

Collaborative Virtual Environments

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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

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Virtual Reality

Virtual environment (VE)

3D virtual world

Simulated by computers



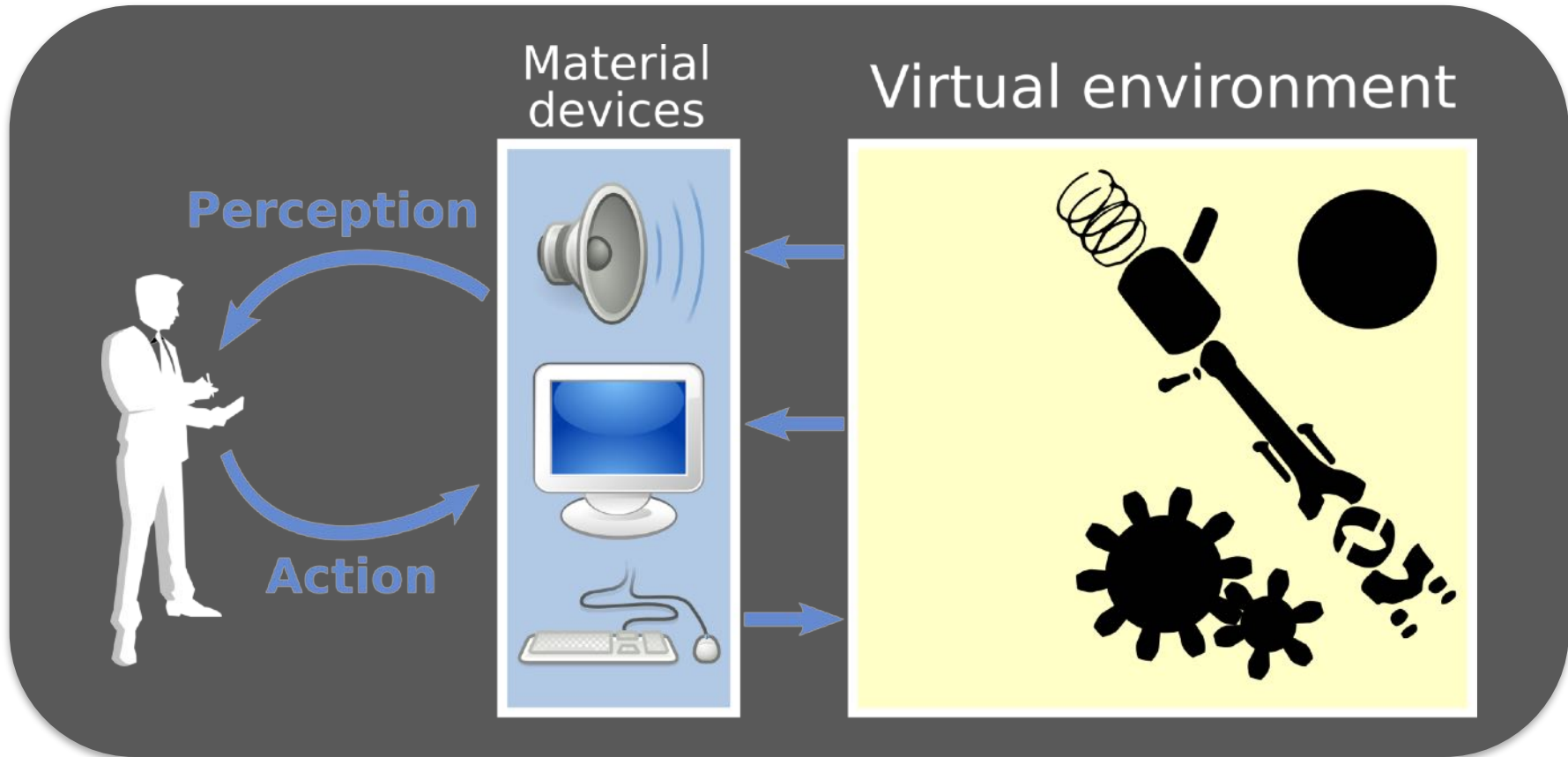
Interaction in real-time

Through various material devices

Immersion

Multi-sensorial perception of the VE

Action/perception loop



Immersive devices



Ivan Sutherland (1968)



HTC Vive



CAVE (Univ. Chicago)



EVE (LISN)

The power of immersion

Body perception



Anatole Lécuyer

Cure phobia



Inria Reves

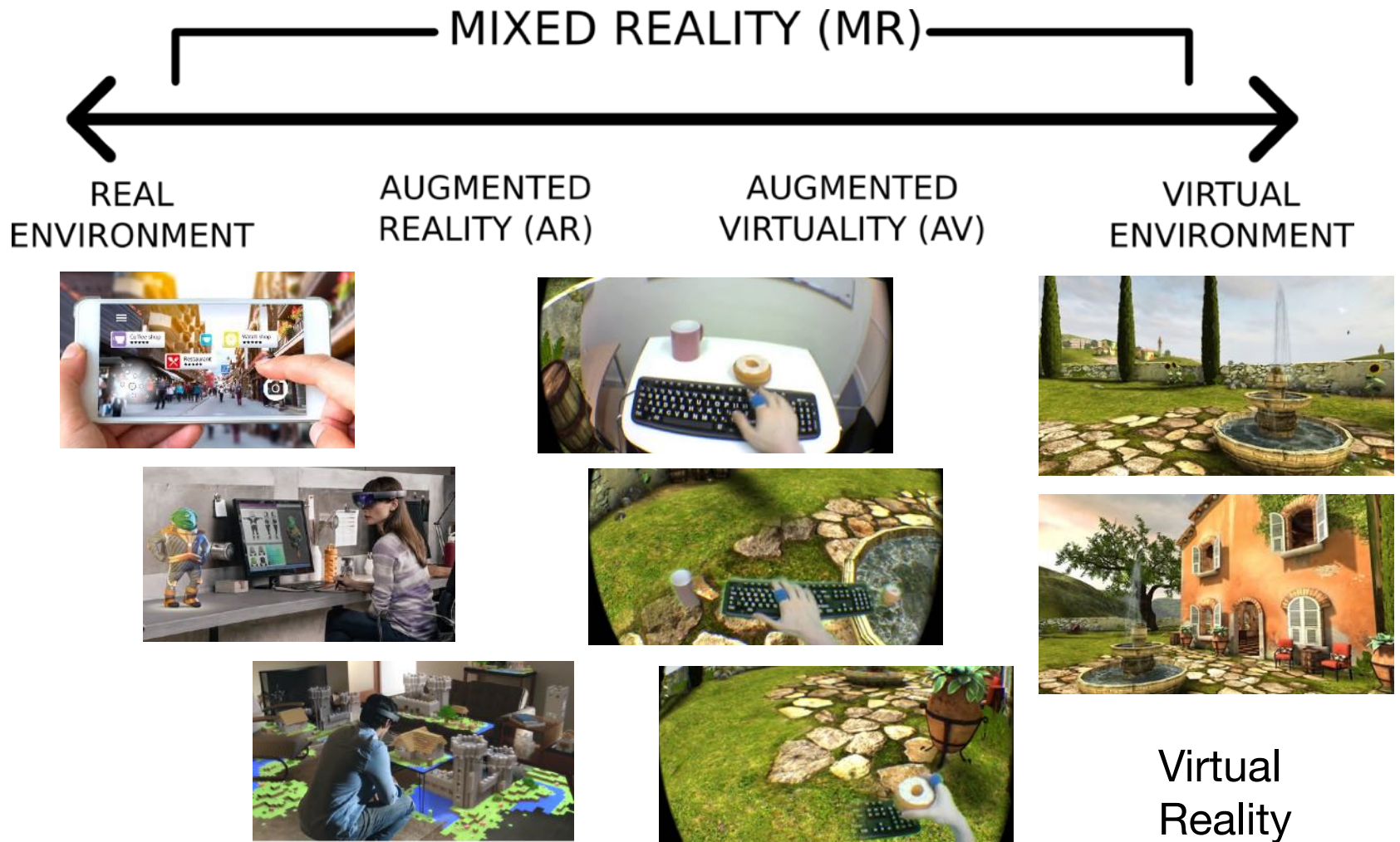
Augmented Reality

Real environment + Virtual environment

Add virtual information onto the real environment

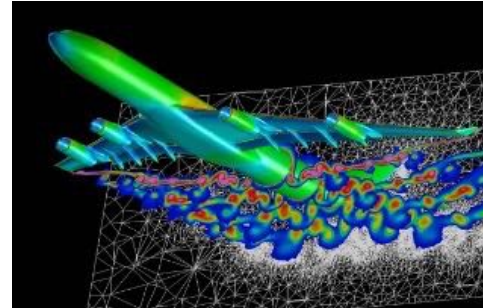


Milgram Continuum



Applications of Mixed Reality

Scientific data analysis



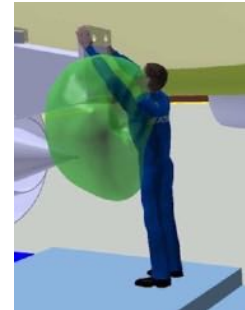
Industrial applications

Design, conception

Fabrication



Training, education



Phobia therapy, rehabilitation



Entertainment



Video games

Virtual visits of museums

Social communication (telepresence)



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Interaction

3 kinds of interaction techniques [Hand, 1997]

Viewpoint manipulation (navigation)

Object manipulation (interaction)

