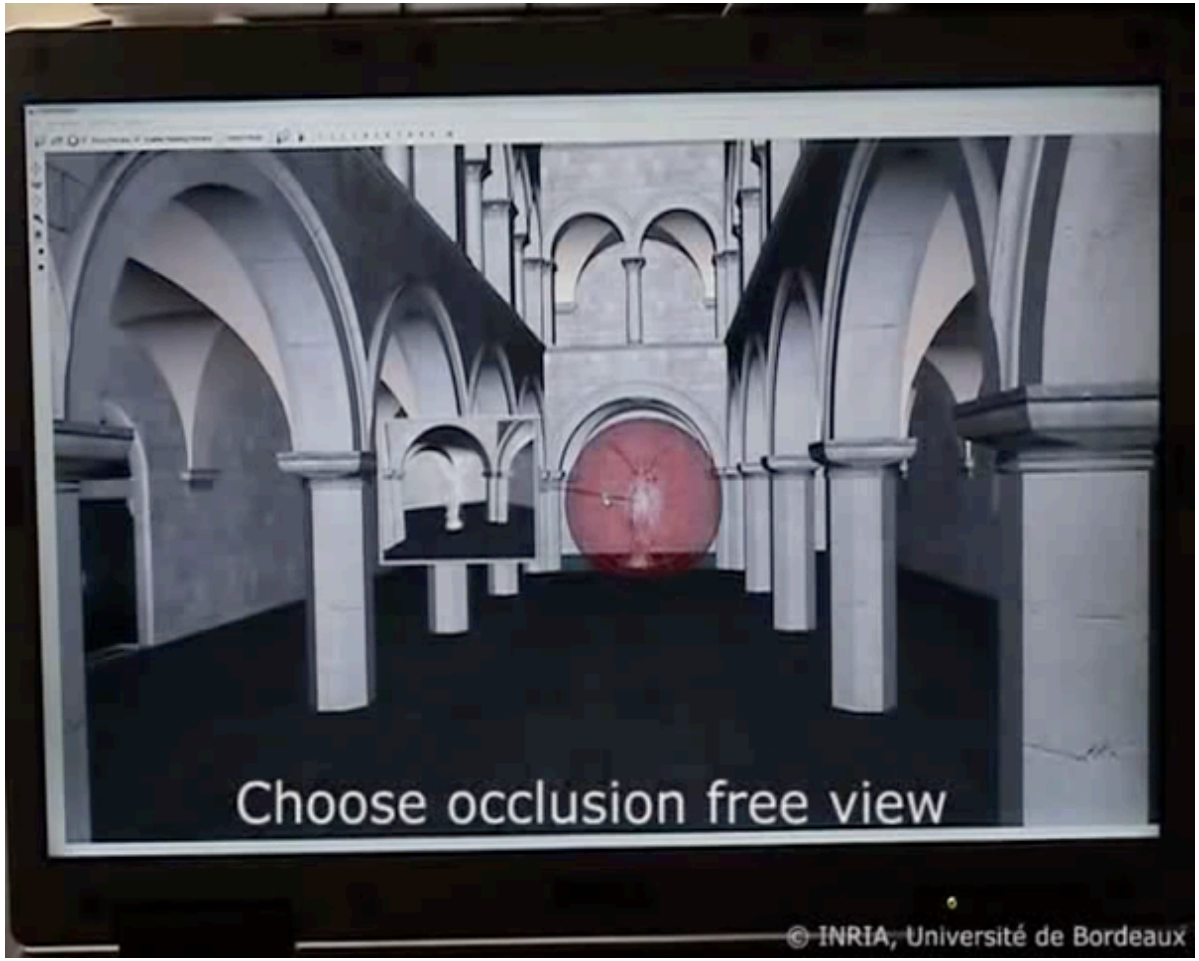
Navigation

Exocentric techniques

- Navidget [Hachet et al., 2008]
- Grabbing the air [Mapes et Moshell, 1995]

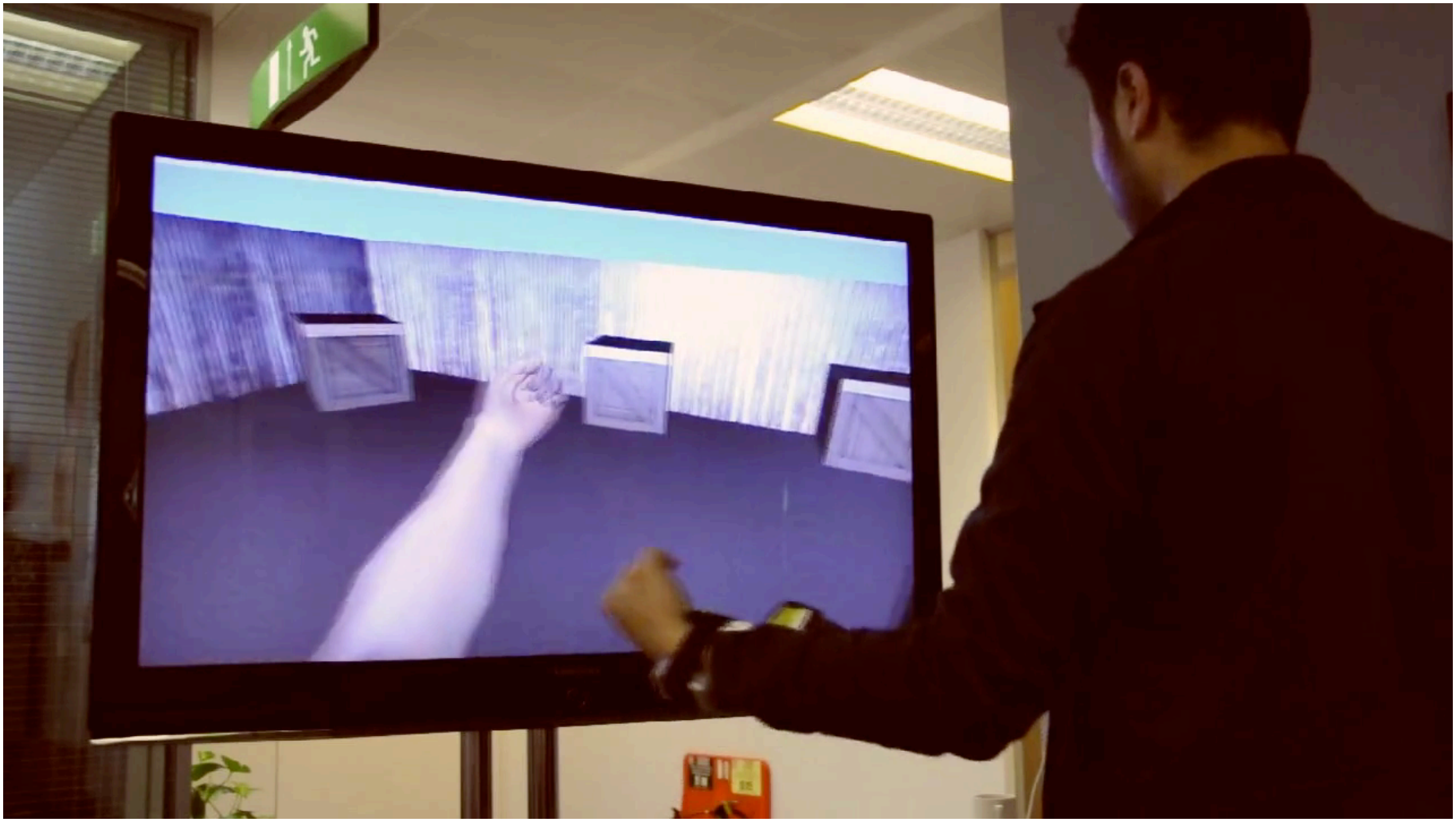


Navigation



Navidget [Hachet et al., 2008]

Navigation



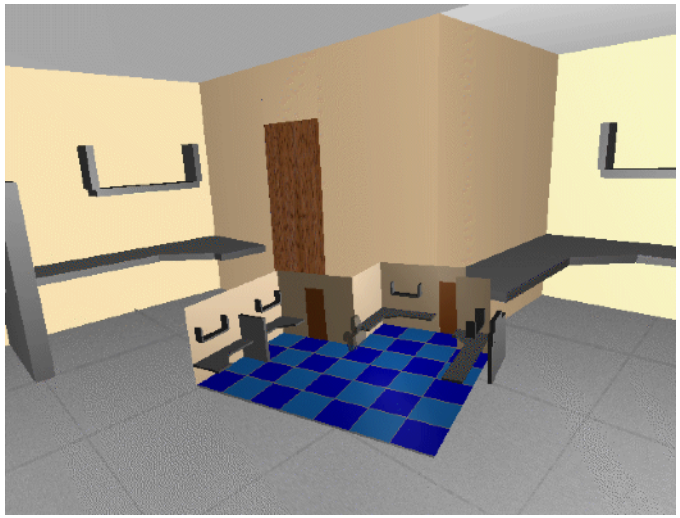
Grabbing the air [Mapes et Moshell, 1995]

Navigation

Assisted navigation techniques

Select the destination

- Pointing
- World In Miniature (WIM) [Stoakley et al., 1995]
- List of defined path

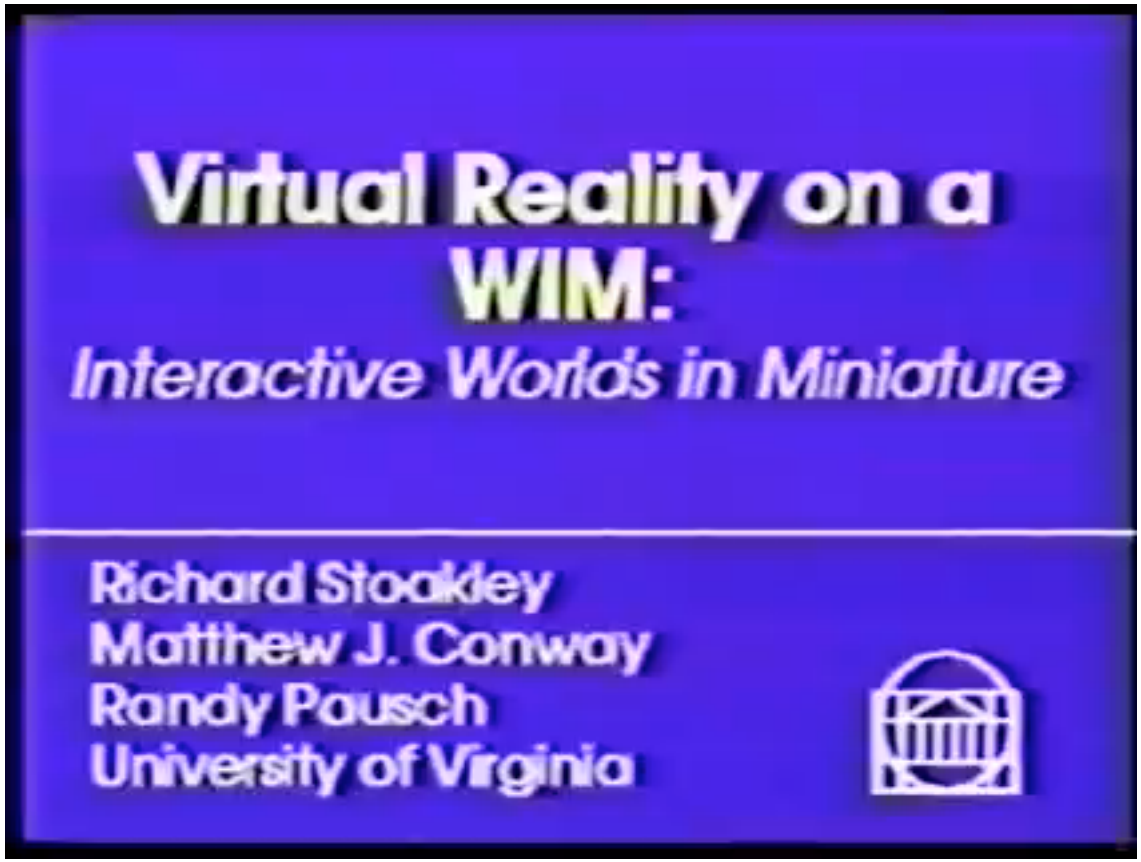


[Stoakley et al., 1995]

Move to destination

- Teleportation [Ruddle et al., 2000]
- Interpolation [Mackinlay et al., 1990]
- “Guided visit” metaphor [Elmqvist et al., 2007]

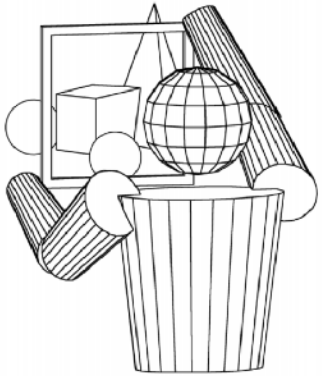
Navigation



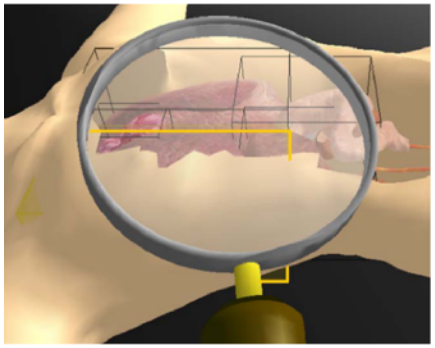
World In Miniature (WIM) [Stoakley et al., 1995]

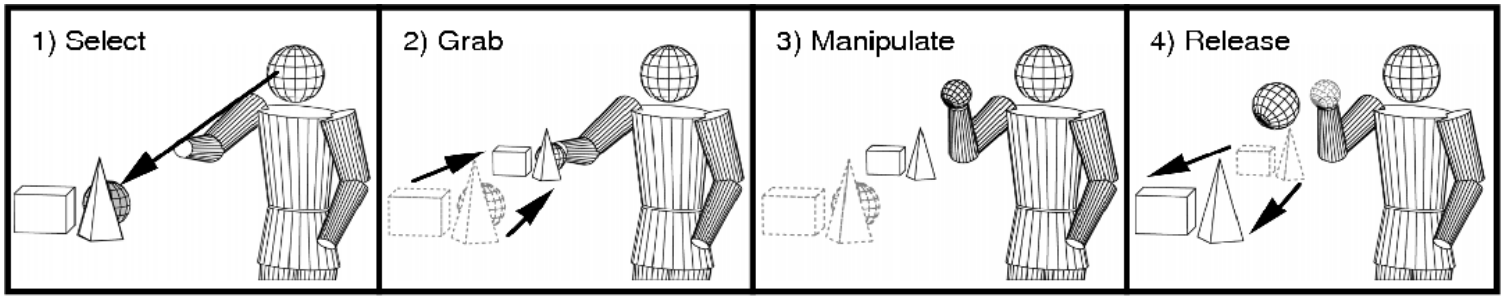
Navigation

- Multi-scale techniques
  - Manuel scale modification
    - An additional DoF
    - Head-butt Zoom [Mine et al., 1997]



  - Automatic scale modification
    - Bounding Boxes [Kopper et al., 2006]
    - Scaled-world grab [Mine et al., 1997]

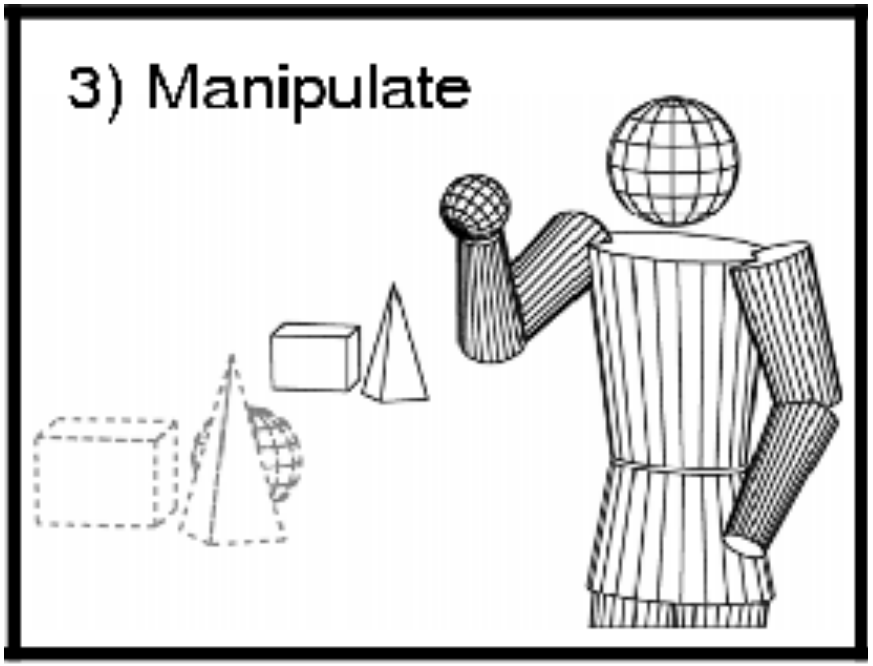




Object Manipulation

2 main tasks

- Selection
- Manipulation



Object Manipulation

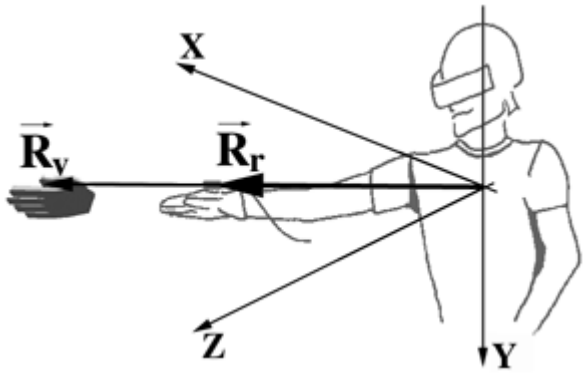
Virtual Hand [Jacoby et al., 1994]

Select and manipulate by touching

"Go-Go" metaphor
[Poupyrev et al., 1996]

