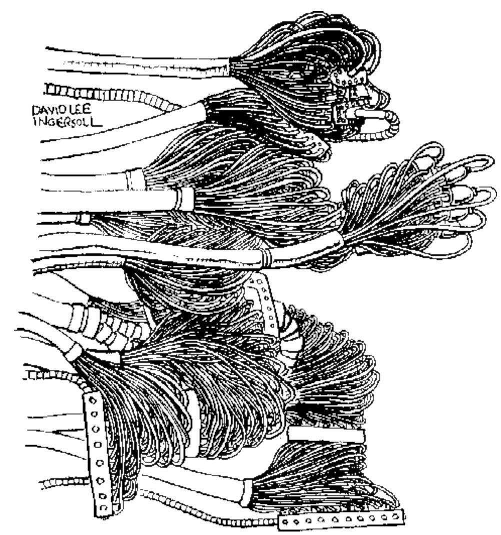
Virtual Reality & Physically-Based Simulation

Input Devices



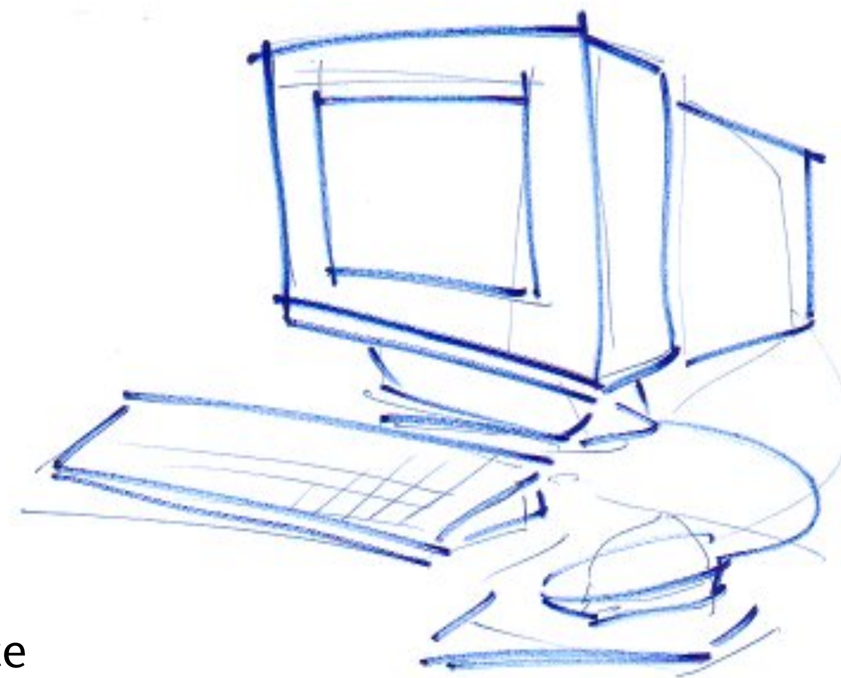
G. Zachmann

University of Bremen, Germany

cgvr.cs.uni-bremen.de

The "Bill Buxton Test"

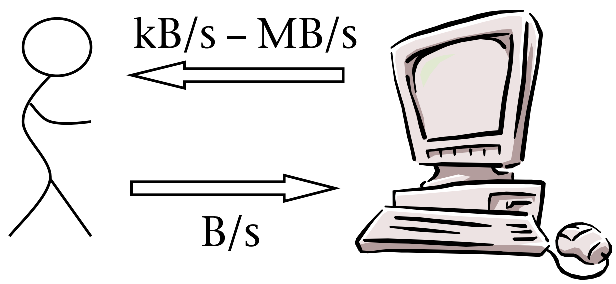
- Draw a computer within 15(!) seconds
- Ca. 80% of all people draw something like this:
  - Monitor
  - Keyboard
  - Mouse
- Remarkable:
  - No "computer" in the drawing!
  - Message: users don't see
    the system as a computer,
    they just see a device on its surface
    (i.e., they only see its I/O interface),
    and they just perceive some kind of I/O behavior

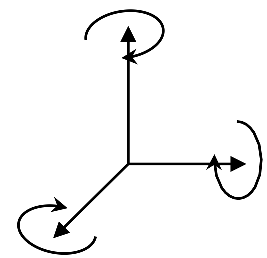


Extreme Examples of "*Intrusive*" I/O Devices

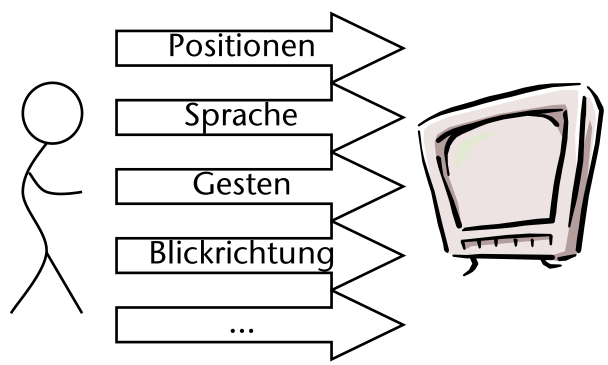
Why are Devices (until now) so Important in VR?

- They are the "playground" for many researches in VR
- Vision: *no* input devices at all!
- Bandwidth with conventional devices:



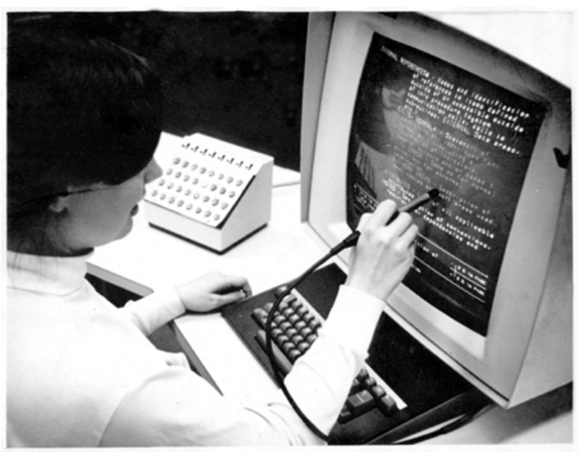


- *Degrees of Freedom* (DOFs)
- Multimodal devices/input:



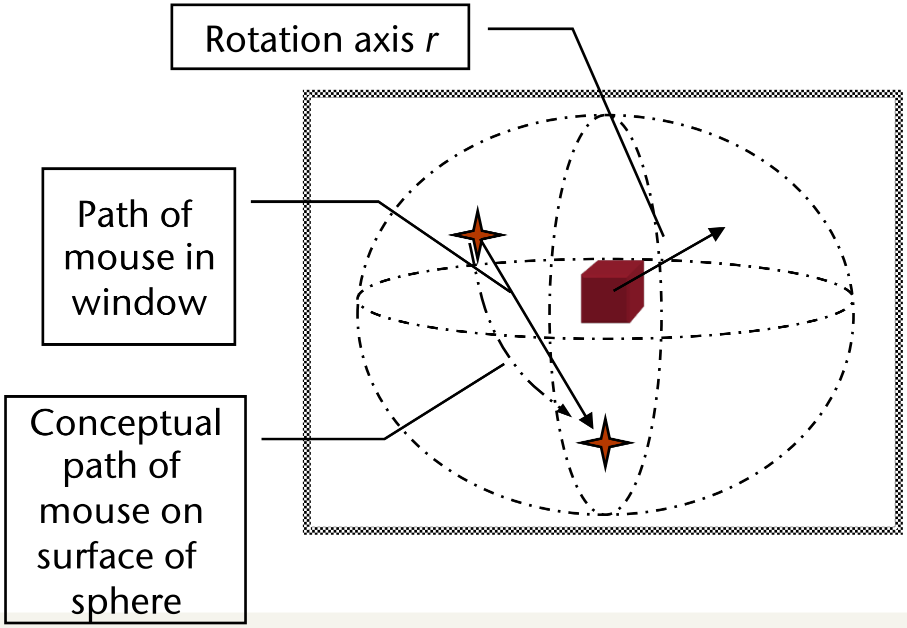
Classical Input Devices

- Mouse:
  - Precise, inexpensive
  - Only 2D, input of orientations is cumbersome
- Drawing tablet:
  - Precise, very well suited for … drawing
  - 2D, input of orientations is virtually impossible
- Light pen (early version of touch/tablet screen)