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.*

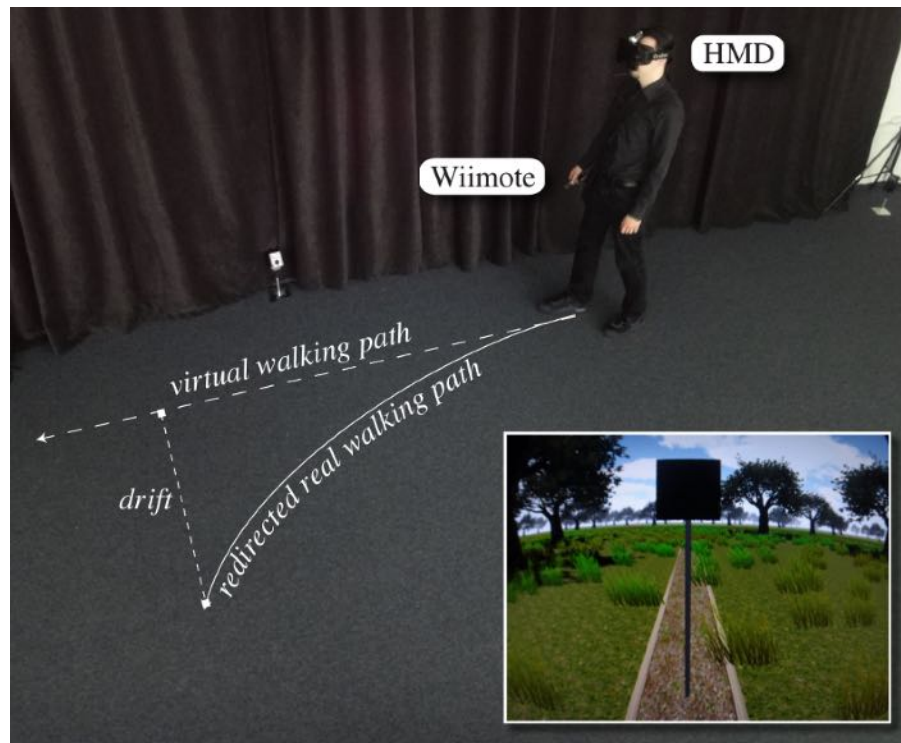
Navigation

Egocentric techniques

Walking metaphor

Flying metaphor

Driving metaphor

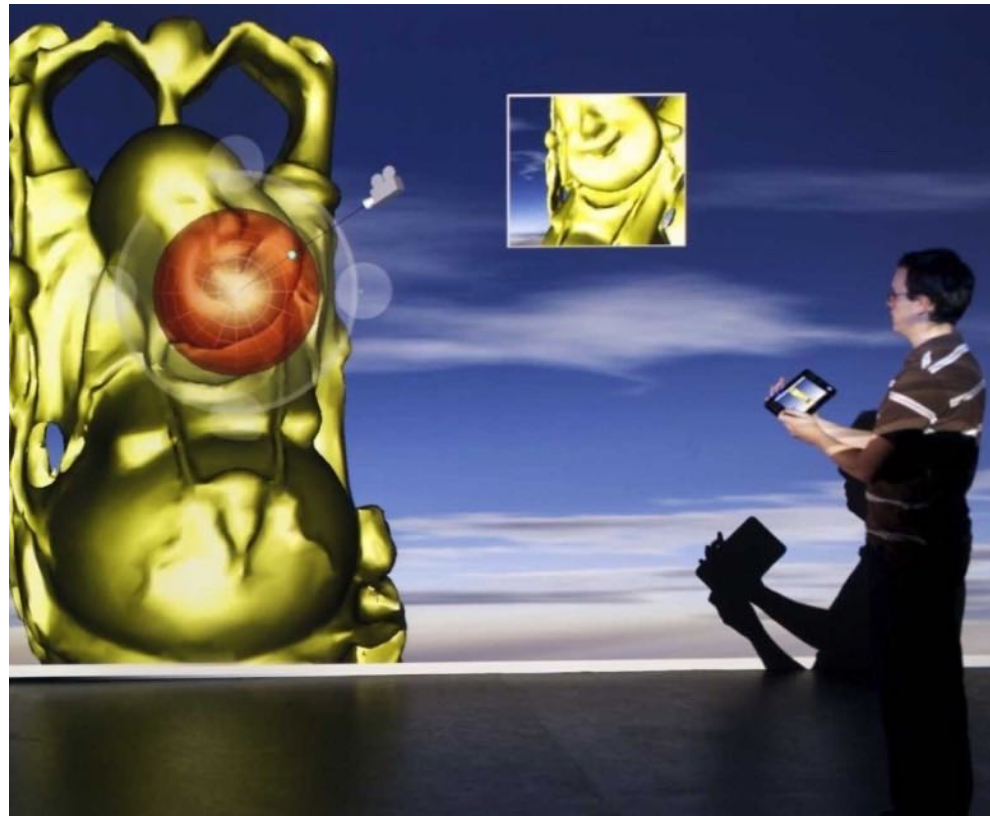


Navigation

Exocentric techniques

Navidget [Hachet et al., 2008]

Grabbing the air [Mapes et Moshell, 1995]



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 (pre-)defined paths



[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]



Object Manipulation

Virtual Ray [Mine, 1995]

Mimics a laser pointer

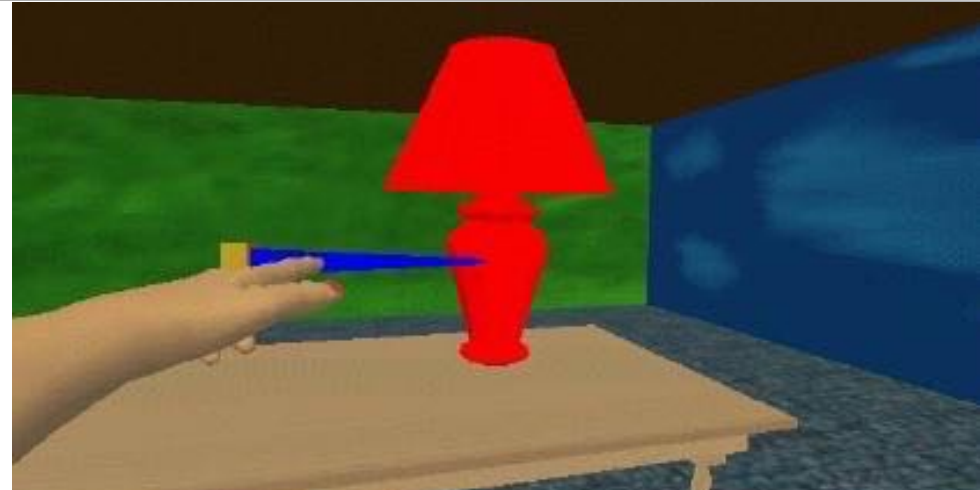
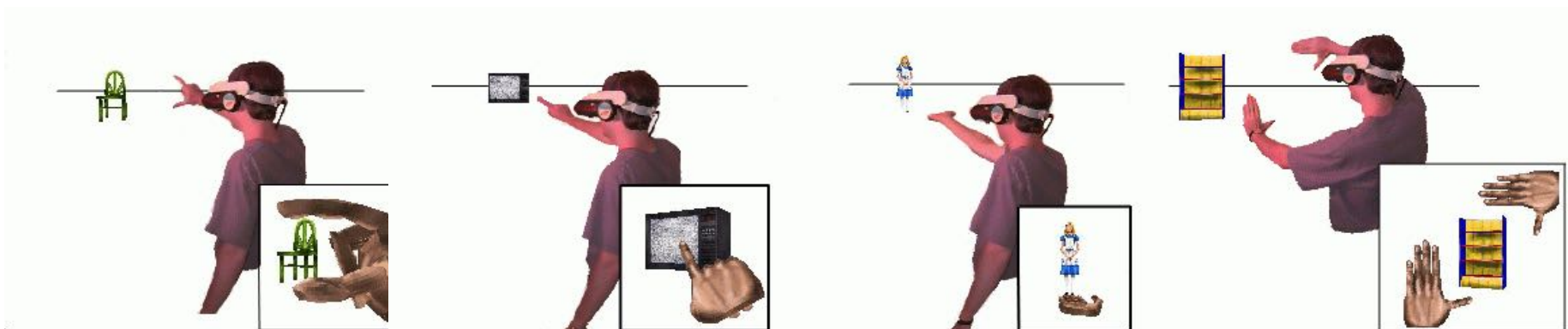


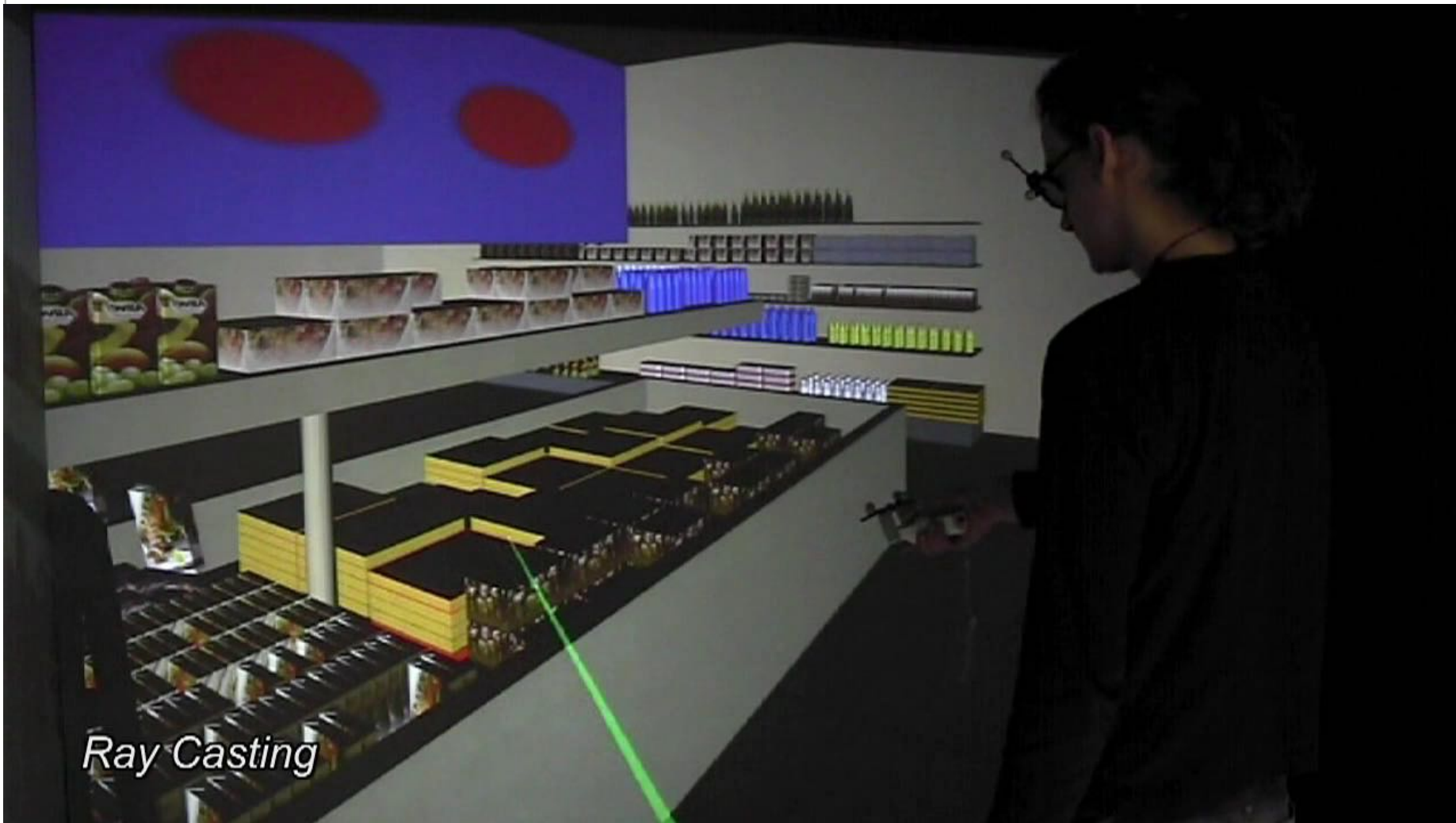
Image plan Interaction [Pierce et al., 1997]