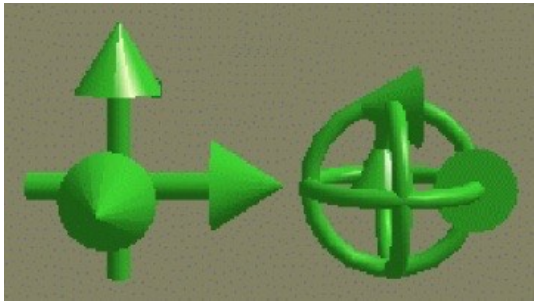
Extend the virtual hand

Move exponentially



3D cursor [Zhai et al., 1994]

Position or speed control



Object Manipulation

Virtual Ray [Mine, 1995]

Mimic a laser pointer

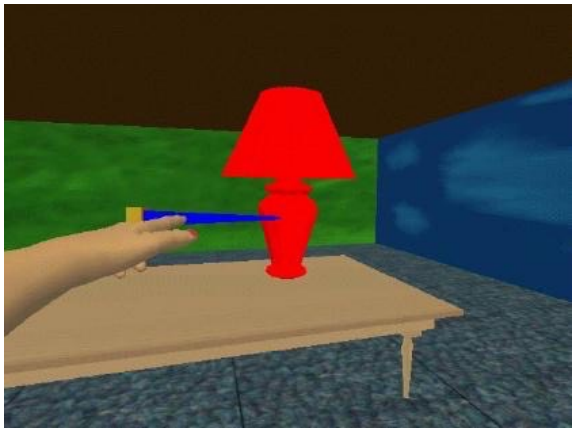
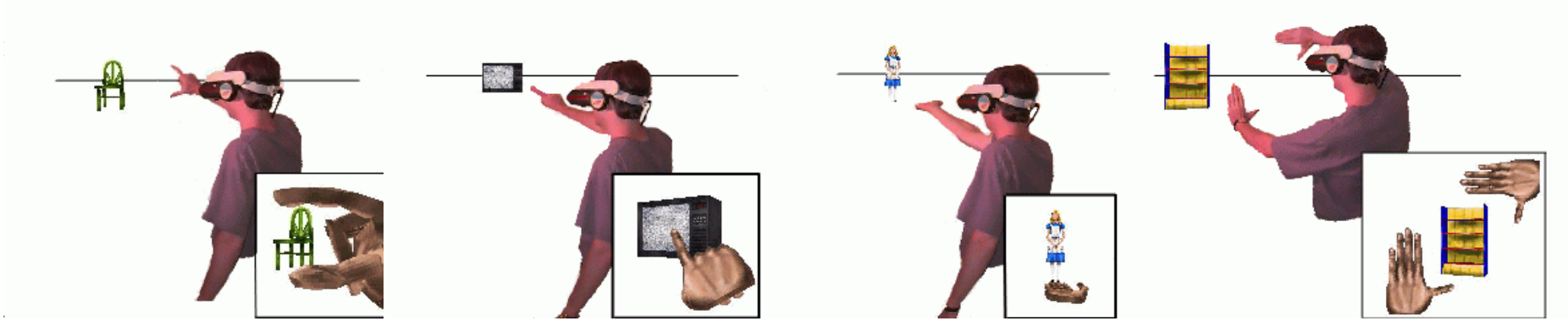
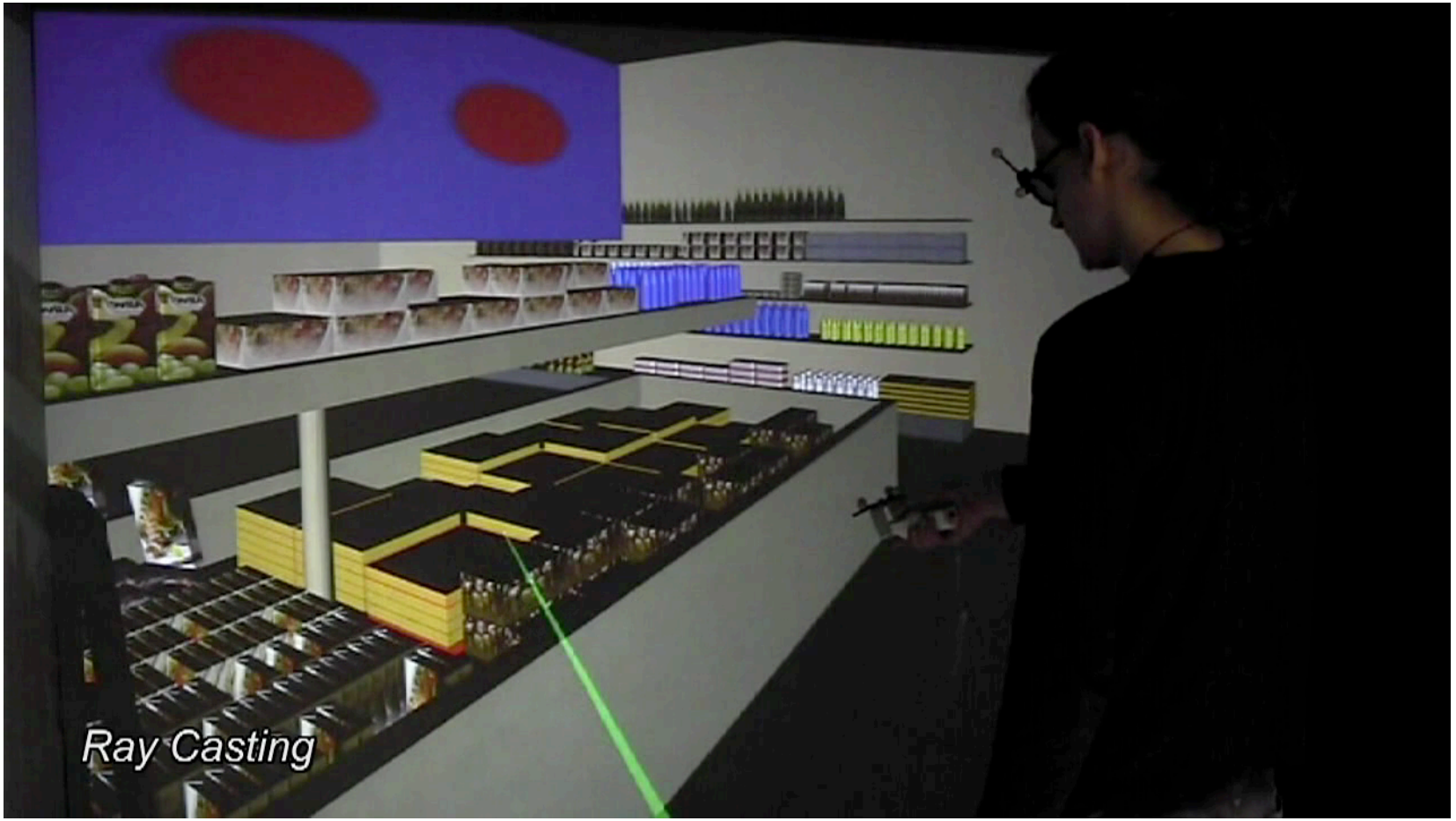


Image plan Interaction [Pierce et al., 1997]

Select by pointing with one part of the body



Object Manipulation



Virtual Ray [Mine, 1995]

Object Manipulation

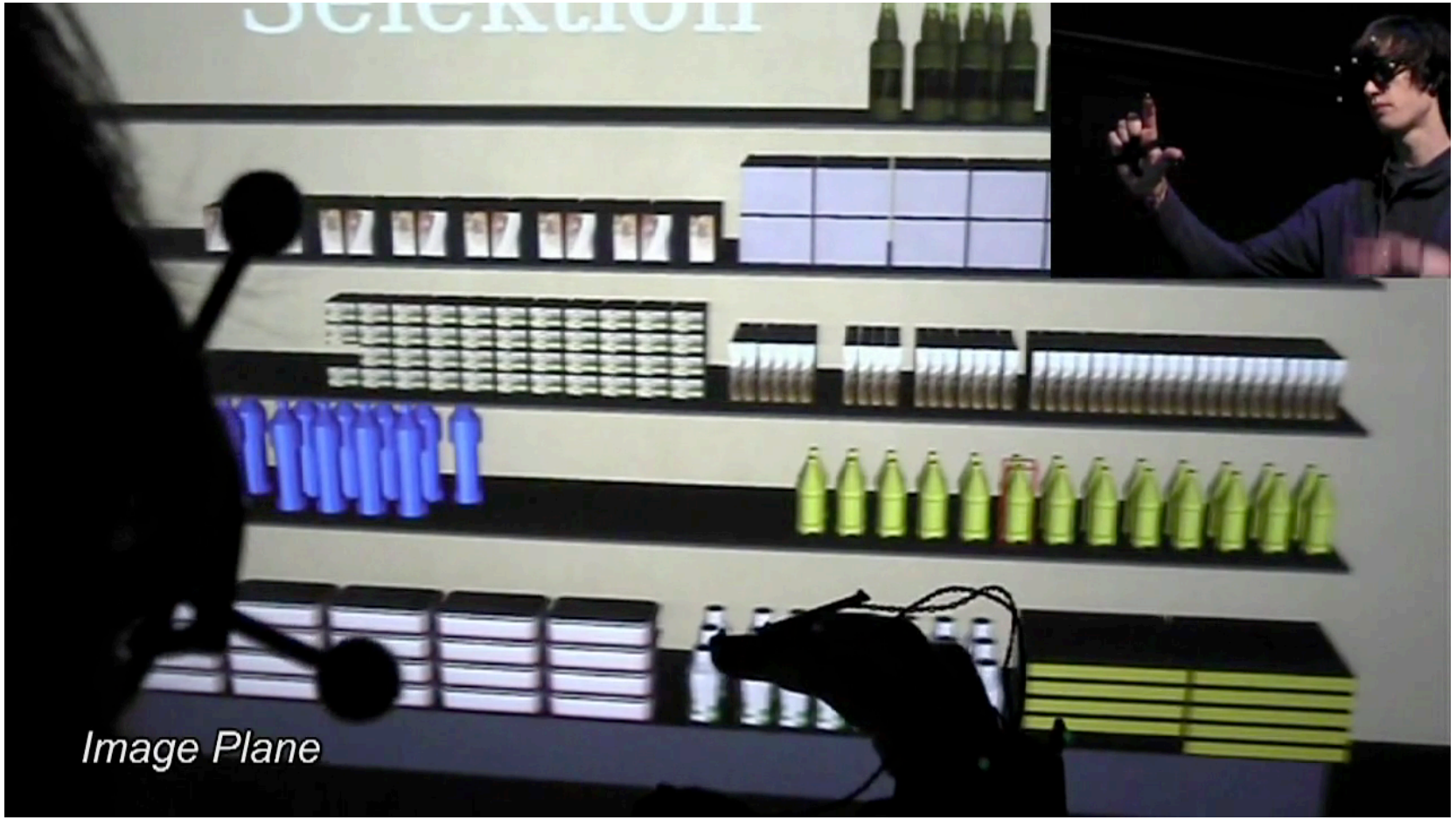


Image plan Interaction [Pierce et al., 1997]

Object Manipulation

Selection techniques not always suitable for manipulation

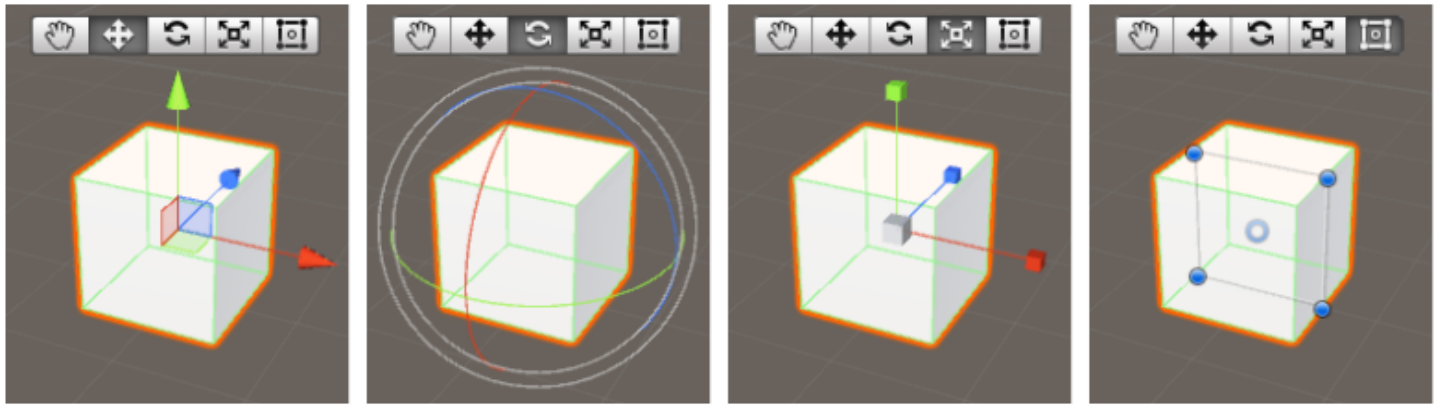
Ex: virtual ray for rotations

Combining several interaction tools

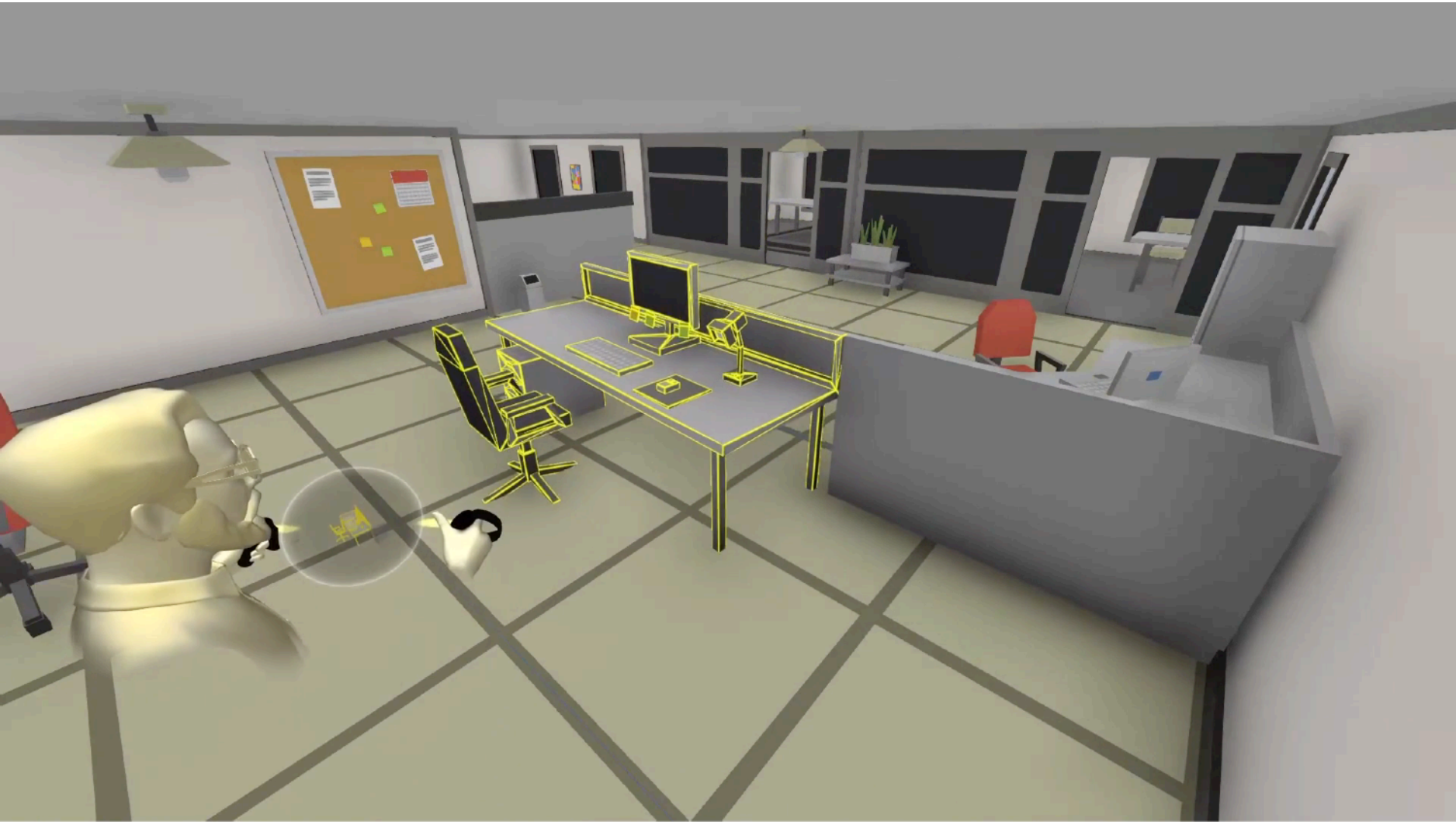
HOMER [Bowman et Hodges, 1997]

Move the manipulated object close to the user

Attached the interaction tools to the objects



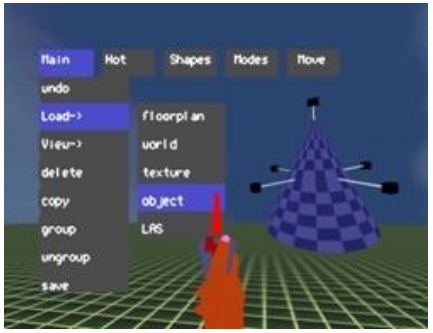
Multi-object manipulation



Application Control

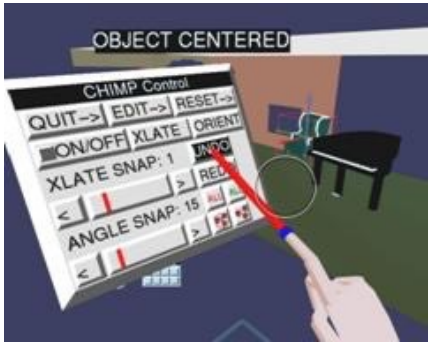
Control

- Application (exit, pause,…)
- Rendering parameters
- Tools/actions selection



[CDS – Bowman et al., 1991]

