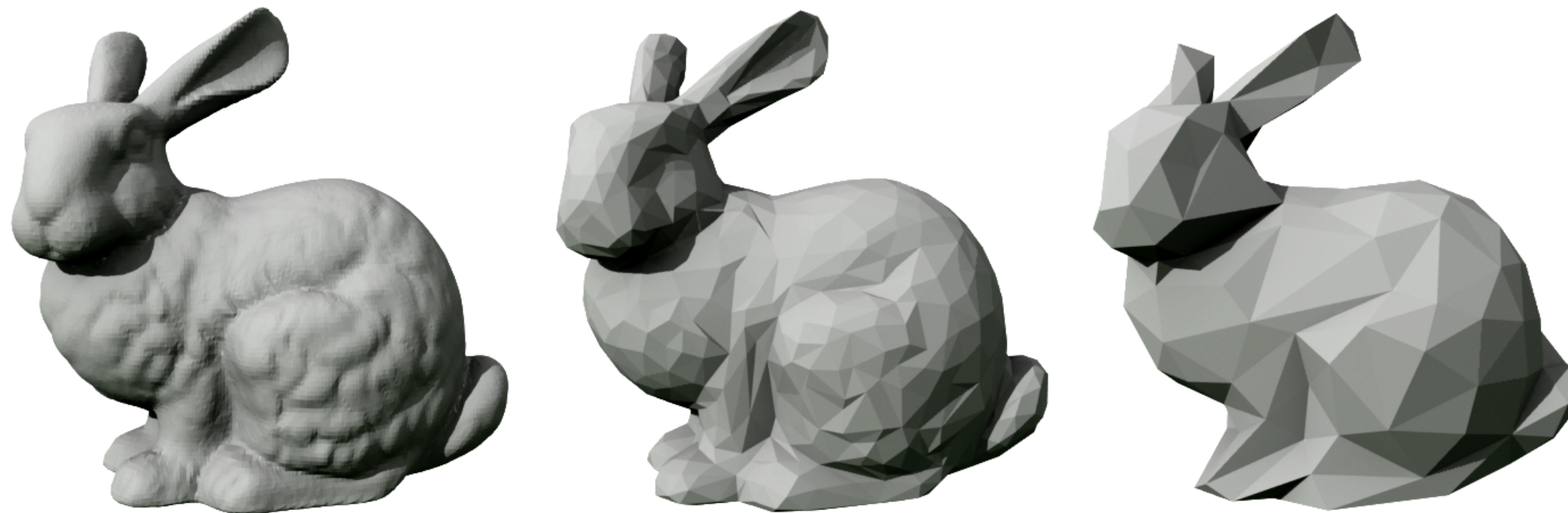


# Computer Graphics 1

Ludwig-Maximilians-Universität München  
Summer semester 2020

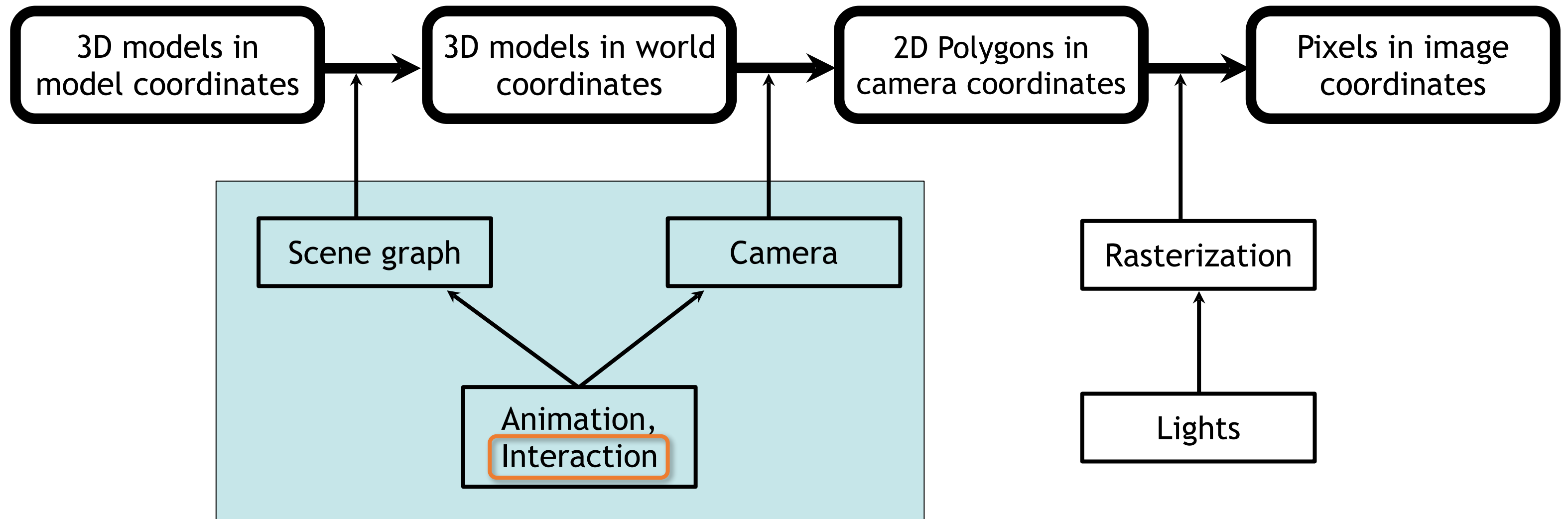
Prof. Dr.-Ing. Andreas Butz

lecture additions by Dr. Michael Krone, Univ. Stuttgart



[https://commons.wikimedia.org/wiki/File:Stanford\\_bunny\\_gem.png](https://commons.wikimedia.org/wiki/File:Stanford_bunny_gem.png)

# The 3D rendering pipeline (*our version for this class*)



# Chapter 9 – Interaction in 3D

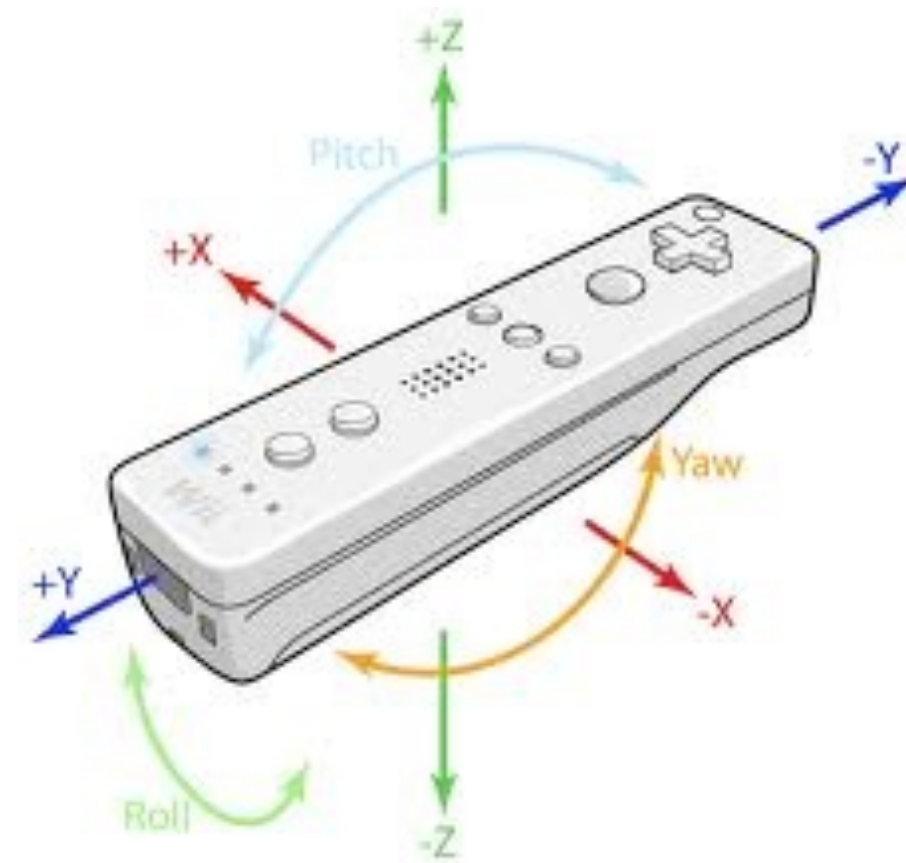
- Input Devices & Methods for 3D Graphics
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# 2D, 3D, and Interaction

- Interface based on 2D rectangular image
  - Rendering pipeline ends in 2D (raster) image
  - Most positional input devices (mouse, tablets, touch screens) designed for 2D
- Many interactions affect 3D world (scene graph)
  - Mapping of 2D-based interaction into 3D world
- Special interaction devices for 3D remain rarely used
  - Game controllers may change the situation



3D Mouse  
(3Dconnexion SpaceNavigator)



Nintendo Wiimote

# Special Interaction Devices for 3D

- 3D Connexion SpaceMouse
  - 6 Degrees of Freedom (6DoF)
  - Often used for CAD/3D modelling