Select by pointing with one part of the body



Object Manipulation

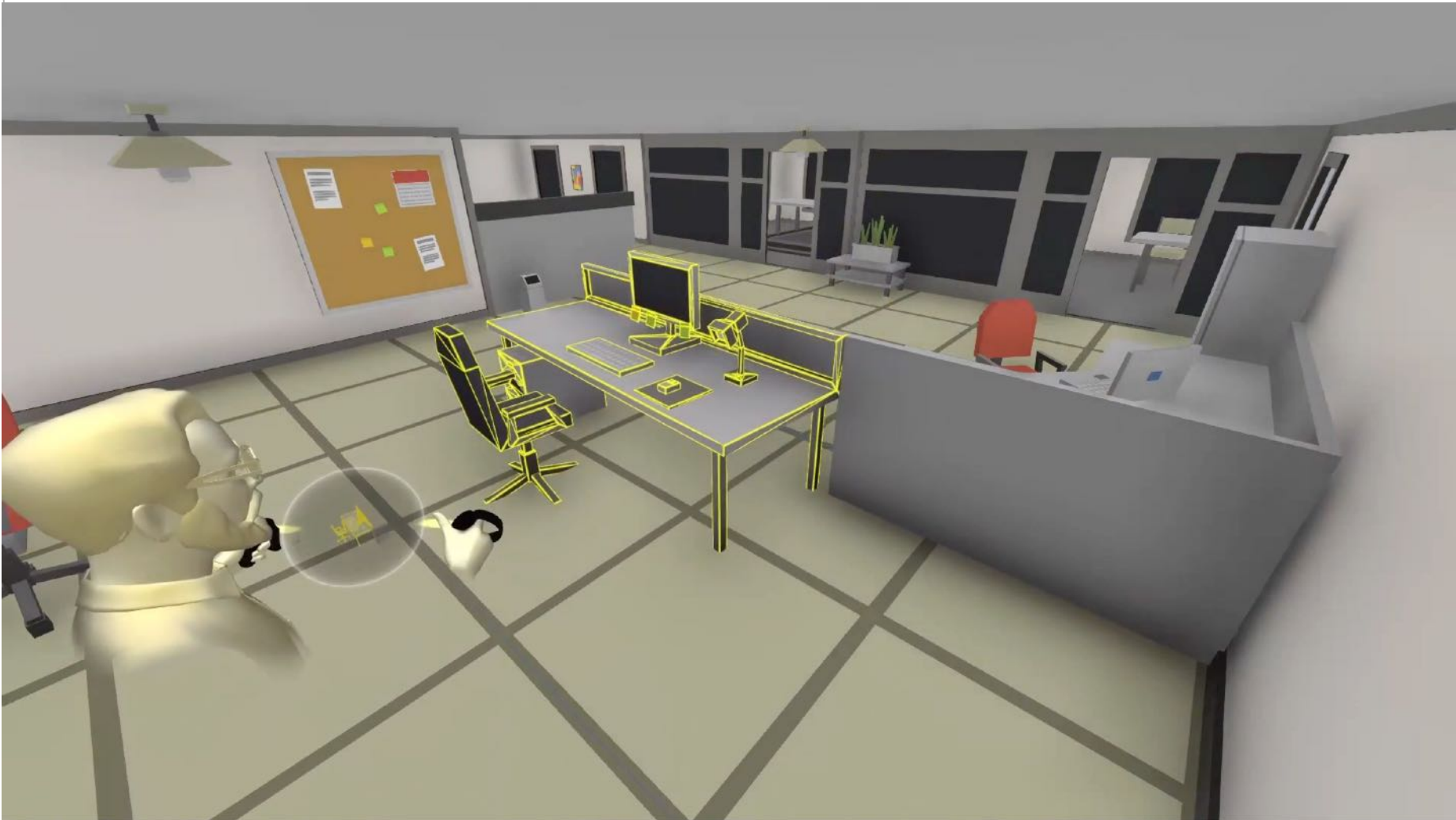
Virtual Ray [Mine, 1995]



Ray Casting

Multi-object manipulation

Containers & controls in Spacetime [Xia et al., 2018]



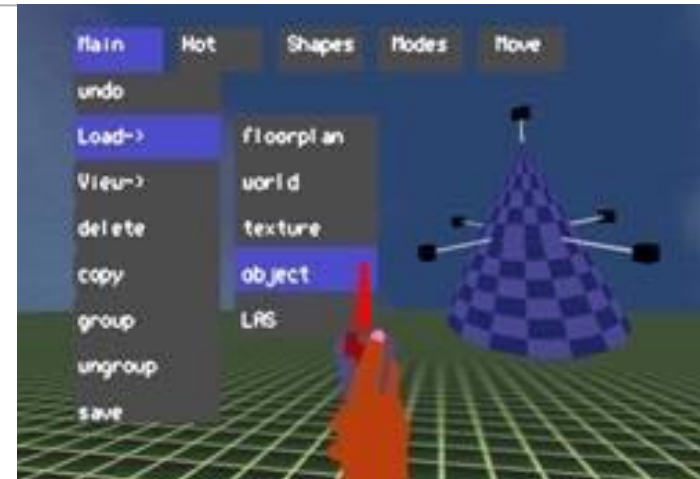
Application Control

Control

Application (exit, pause,...)

Rendering parameters

Tools/actions selection



[CDS – Bowman et al., 1991]

Techniques used

2D menus

3D menus

Control on a tablet/smartphone



[CHIMP – Mine et al., 1997]

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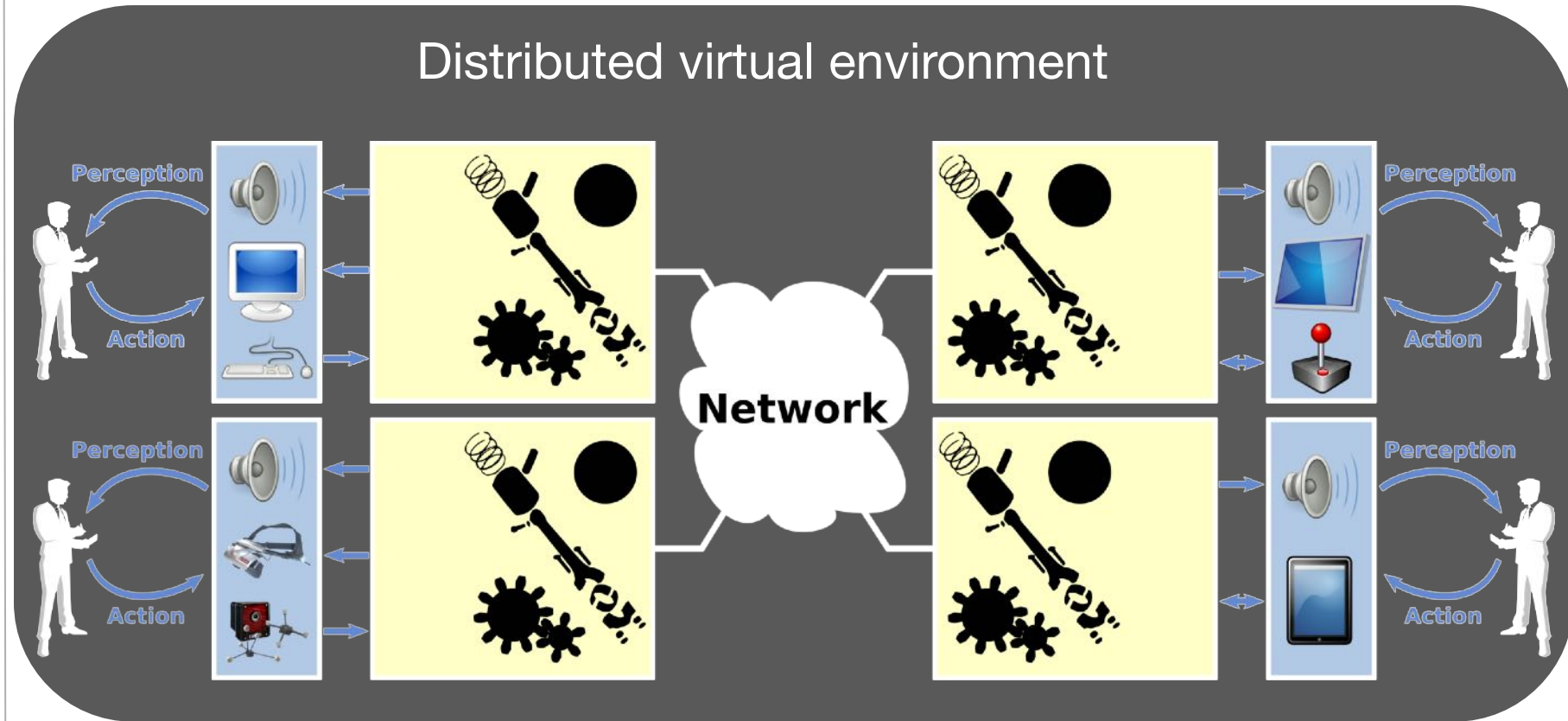
Awareness and Communication