[Coquillart et al., 1999]



[CHIMP – Mine et al., 1997]

Techniques used

- 2D menus
- 3D menus
- Control on a tablet/smartphone

Outline

Introduction to Mixed Reality (MR)

Overview of Interaction in MR

Collaboration in MR

- Remote Collaboration
- Co-located Collaboration

Awareness and Communication

Collaborative Interaction

- Navigation
- Co-manipulation

Collaboration in Mixed Reality

Several users work/play together in a VE

- Co-expertise of 3D data
- Complex manipulation (real or virtual)
- Training
- Social presence (telepresence)

Outline

Introduction to Mixed Reality (MR)

Overview of Interaction in MR

Collaboration in MR

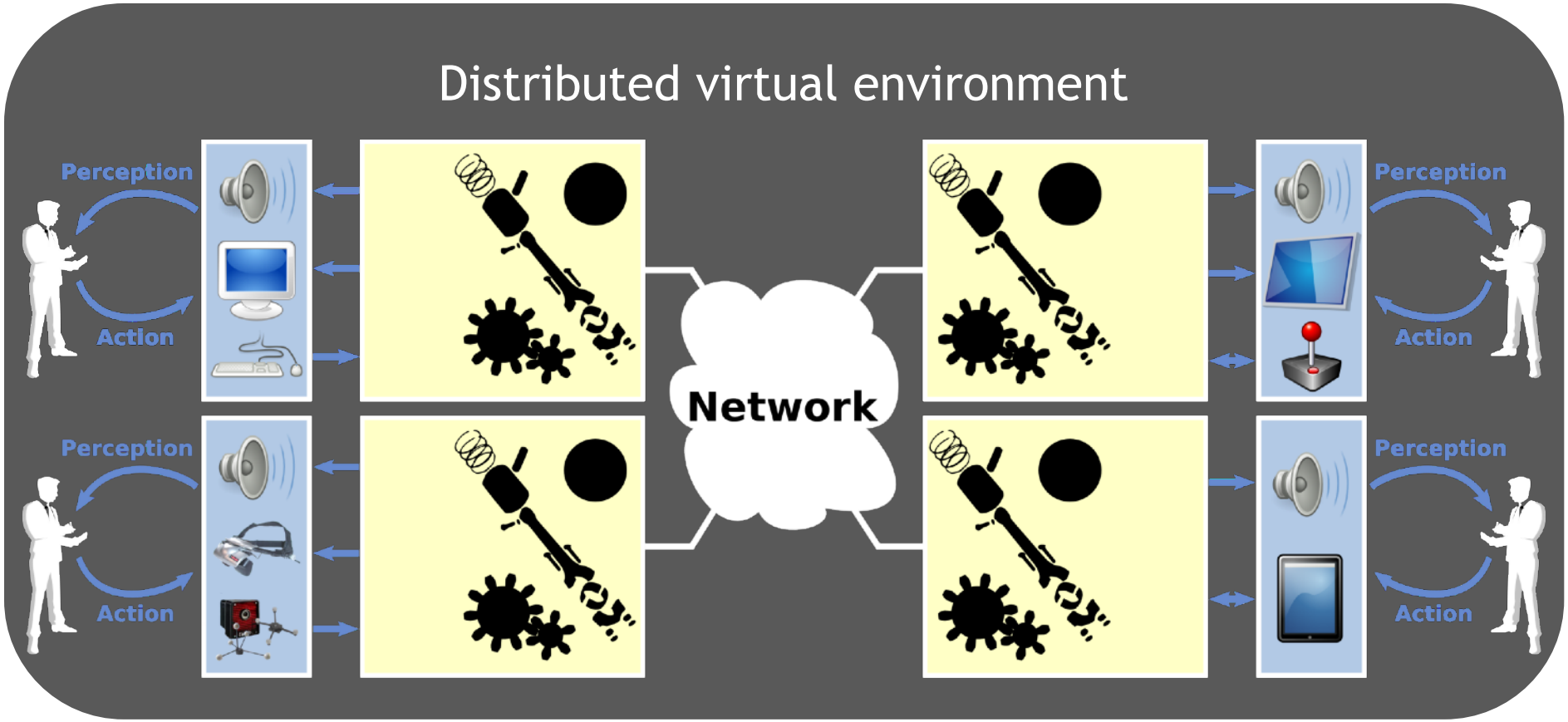
- Remote Collaboration
- Co-located Collaboration

Awareness and Communication

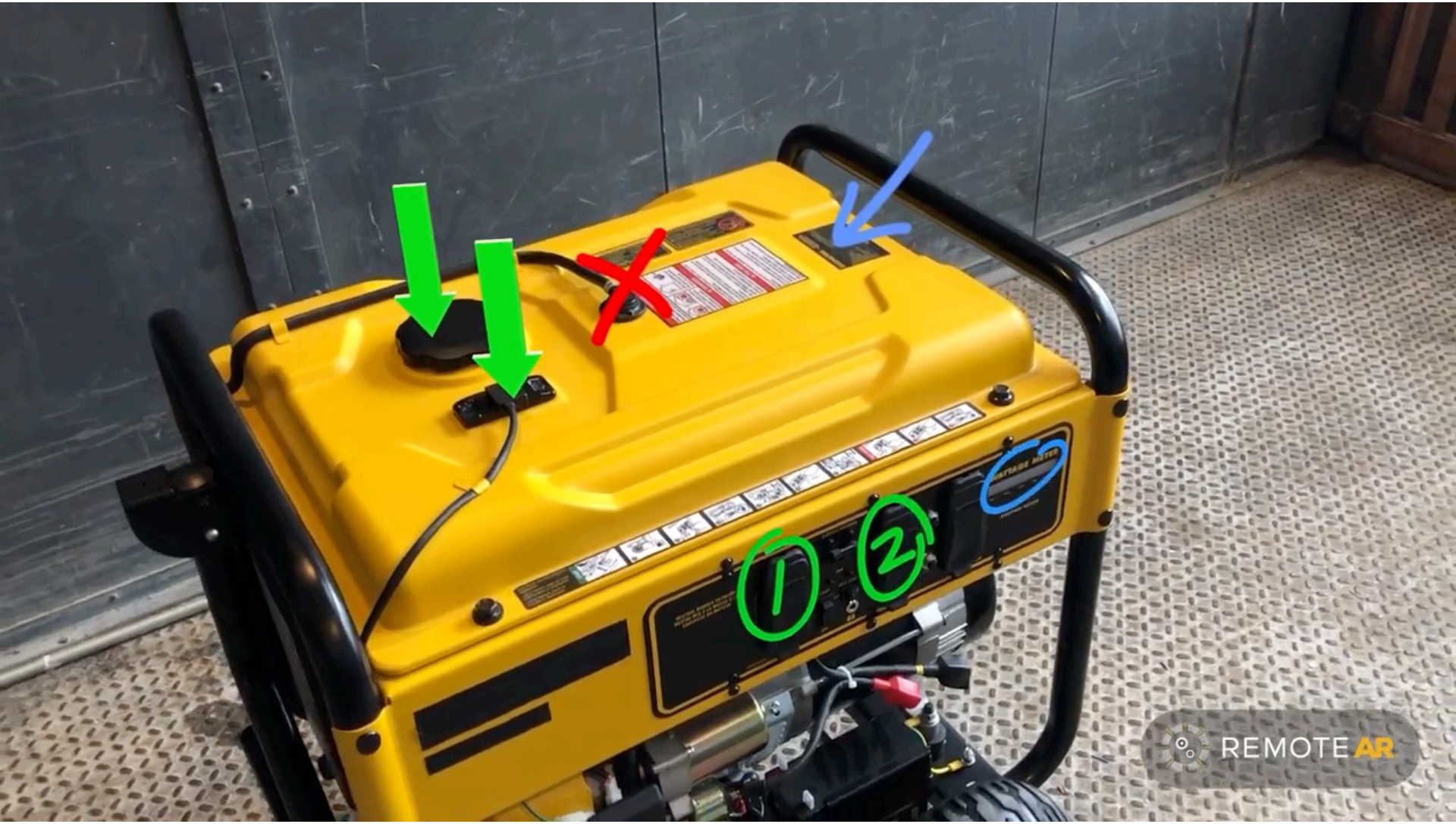
Collaborative Interaction

- Navigation
- Co-manipulation

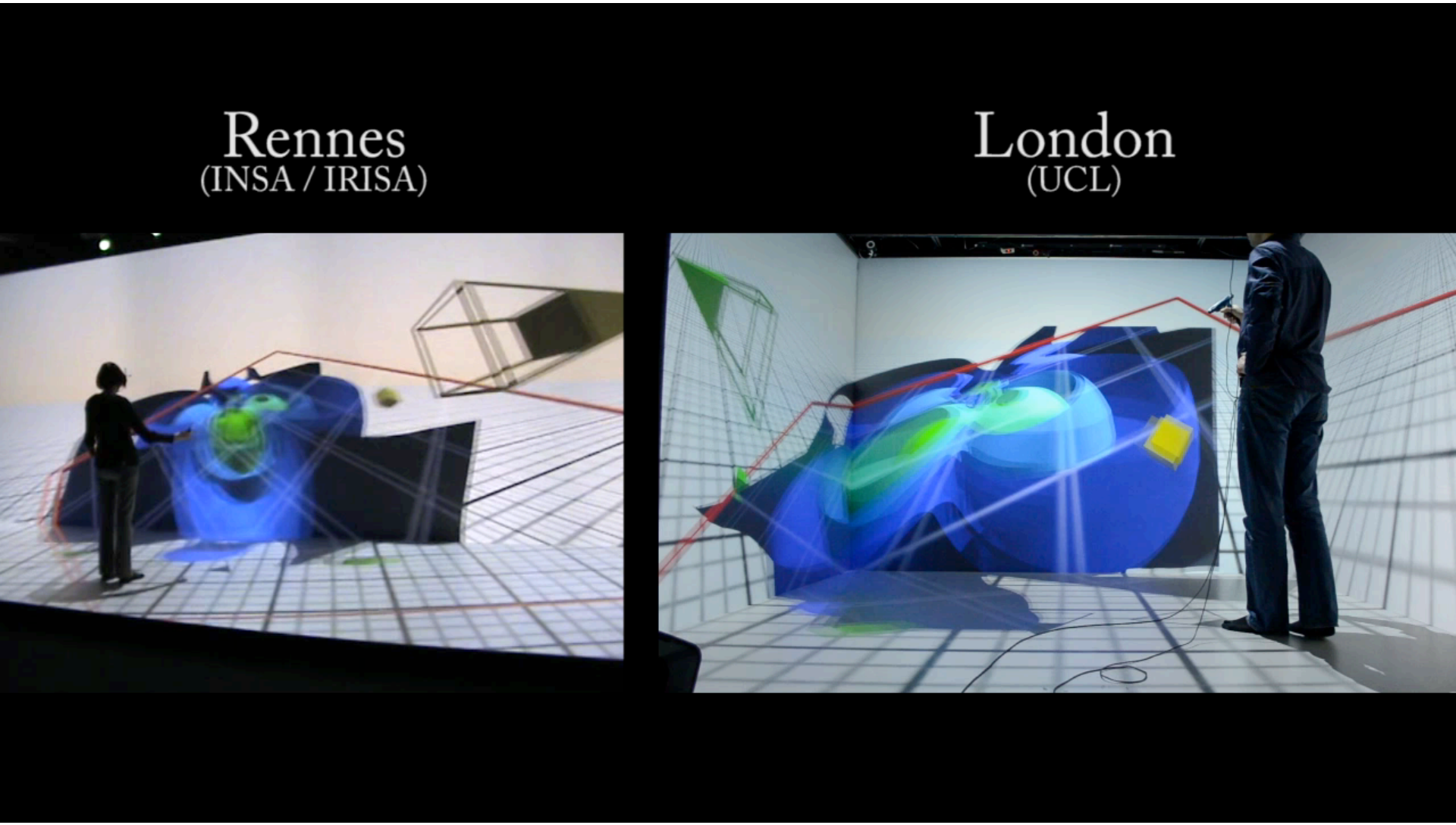
Remote Collaboration



Remote Collaboration in AR



Remote Collaboration in VR



Outline

Introduction to Mixed Reality (MR)

Overview of Interaction in MR

Collaboration in MR

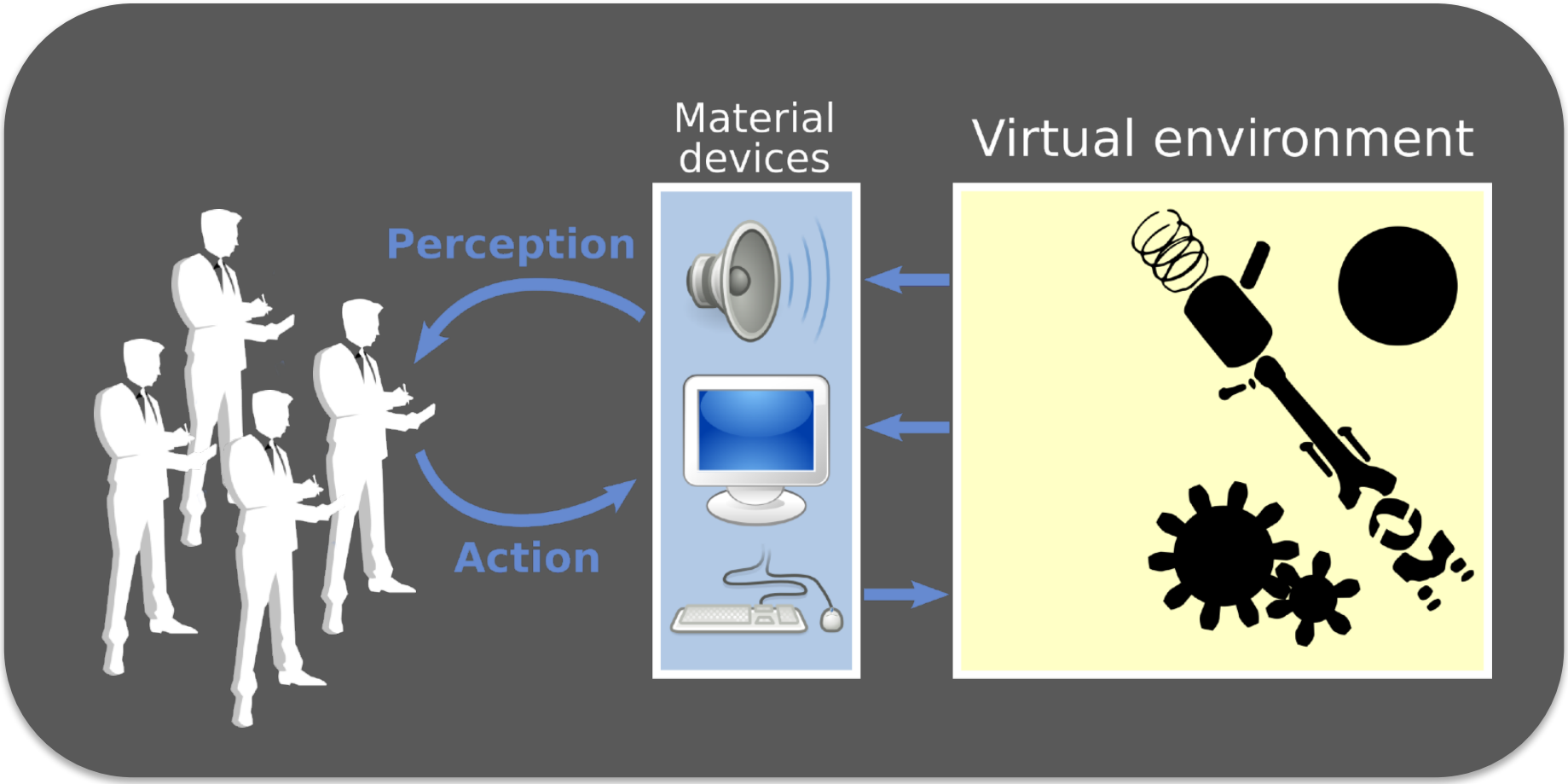
- Remote Collaboration
- Co-located Collaboration