Images: <http://www.3dconnexion.de/>



# Example for stationary navigation: Virtuix Omni







# Jaron Lanier's Data Glove (1987)



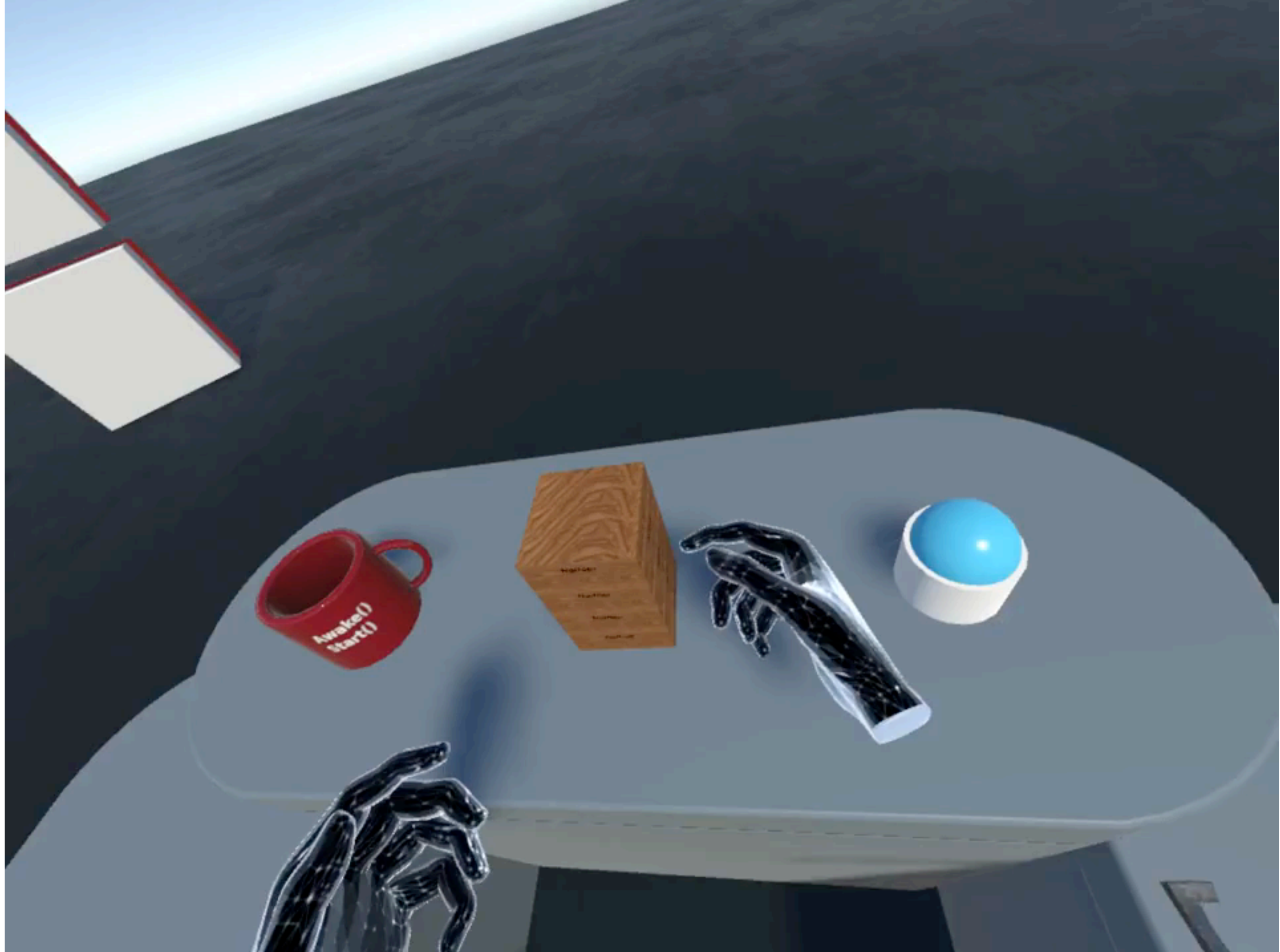


<https://www.youtube.com/watch?v=fs3AhNr5o6o>

# Noitom Hi5 VR glove [<https://hi5vrglove.com>]

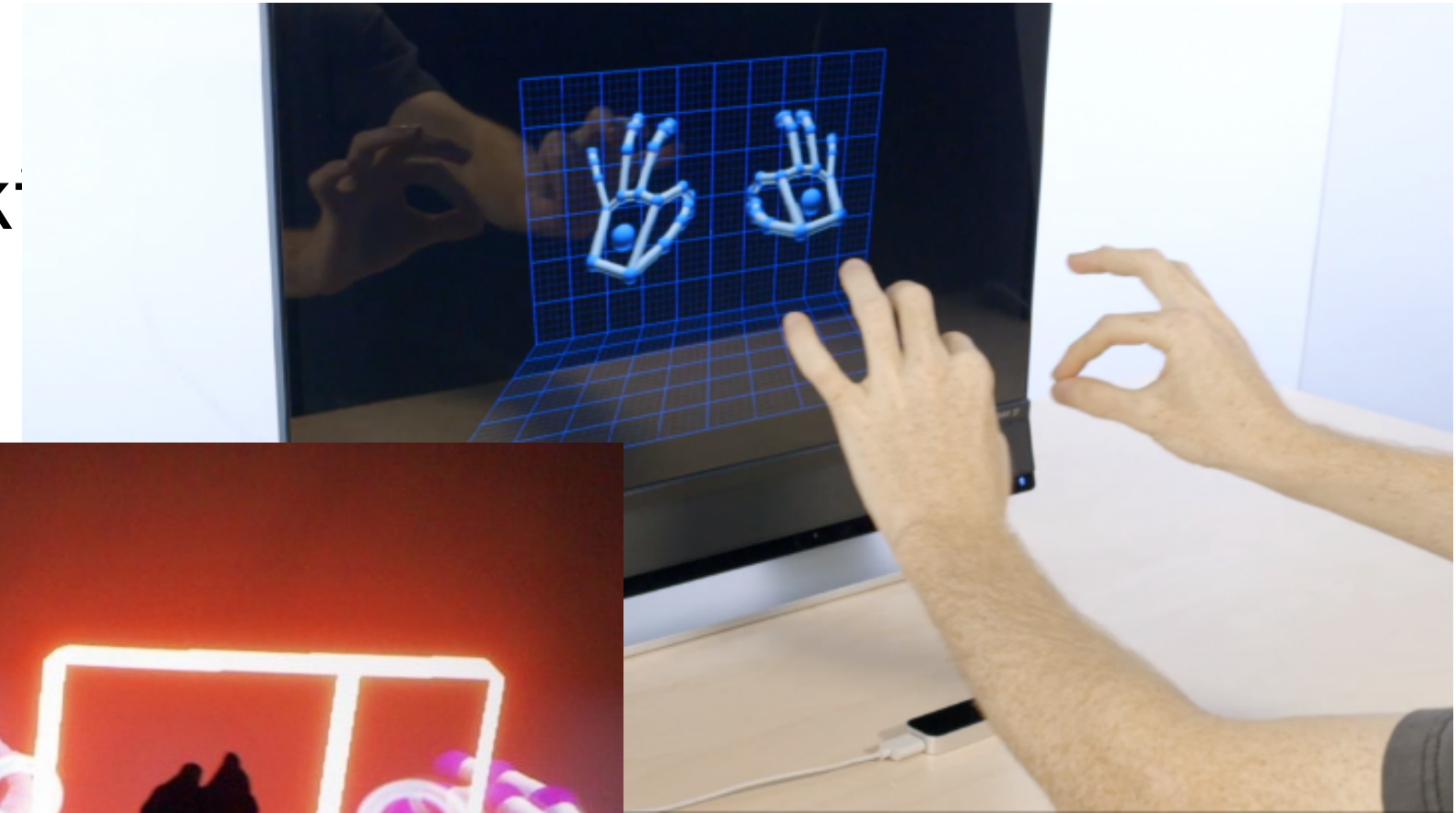
- Full-hand motion capture with high performance motion tracking sensors
  - 9-axis IMU
- Orientation output rate of 90 fps
- Absolute position and orientation output
  - used with optical tracking system
- Plug-and-play with optional calibration modes for higher accuracy
- Built in rumbler with SDK access
- Powered by one AA battery
- Single or duo hand modes
- Compatible with HTC Vive

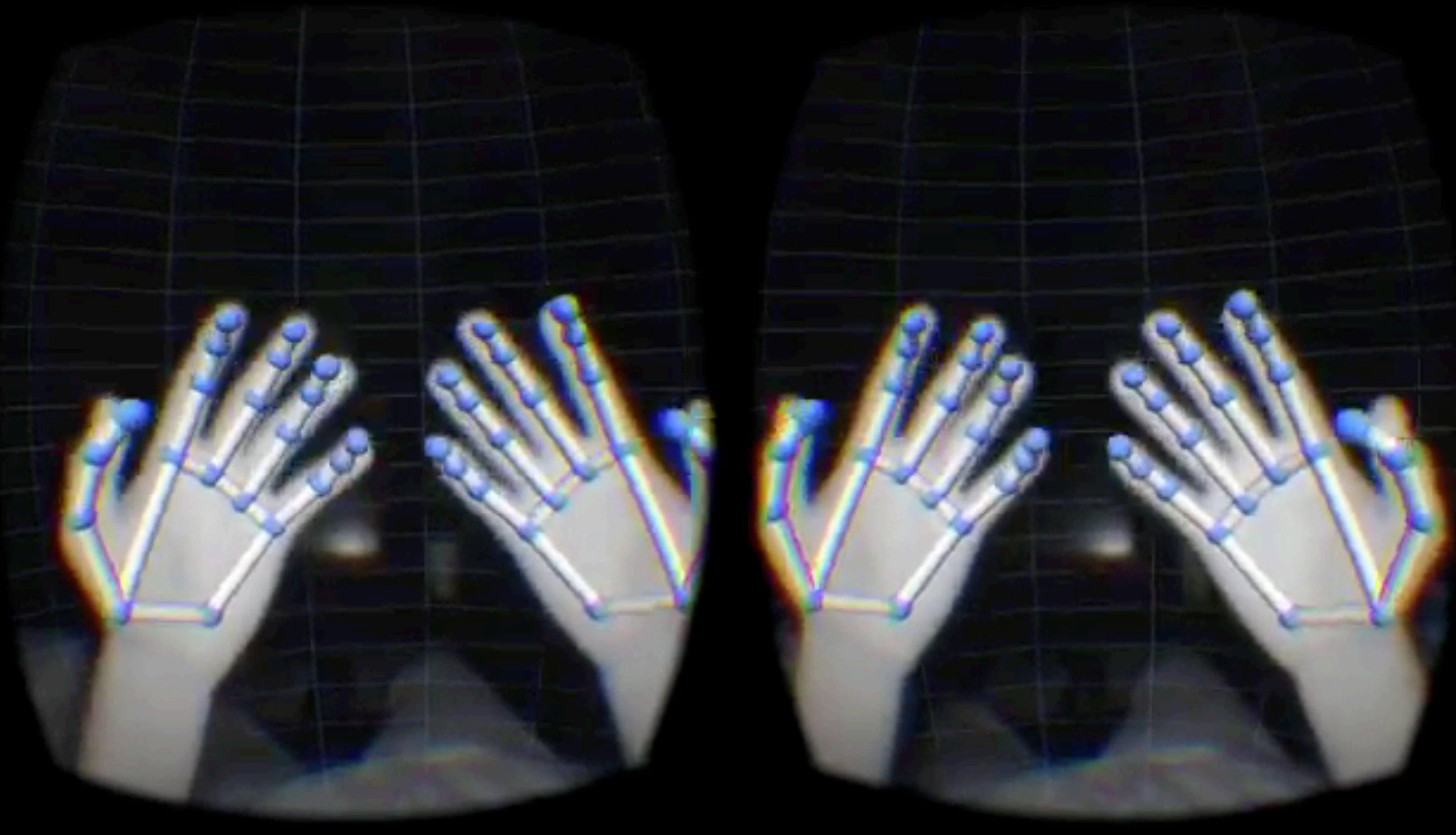




# Freehand Interaction Devices for 3D

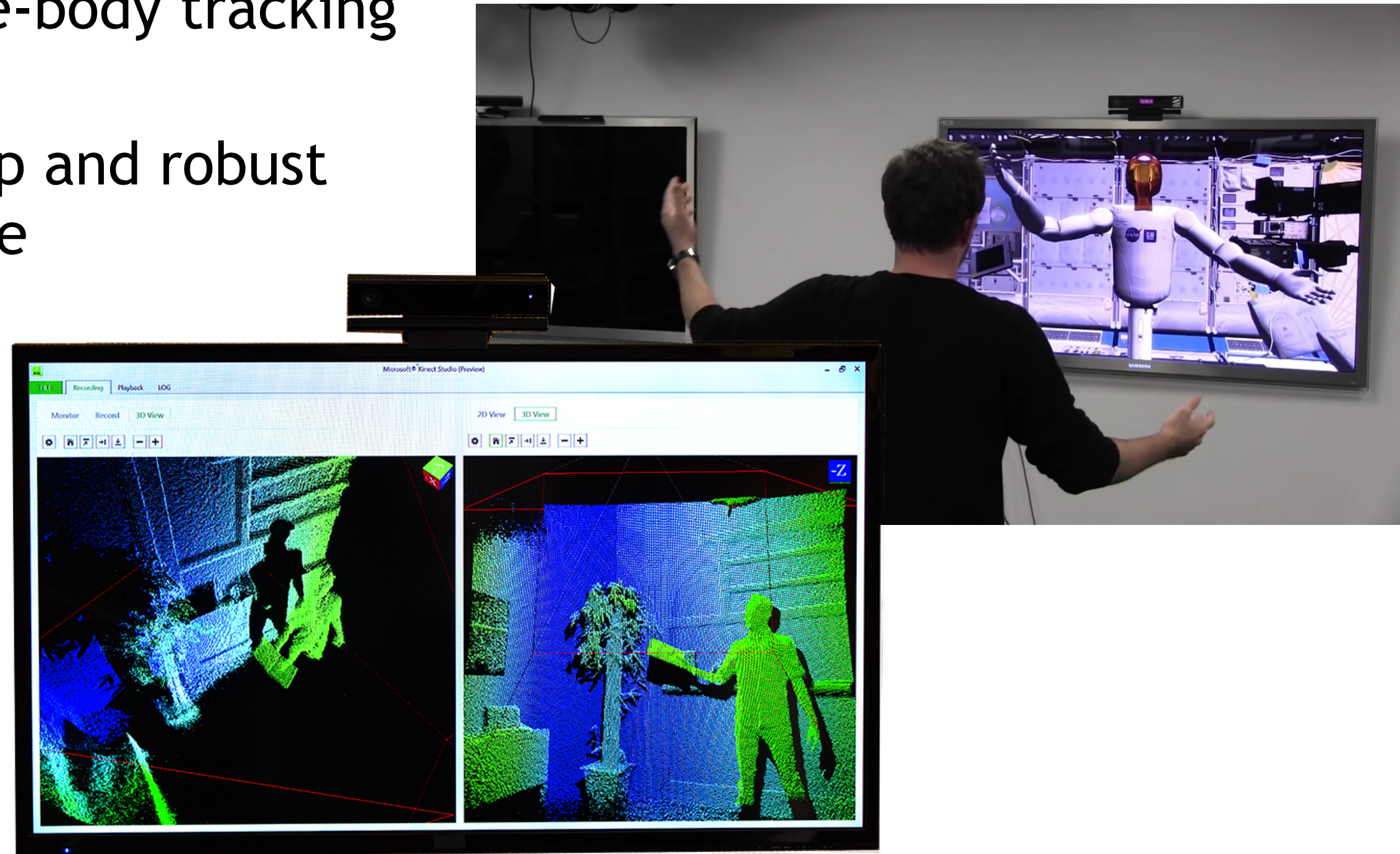
- Leap Motion
  - Camera-based near-field hand track
  - Often combined with VR headsets