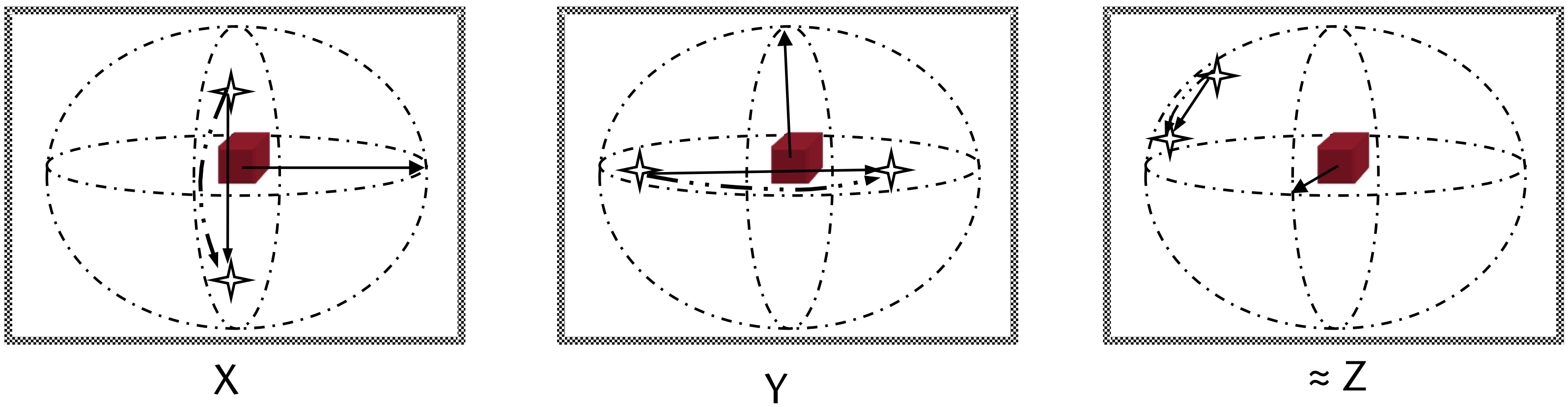


Virtual Trackball

- Problem: how to enter orientations with a mouse?
- Idea:
  - Put sphere around object / scene
  - Sphere can rotate about ist center
  - Mouse drags point on surface of the sphere
- Calculation of rotation:
  1. Start point $p_1 = (x_1,y_1)$, end point $p_2 = (x_2,y_2)$
  2. $z = \sqrt{x^2 + y^2}$
  3. $\overline{r} = \overline{p_1} x \overline{p_2}$



- With a virtual trackball, you can rotate about all axes (except one):



- Improvements:
  - "*Spinning trackball*" (à la Inventor) makes "re-grabbing" the ball unnecessary
  - "*Locking*" for exact rotations about one coordinate axis

Desktop Devices

- Spacemouse:
  - 6 DOFs
  - Suitable for CAD, viewpoint navigation in general, rotation of the whole scene

- Steering wheel
  - With force feedback
- Others ? ...

Beyound Desktop: CAT — Control Action Table

- 6 DOF, plus tablet

Project "IPARLA", INRIA, France

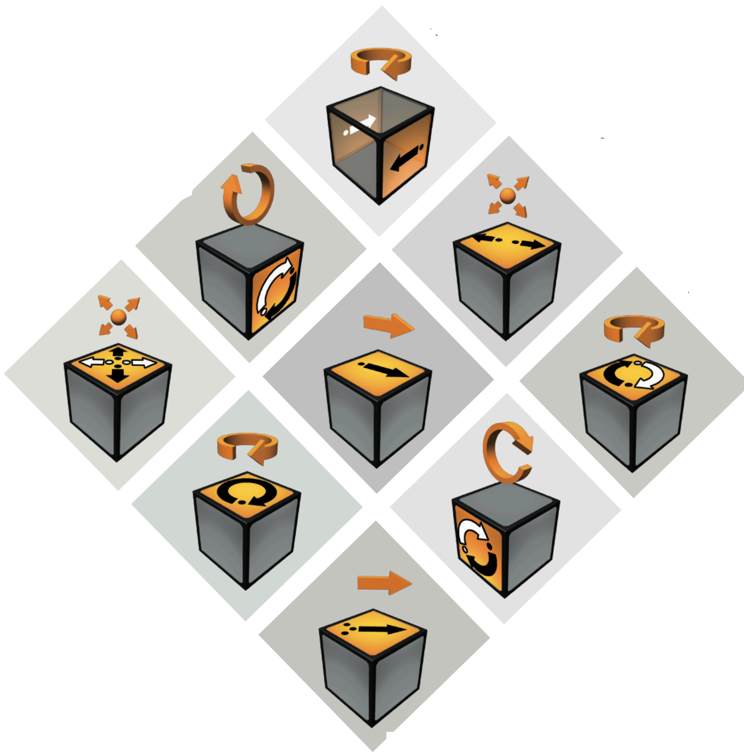
Isotonic vs Isometric Sensing

- Isotonic = "same muscle tension during contraction of the muscle"
- Isometric = "same muscle length although muscles contract"

- Definition isotonic sensing device:
  The user can move the device (or just that DoF) all the way without changing muscle tone.
- Examples:
  - The rotational DoF's of the CAT
  - The tracking sensors of a tracking device
- Definition isometric sensing device:
  The device (or just that DoF) does not move when the user pushes/pulls the device, no matter how hard she pushes/pulls.
- Examples:
  - The translational DoF's of the CAT
  - The spacemouse (not purely isometric)

Cubtile

- 5 multi-touch surfaces arranged in a cube
- Bonus: very neat illumination ☺



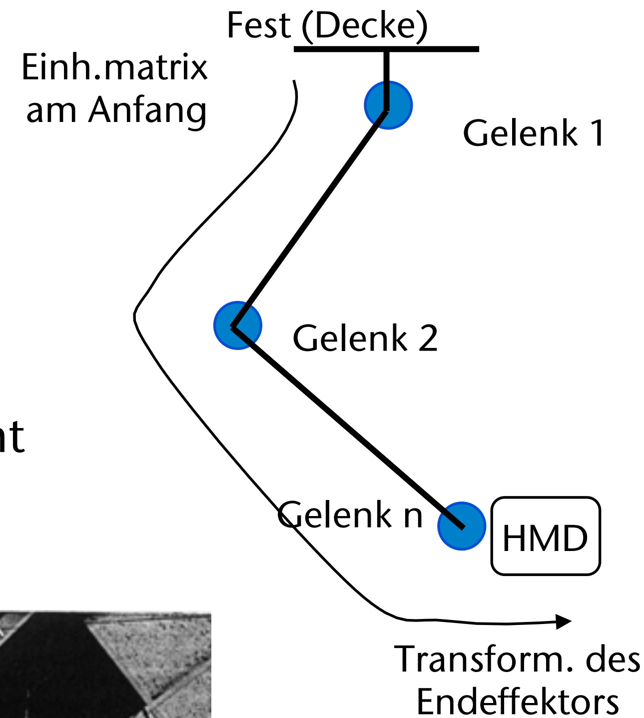
Tracking

- Task: determine "where is X of the users?"
  - X = head, hand, eyes, feet, whole body, ...
- Requirements:
  - *Non-intrusive*
  - High precision (1 mm)
  - Low latency (1 msec)
  - High *update rate* (100 Hz)
  - Works in all environments and conditions
  - Large working volume
- Doesn't exist (yet?)!