Collaborative Interaction

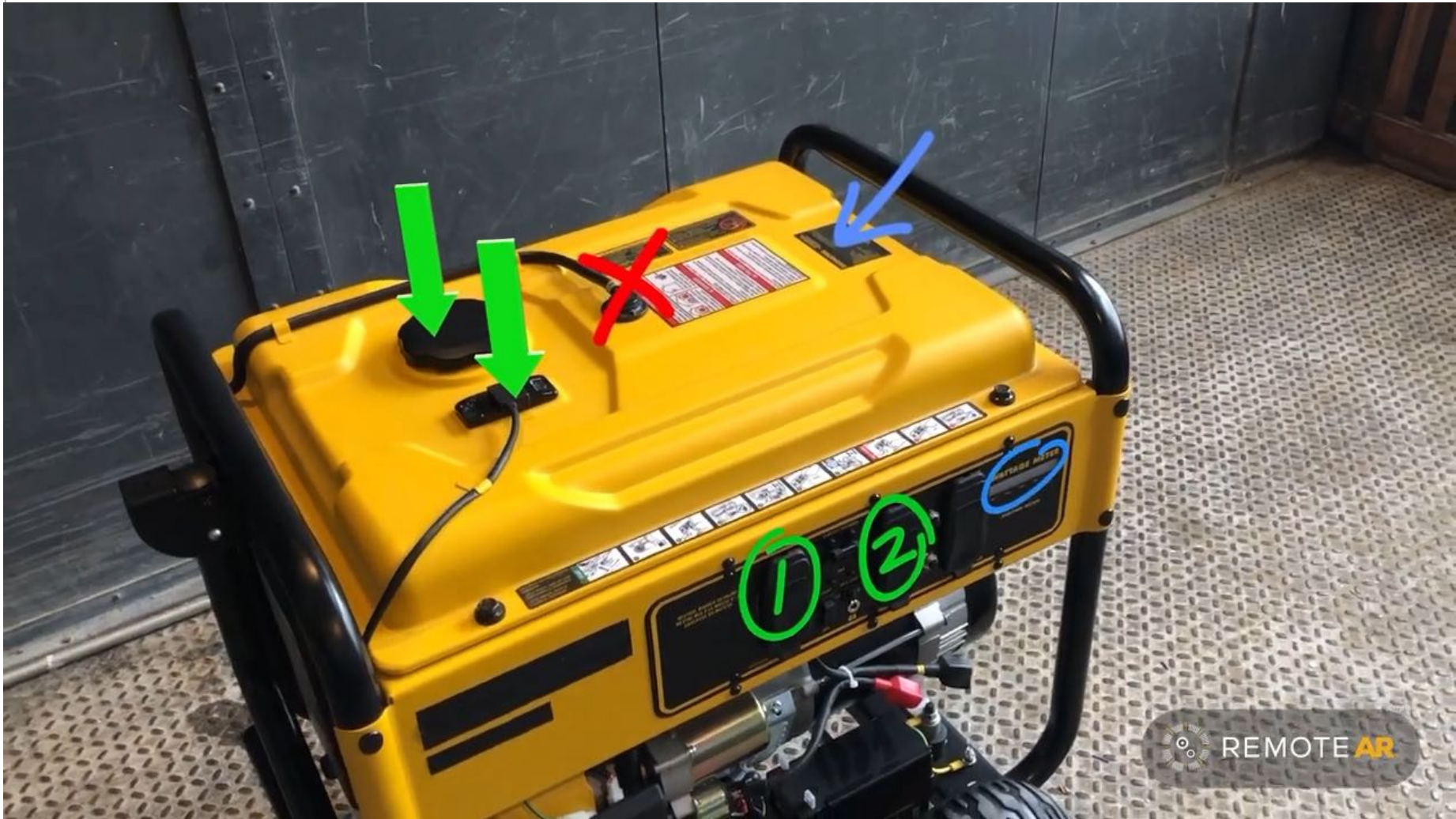
- Navigation

- Co-manipulation

Remote Collaboration

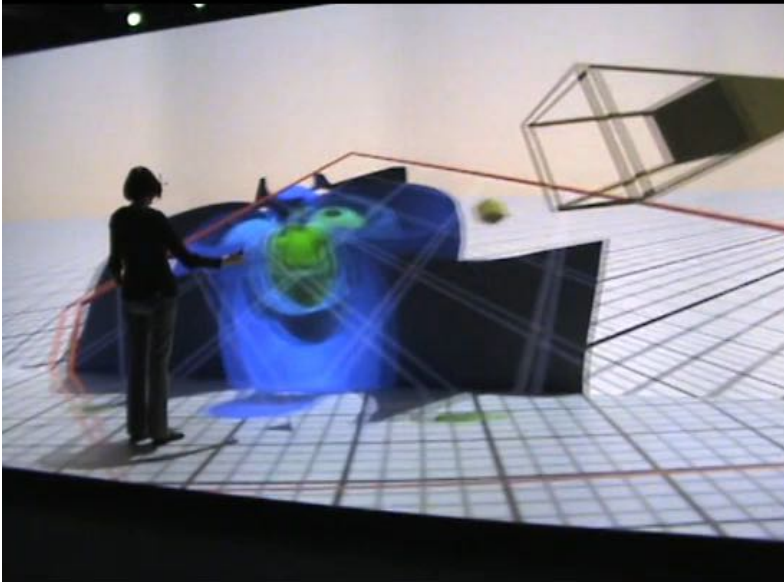


Remote Collaboration in AR

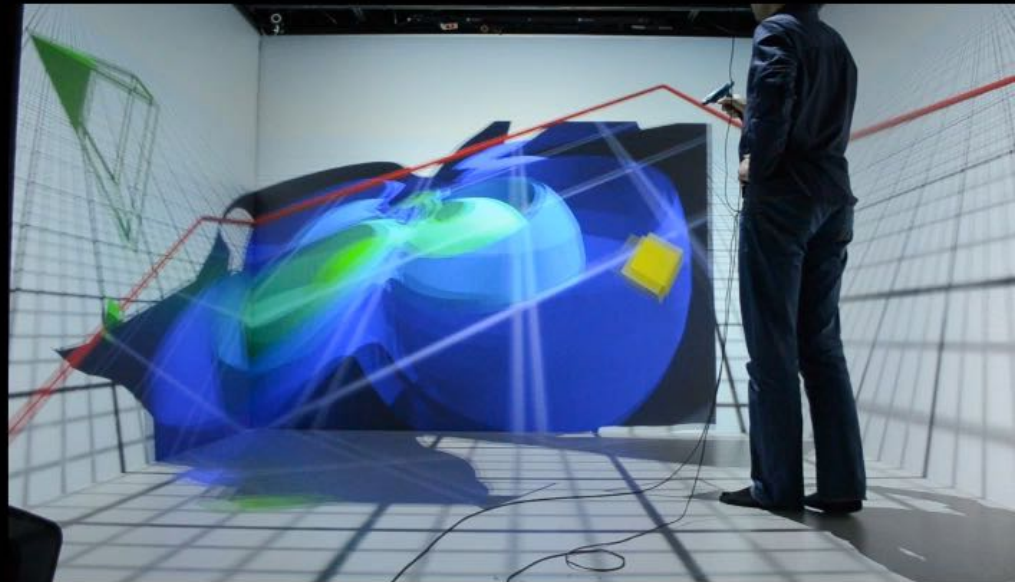


Remote Collaboration in VR

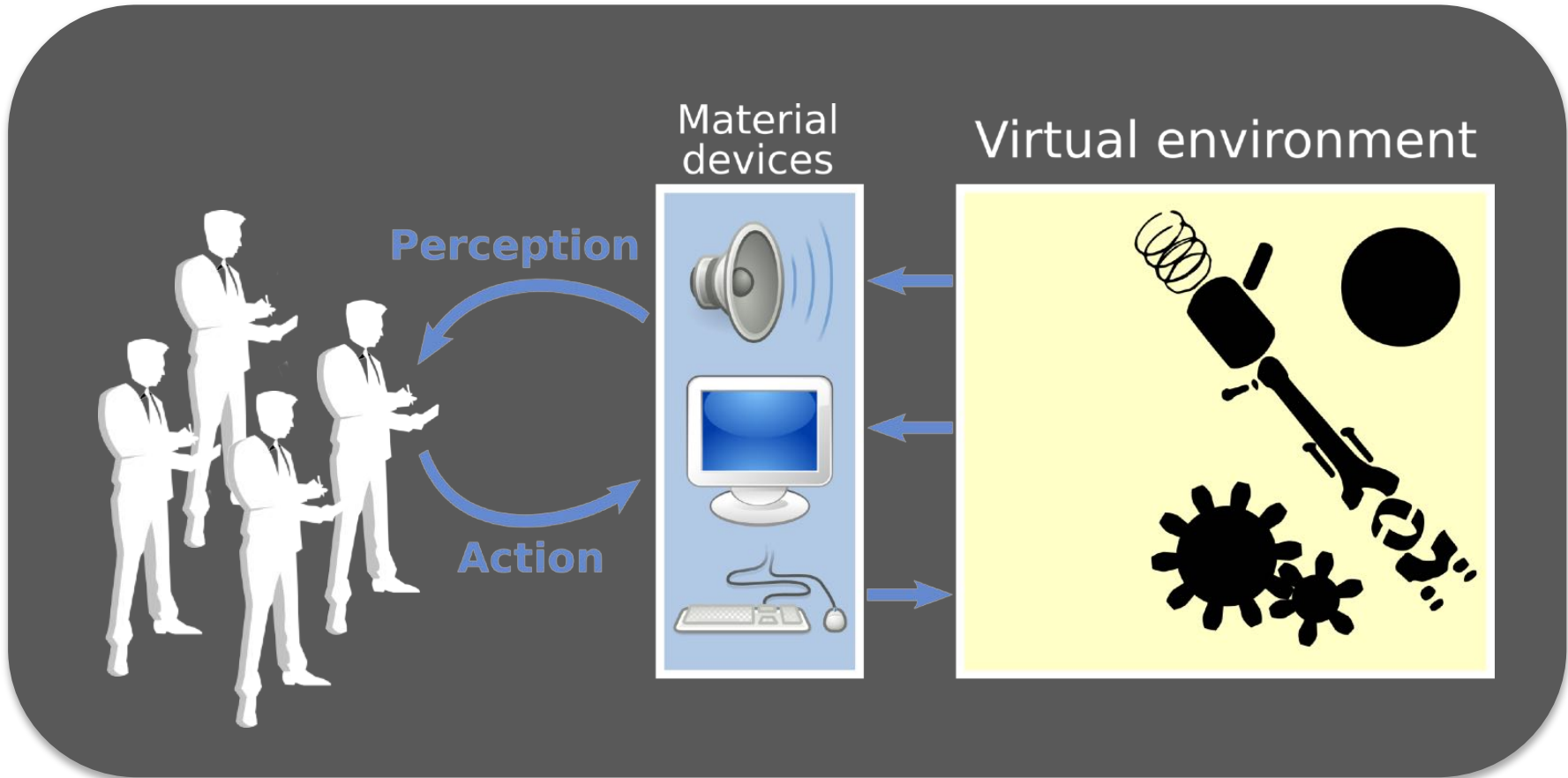
Rennes
(INSA / IRISA)



London
(UCL)