# Freehand Interaction Devices for 3D

- Microsoft Kinect (v2)
  - Camera-based whole-body tracking
  - Designed for games
  - Widely used as cheap and robust 3D interaction device



# Special Interaction Devices for 3D

- Optical tracking
  - (Stereo) Camera + image processing (e.g., OpenCV)
  - Marker-based systems (Motion Capturing)



<http://www.ar-tracking.com/>  
<https://www.optitrack.com/>



<http://www.vis.uni-stuttgart.de/>



<http://www.svcl.ucsd.edu/>



# Special Interaction Devices for 3D

- Geomagic Touch
  - Haptic 6DoF input device
  - e.g. used for surgical simulations



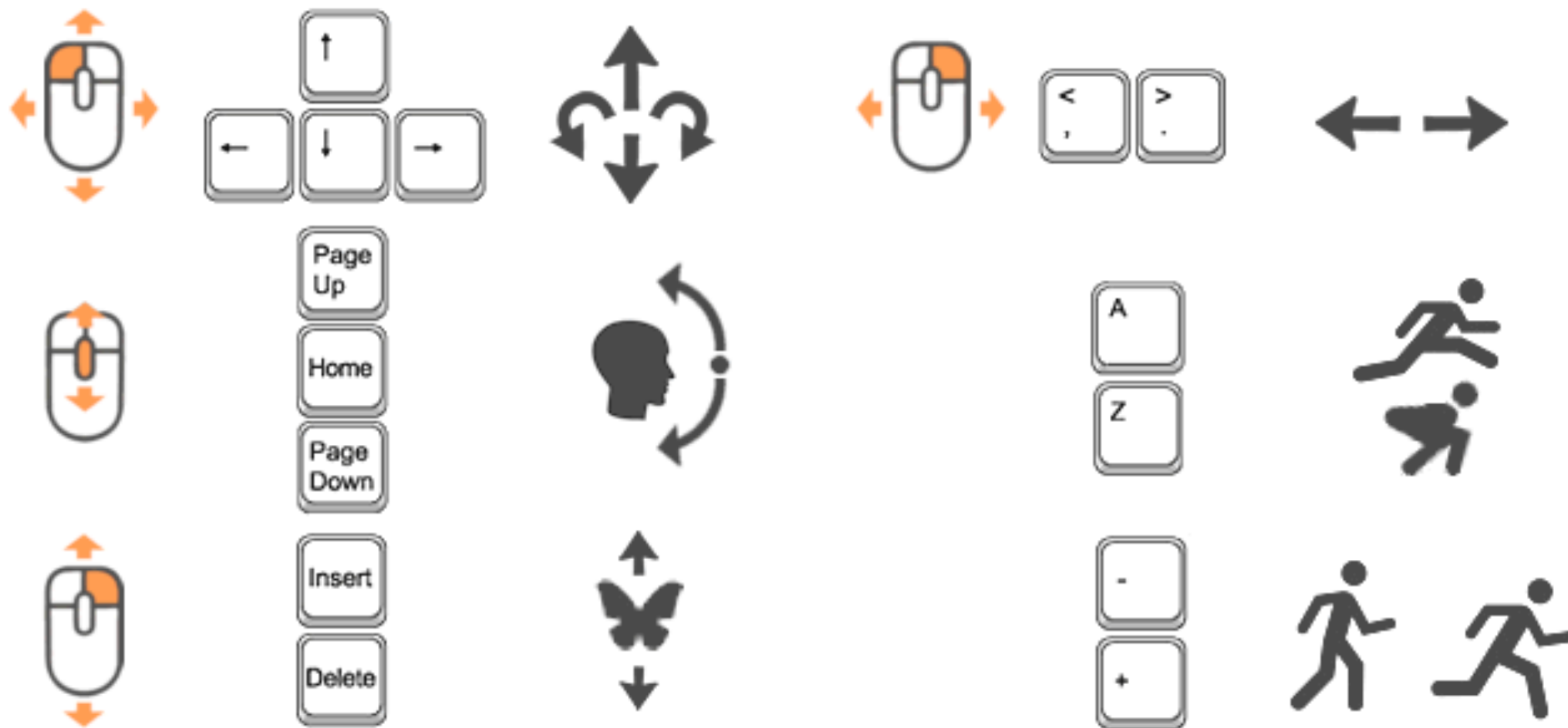
<http://www.geomagic.com/de/products/phantom-omni/overview>

# Chapter 9 – Interaction in 3D

- Input Devices & Methods for 3D Graphics
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# Navigation in a 3D scene

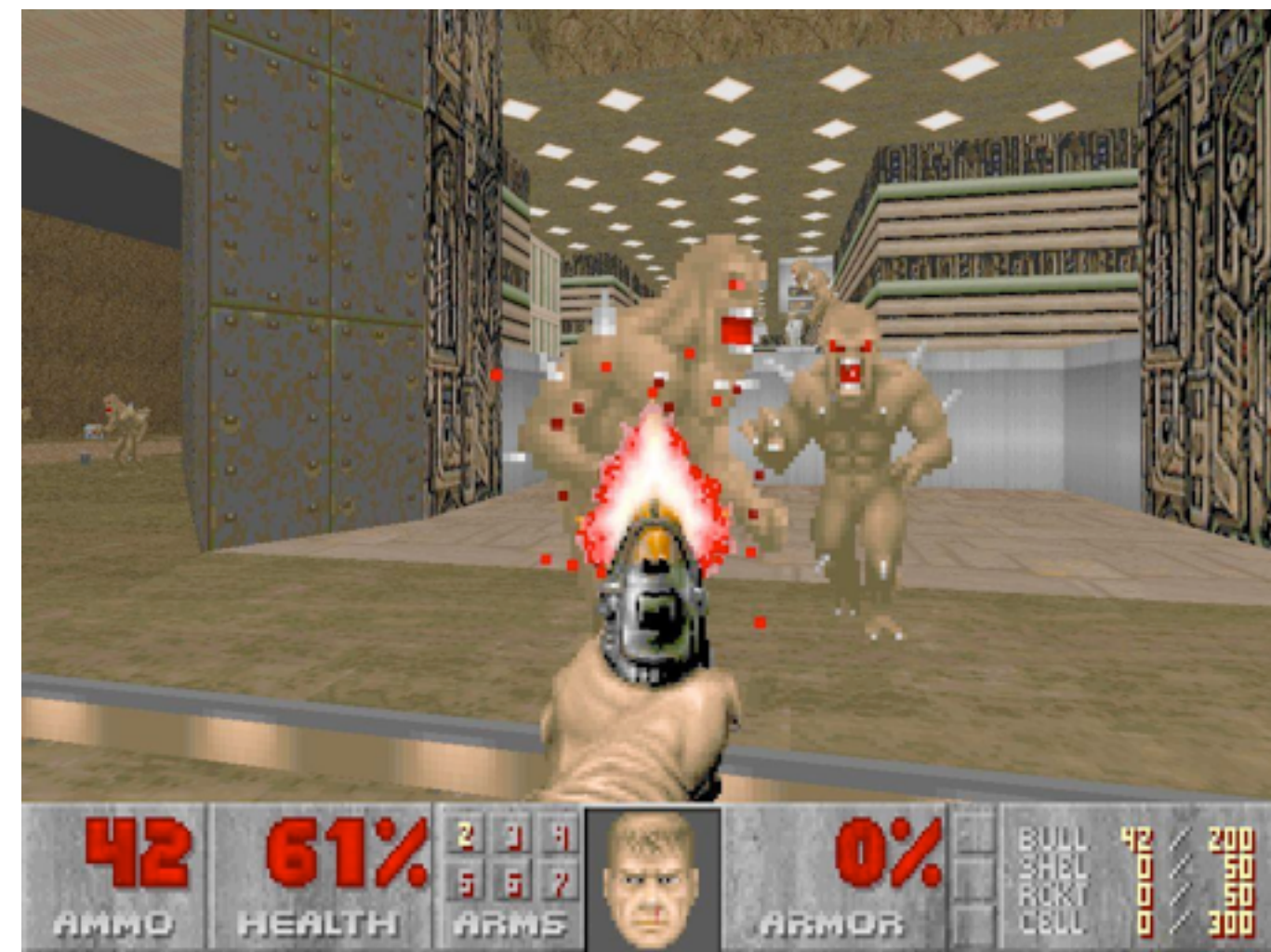
- Two possible perspectives (and mental models):
- Move around or turn a 3D object (inspect)
  - Camera or object actively controlled
- Move within a 3D world (walk/fly)
  - Way of moving often borrowed from real world (walk, fly, drive, ...)
  - Camera often associated with an “avatar”



<http://castle-engine.sourceforge.net/view3dscene.php>

# Walk Mode

- Well known from many ego shooter games
- Use mouse or (cursor) keys to
  - Move forward or backward
  - Turn left or right
- Ground level needs to be defined
- Up always stays up
- „Gravity“ keeps avatar to the ground
- Additional actions may be defined (Jump,...)
- User can get lost or trapped
- Often used in conjunction with navigation aids



<http://revistagames.files.wordpress.com/2009/12/doom11.jpg>

[http://cache.kotaku.com/assets/resources/2007/05/tomb\\_raider\\_wii\\_500.jpg](http://cache.kotaku.com/assets/resources/2007/05/tomb_raider_wii_500.jpg)



# Fly Mode

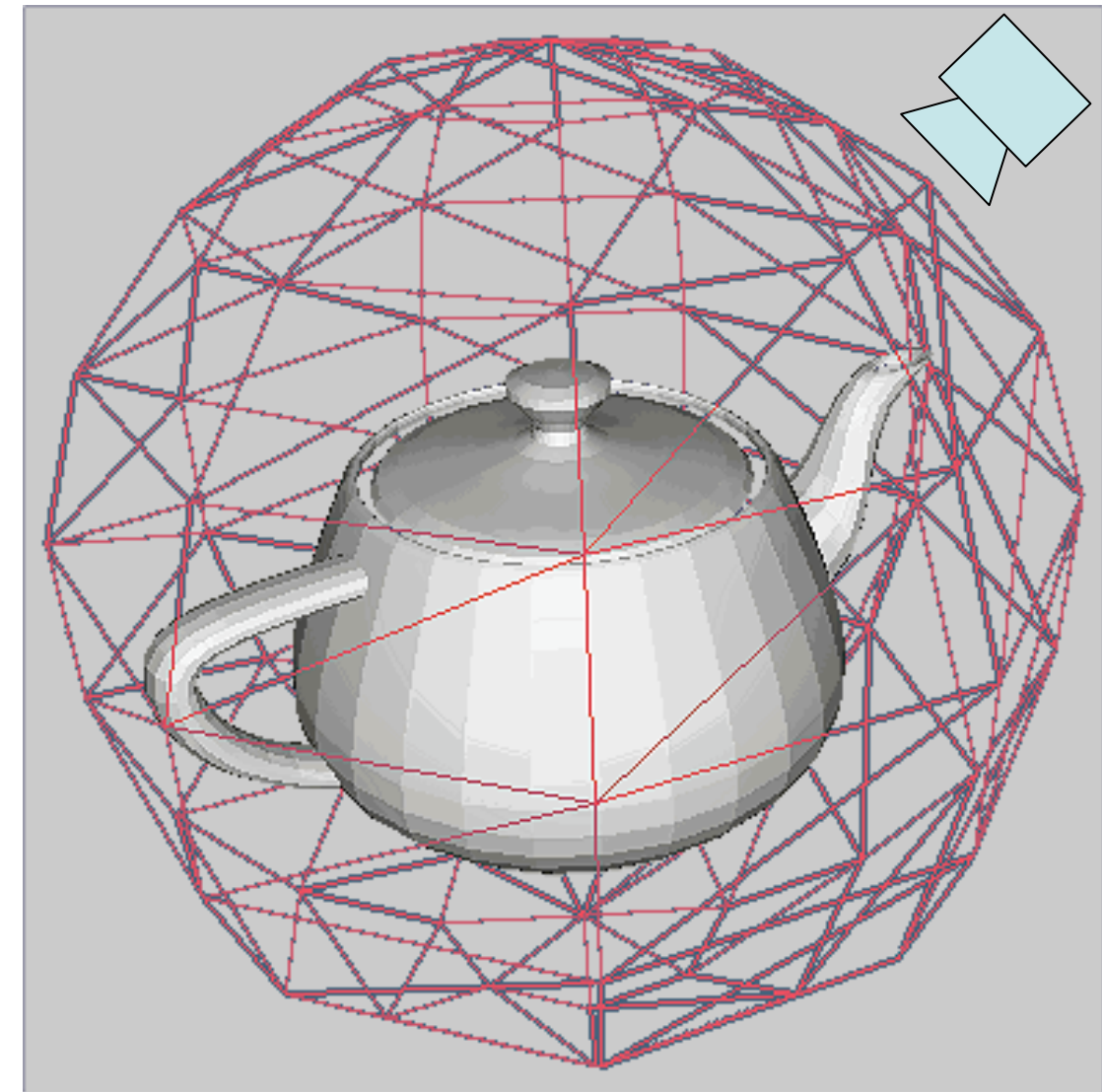
- Just like walk, but get rid of gravity
- Additional key or mouse mappings for up/down
- Can still be reasonably constrained
  - Up stays up
  - Gravity eventually pulls you down
- Can be fully unconstrained
  - Additional mapping for roll left/right
  - Scene can become all mixed up
- Provides better overview
  - Just fly up high to see all terrain