- Technologies for tracking:
  - Mechanical
  - Electro-magnetic
  - Acustic (ultra sound)
  - Optical
  - Computer vision-based
  - Inertia sensors
  - Laser
  - GPS
  - Hybrids

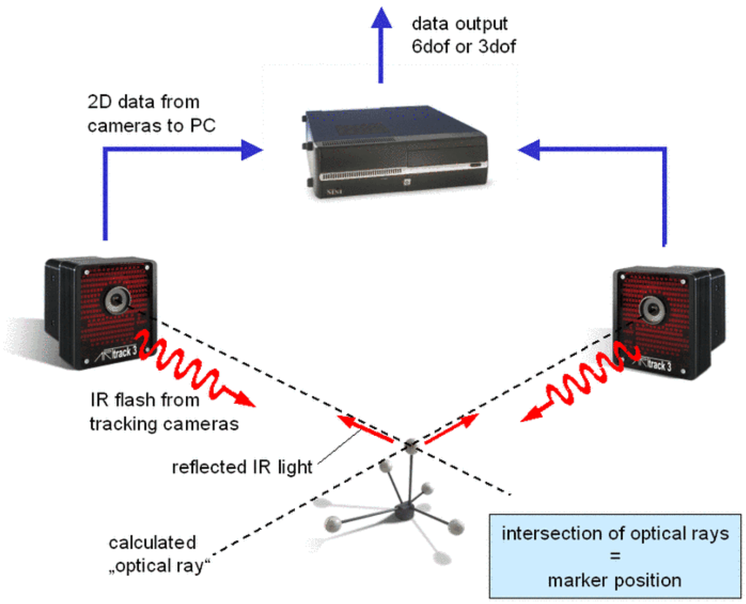
Mechanical

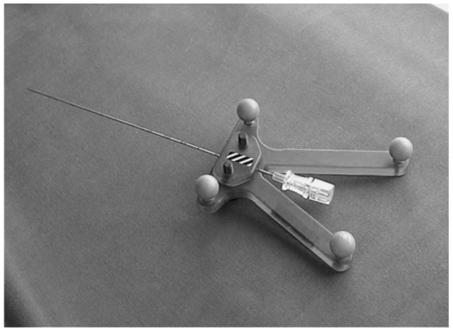
- Advantages:
  - Precision
  - Low Latency
  - No distortion by metal in environment
- Disadvantages:
  - Uncomfortable
  - Working volume
  - "Dead" zones
  - Intrusion
  - Calibration
  - Inertia b/c of mass

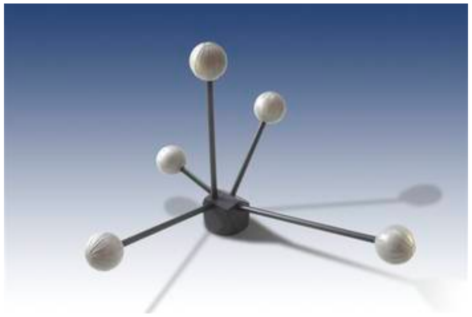


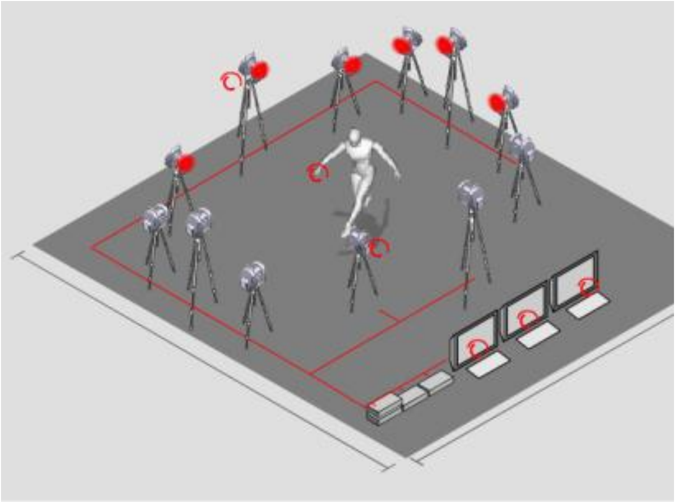
Optical Tracking

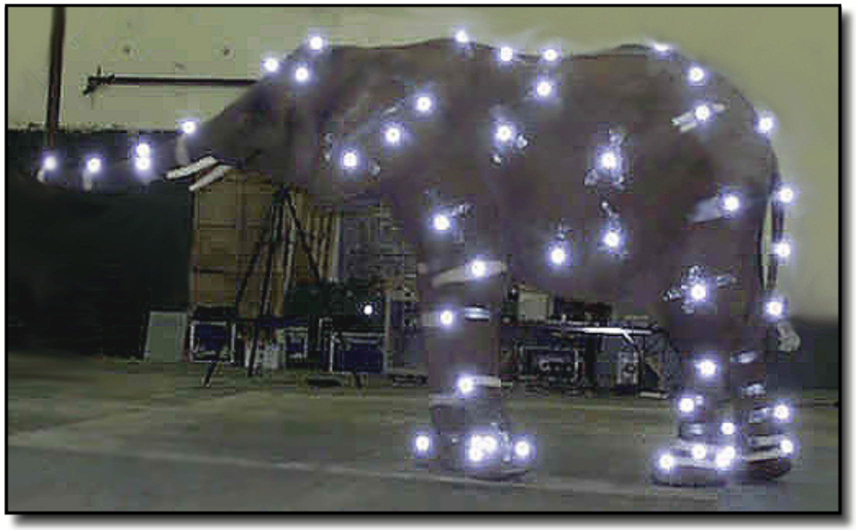
- Idea: track highly reflective markers using IR cameras
- 1 marker → position
  - By way of triangulation
- ≥3 markers (a "*rigid body*") → position and orientation
- Standard technology for body tracking in animation studios and for game dvelopment
  - Motion capturing (MoCap)