Co-located Collaboration

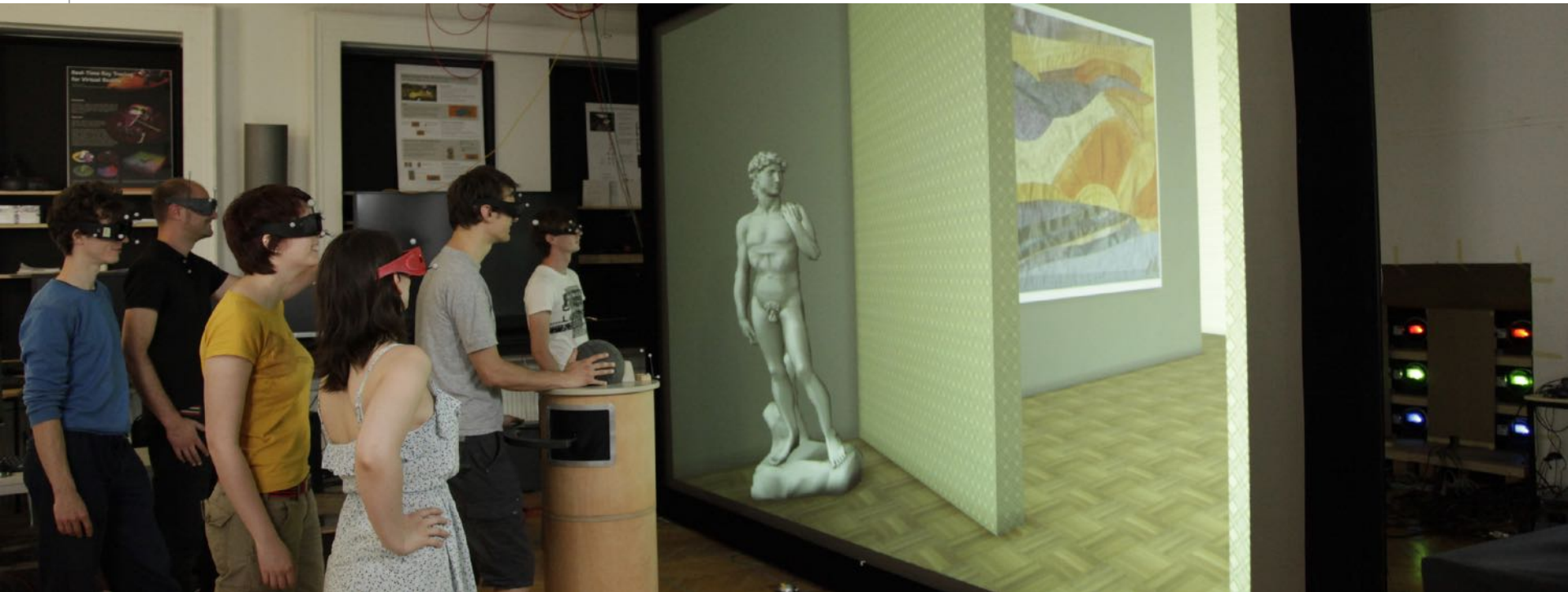


Co-located Collaboration in AR



Co-located Collaboration in VR

Integrate several users in a VE with the same devices

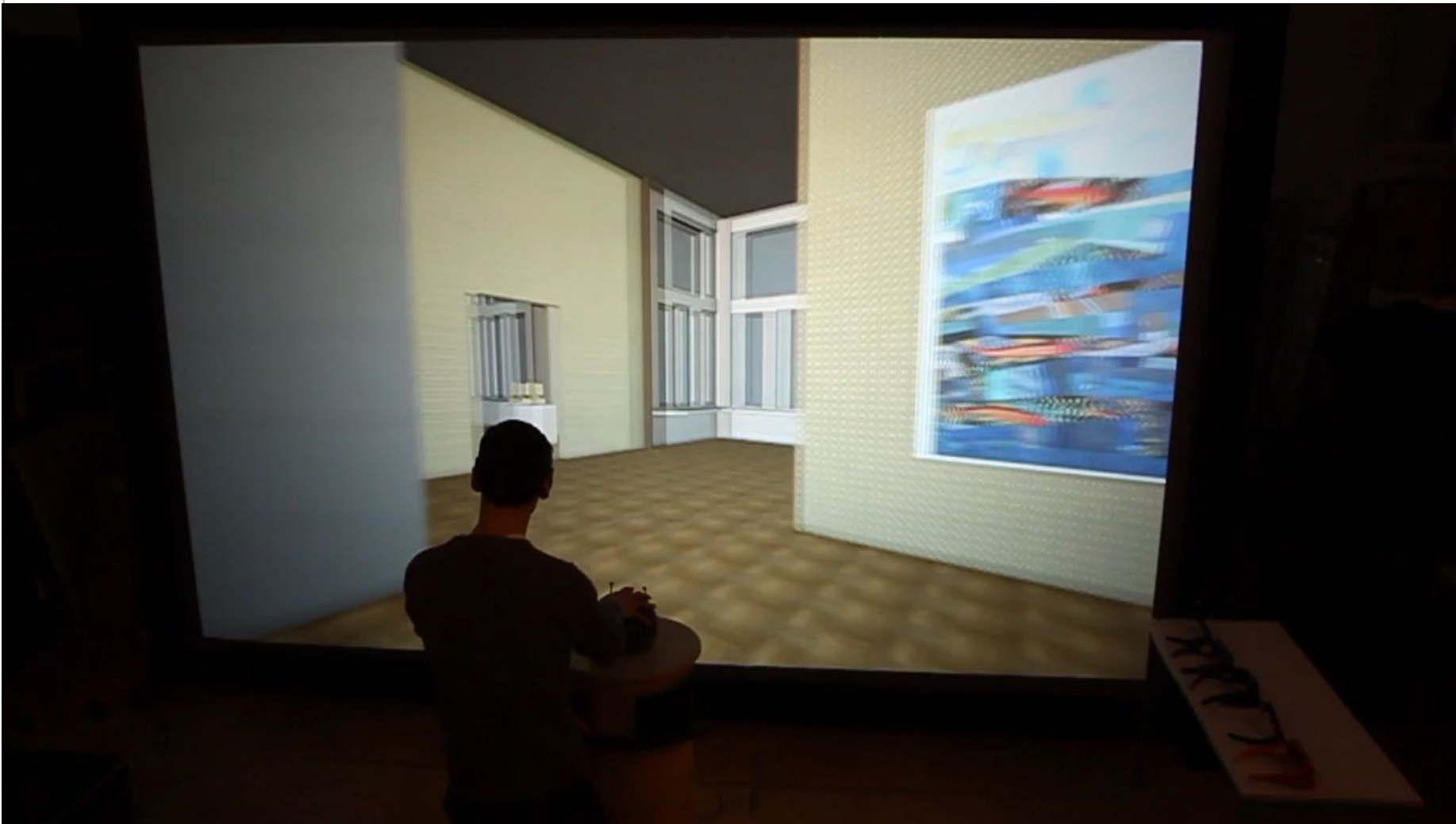


[Kulik et al., 2011]

Multi-stereoscopic display

Integrate several users in the same devices

[Kulik et al., 2011]

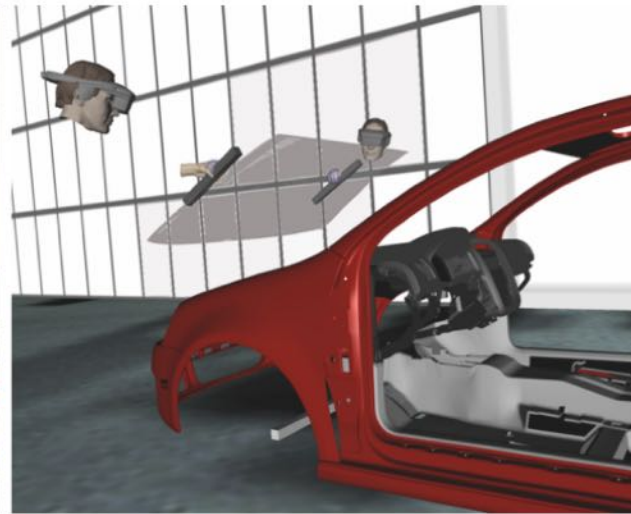


Co-located Collaboration in VR

Users cannot see the other in the real world

Users can hear the other

Users can feel the haptic force of the other



Mutual human actuation

[Cheng et al., UIST 2017]



Co-located *vs.* Remote

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

2 users with AR headsets in the same room?

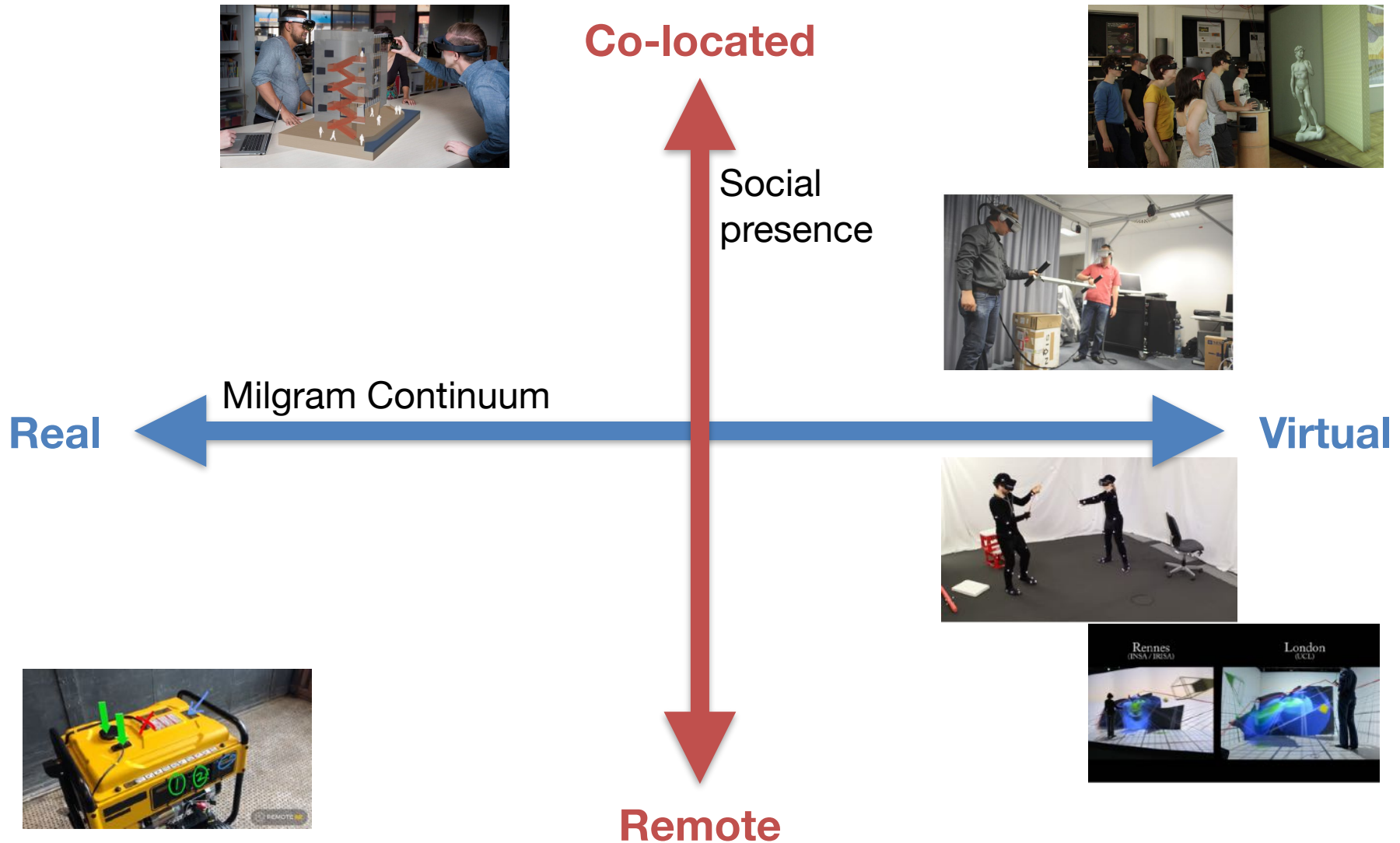
2 users in a CAVE?

2 users with HMDs in the same room?

2 users with HMDs in a different room?

2 users with HMDs & headphones in the same room?

Collaboration in MR



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Awareness

Perception of the other users

Where are they?

What are they doing?

What are they looking at?