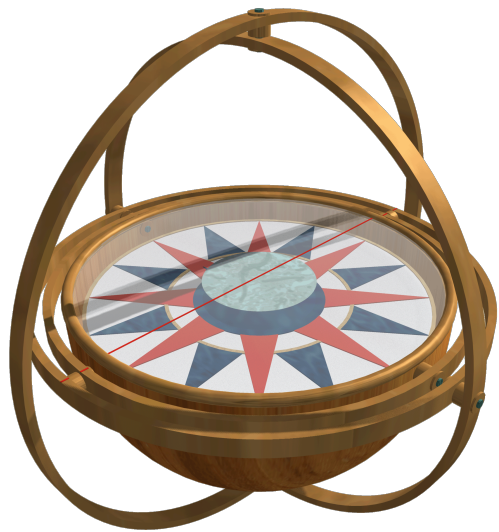
[http://www.blogcdn.com/socialsoftware.weblogsinc.com/media/2006/01/second\\_life\\_web.jpg](http://www.blogcdn.com/socialsoftware.weblogsinc.com/media/2006/01/second_life_web.jpg)

# Examine Mode

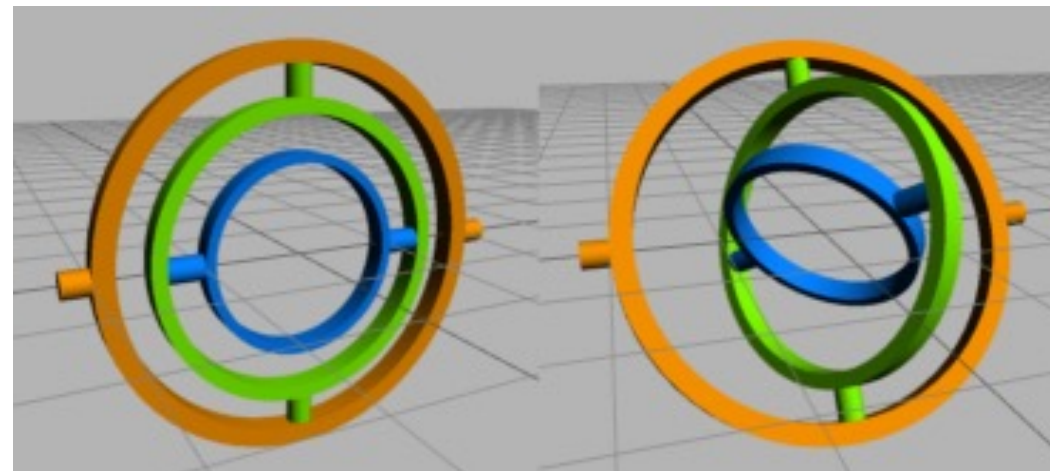
- Object to be examined is at the center of an invisible bounding sphere
- Mouse click touches (“grabs”) the sphere and mouse move drags its surface around
- No constraints, up doesn’t stay up
- Can easily get lost and turn world upside down
- Motion can be constrained to one axis
  - Less danger to get disoriented
  - Danger of a „gimbal lock“ state



[http://docs.autodesk.com/3DSMAX/13/ENU/Autodesk 3ds Max 2011 Help/images/MED/Zelda-Ref/ill/ill\\_boundingSphere.png](http://docs.autodesk.com/3DSMAX/13/ENU/Autodesk%203ds%20Max%202011%20Help/images/MED/Zelda-Ref/ill/ill_boundingSphere.png)



<http://www.codex-madrid.rwth-aachen.de/madrid1/f013vd/index.html>



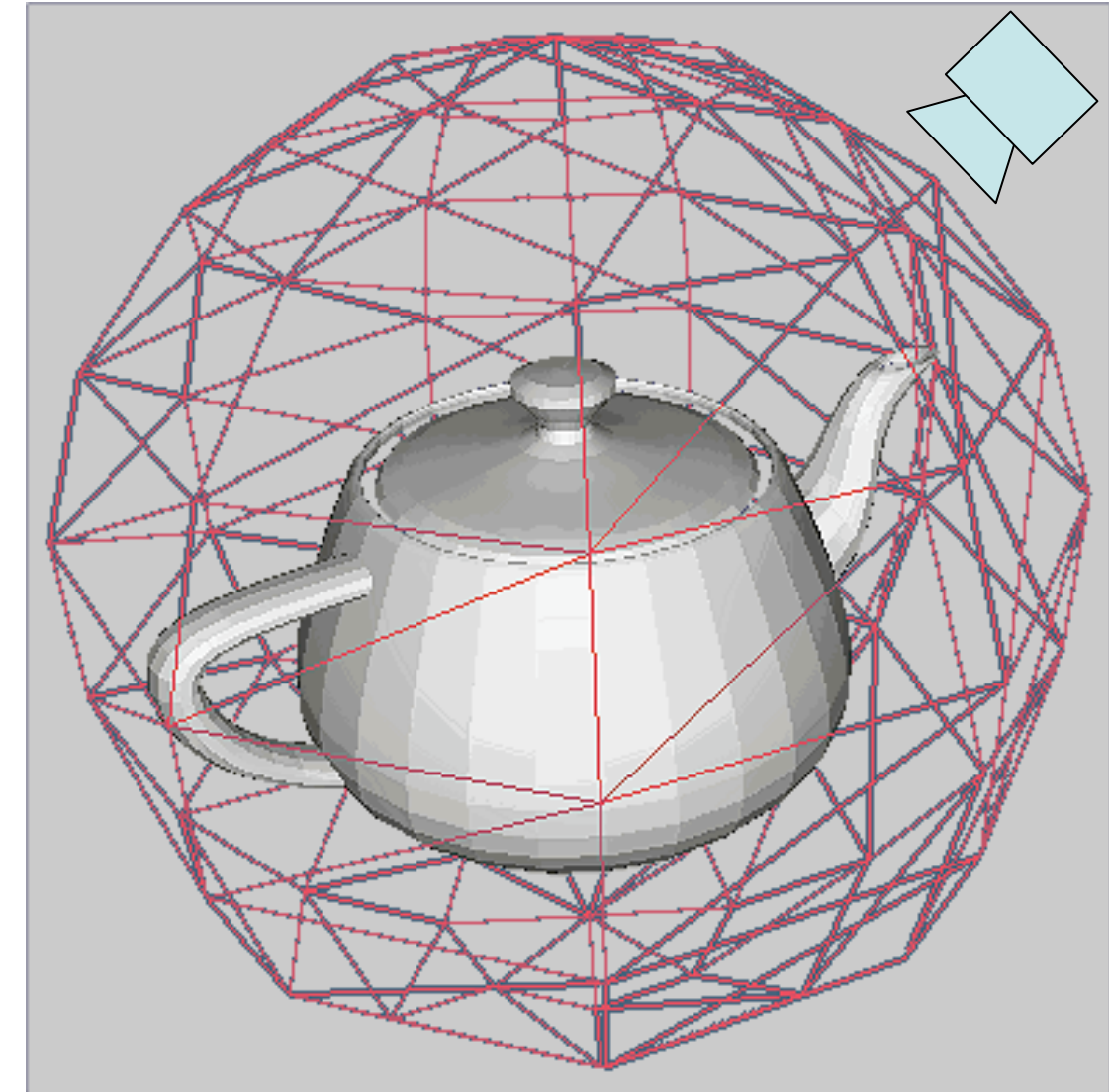
<http://www.deepmesh3d.com>

## Quiz:

There is one place on earth, from which you can go 10 km south, 10 km east and 10 km north and you arrive at the same point. Where is this?

# Scene in Hand - Camera in Hand

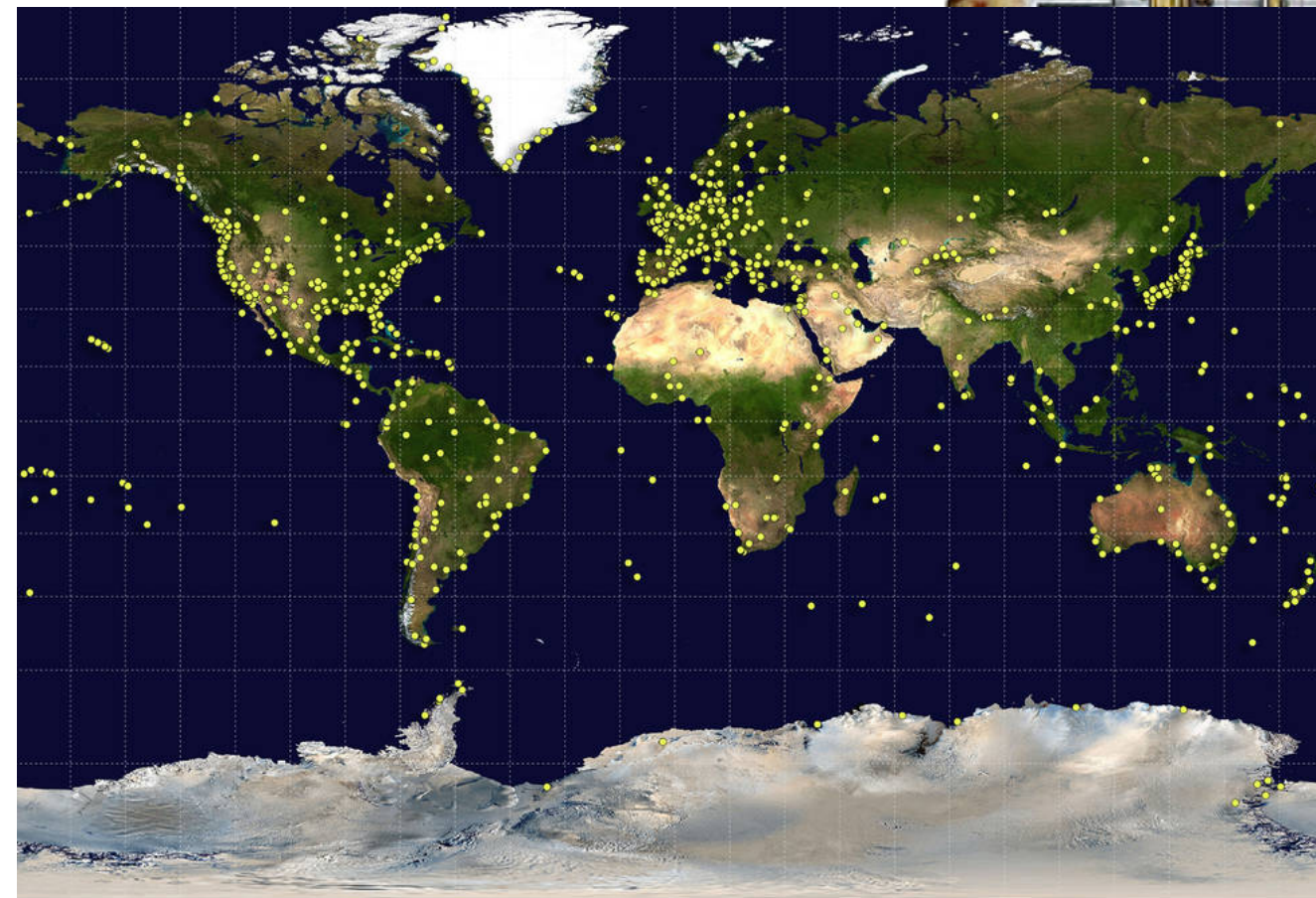
- In *Examine mode* there are two interface metaphors
  - They result in exactly opposite motions
- Scene in hand
  - Moving the mouse left turns the scene left
- Camera in hand
  - Moving the mouse left moves the camera left
  - This causes the scene to turn right
- Further reading:
  - [Ware & Osborne 1995: Exploration and Virtual Camera Control in Virtual Three Dimensional Environments]