Awareness and Communication

Collaborative Interaction

- Navigation
- Co-manipulation

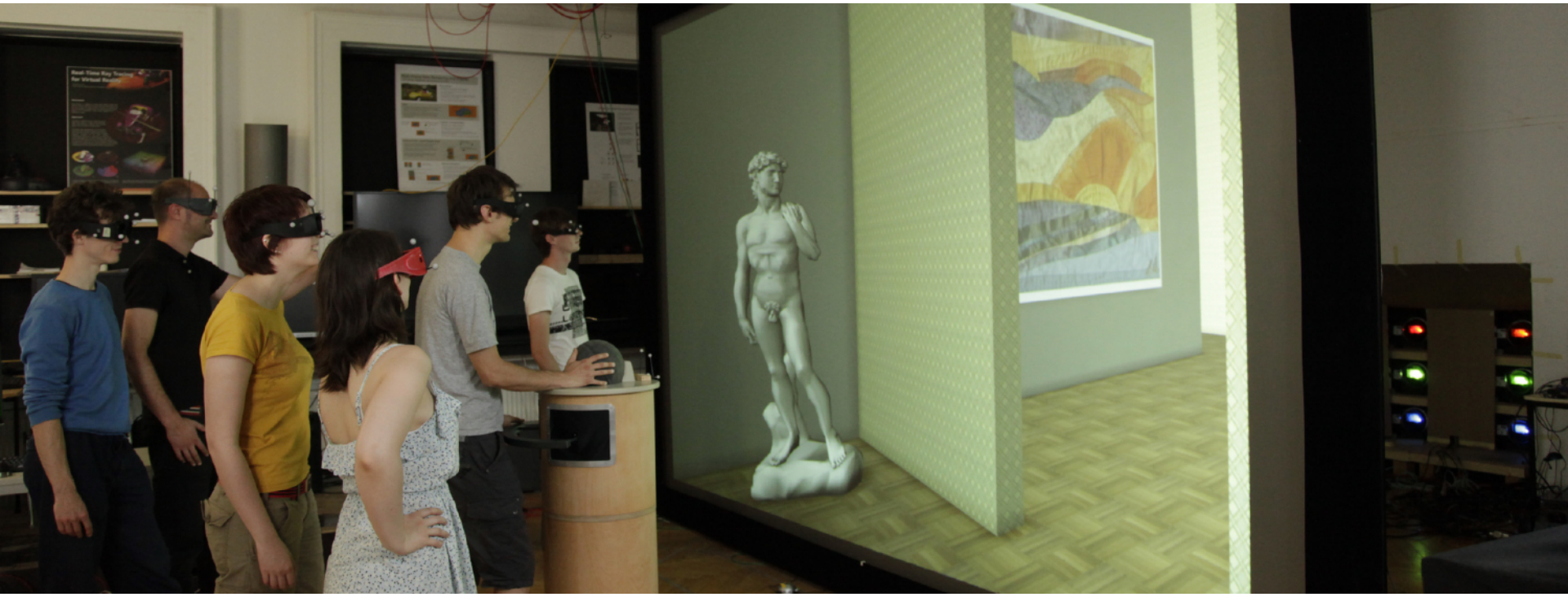
Co-located Collaboration



Co-located Collaboration in AR

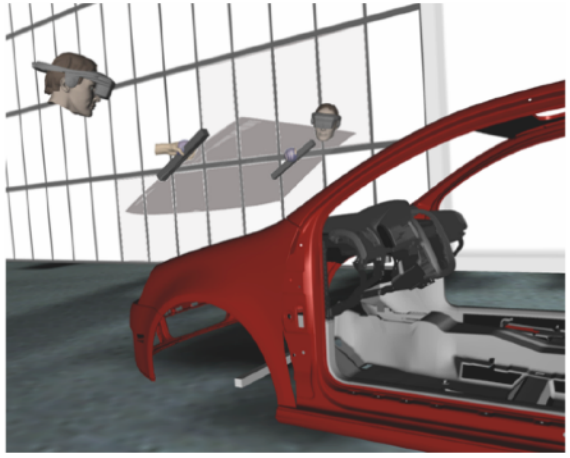
Co-located Collaboration in VR

Integrate several users in a VE with the same devices



Multi-stereoscopic display

Co-located Collaboration in VR


Users cannot see the other in the real world

Users can hear the other

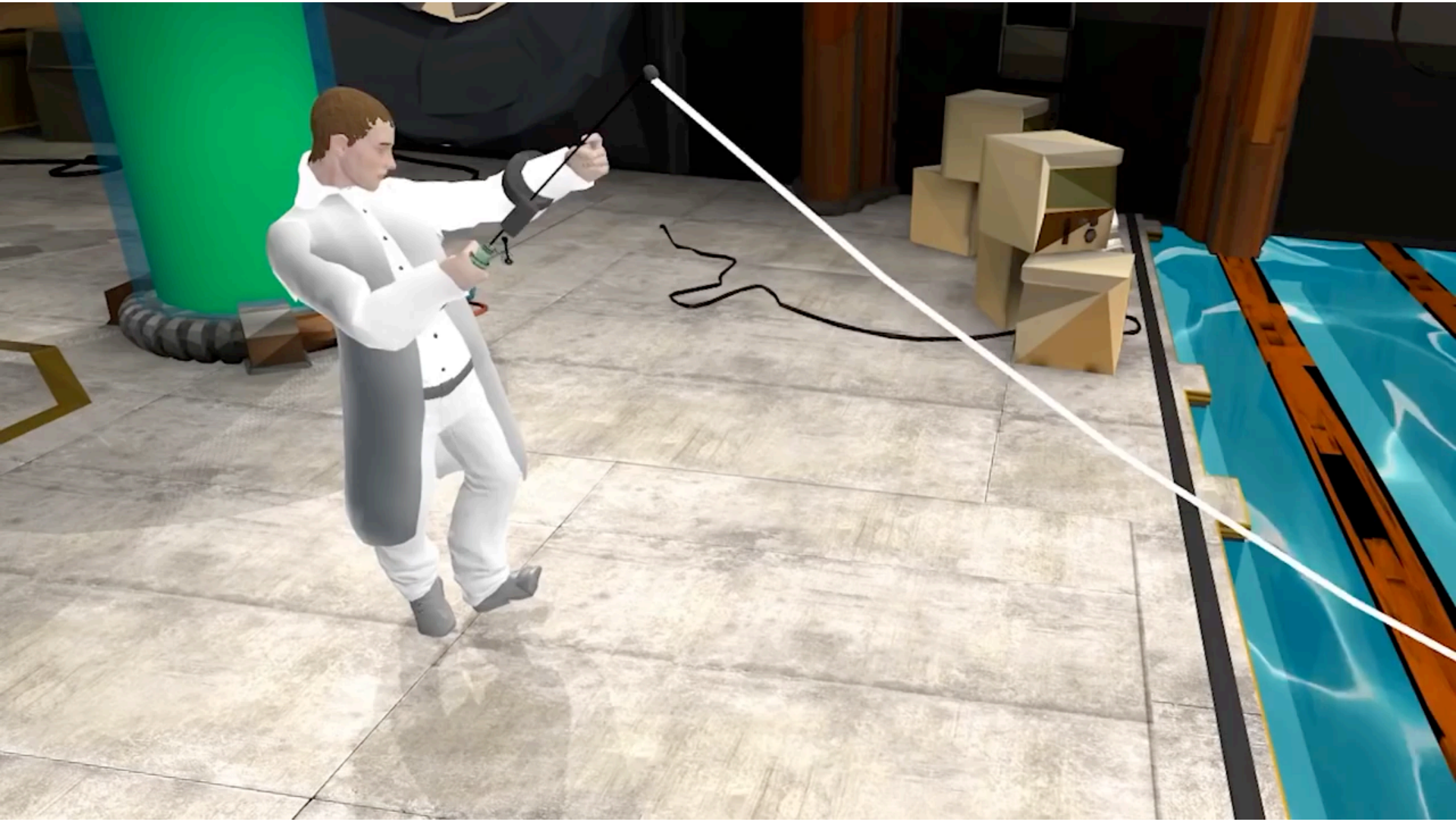
Users can feel the haptic force of the other

Co-located vs. Remote

Limits between co-located and remote collaboration are not clearly defined

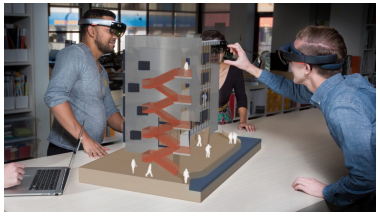
- 2 users with AR headsets in the same room?
- 2 users in a CAVE?
- 2 users with HMDs in the same room?
- 2 users with HMDs in the different room?
- 2 users with HMDs et headphones in the same room?

Unwanted collaboration



[Cheng et al., UIST 2017]

Collaboration in MR



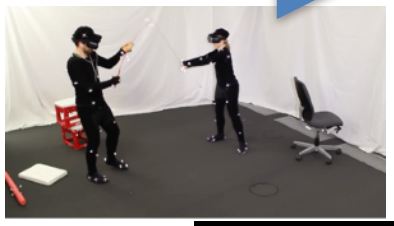
Co-located

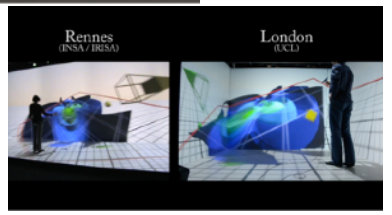
Social presence

Milgram Continuum

Real

Virtual





Remote

Outline

Introduction to Mixed Reality (MR)

Overview of Interaction in MR

Collaboration in MR

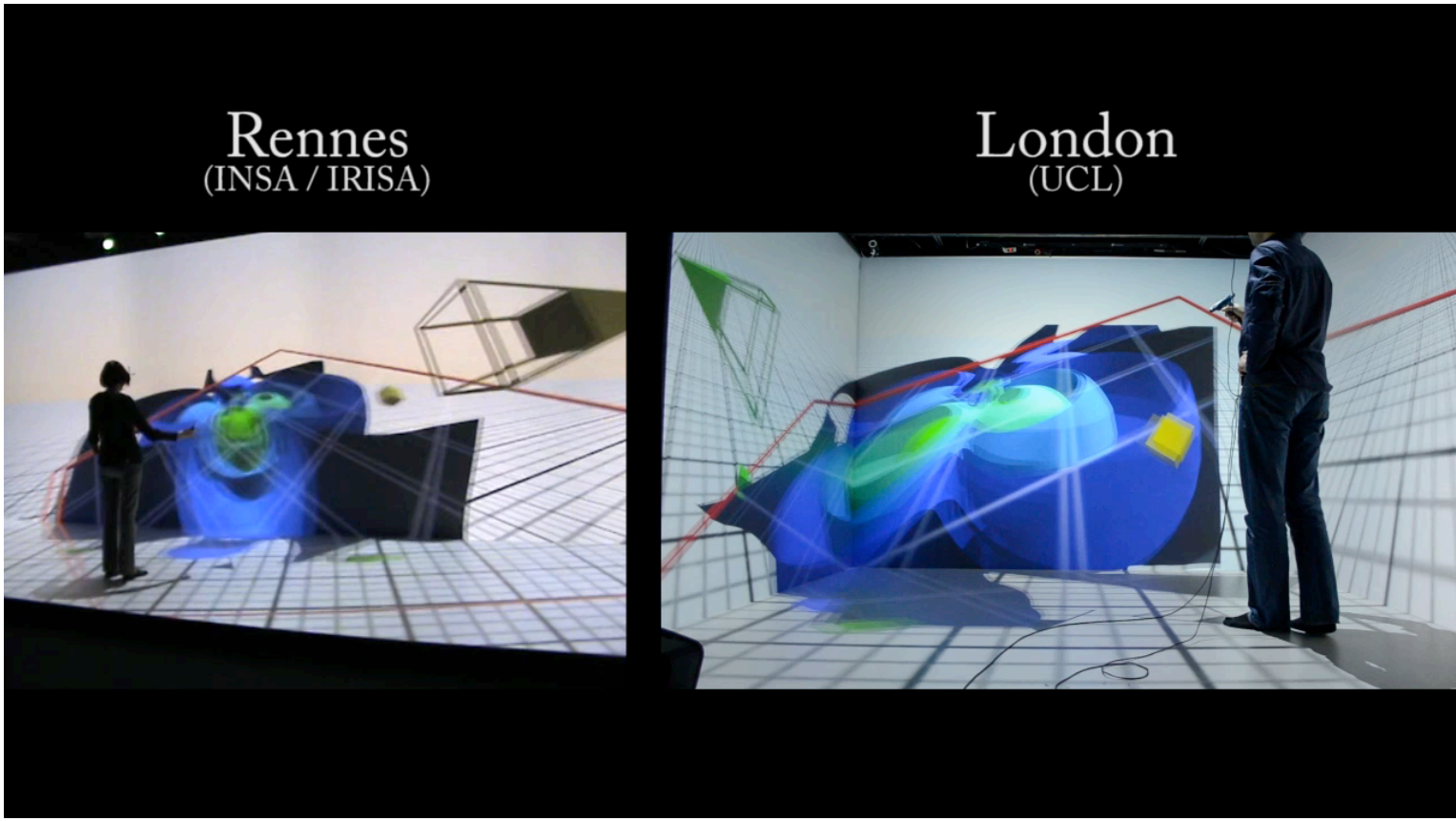
- Remote Collaboration
- Co-located Collaboration

Awareness and Communication

Collaborative Interaction

- Navigation
- Co-manipulation

Social Presence



[Fleury et al., VRST 2012]

Simplified Avatars

Collaborative interaction

Social Presence

[Facebook Social VR Demo - Oculus Connect 2016]

Animated avatars

Collaborative interaction

Video facilites

Social Presence

Real 3D video integration

[Beck et al., IEEE VR 2013]

Collaborative interaction

Specific tools for collaboration

Awareness

Perception of the other users

- Where are they?
- What are they doing?
  - What are they looking?
  - Are they looking at me?
- What could they do ?
  - Can they see me?
  - Could they see what I am showing to them?
  - Could they do what I am asking them to do?

Awareness

Improve the mutual understanding

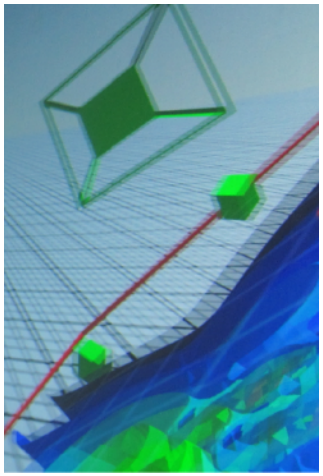
- Just next to me… But where are you?
- Just in front of me … But where are you looking at?
- Etc.

Multi-sensorial restitution

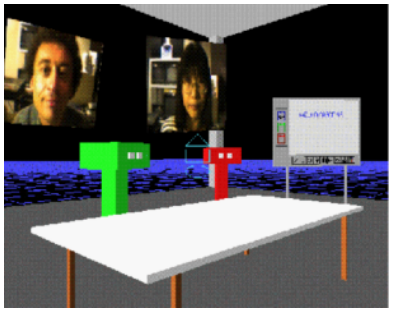
- Visual awareness
- Audio awareness
- Haptic awareness

Visual Awareness

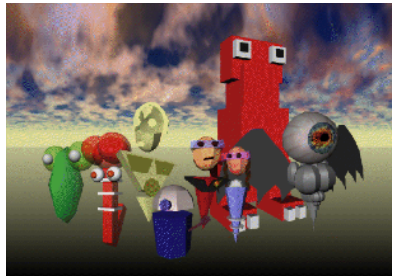
Avatar: representation of users in the VE



[Fleury et al., 2012]



[DIVE, 1991]



[CALVIN, 1996]

[Fleury et al., 2008]

[Second Life, 2005]

[Fleury et al., 2013]

[Beeler et al., 2010]

Visual Awareness

Animation of the avatars

Kinect Avatar

Body tracking

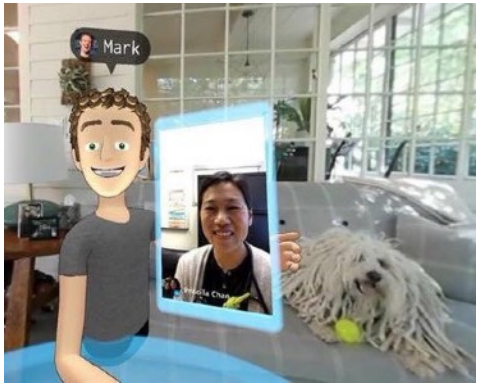
Kinect Avatar

Telepresence in virtual reality

Animated virtual characters

Real 3D video integration

Video facilities



Audio Awareness

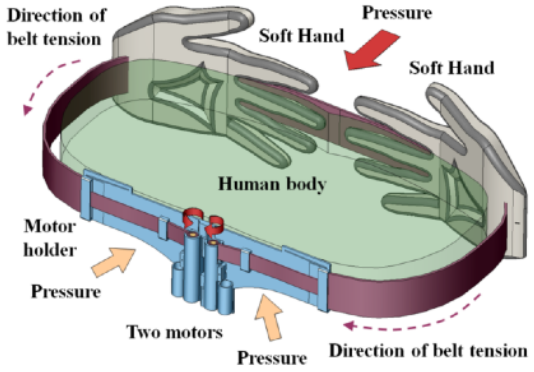
Spatialized voice restitution

Remote users' noises

- Give a lot of information
  - Where they are
  - What they are doing
    - Add some sounds to describe the actions
- Need to be spatialized sounds

Haptic Awareness

- Force feedback of the others
  - Direct
    - Touch the others through haptic devices
      - Virtual handshake
      - Affective haptic
    - Can be asymmetrical
  - Indirect
    - Manipulate an object together
    - Feel the force apply by the other on the object



Awareness Model

Spatial Model of Interaction [Benford et al., 1994]

Compute which users can interact which others

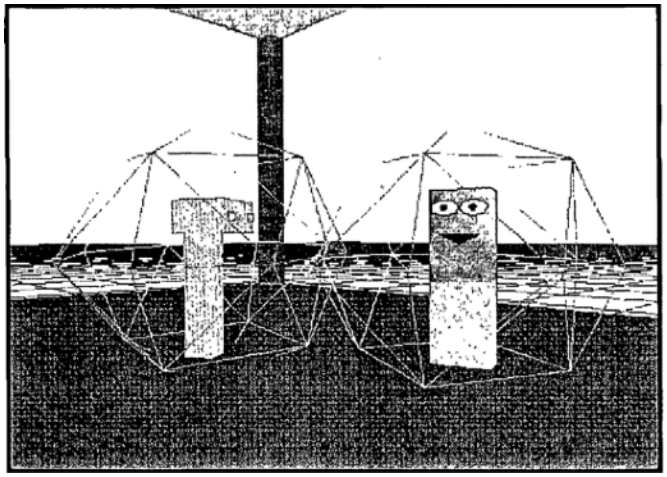
Measure of awareness between two users

Medium

A typical communication medium
Ex: audio, visual, haptic, etc.