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 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

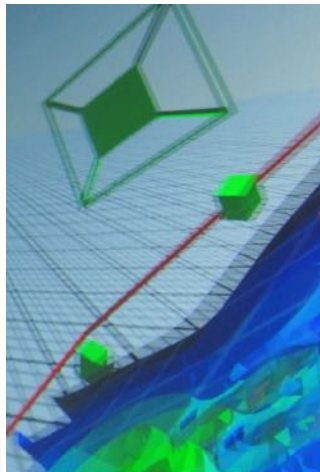
Visual awareness

Audio awareness

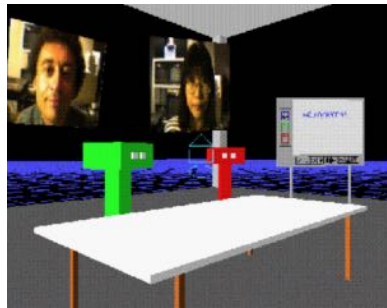
Haptic awareness

Visual Awareness

Avatar: representation of users in the VE



[Fleury et al., 2012]



[DIVE, 1991]



CALVIN, 1996



Second Life, 2005



[Beeler et al., 2010]

Kinect Avatar

THE TECHNOLOGY BEHIND
avatar**KINECT**TM

Embodiment and sense of presence

Self-image

Body swapping

Milgram experiment

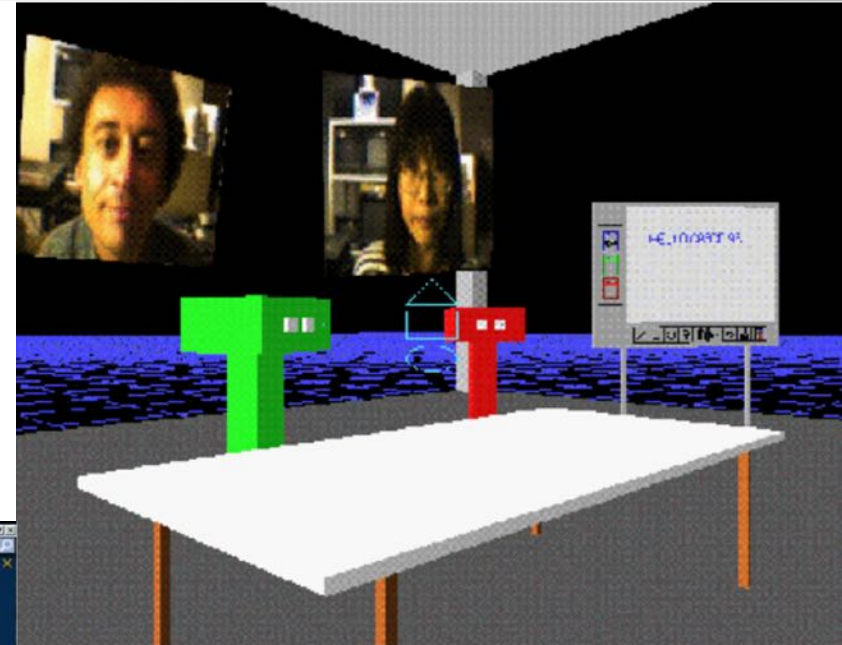
[Mel Slater]



Social Presence

Animated avatars

Collaborative interaction



DIVE (1991)



Second Life (2005)

Social Presence

Animated avatars, Collaborative interaction, Video facilities

[Facebook Social VR Demo - Oculus Connect 2016]



“The metaverse”



Cross-game Avatar Platform for the Metaverse

One avatar, many worlds to explore.

[Create Avatar](#) or [Are you a developer?](#)

Used by 2500+ developers. [See all](#) →



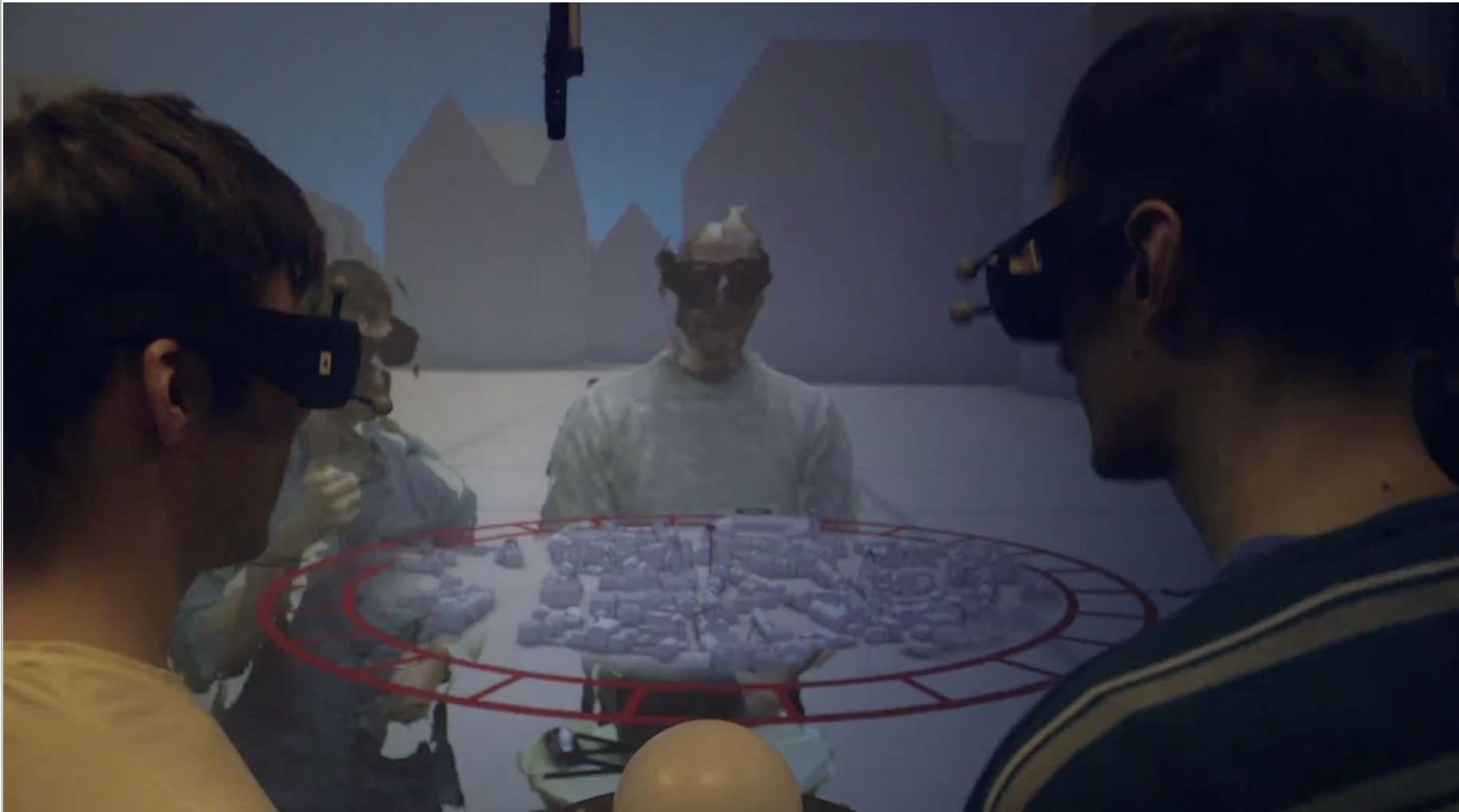


Ready player me

Social Presence

Real 3D video integration, Collaborative interaction,
Specific tools for collaboration

[Beck et al., IEEE VR 2013]



Telepresence in virtual reality

Animated virtual characters

Real 3D video integration

Video facilities



Audio Awareness

Spatialized voice restitution

Remote users' noises

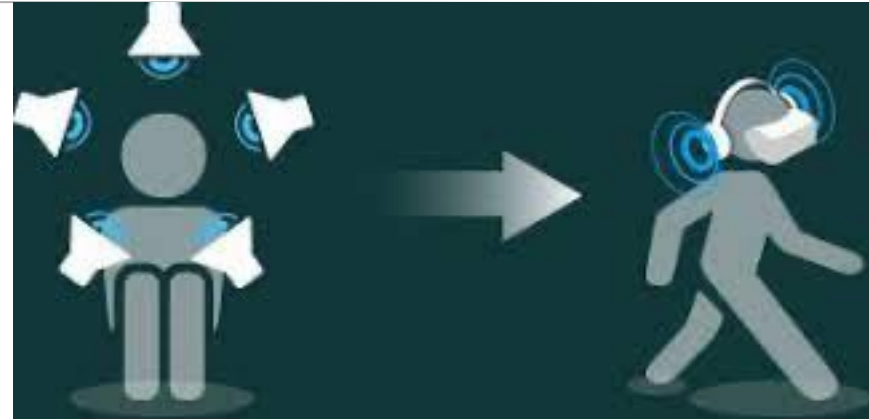
Give a lot of information

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

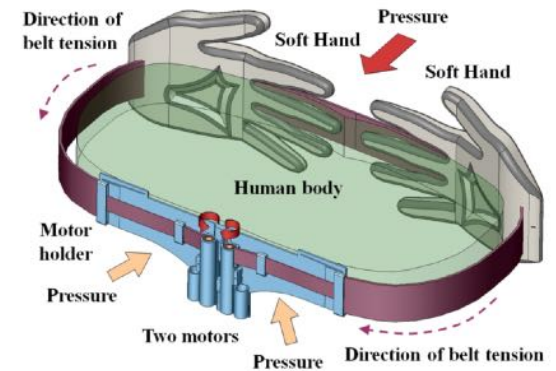
Direct

Touch the others through haptic devices

Virtual handshake

Affective haptic

Can be asymmetrical



Indirect

Manipulate an object together

Feel the force applied by the other on the object

Awareness Model

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

Compute which users can interact with which others

Measure of awareness between two users

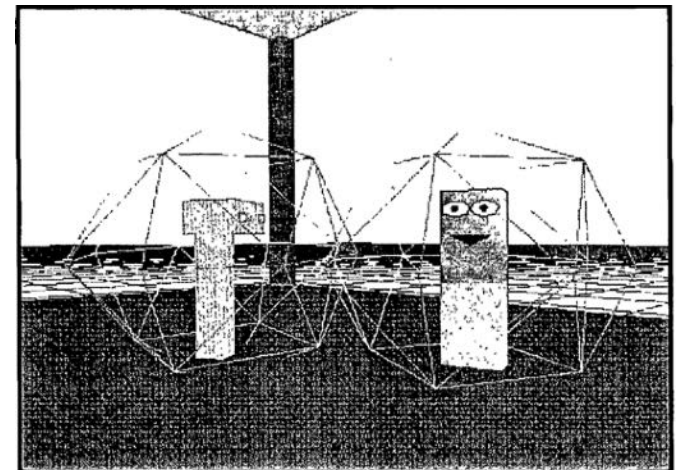
Medium

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]

Aura determines potential interactions
(on a technical point of view)

Users are responsible for controlling interactions

Measure of awareness between two users

Asymmetrical

Dependent of the **Medium**
(i.e. different for each **Medium**)

Introduction of the **Focus** and **Nimbus**

Awareness Model

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

Focus

Area where a user perceives the others

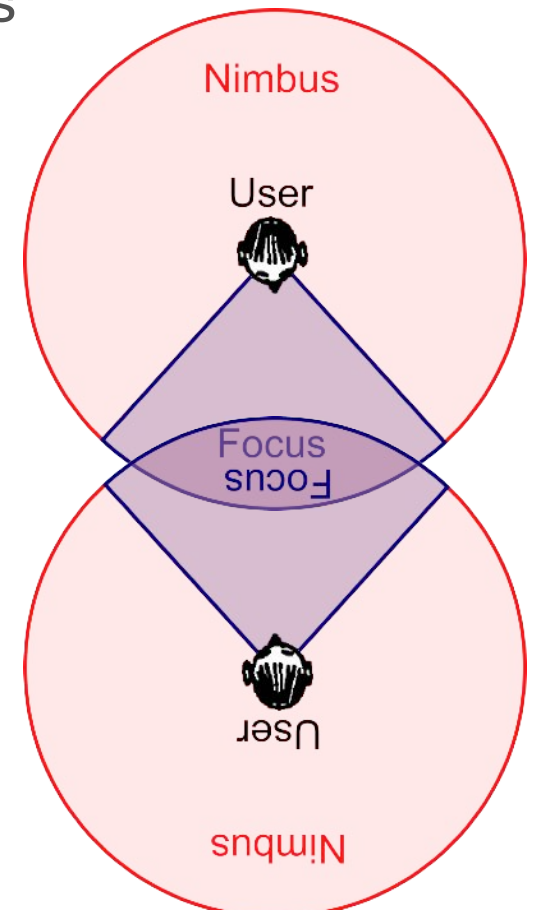
For each particular **Medium**

Nimbus

Area where the others can perceive a particular user

For each particular **Medium**

Different from the **focus**



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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 others follow