[http://docs.autodesk.com/3DSMAX/13/ENU/Autodesk 3ds Max 2011 Help/images/MED/Zelda-Ref/ill/ill\\_boundingsphere.png](http://docs.autodesk.com/3DSMAX/13/ENU/Autodesk%203ds%20Max%202011%20Help/images/MED/Zelda-Ref/ill/ill_boundingsphere.png)

# Navigation Aids

- Maps
  - Provide overview and orientation
  - Can provide additional info (objects, enemies)
- Compass
  - Shows heading info
  - Helps keeping track of orientation, e.g., in a maze



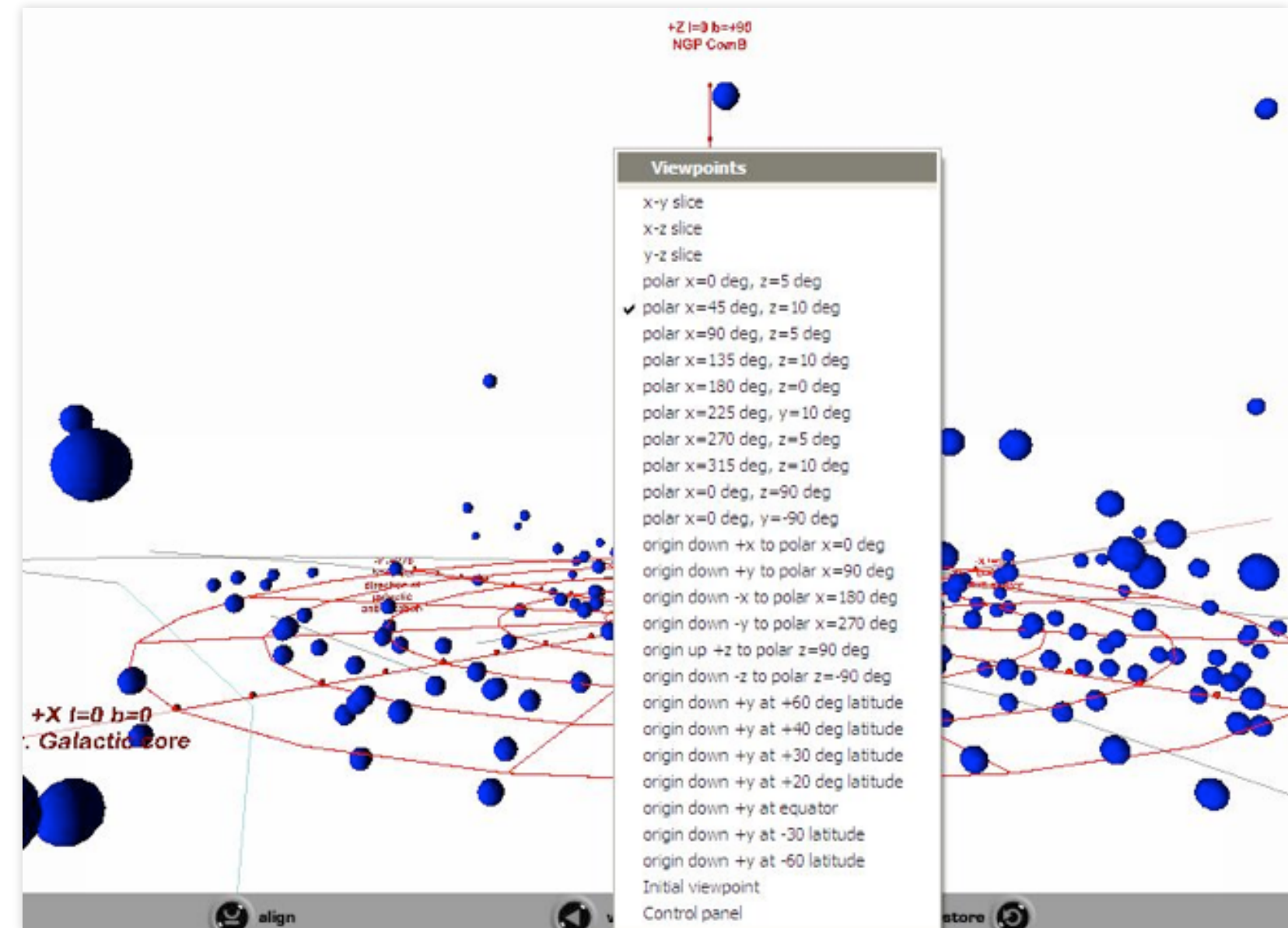
<http://www.nasa.gov>

[http://www.wizards.com/dnd/images/rhod\\_maps/95695.jpg](http://www.wizards.com/dnd/images/rhod_maps/95695.jpg)



# Fixed Viewpoint Transitions

- Define multiple viewpoints (cameras) in scene
- Move from one viewpoint to another
  - Animate camera movement
  - Camera „cut“
- Always land in a safe and known state
- Use in conjunction with other navigation
  - Provides a “safe anchor”
- Determination of optimal viewpoints is an area of ongoing research



<http://fisherka.csolutionshosting.net/astronote/Clarkxref/img/HelpViewMenuActivated.jpg>

# Chapter 9 – Interaction in 3D

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# Picking

- Given a mouse position, which object in the 3D scene is hit by it?
  - Potentially several
  - We may want all to select from them, or just the first (i.e., closest)
- Intersect ray with all objects (as in raytracing)
- Cheaper: OpenGL picking by modified rendering
  - (see next slide)
- Very simple: color coding
  - Define unique color for each object (independent of actually rendered color)
  - Render with these special colors on back buffer (invisible to user)
  - Derive object identity from color of pixel
  - Assumes double buffering. Do not swap front and back buffer here!
- <http://www.lighthouse3d.com/opengl/picking/>

# OpenGL Picking

- Uses a special rendering mode (`GL_SELECT`)
  - Rendering only internally for picking, not actually shown on display!
- Can deliver all objects at a certain (2D specified) position
  - Using a *pick buffer* to store found objects
  - Objects (→ multiple triangles) can be assigned an unique ID (number) for this
  - Otherwise just minimum and maximum depth are recorded
- Uses a *pick window*
  - Small viewing volume around the mouse
- Basic sequence:
  - Prepare pick buffer and object IDs
  - Get window coordinates of mouse
  - Enter selection mode
  - Define pick window and render all objects/Polygons in that smaller volume
  - Exit selection mode and identify objects rendered in pick window

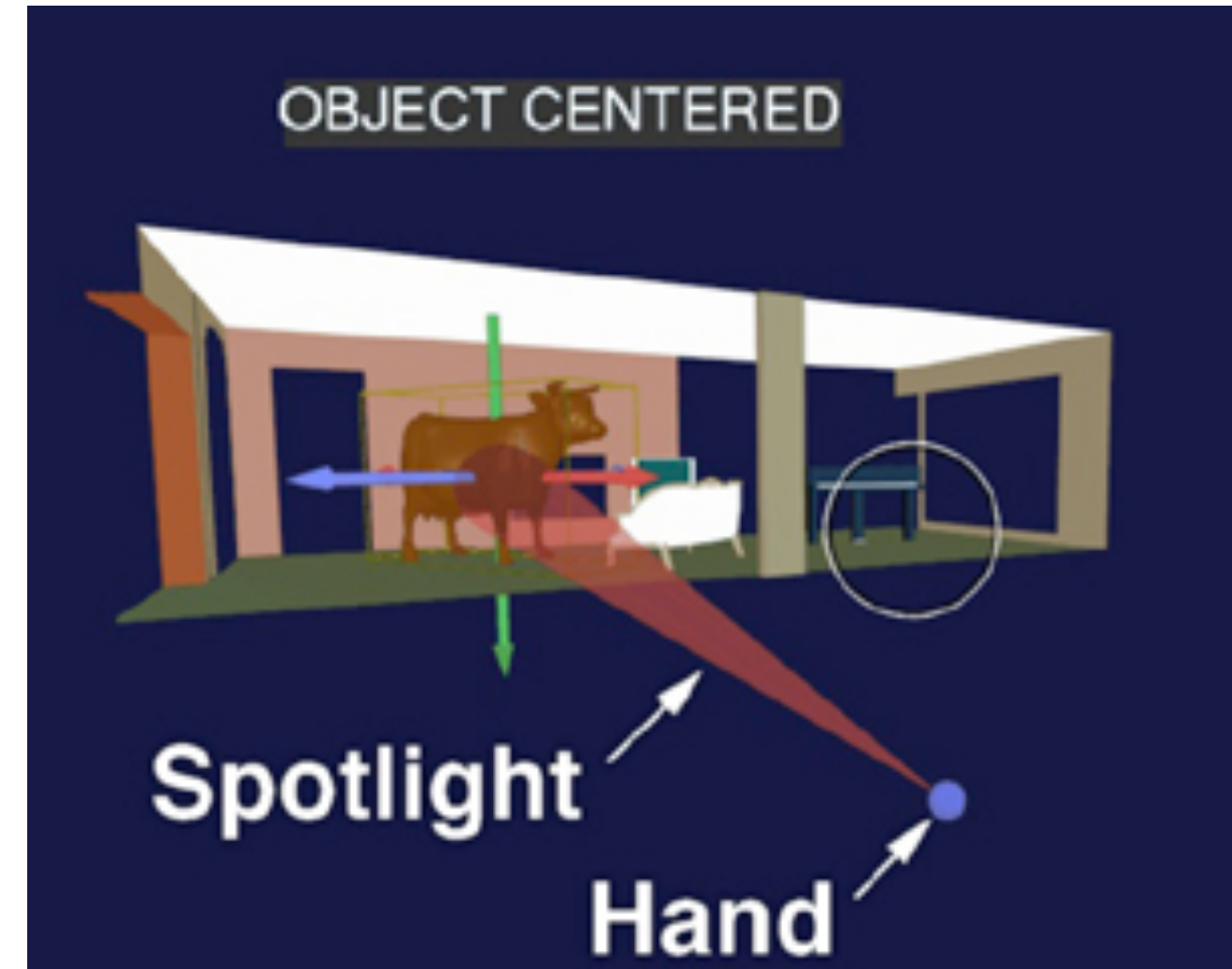
# Direct Hand Manipulation (3D Cursor)

- Move a cursor (or hand) in 3D space with input device
  - 3DOF space mouse directly
  - Regular mouse with modes
- Select object by moving the 3D cursor directly to its position
- Efficient object retrieval via octrees
- Problem: object may be out of reach



# Ray and Beam casting

- Technique for selecting objects out of reach
- Given an immersive 3D world (HMD, data glove,...)
  - Compute a ray or beam from the hand into the scene
  - Find the first intersecting object
  - Susceptible to jitter (think of a laser pointer)