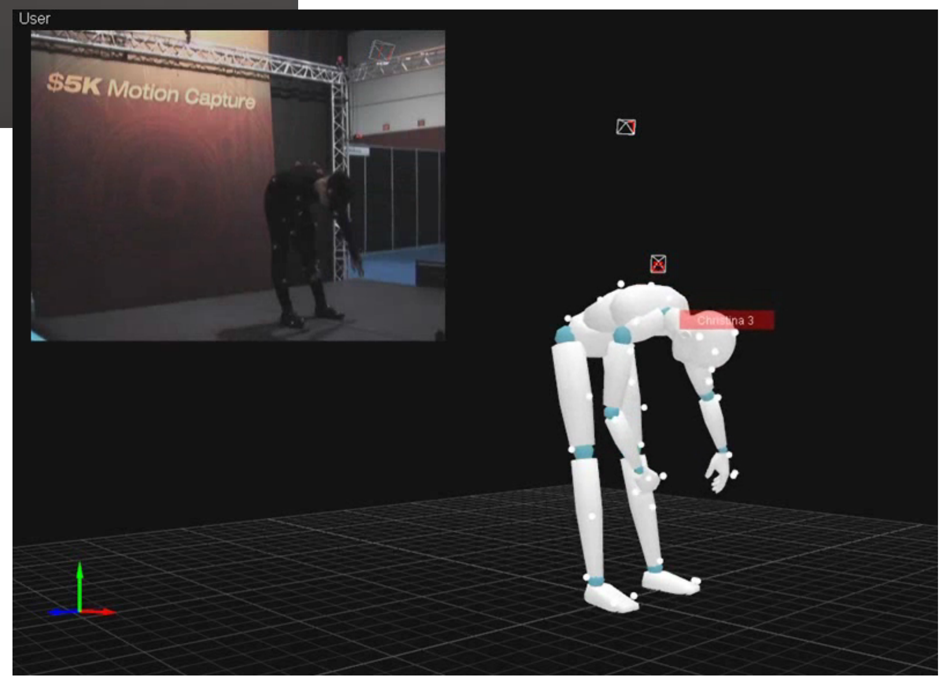




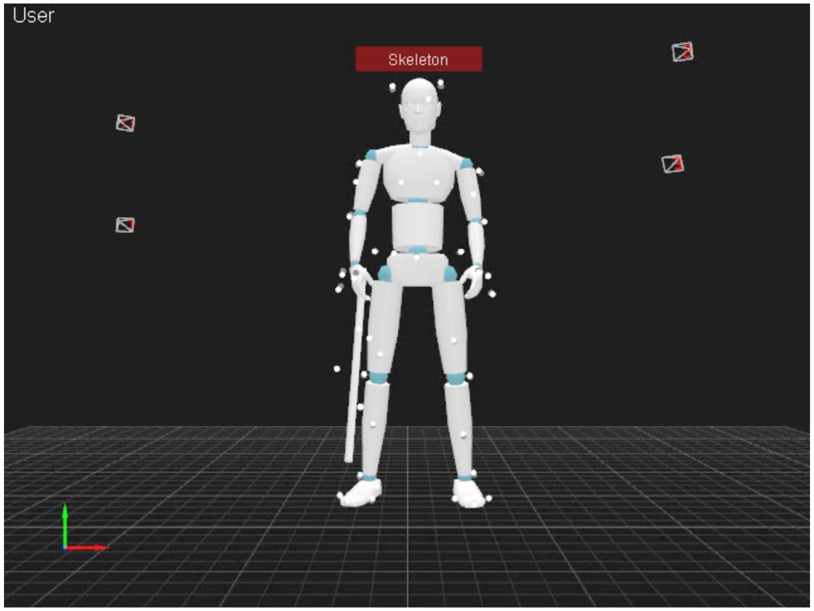


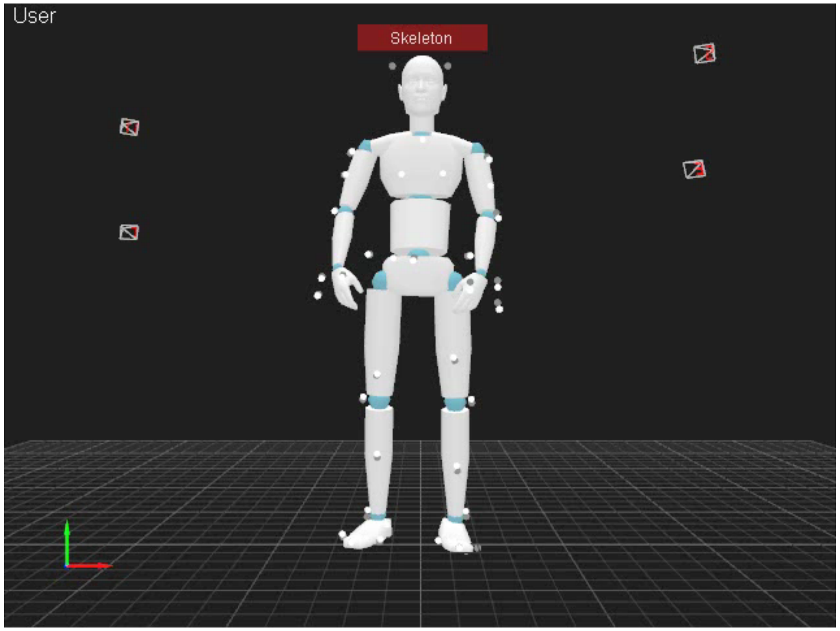
- Advantages:
  - Free movement for users / actors
  - Large working volume
  - High *sampling rate* (typically 120-250 Hz)
  - *Facial animation* is possible, too
- Disadvantages:
  - *Line-of-sight* needed (mitigation: lots of cameras)
  - Price ($40,000 – $140,000)
    - New systems cost only about $6,000

Fluid Images



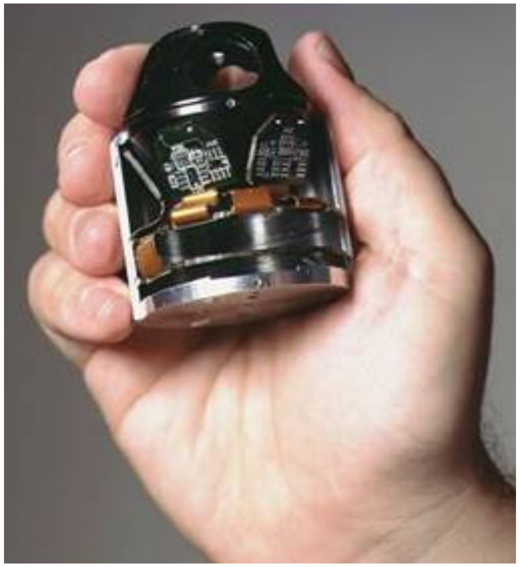
NaturalPoint (OptiTrack)


User
Skeleton


User
Skeleton

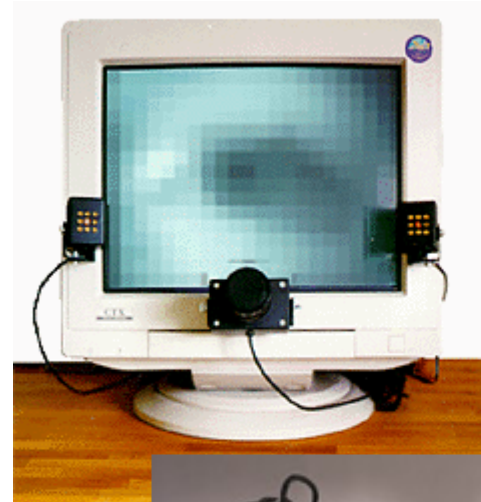
Optical Tracking "*Inside Out*"

- Camera on the head of the user, array of markers (e.g., pulsed LEDs) on the ceiling
- Advantages:
  - Only 1 camera needed
  - Fast (up to 1 msec, 1000 Hz)
  - Precise (1/10 mm)
- Disadvantages:
  - How to track a user's hand?
  - Time- and hardware-consuming installation
- Example: UNC's "HiBall"
  http://www.cs.unc.edu/~tracker/



Eye Tracking

- Where are the user's eyes?
  Where does the user look at?
- Applications:
  - Head tracking
  - Controlling LODs
  - Autostereo monitors
- Problems:
  - Precision
  - Sometimes additional hardware is needed



Acoustic Tracking

- Similar to sonar:
  - 1 ultra sound source
  - 3 receivers (for 3 DOFs)
  - Travel time → position
- Advantages:
  - Very inexpensive
- Disadvantages:
  - Echos
  - *Line-of-sight* prerequisite
  - 3 transmitters needed for 6 DOFs
  - Small range
  - Precision: speed of sound depends on air temperature, humidity, etc.

Inertia Sensors

- Measures acceleration in one direction
- Advantages:
  - No transmitter necessary
  - Very small sensors
- Disavantages:
  - Drift
- Often combined with other tracking technologies to compensate for drift, e.g., ultra sound

Laser

- Measures just distance / position
- So far being used only in manufacturing industries (CNC machines)

Electromagnetic Tracking

- Transmitter =
  - 3 orthogonal coils (using 3 different frequencies)
  - Emit 3 orthogonal electromagnetic fields
- Sensor = receiver =
  - 3 orthogonal coils, too
  - Receive 9 signals in total
- Phase shifts between transmitted and receive signal → distance
- Strength of the 9 different signals → orientation
- Advantages:
  - Small sensors; Working volume = 3 m (or more)
- Disadvantages:
  - Tethering (cables)
  - Metal in environment has severe impact in field distortions
  - Noise