Focus and **Nimbus**

Sub-space bounding the presence in a particular **Medium**



[Benford et al., 1994]

Awareness Model

Spatial Model of Interaction [Benford et al., 1994]

Focus

Area where a user perceive the others

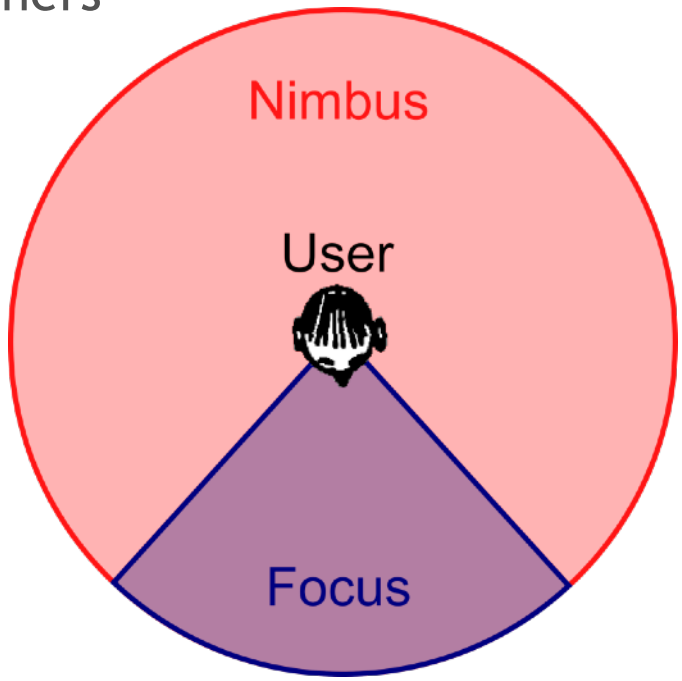
For each particular **Medium**

Nimbus

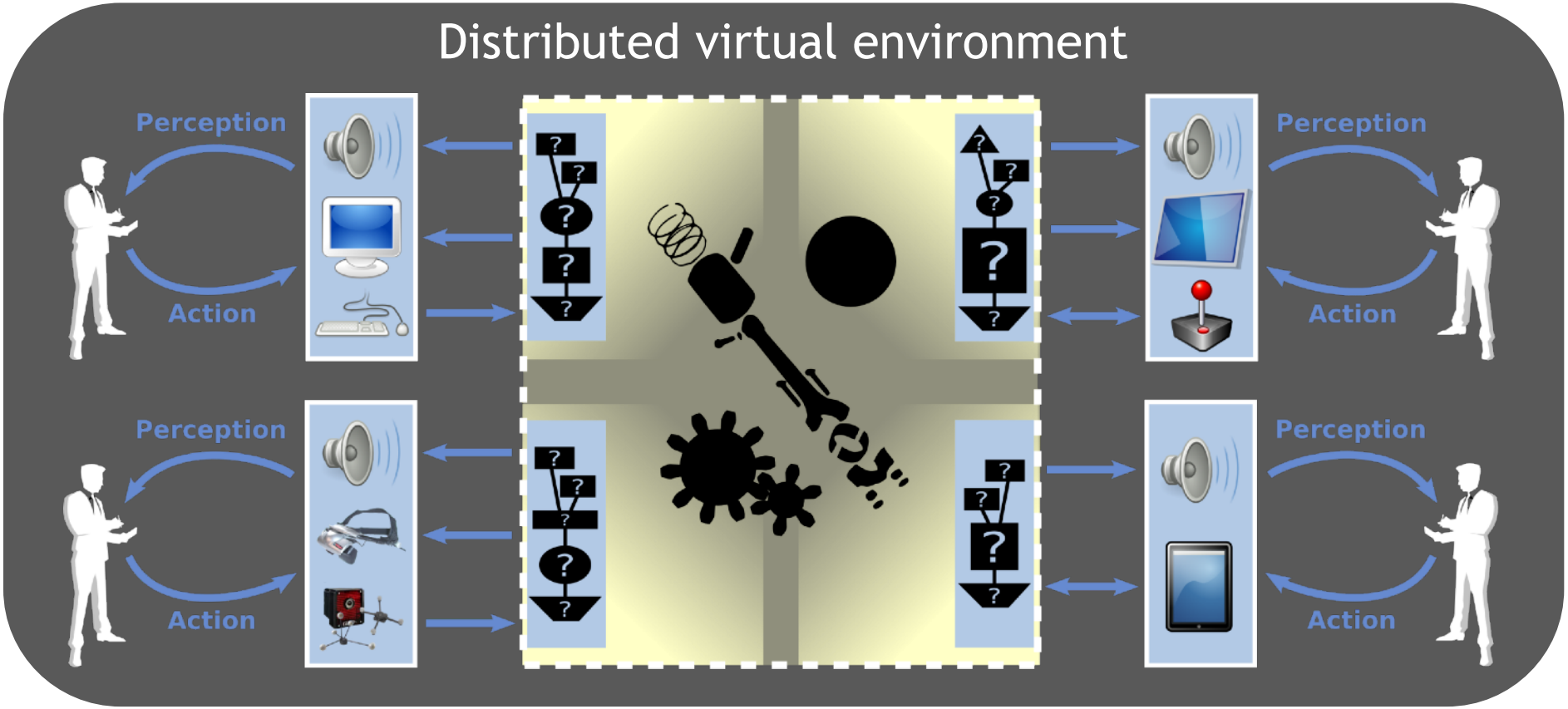
Area where the others can perceive a particular user

For each particular **Medium**

Different from the **focus**



Activities/Capabilities Perception



⇒ How can users understand what the others are doing?

⇒ How can they understand what the others can do?

Interaction Workspaces

3D space in the real world

- Associated to a particular material device
- Perceive or interact with the virtual world
- Ex: visual, audio, haptic, physical displacement, etc.

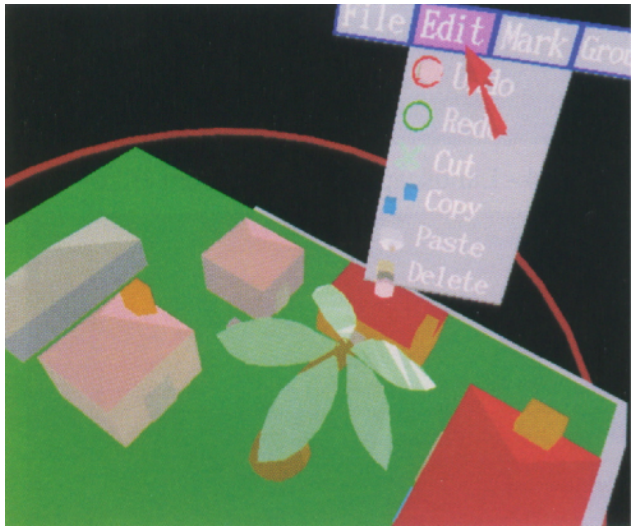
Why integrating these interaction workspaces?

- Each user can have different interaction workspaces
- Take into account workspaces for users' interaction
  - Adapt the interaction techniques
  - Capabilities perception

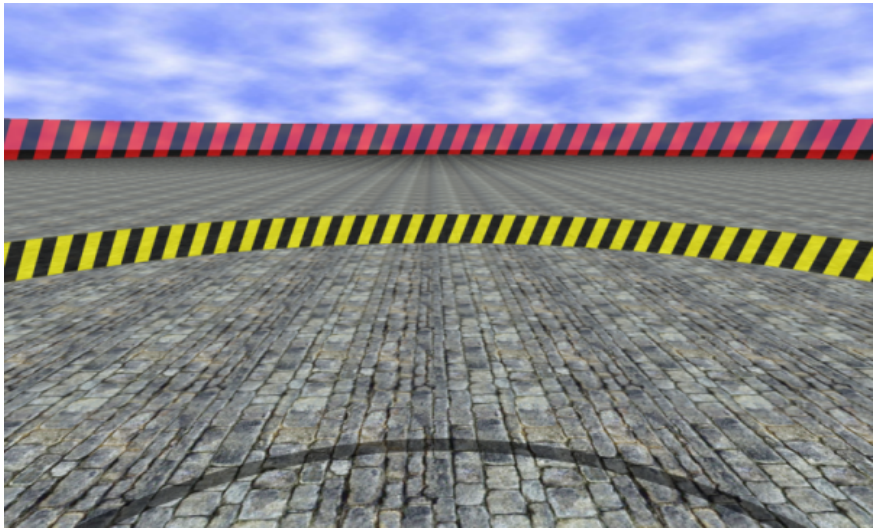
Examples of Interaction Workspaces

User's physical displacement workspace

- Magic Carpet in 3DM [Butterworth et al. 92]
- Magic Barrier Tape [Cirio et al. 09]



Magic Carpet

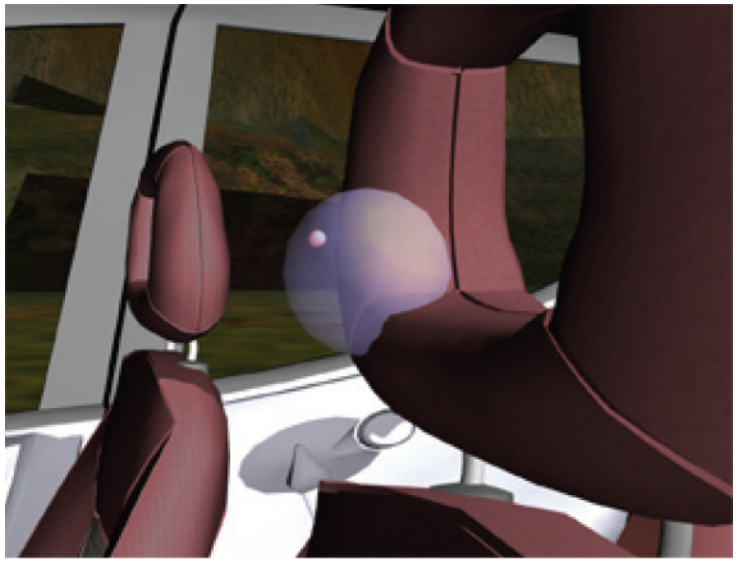


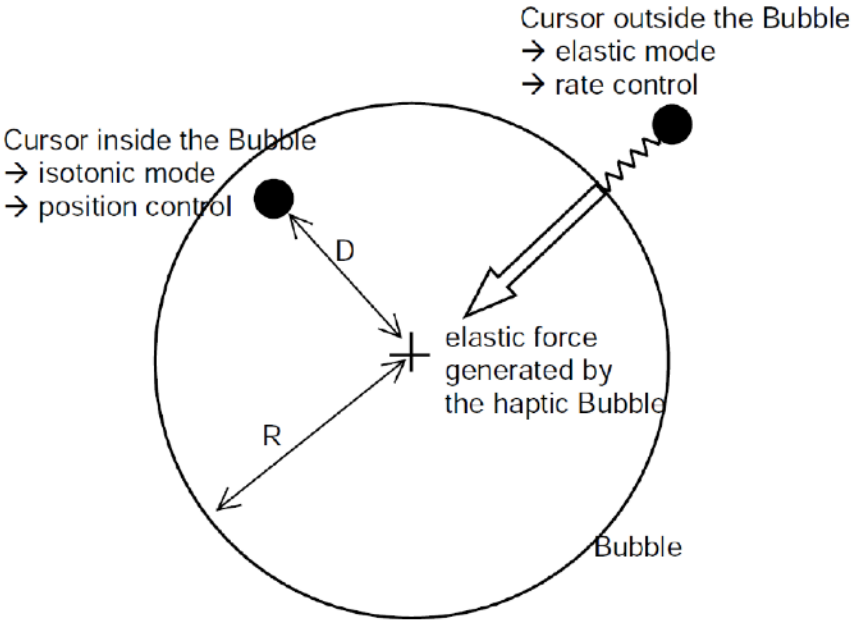
Magic Barrier Tape

Examples of Interaction Workspaces

Haptic interaction workspace

Bubble technique [Dominjon et al. 05]

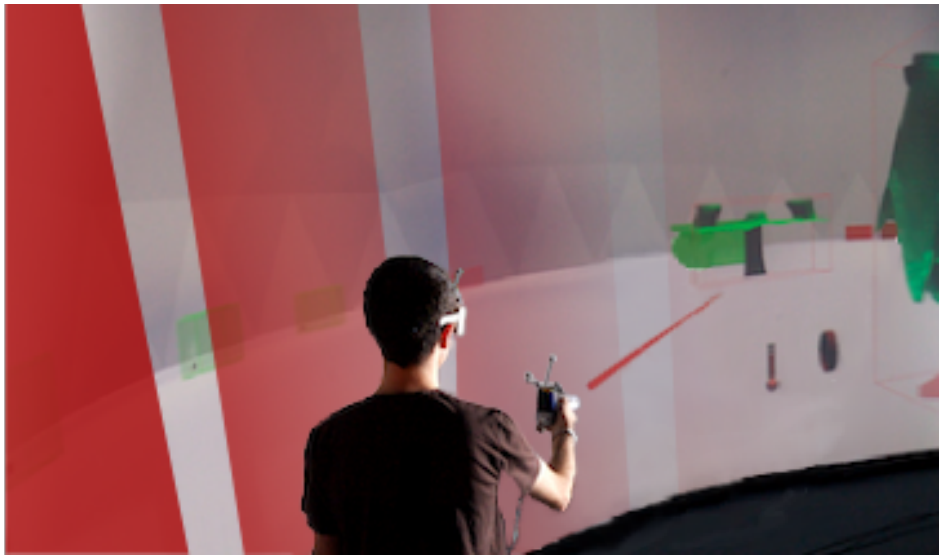




Capabilities Perception

Example for the user himself:

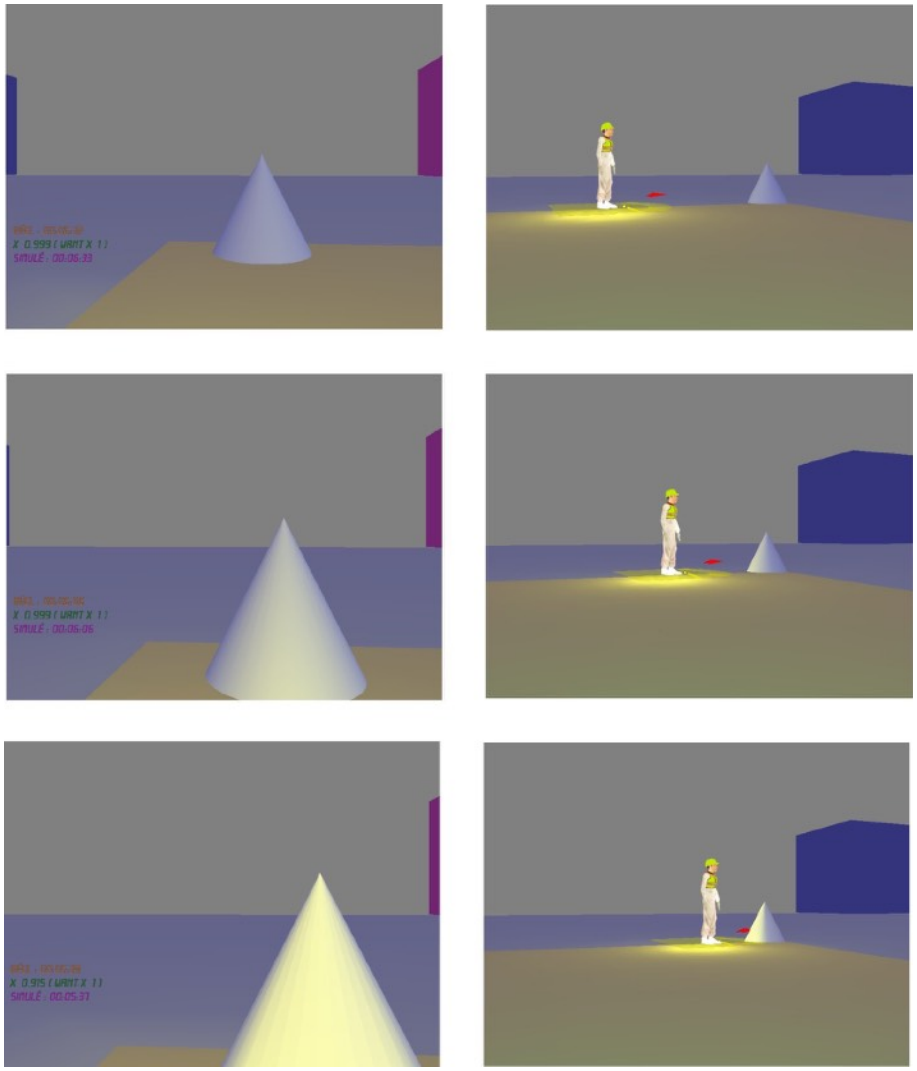
User’s displacement workspace



Capabilities Perception

Example for another user:

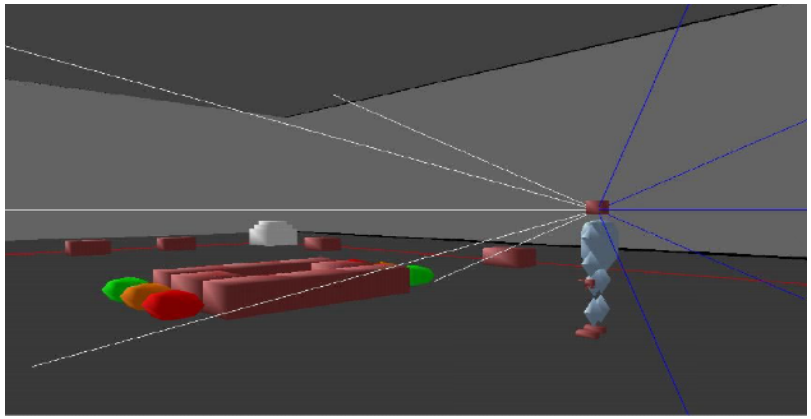
Interaction workspace



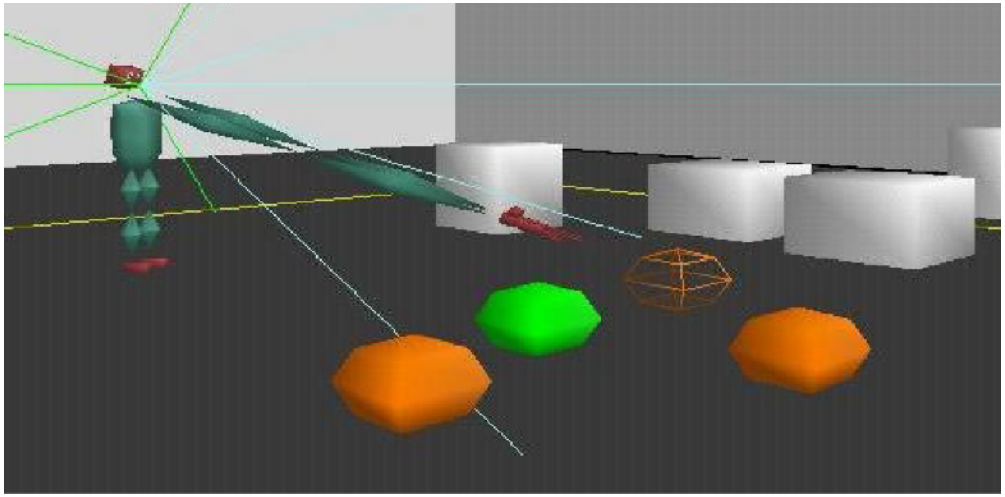
Activities Perception

What is the user seeing?