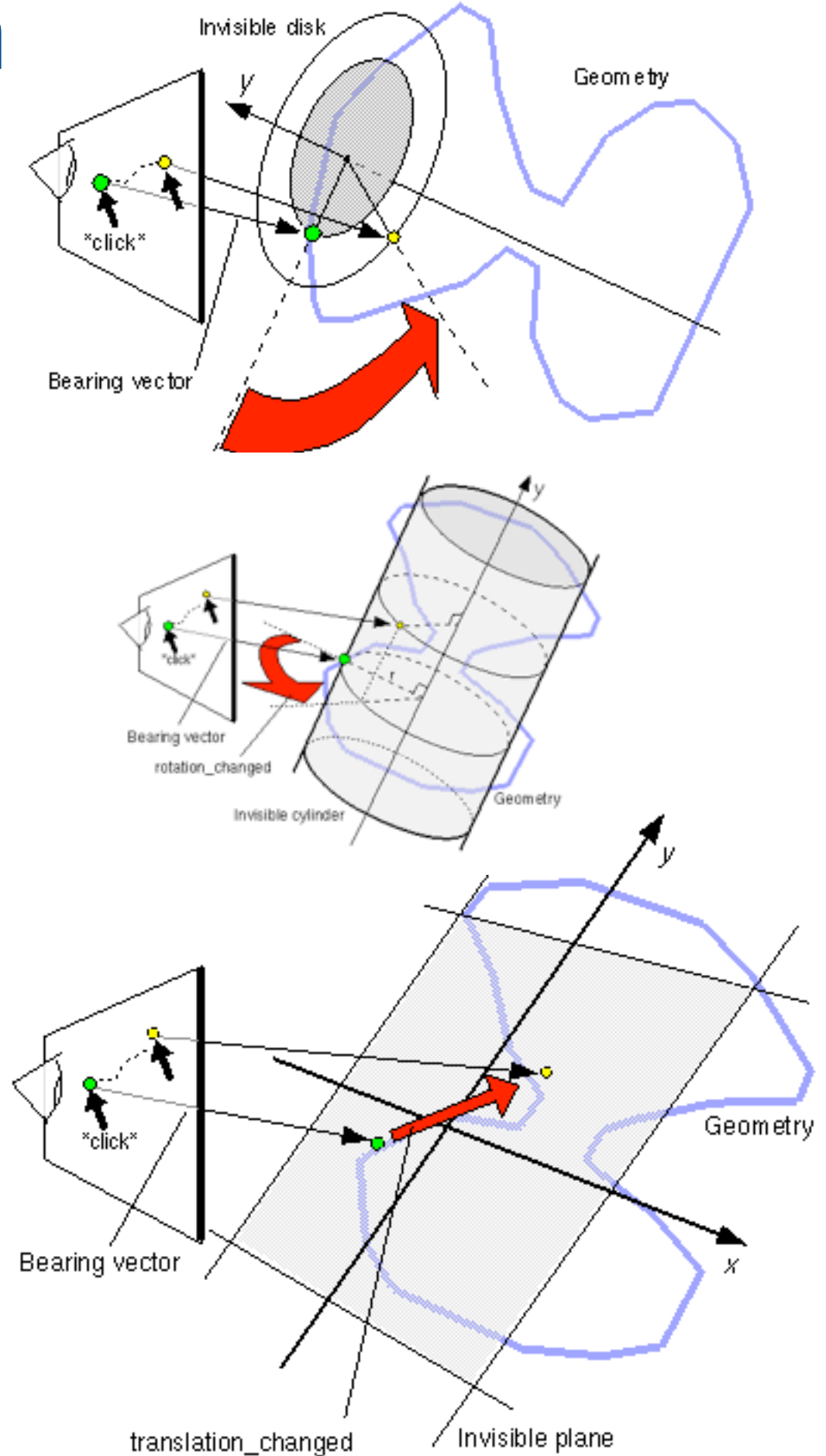


[http://w3-mmt.inf.tu-dresden.de/english/projekte/CONTIGRA/Realisierung/Widget\\_Classification/images/spotlight.jpg](http://w3-mmt.inf.tu-dresden.de/english/projekte/CONTIGRA/Realisierung/Widget_Classification/images/spotlight.jpg)

- Further reading:
  - [Mark R. Mine, '95: Virtual Environment Interaction Techniques]
  - <https://pdfs.semanticscholar.org/69ff/1367d0221357a806d3c05df2b787ed90bdb7.pdf>

# Manipulation with Constrained Motion

- Select an object in the scene using the techniques above
- Unconstrained motion would need 3 DOF input
- Constrain motion to 1 or 2 dimensions
- Example in VRML:
  - Cylinder sensor: object rotates about 1 axis (1 DOF)
  - PlaneSensor: object moves in a plane (2 DOF)



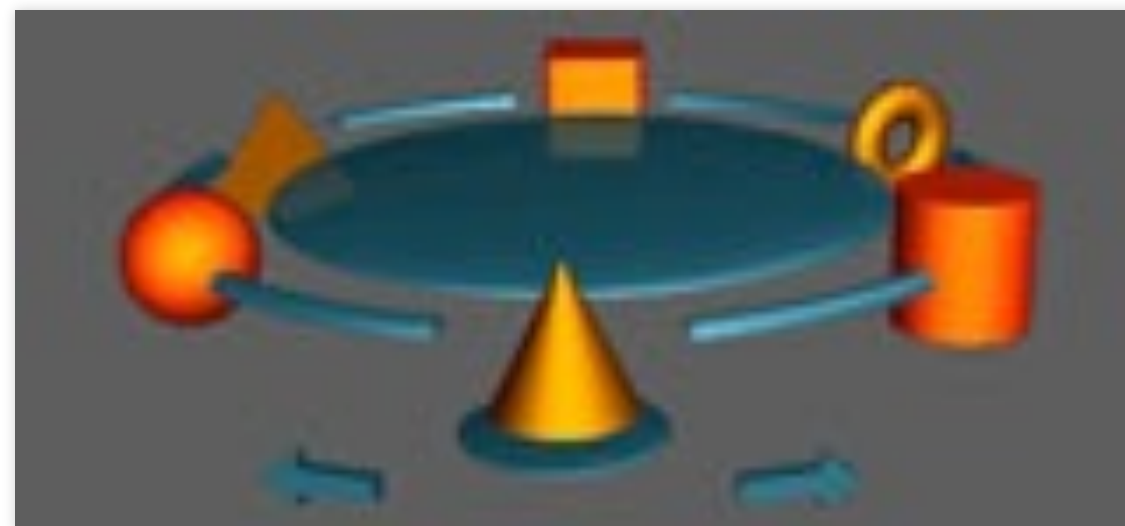
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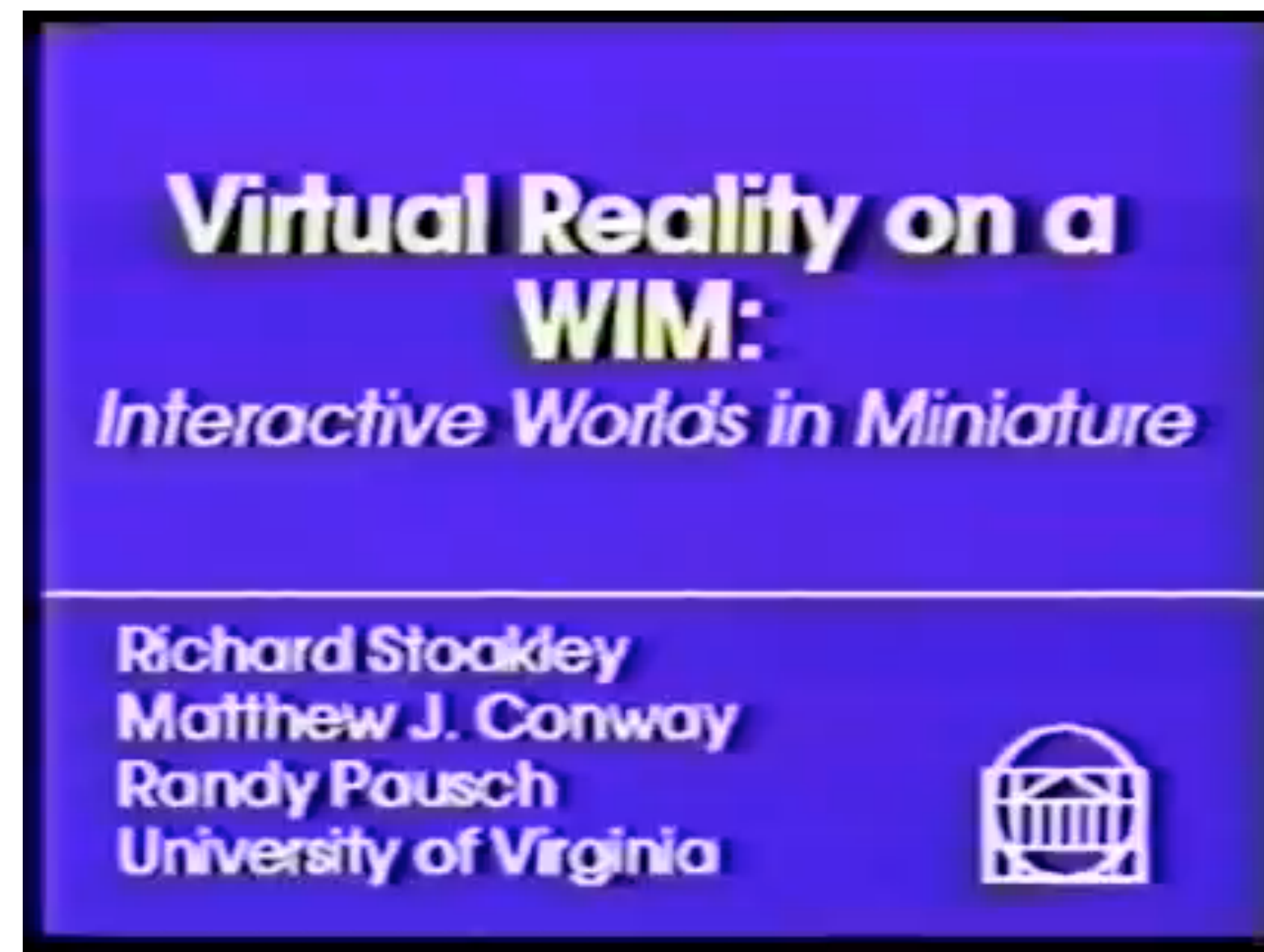
# 3D Widgets

- Tools which are mostly part of the 3D scene themselves
- Used for object selection, manipulation and navigation/inspection
- Many examples at Raimund Dachsel's collection
  - <http://www.3d-components.org/> (now offline, sorry...)



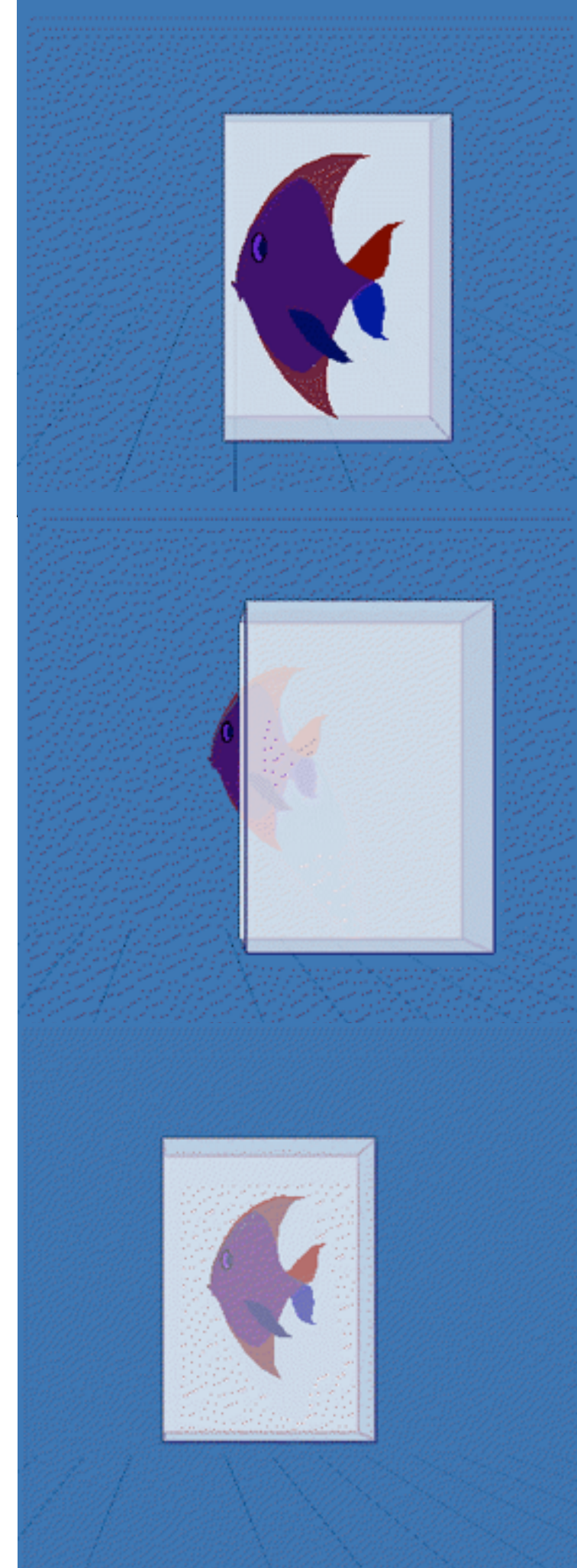
# World in Miniature - WIM

- Miniature copy of the entire 3D world
  - Can be manipulated in the hand
  - Acts as a representation of the big world
  - Feels like a 3D map
- Interaction techniques using a WIM:
  - Quickly changing the point of view
  - Object selection over a distance
  - Object manipulation
- Further reading:
  - [Stoakley et al. 1995: Virtual reality on a WIM: interactive worlds in miniature]
  - <http://www.cs.cmu.edu/~stage3/publications/95/conferences/chi/paper.html>