Characteristics of Tracking Systems in Gerenal

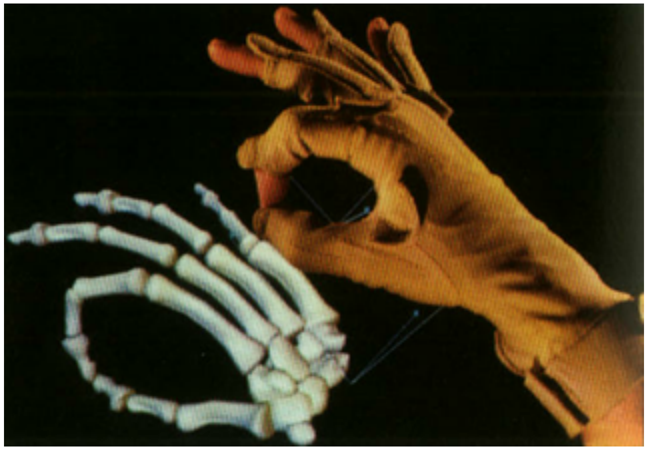
1. # DOFs
2. Precision, drift, replicability
3. Update rate, latency
4. Noise
5. Additional buttons
6. E*ase-of-use*, *tethering* (=cables) – *unintrusiveness*!
7. Working volume
8. Price

3D Pointers

- Analogue to 2D mouse
- Hardware = tracker with buttons
  - Sometimes with additional joystick, etc.
- Names: *flying mouse*, *flying joystick*, *wand* (= Stab), *bone*, *fly-stick*, etc…
- Advantage: physical object induces a strong feeling of presence while grasping a virtual object

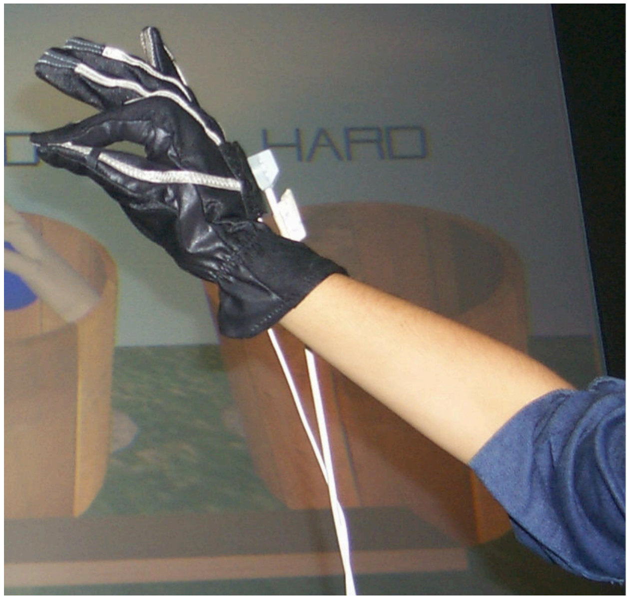
The Dataglove

- "Tracks" fingers of human hand = measures angles of joints
- One of the very eary VR devices
- Different numbers of sensors:
  - 12 = 4 (thumb) + 4x2 (2 sensors per finger)
  - 22 = 4 (thumb) + 4x3 (3 sensors per finger) + 3 sensors between fingers + 1 sensor on back of hand (Handrücken)
- Sensor technologies:
  - Glas fiber (not very robust)
  - Bimetallic strips
- Disadvantages:
  - Low precision
  - Glove by and itself (not really accepted)



Variants

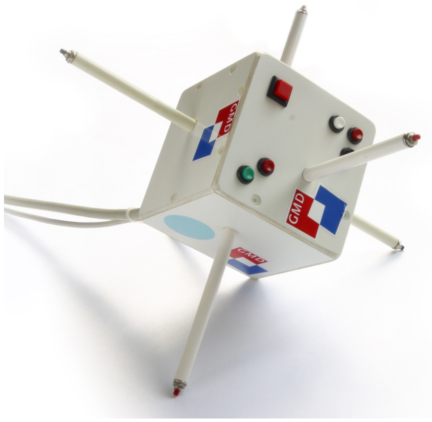
- Pinch glove:
  - No tracking, just detects contact between finger tips → each finger acts like a button
- Usefuly only using 2 tracked pinch gloves; with, though, pretty clever navigation and manipulations can be performed:
  - Grasping and moving
  - Scaling (using *handles* à la Inventor)
  - Will be presented later …
- Disadvantage: a virtual hand cannot be rendered

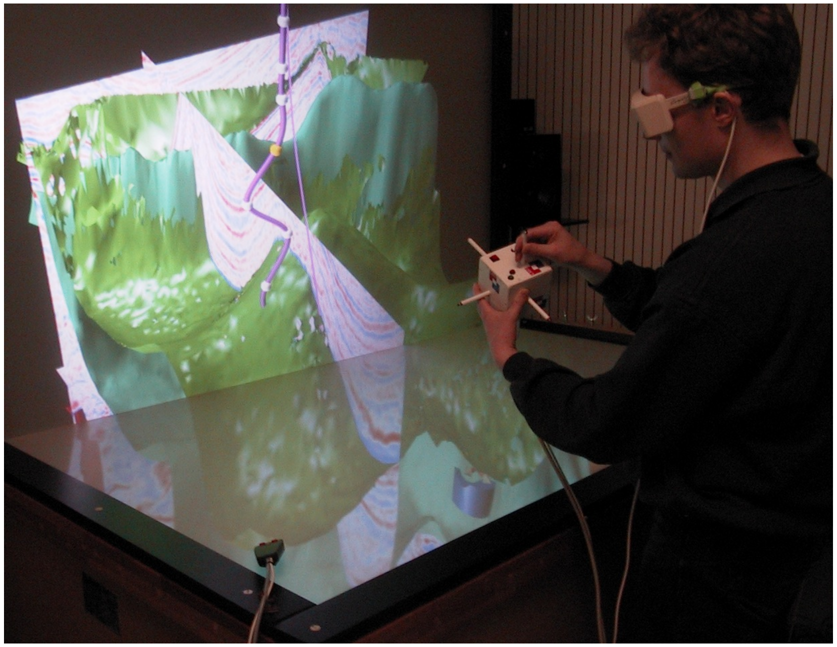


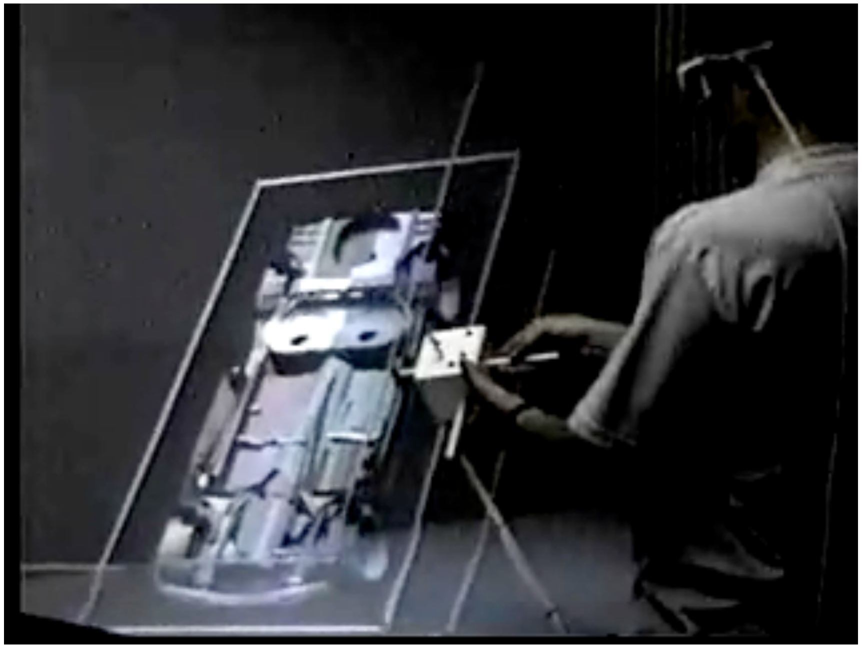
- The P5 from Virtual Realities (www.vrealities.com):