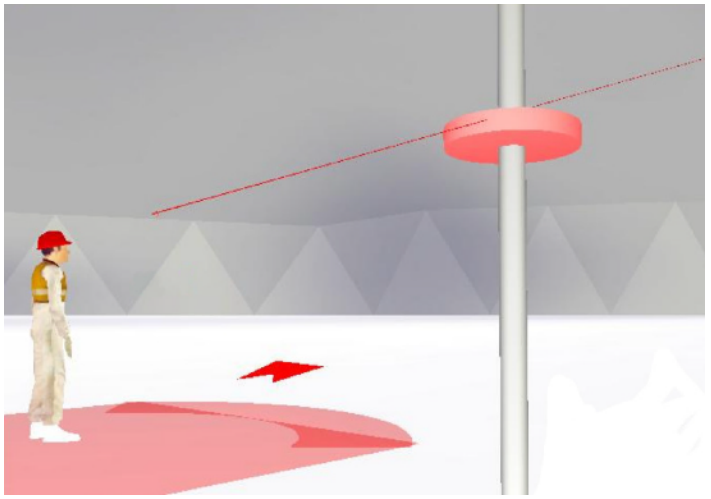
[Fraser et al., 1999]



What is the user doing?



[Fraser et al., 1999]



[Duval et al., 2008]

Outline

Introduction to Mixed Reality (MR)

Overview of Interaction in MR

Collaboration in MR

- Remote Collaboration
- Co-located Collaboration

Awareness and Communication

Collaborative Interaction

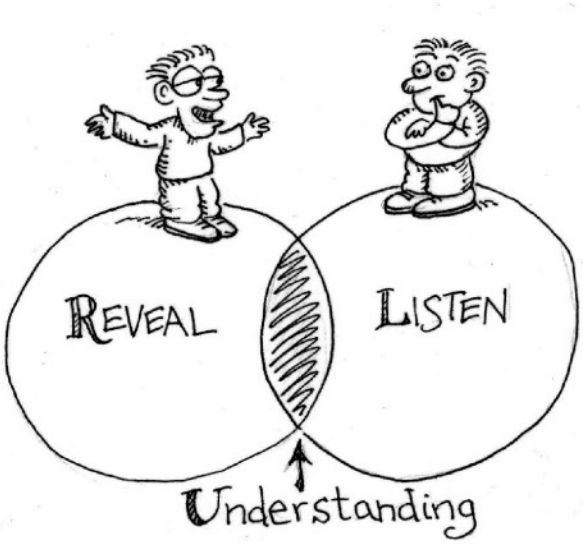
- Navigation
- Co-manipulation

Voice communication

Essential for collaborative application

- Compensate a bad perception of the VE [Hindmarsh et al., 1998]
- Share different point of view

However:



Voice communication induces also discontinuity in interaction

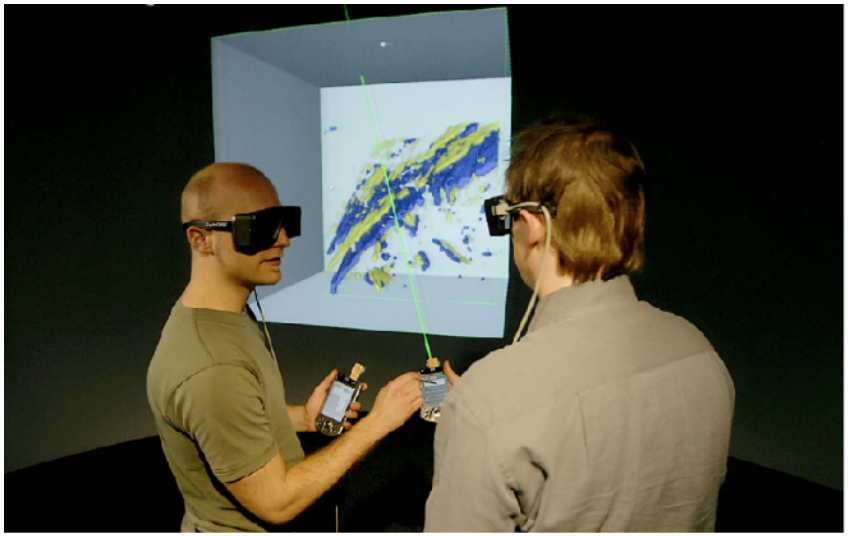
[Bowers et al., 1996]

⇒ Users need specific tools for communication

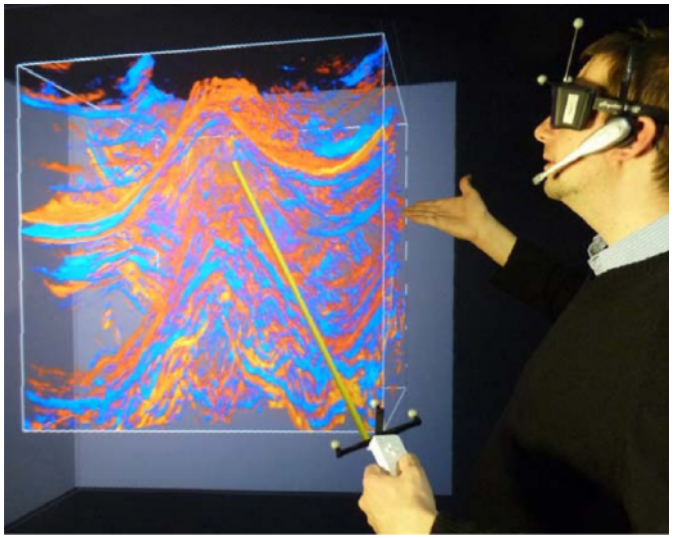
Tools for communication

Virtual Ray

- Laser pointer metaphor
- Easy and intuitive manipulation



[Simon, 2005]

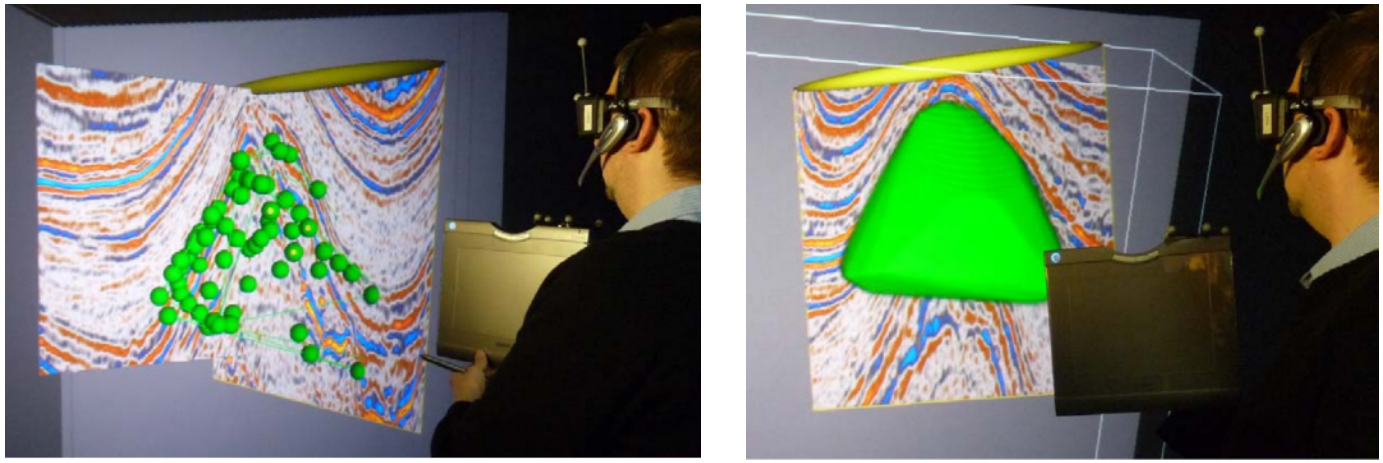


[Schild et al., 2009]

Tools for communication

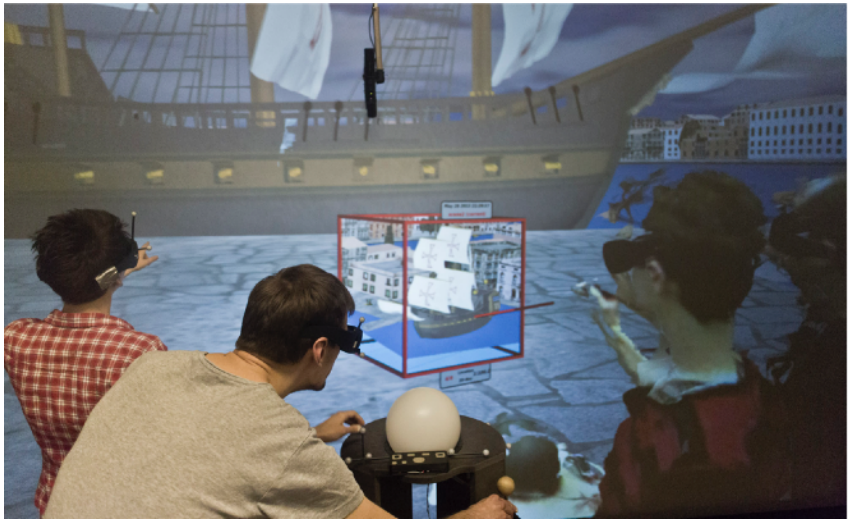
Annotations

- Sketching, text, audio, videos
- Especially relevant for scientific data analysis
- Synchronous and asynchronous collaboration



[Schild et al., 2009]

Tools for communication



Photoportals

- Shared 2D or 3D views
- Annotations
- Interaction with the shared views

Photoportals
[Kunert et al., CSCW 2014]

Photoportals: Shared References in Space and Time

André Kunert, Alexander Kulik, Stephan Beck, Bernd Fröhlich

Starring: Jan Beckmann, Anniek Vetter, André Kunert, Felix Trojan and Eik List
Voice: Ben Sassen
Production: Marcel Karnapke

3D model of Castle Vianden (Luxembourg)
Courtesy of ArcTron 3D GmbH (www.arctron.com)

Additional 3D Models from Blendswap Members:
Sizzler, Hjford, Michal David, Nicolas Damore, Ian57, Komtraya

CSCW 2014

Bauhaus-Universität Weimar
VR-Systems Group

Outline

Introduction to Mixed Reality (MR)

Overview of Interaction in MR

Collaboration in MR

- Remote Collaboration
- Co-located Collaboration

Awareness and Communication

Collaborative Interaction

- Navigation
- Co-manipulation

Collaborative Navigation

Collaborative virtual environment

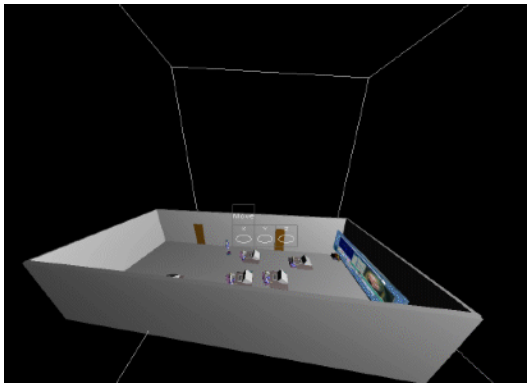
- WYSINWIS (What Your See Is Not What I see)
  - Each user can have its own viewpoint

- But, sometime users need:
  - To share the same viewpoint
  - To meet somewhere in the VE
  - To guide others in the VE
  - To follow each other

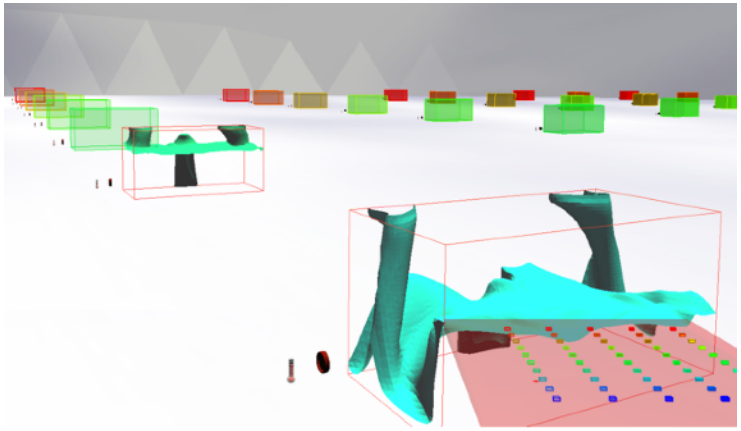
Collaborative Navigation

3 main modes of collaborative navigation

- Share the same point of view
  - One user drives, the other follows
- One move and the other follows with an offset
  - One user drives, the other can modify his offset
- World in Miniature
  - Guide the others through the WIM
  - Move the others through the WIM



[CALVIN, 1996]



Viewpoints sharing

[Duval et al., 2008]

Context: scientific data analysis

Users can:

- Save interesting viewpoints
- Select on particular viewpoint
- Travel cross of the saved viewpoints of a particular user

Group Navigation

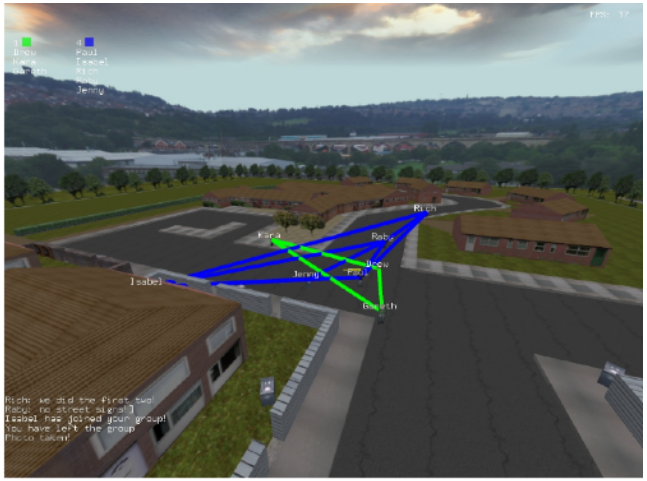
[Dodds et Ruddle, 2008]

Users are part of a predefined group

Each user can travel independently

Functionalities help to travel with the group

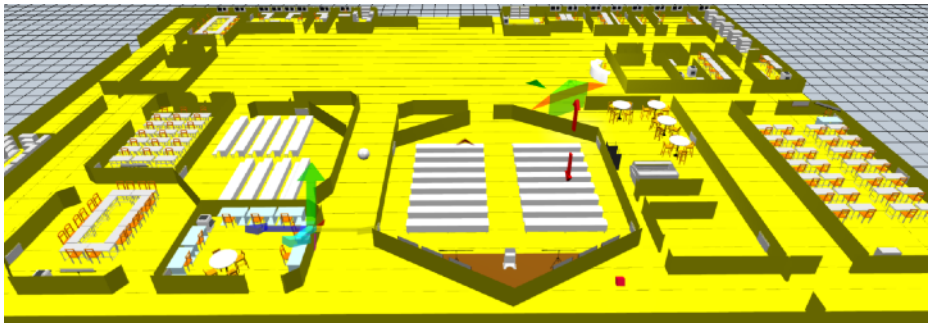
- To follow the first member of the group
- To come back at the middle of the group (mean of member positions)



Collaborative teleportation

Guidance techniques

[Nguyen et al., 2013]