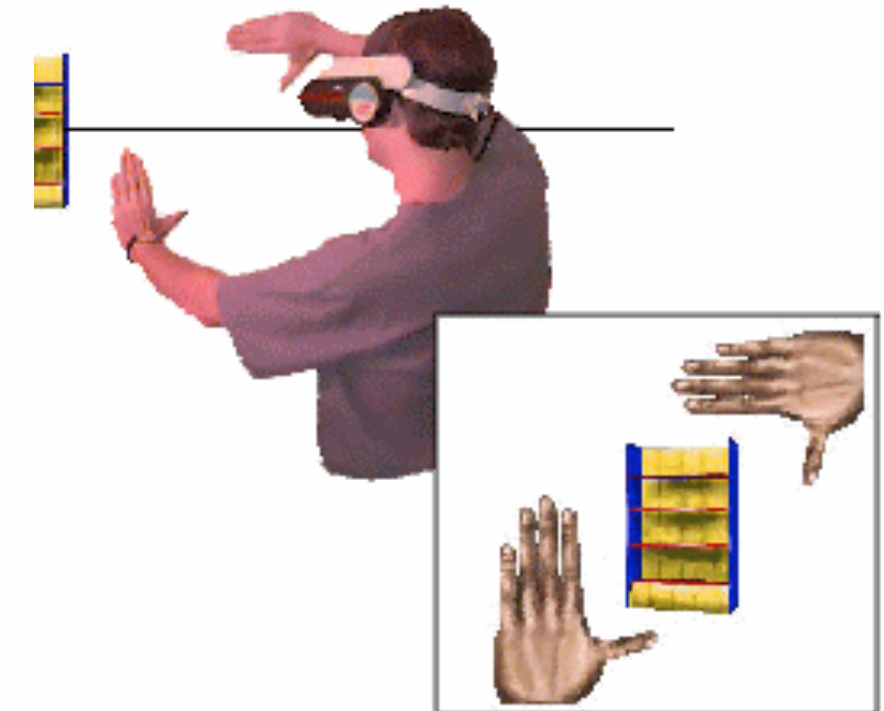
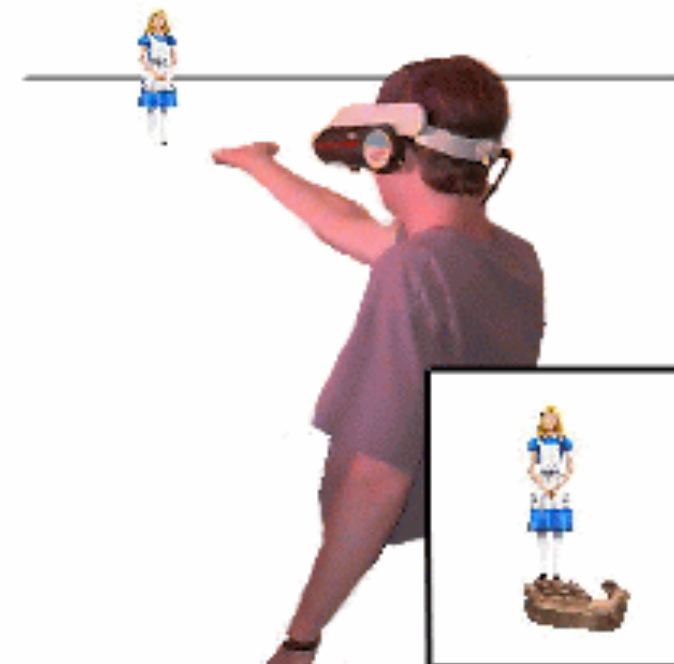
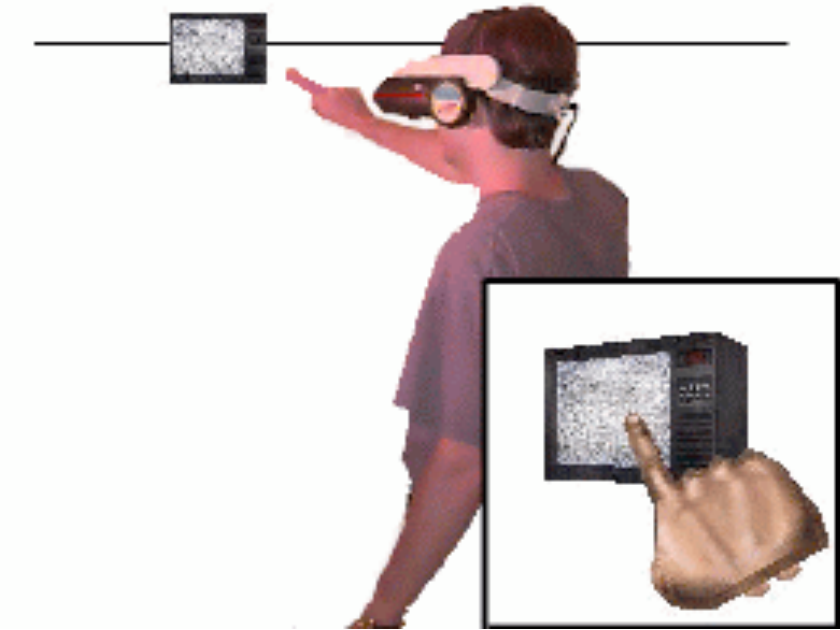
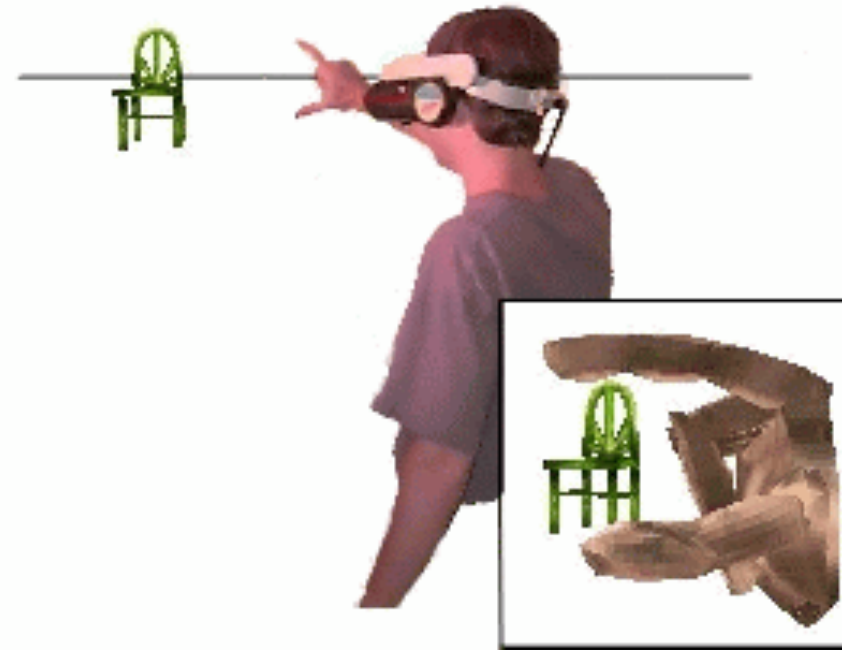
# Silk Cursor

- Use a semi-transparent volume as a 3D cursor
- Controlled in 3 degrees of freedom
  - Translation along 3 axes
- Judge depth ordering by the partial occlusion effect
- Used to select objects out of reach
  
- Further reading:
  - [Shumin Zhai, William Buxton, Paul Milgram: The Partial-Occlusion Effect: Utilizing Semitransparency in 3D Human-Computer Interaction, 1996]
  - [http://etcclab.mie.utoronto.ca/people/shumin\\_dir/SILK/silk.html](http://etcclab.mie.utoronto.ca/people/shumin_dir/SILK/silk.html)



# Image Plane Interaction

- Used with HMDs
- Find finger positions in the image
- Cast a ray into the scene, and intersect it with objects
- Several techniques proposed:
  - Head crusher
  - Sticky finger
  - Lifting palm
  - Framing hands



## • Further reading:

- [Pierce et al. 1997: Image Plane Interaction Techniques In 3D Immersive Environments]
- <http://www.cs.cmu.edu/~stage3/publications/97/conferences/3DSymposium/HeadCrusher/>

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# PerspectiveTable

- Shared Project between RWTH Aachen & LMU München
  - parallel development (2013)
- based on two curved desk prototypes
  - combining large horizontal and vertical Touch Displays