Other High-Dimensional Input Devices

- Cubic Mouse:
  - Number of DOFs = 9

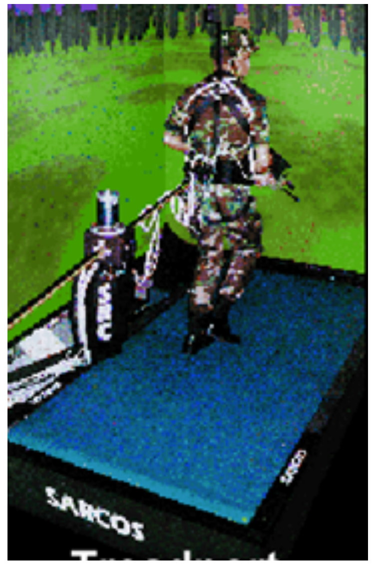




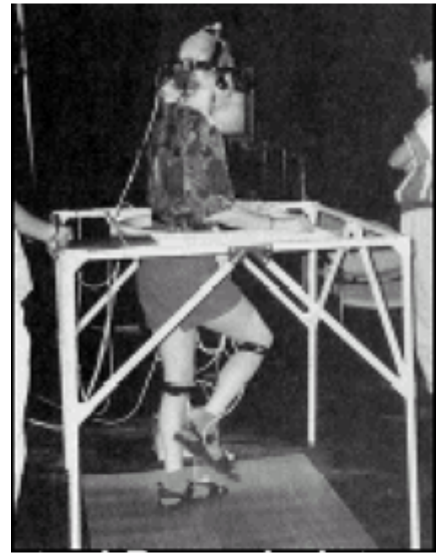


Locomotion Devices

Sarcos, Utah



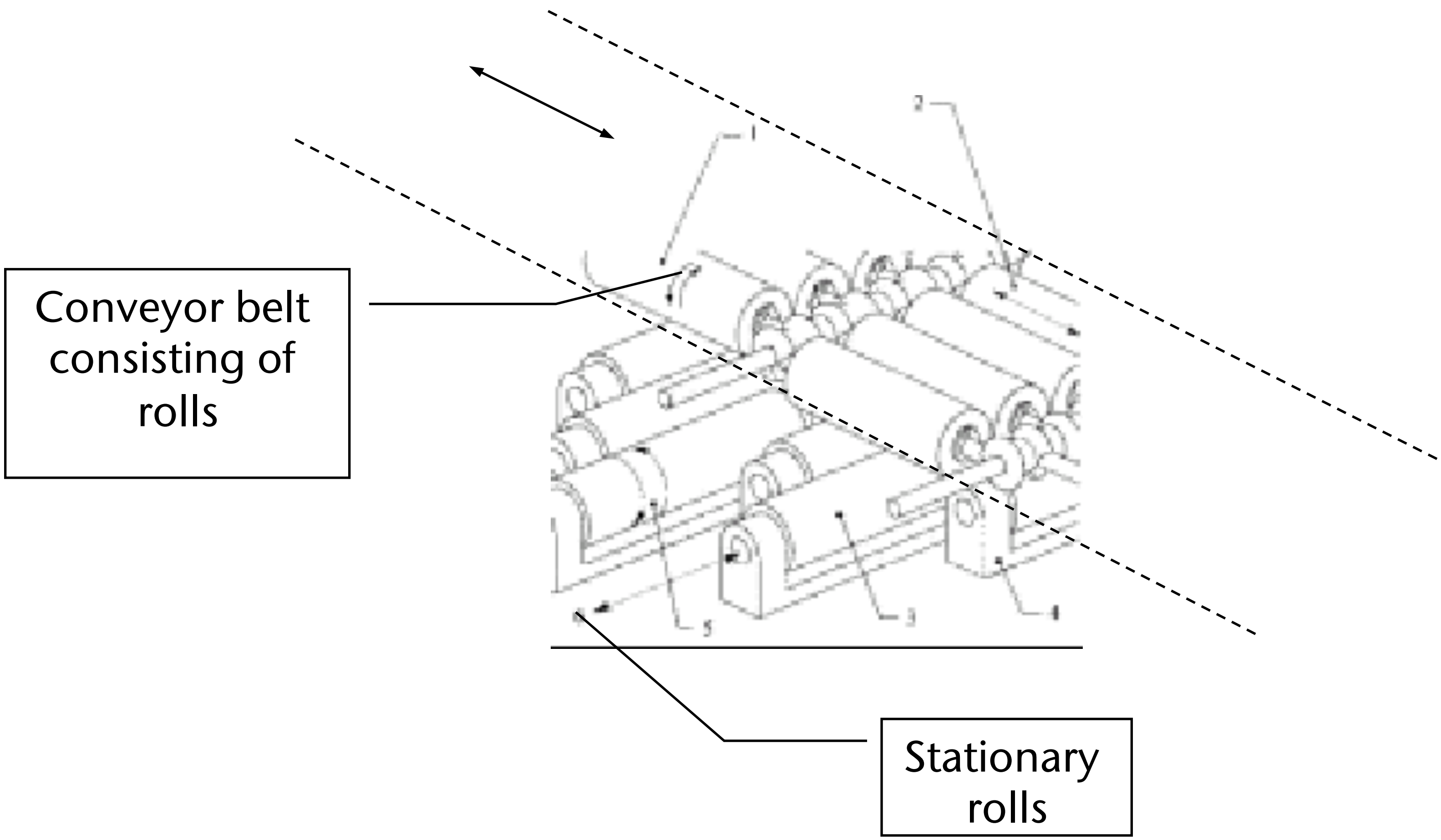
Sarcos



Uni Tsukuba, Japan

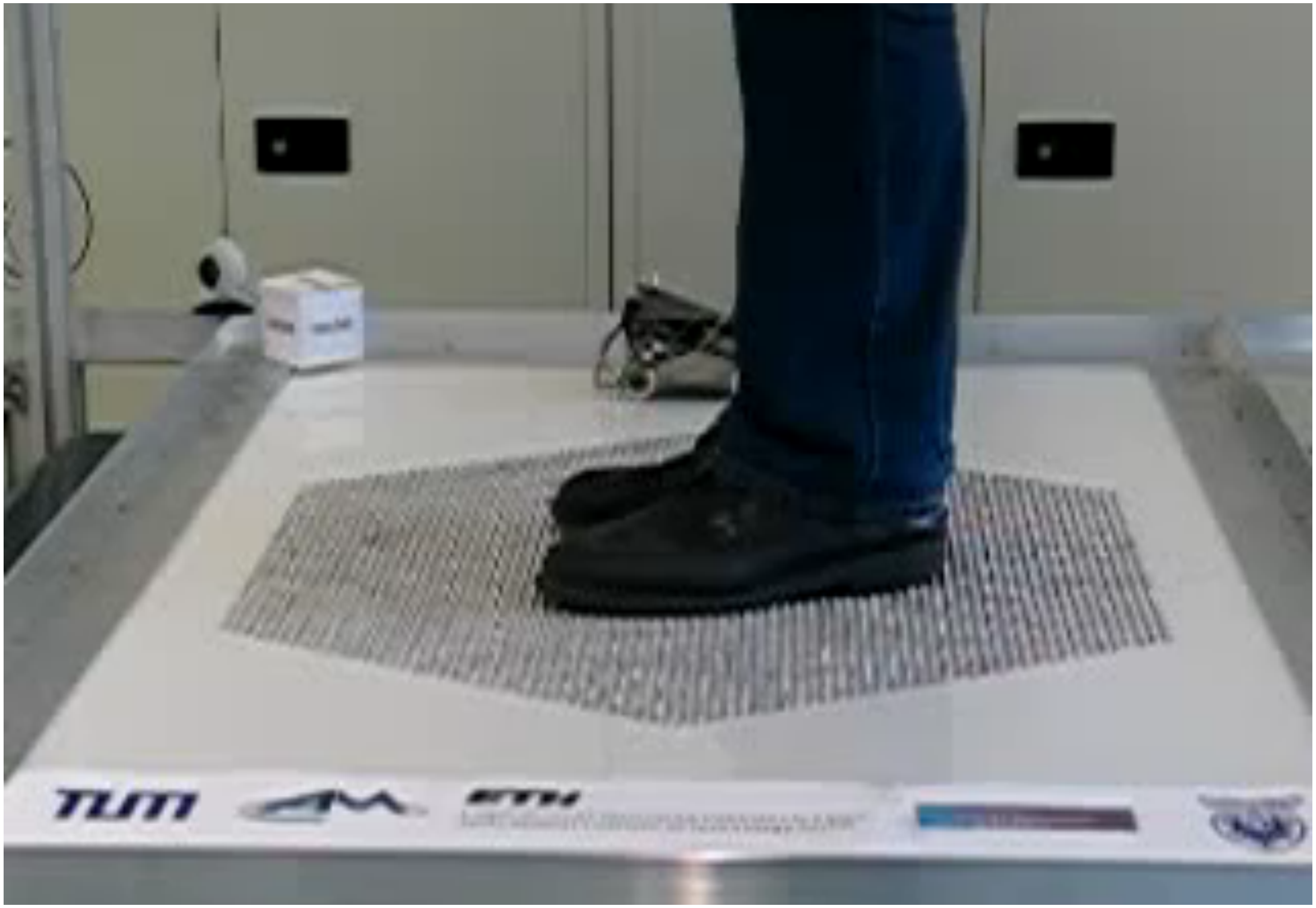
- *Omni-directional treadmill* (omni-direktionale Tretmühle)

Virtual Space Devices, Inc.