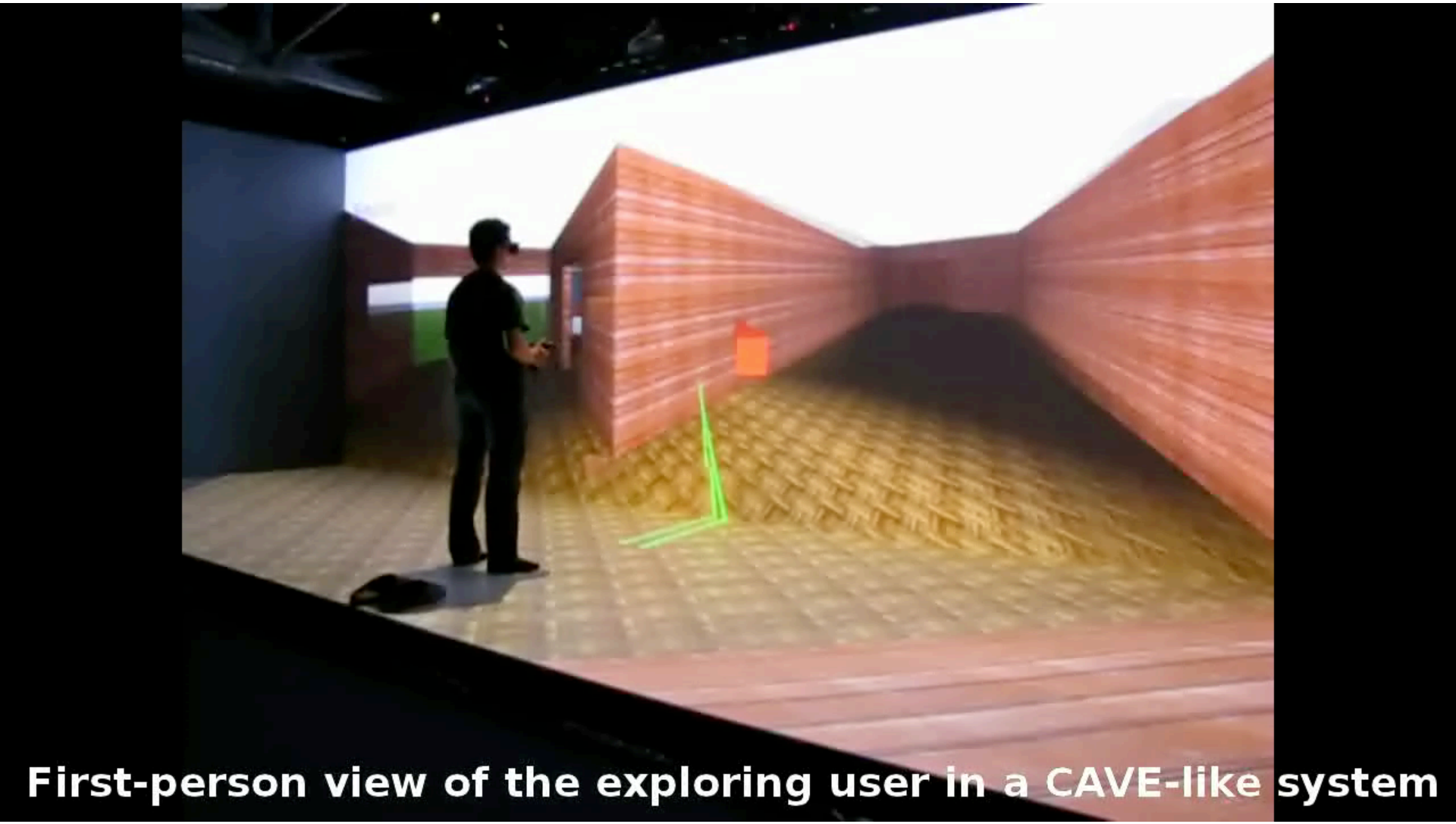


Context: collaborative navigation in a building

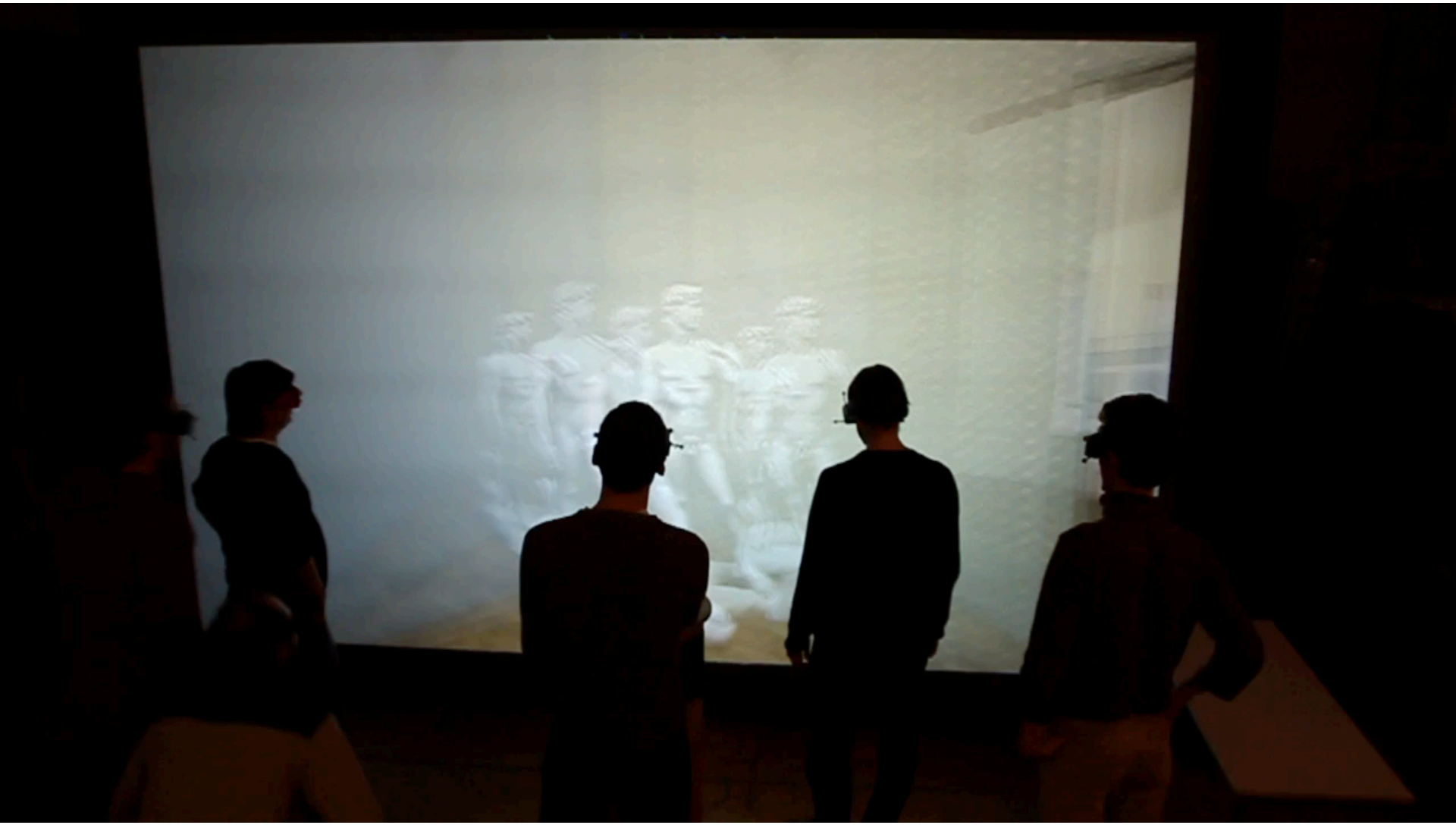
- User 1 is in an immersive room
  - Find several targets in the building
- User 2 is in front a desktop workstation
  - Guide the other user using a WIM
- Not verbal communication

Guidance techniques

[Nguyen et al., 2013]



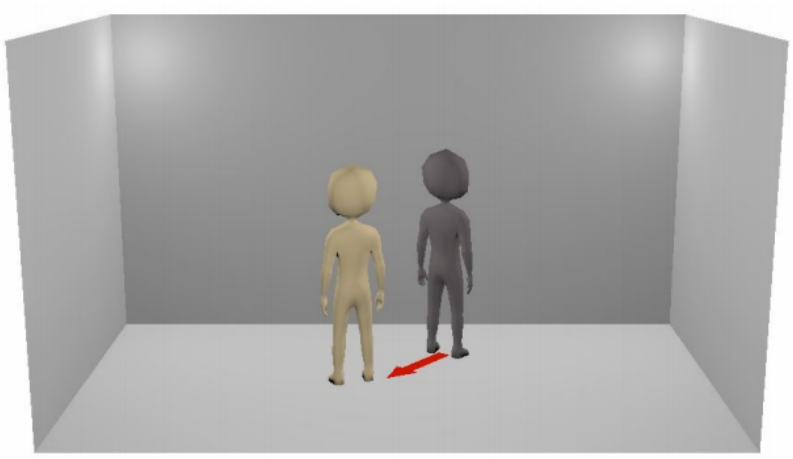
Co-located Navigation

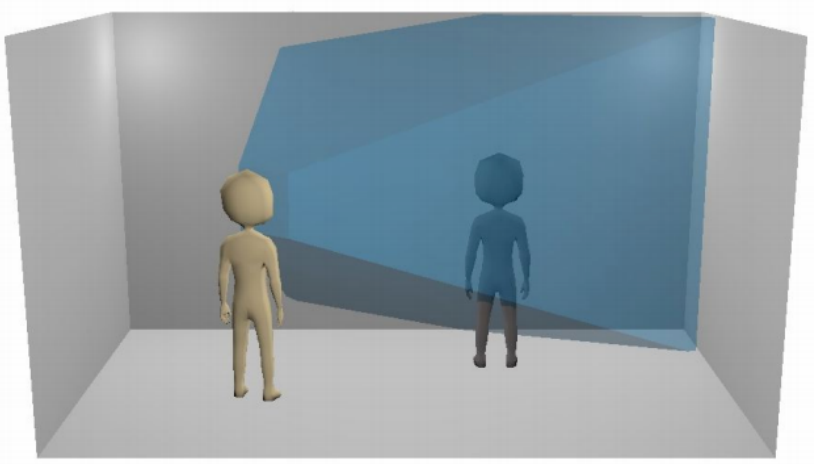


Co-habitation in a CAVE
[Chen et al., 2015]

Problems arise when several users are co-located in a CAVE

- Collisions
- Occlusion





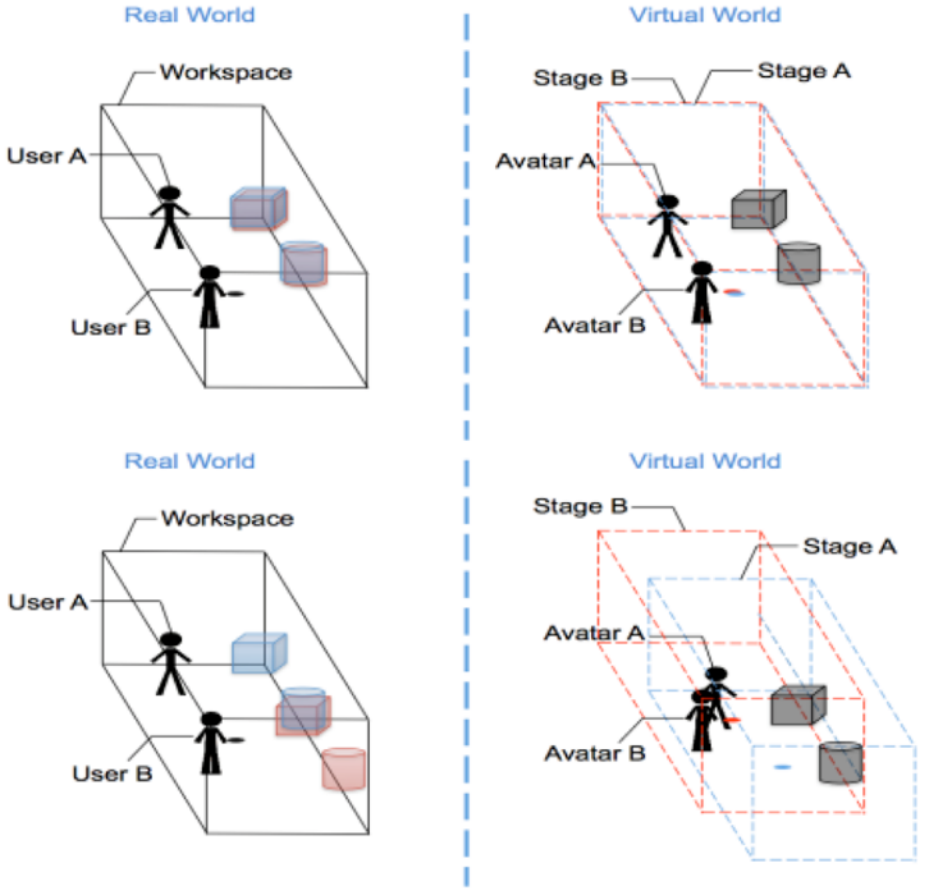
Co-habitation in a CAVE
[Chen et al., 2015]

Problems arise when several users are co-located in a CAVE

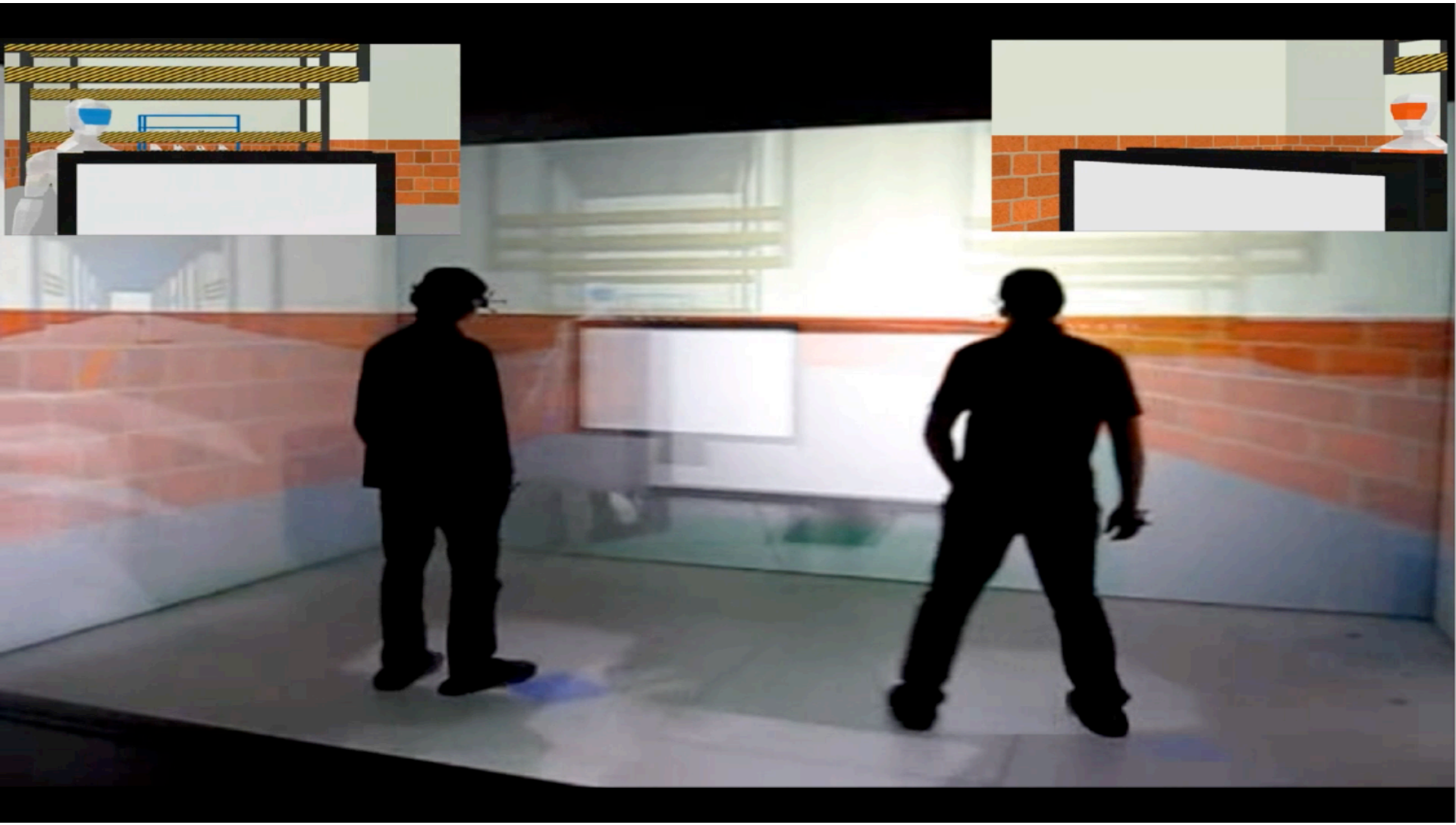
Consistent

vs.

Inconsistent



Co-habitation in a CAVE
[Chen et al., 2015]



Outline

Introduction to Mixed Reality (MR)

Overview of Interaction in MR

Collaboration in MR

- Remote Collaboration
- Co-located Collaboration

Awareness and Communication

Collaborative Interaction

- Navigation
- Co-manipulation

Co-manipulation

Several users manipulate a same virtual object

- Edit a same virtual objet
- Achieve a hard manipulation task in VE
- Mimic the same task than in the real world (training)

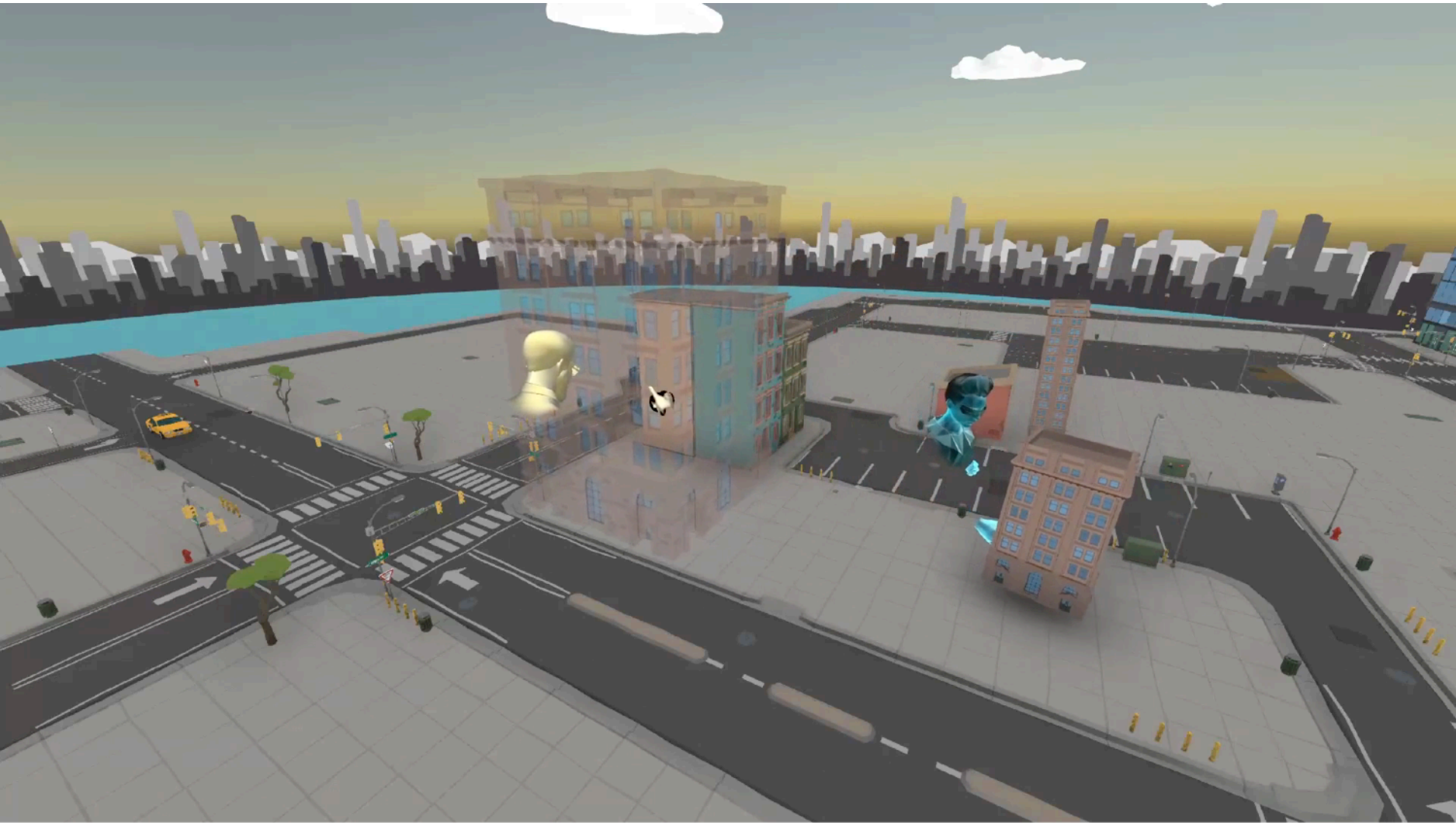
Degree of Freedom (DoF)

- Usually 6 DoF (3 translations, 3 rotations) + the scale
- Some other parameters (color, shape, etc.)