BendDesk

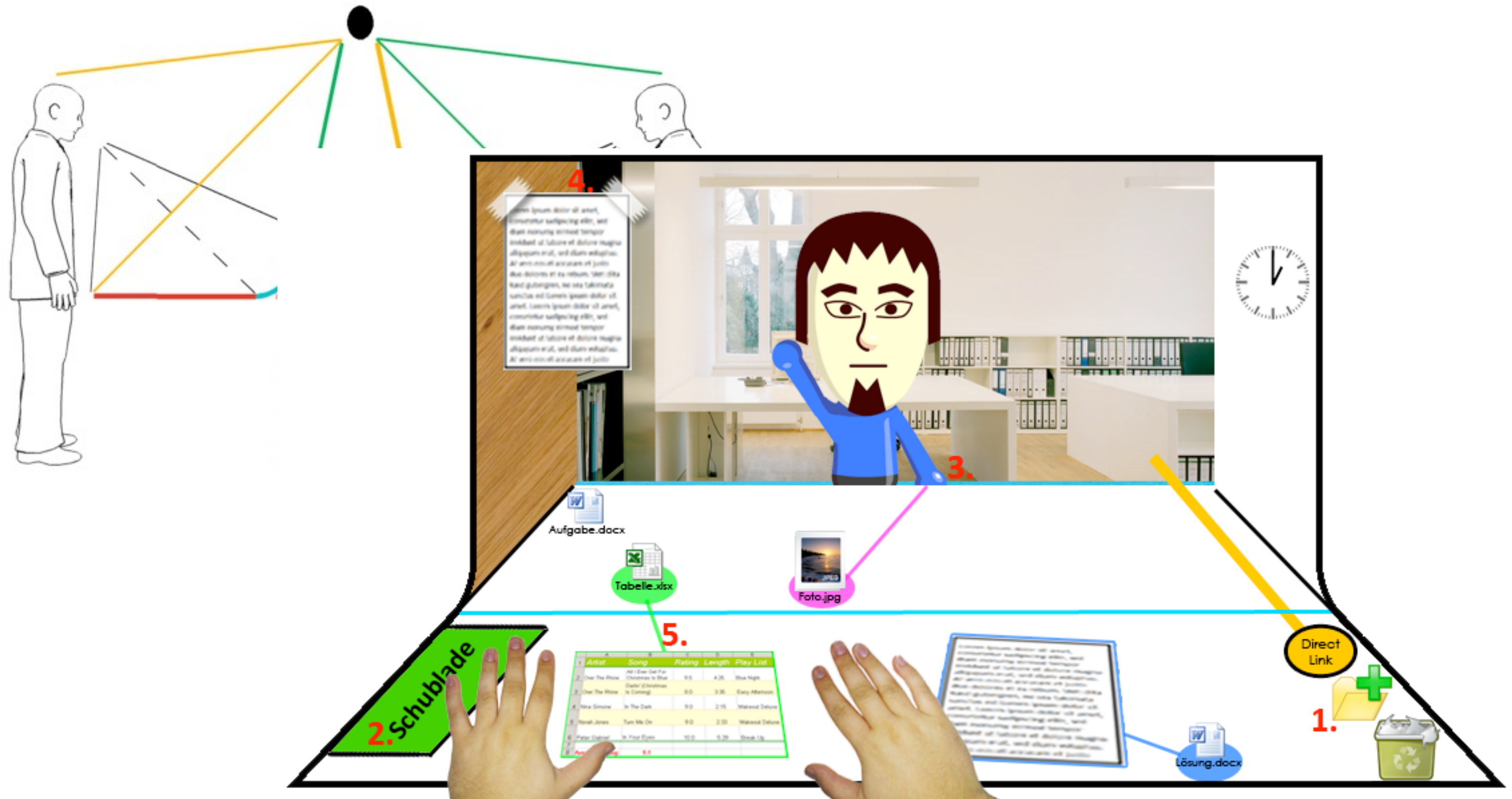
RWTH Aachen



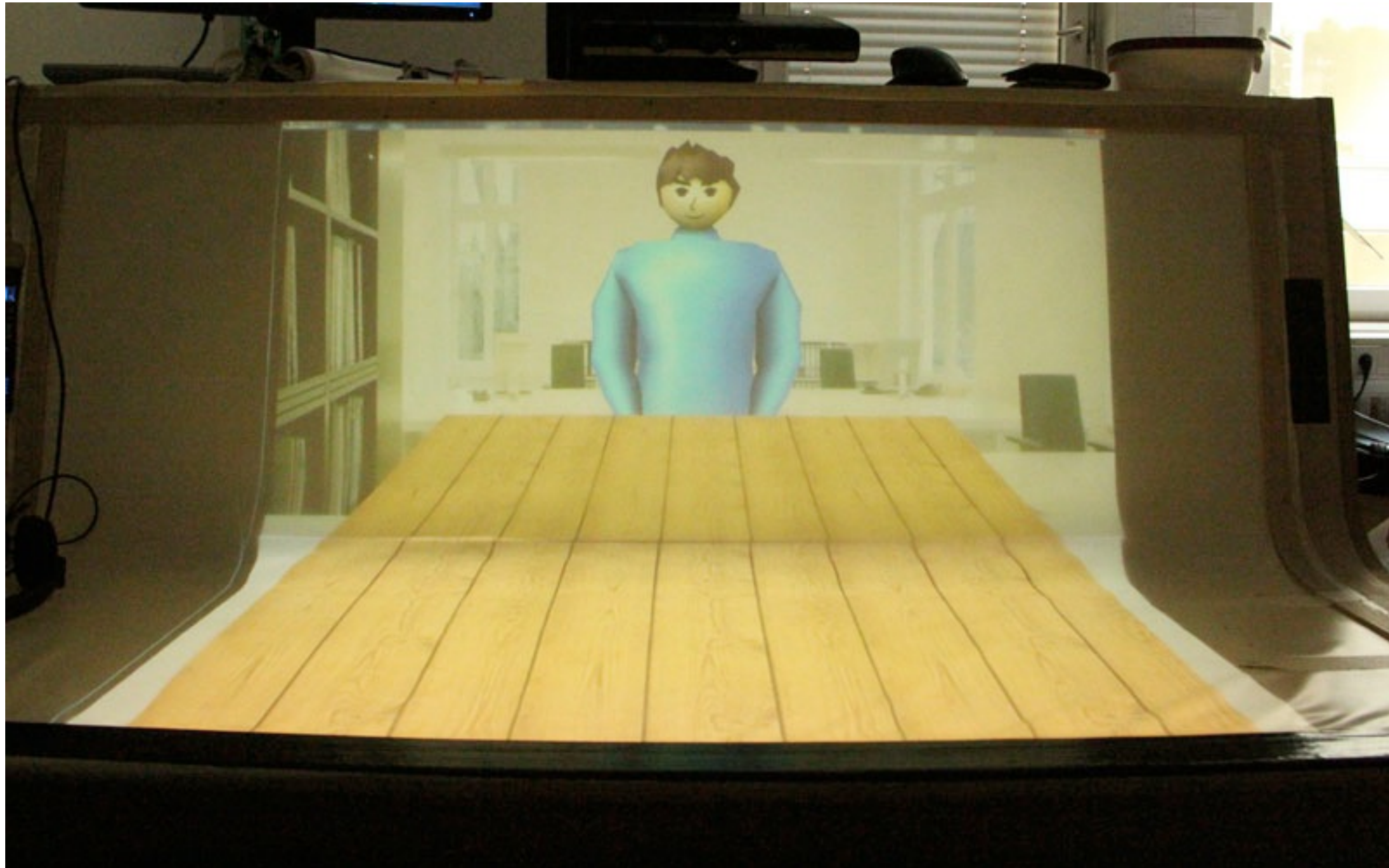
Curve

LMU München

# Telecooperation between two curved desks

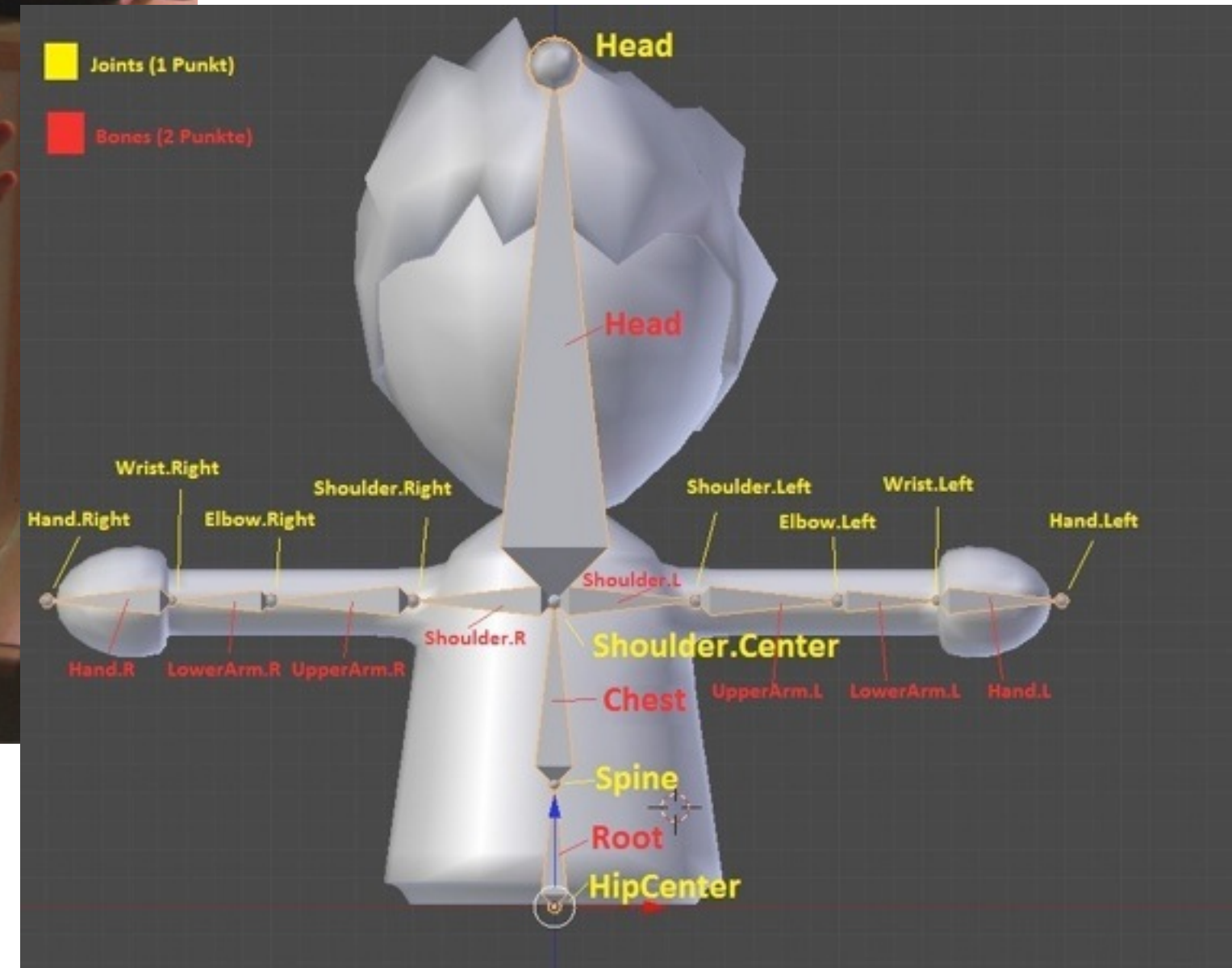


# Counterpart Represented as an Avatar

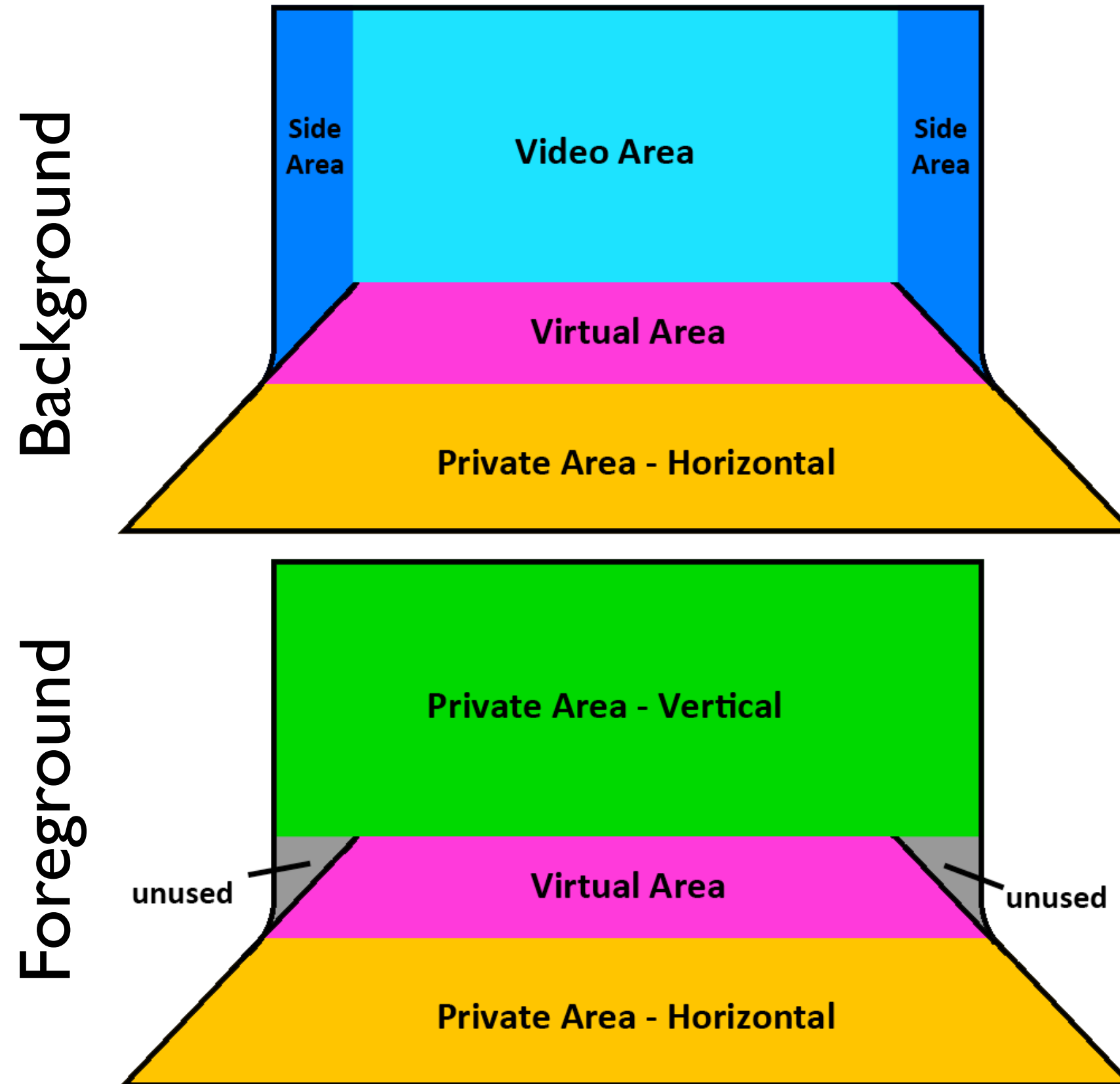




# Skeleton Animation controlled by a Depth Camera (Kinect)



# Working Areas and Metaphors



# Brief discussion: My right, your left??