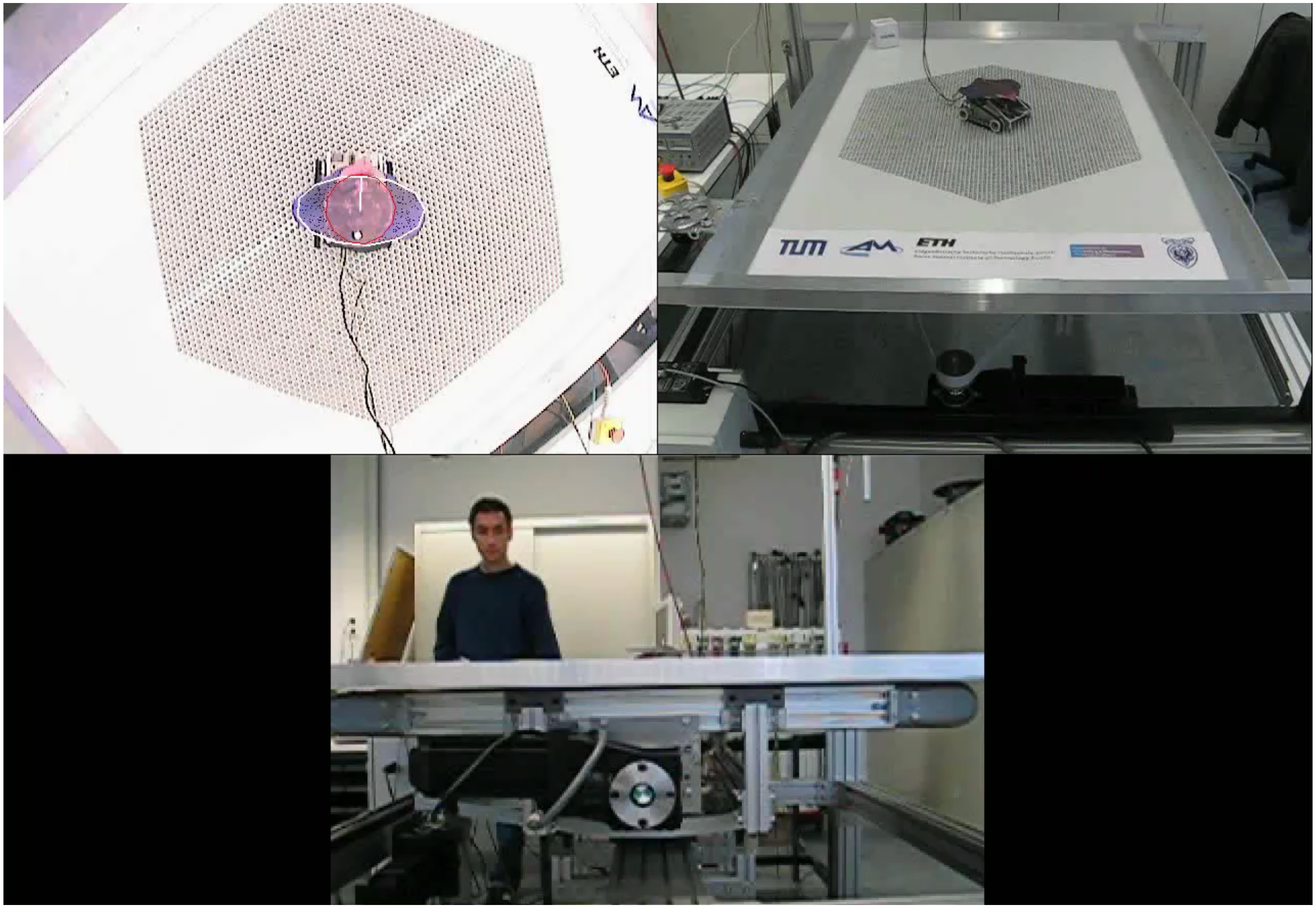

Conveyor belt consisting of rolls
Stationary rolls

Cyberwalk omni-directional treadmill, 2005-2008
TU München

Mode of operation of the Cyberwalk omni-directional treadmill

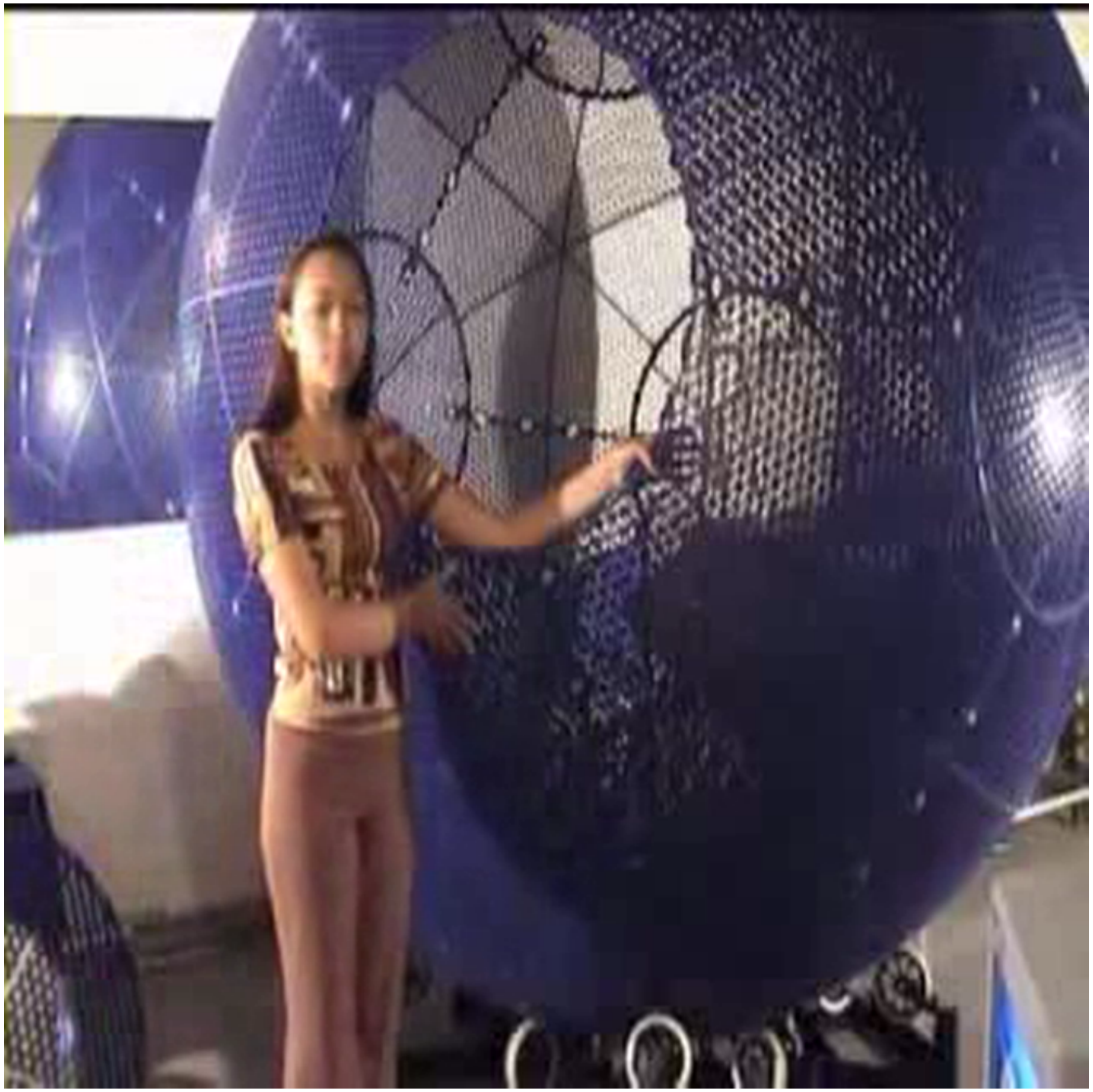


CyberCarpet
Martin Schwaiger, Dr. Thomas Thümmel, TU München



CyberCarpet's mode of operation

- Possible applications:
  - Research on behavior & cognition, brain research
  - Sports medicine
  - Training of soldiers and security staff
  - Fun parks (?)