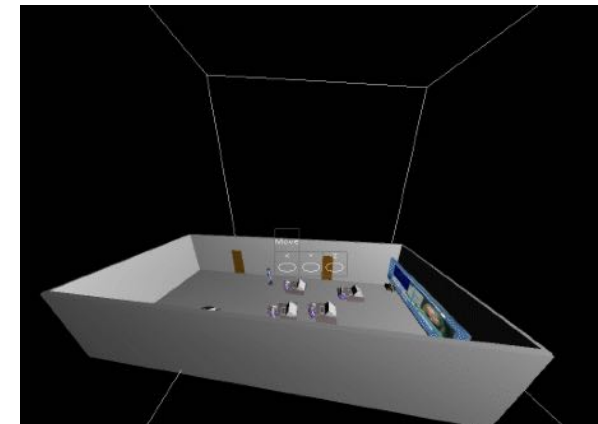
One moves and the others follow with an offset

One user drives, the others can modify their offset

World in Miniature

Guide the others through the WIM

Move the others through the WIM



[CALVIN, 1996]

Group Navigation

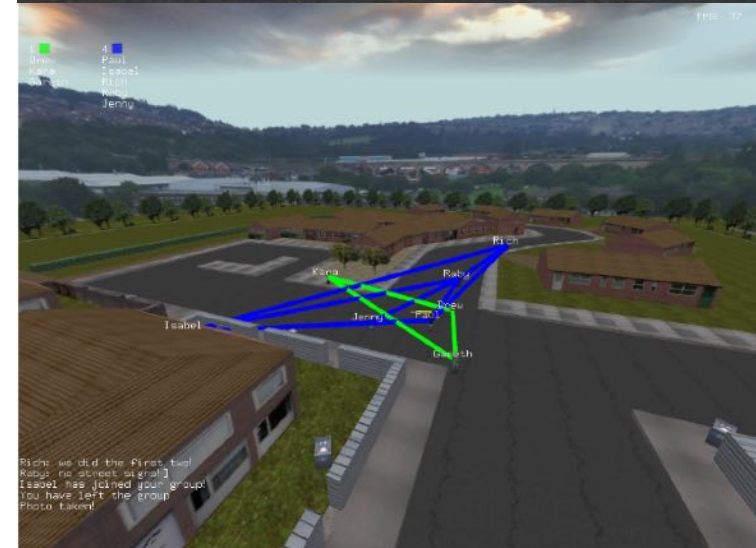
Each user can travel independently, ... or

[Dodds & Ruddle, 2008]

Users can be part of a predefined group, and have functionalities that help them travel with the group

To follow the first member of the group

To come back to the middle of the group
(mean of member positions)



Collaborative teleportation

Spacetime

[Xia et al., 2018]



Co-located Navigation

Integrate several users in the same environment

[Kulik et al., 2011]



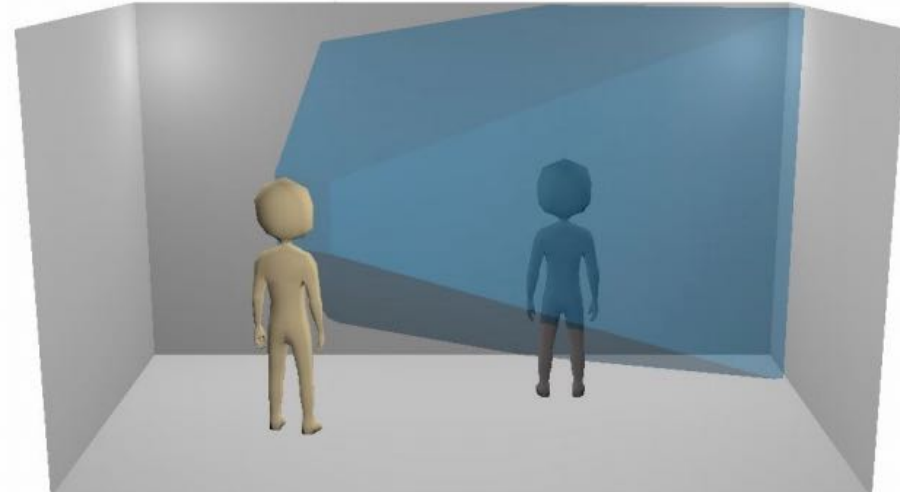
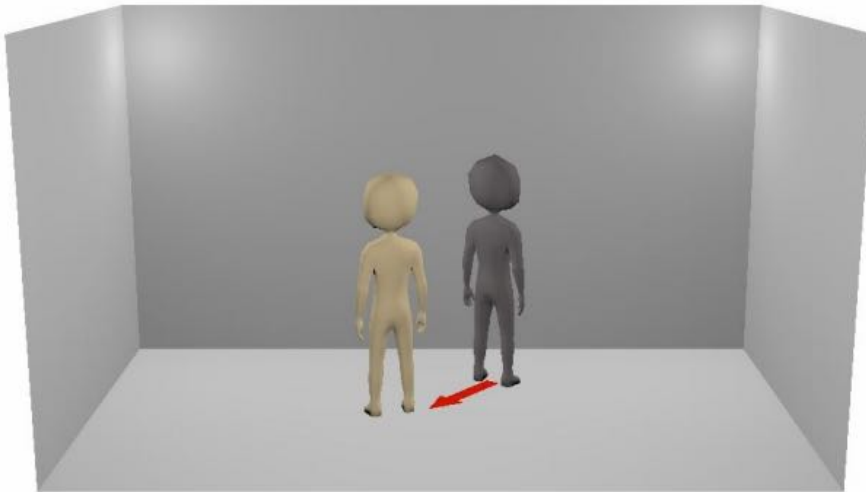
Co-habitation in a CAVE

[Chen et al., 2015]

Problems when several users are co-located in a CAVE

Collisions

Occlusion

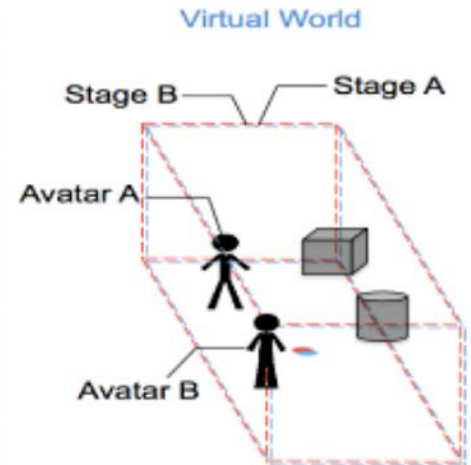
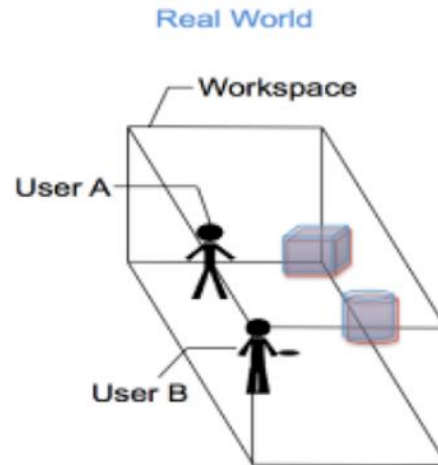


Co-habitation in a CAVE

[Chen et al., 2015]

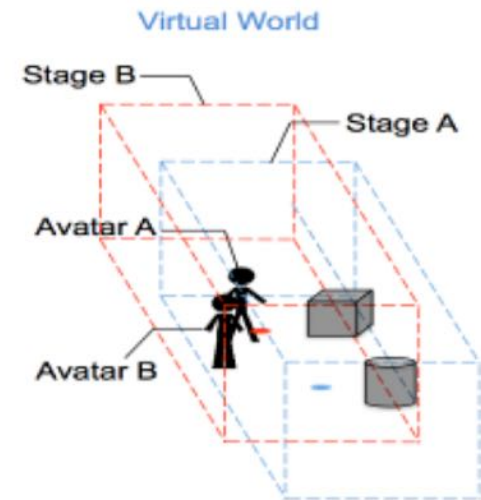
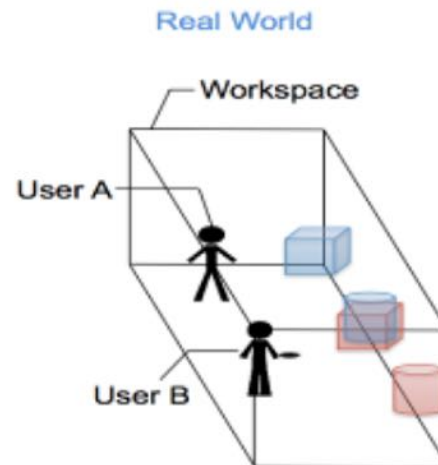
Problems when several users are co-located in a CAVE

Consistent



VS.