3 solutions: users manipulate

- Copies of the object
- Different DoF of an object
- Same DoF of an object

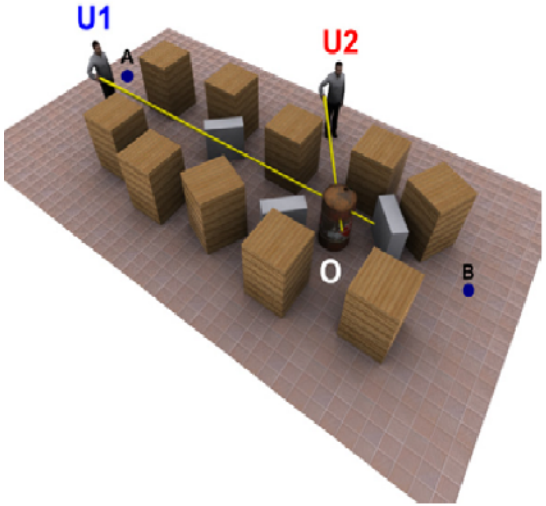
Manipulate copies



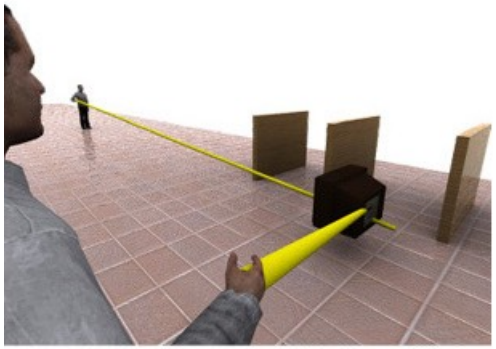
Manipulate different DoF

Users use the same tools

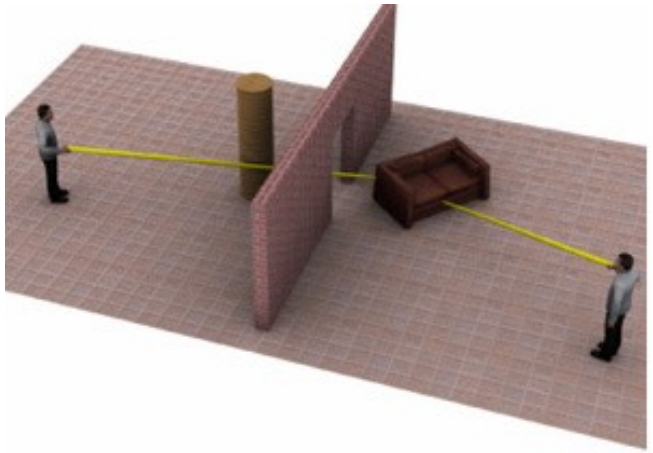
- Ex: two virtual rays [Pinho et al., 2008]
  - Help with obstacles
  - Help when the depth is hard to perceive



User U1's view

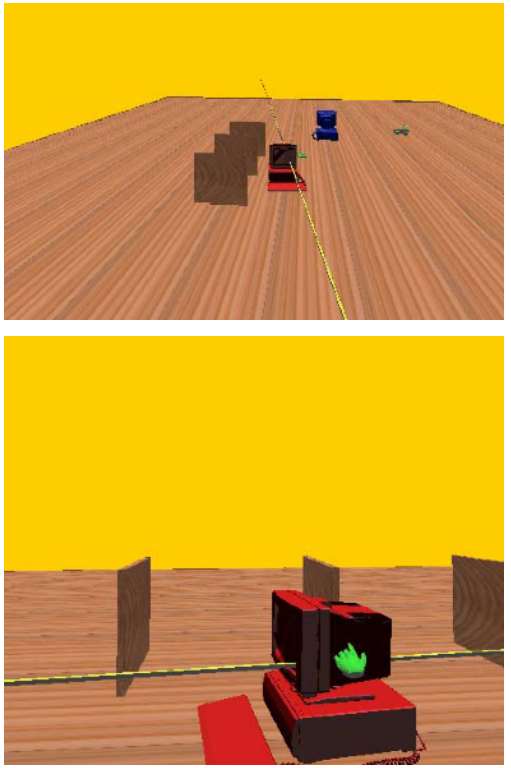


User U2's view



Manipulate different DoF

- Users use different tools
  - Ex: a virtual ray and a virtual hand
    - Virtual ray manages positions
    - Virtual hand manages rotations
  - User studies show [Pinho et al., 2002]
    - Faster, easier and more precise than single user manipulations



[Pinho et al., 2002]

Manipulate the same DoF

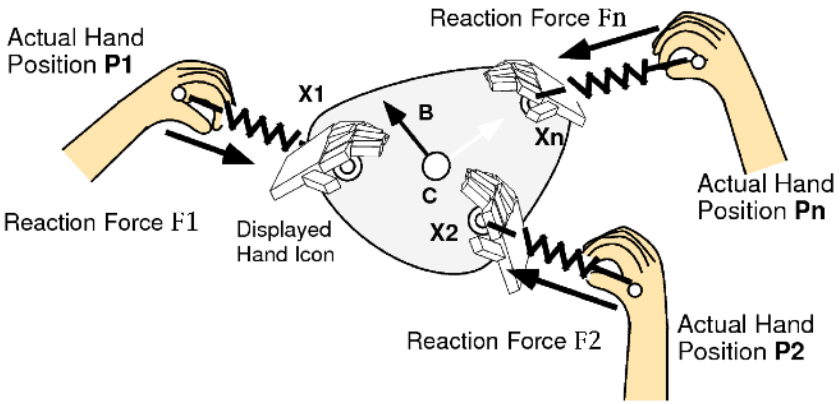
Manipulate together positions and orientations

Compute the mean of each user's actions

Use a physical engine [Noma et Miyasato, 1997]

Positions and orientations are the results of all the forces applied by the users

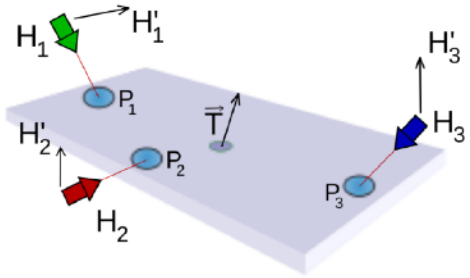
Add springs between users' hands and the object to avoid instability

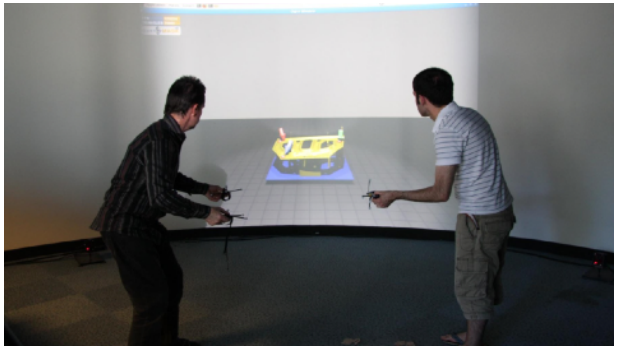


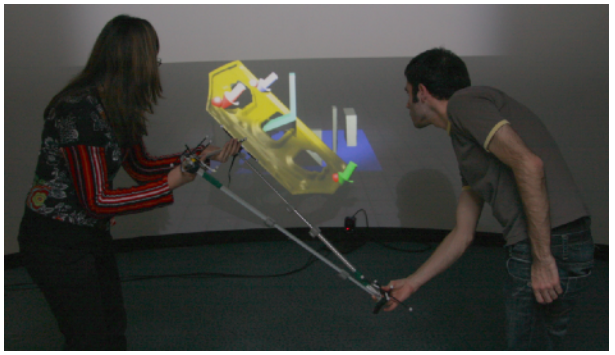
Manipulate the same DoF

Holding together a virtual object

- Need at least 3 control points
- 3 hand manipulation technique [Aguerreche et al., 2009]
  - One user has 2 control points
  - The other has 1 control point
  - Co-located or remote collab. [Fleury et al., 2012]
  - Implemented with a prop (Reconfigurable tangible device) [Aguerreche et al., 2010]



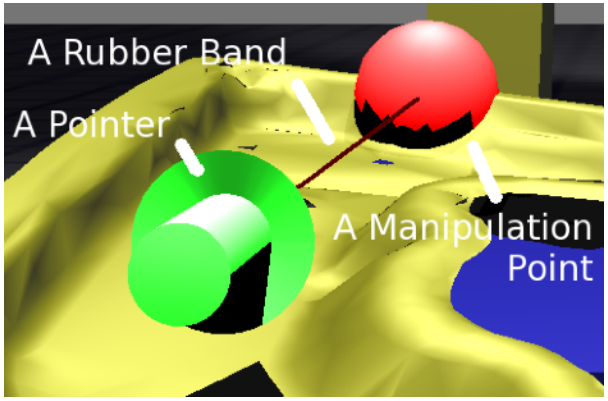




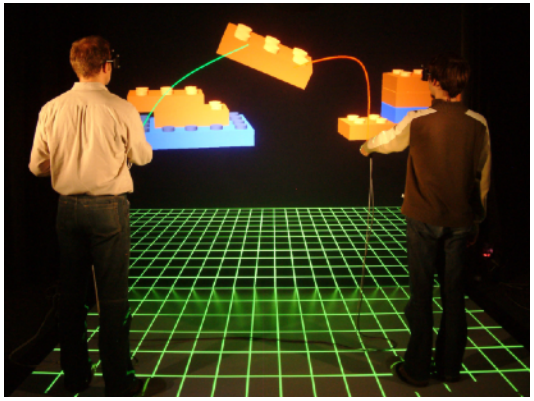
Manipulate the same DoF

Provide feedback to users about their actions

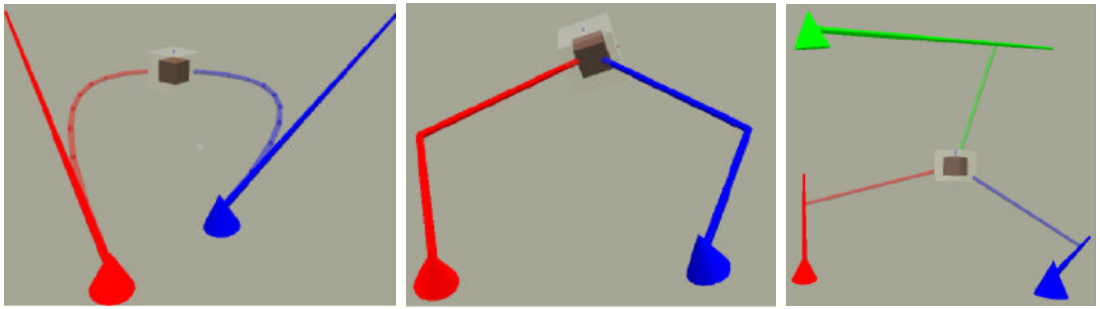
- Force feedback with haptic devices
- Springs or rubber bands
- Curve virtual ray



[Aguerreche et al., 2009]

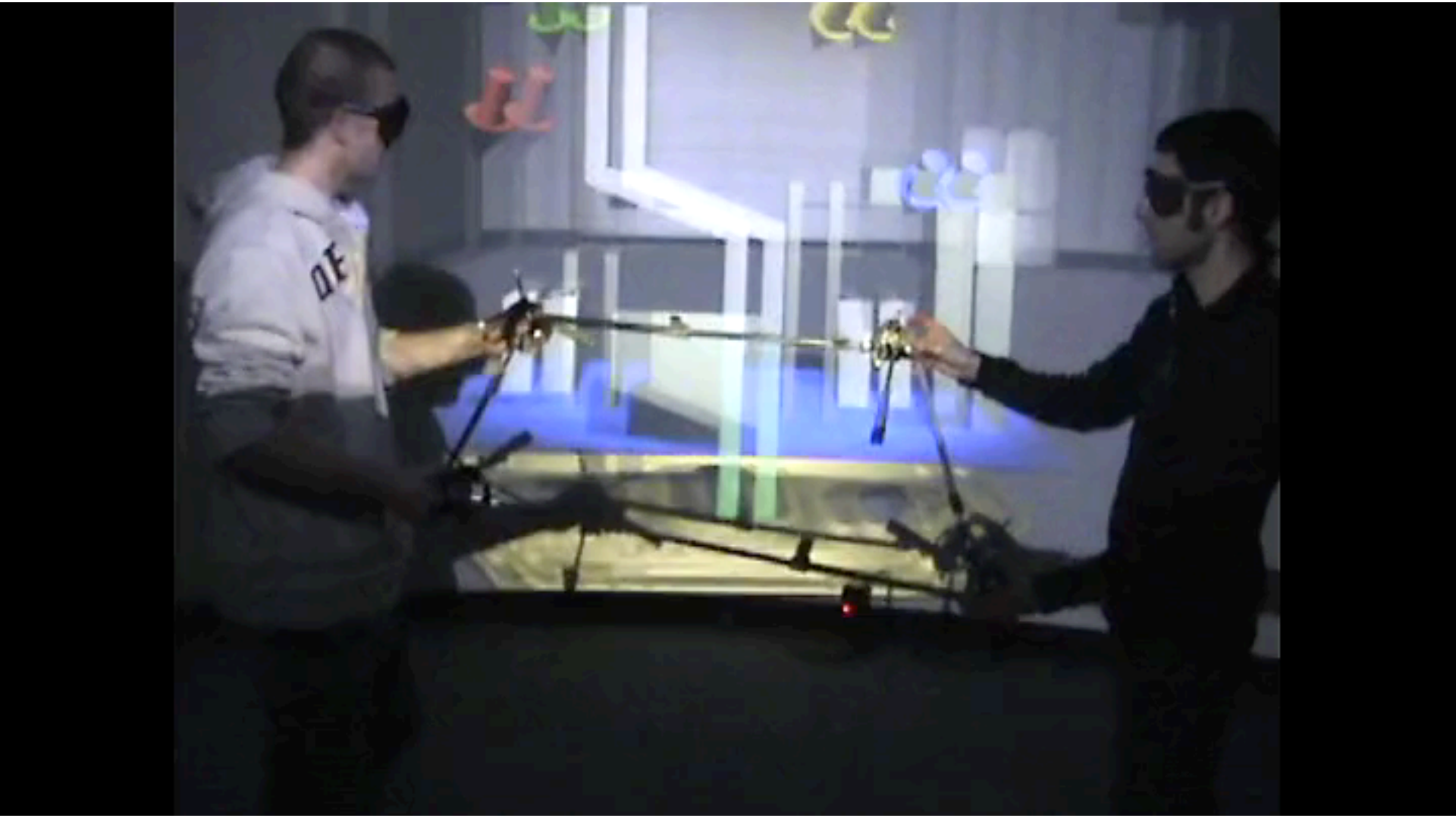


[Riege et al., 2006]

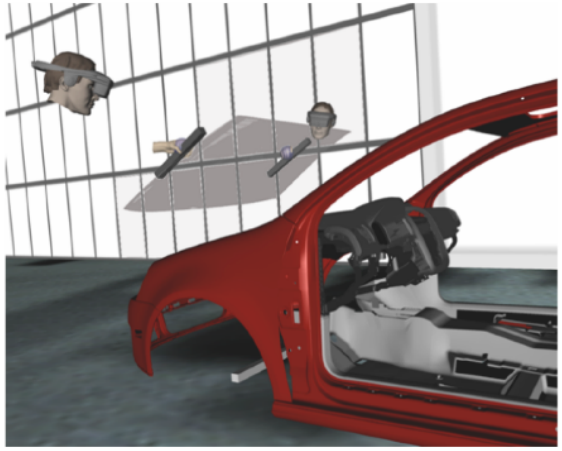


[Duval et Fenals, 2002]

Co-located manipulation
[Aguerreche et al., 2010]



Co-located manipulation


Even if users cannot see the others,

haptic feedback is still important

[Salzmann et al., 2009]

Conclusion

Co-located vs. Remote collaboration

- Social presence is a continuum

Several solutions to represent users in a CVE

- From realistic to simplified solutions
- Activities/Capabilities perception

Usually voice communication

- But not so much tools to improve the communication

Wide range of collaborative interaction

- Navigation together or help the other to navigate
- Move virtual objects together

Conclusion

- Feedbacks of the others are very important
  - Especially for co-manipulation
- Applications of CVE
  - Co-expertise, collaborative review or design
  - Training
    - Learn a collaborative task
    - Learn with a remote teacher
    - Learn with additional virtual content
  - Entertainment (video games, artistic performance, etc.)
  - Social presence (telepresence)