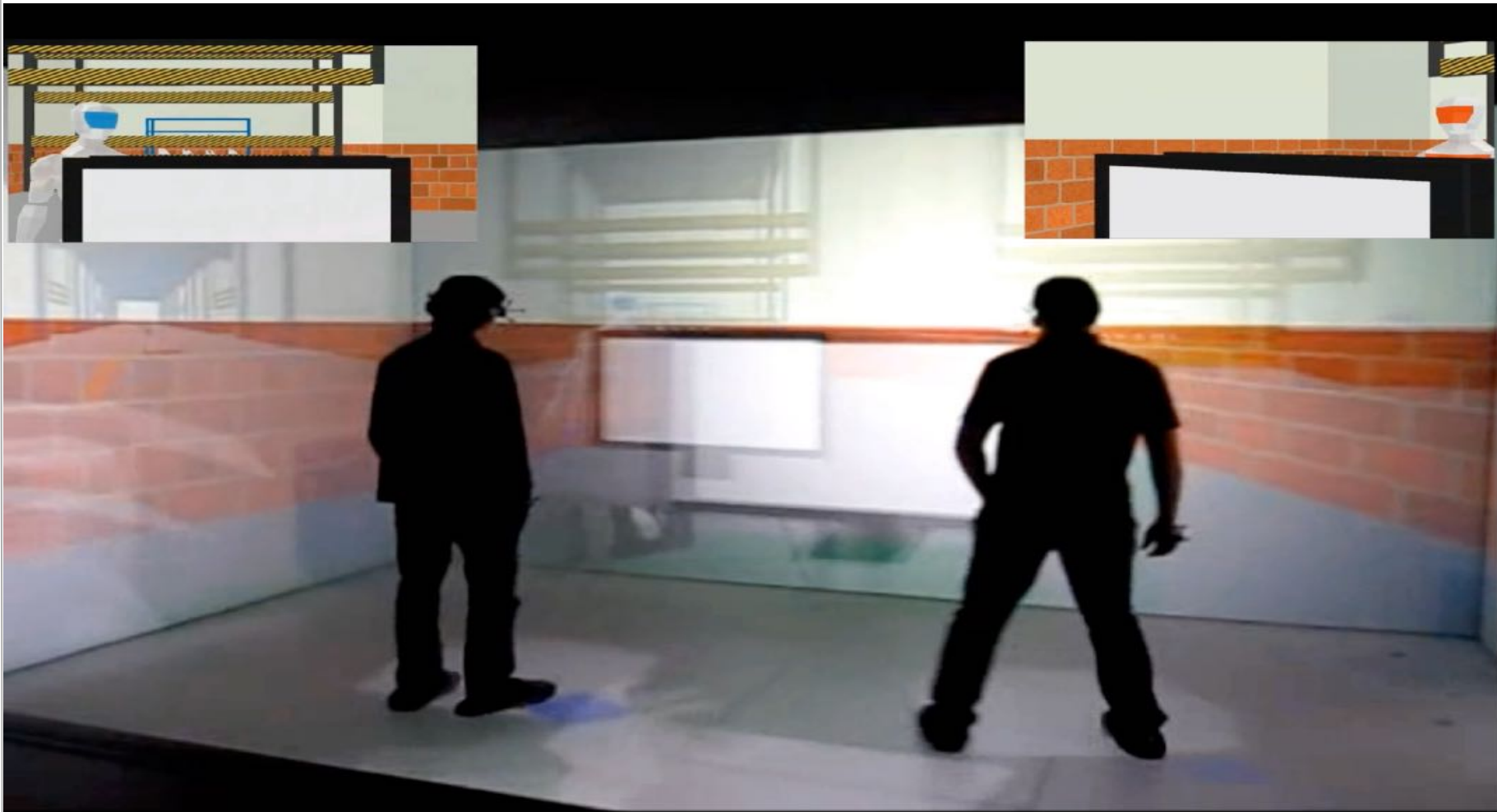
Inconsistent



Co-habitation in a CAVE

[Chen et al., 2015]

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



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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

Spacetime [Xia et al., 2018]



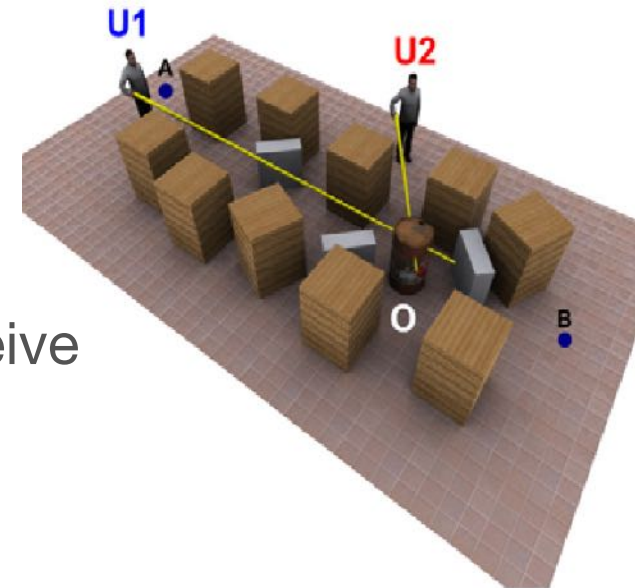
Manipulate different DoF

Users use the same tools

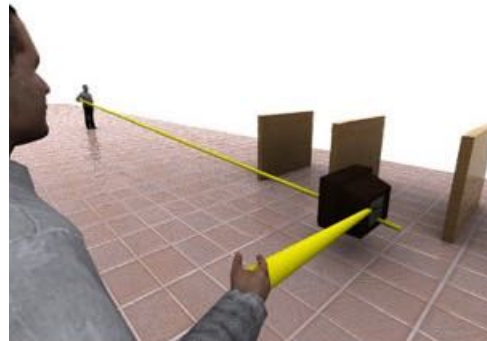
Ex: two virtual rays [Pinho et al., 2008]

Help with obstacles

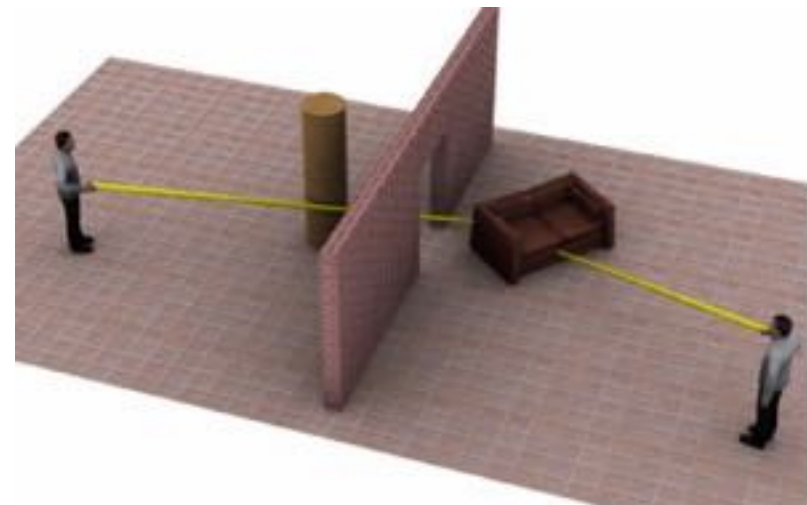
Help when the depth is hard to perceive



User U1's view



User U2's view



Manipulate the same DoF

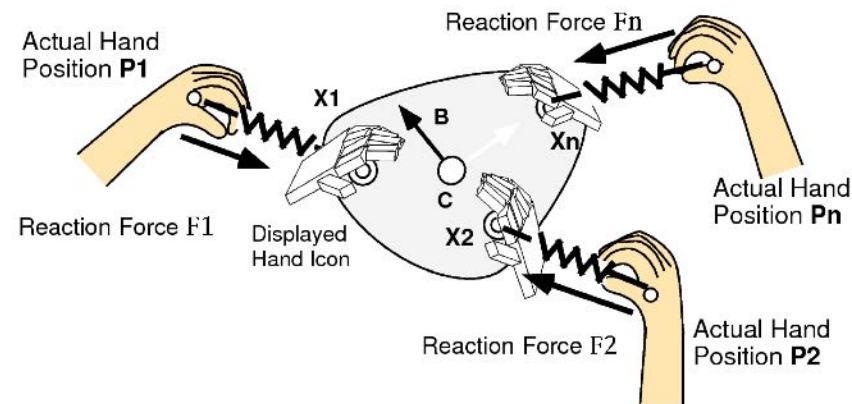
Manipulate together positions and orientations

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

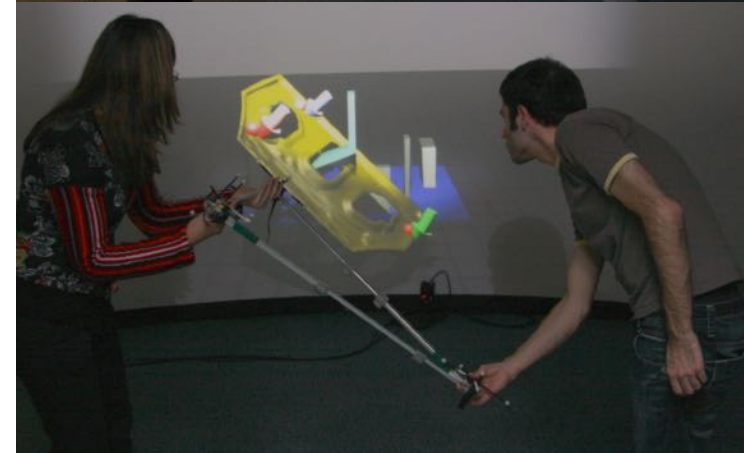
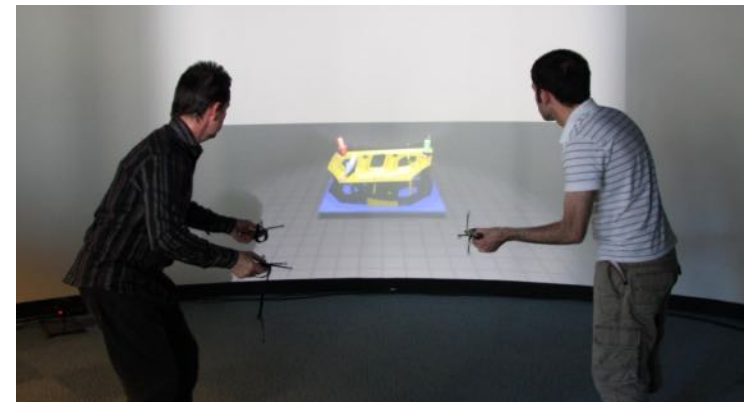
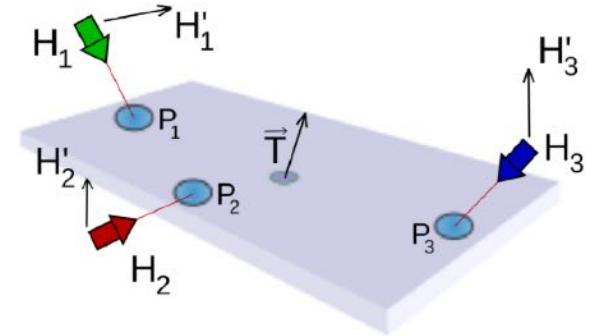
Need at least 3 control points

3 hand manipulation technique
[Aguerreche et al., 2009]

One user has 2 control points

The other has 1 control point

Implemented with a prop
(Reconfigurable tangible device)
[Aguerreche et al., 2010]



Co-located manipulation

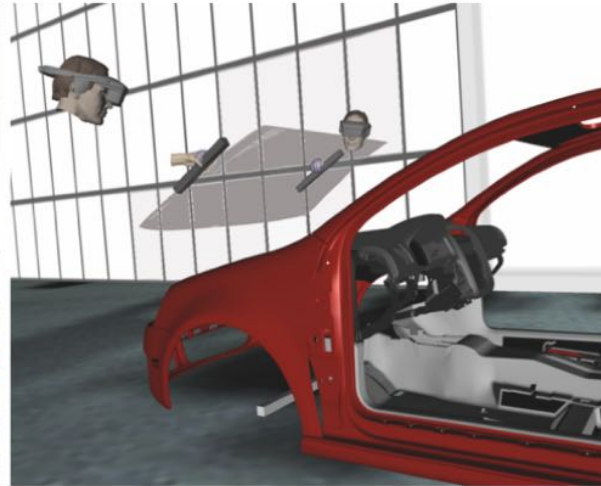
[Aguerreche et al., 2010]



Co-located manipulation

Even if users cannot see the others,
haptic feedback is still important

[Salzmann et al., 2009]



Conclusion



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 still need visual tools to improve the communication

Wide range of collaborative interaction

Navigation together or help the other to navigate

Move virtual objects together

Conclusion

Feedback 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)