  - Architecture:
    - Visualization and realistic exploration of architectural designs
    - Test of escape routes
  - Tests on humanoid robots

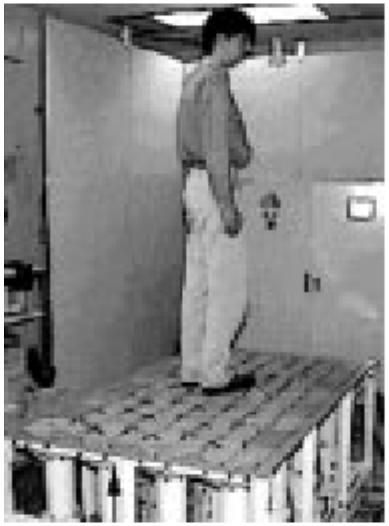


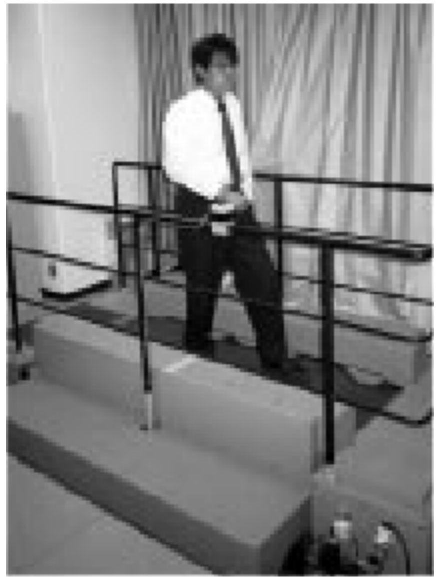
VirtuSphere

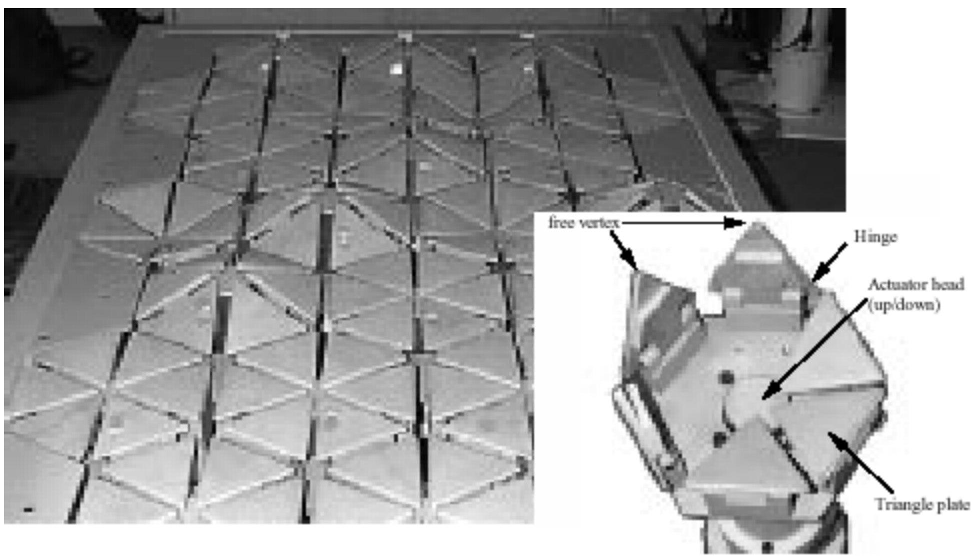
Virtuix: Omnidirectional treadmill for the home [2013]

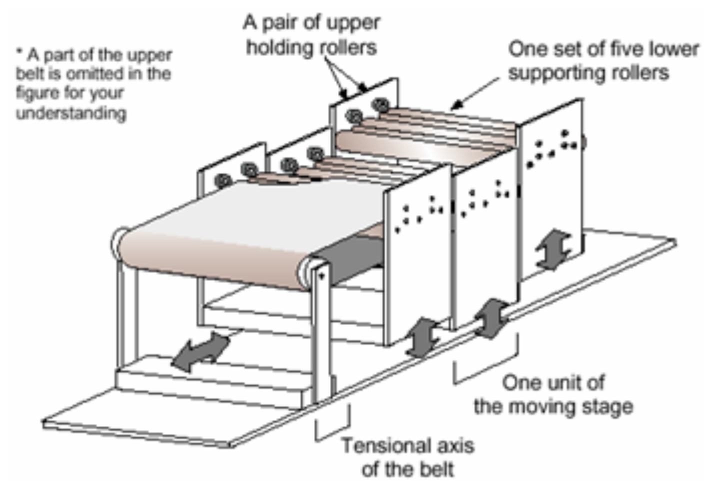
CirculaFloor, 2006

Simulation of Ground for Real Walking



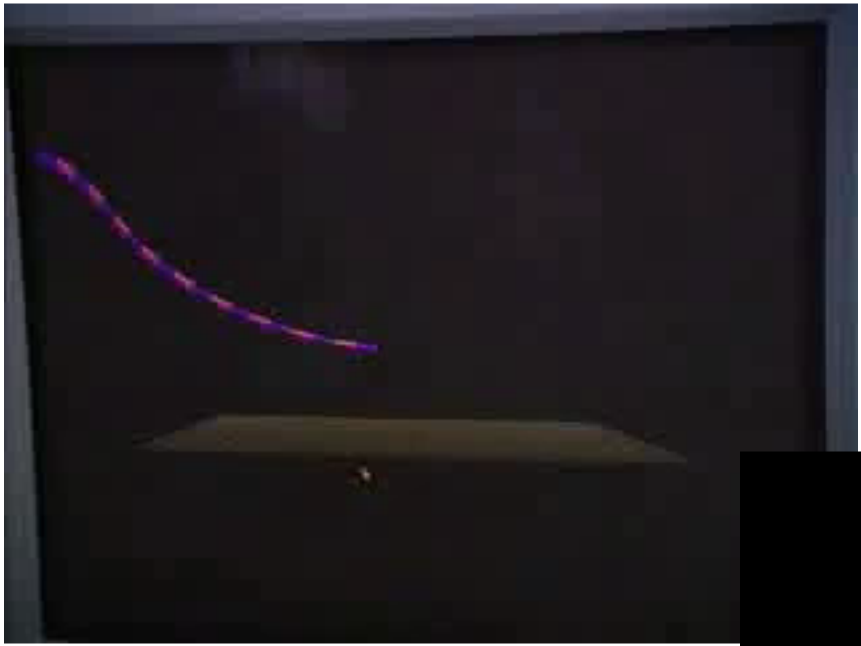






Other Locomotion Devices

Unconventional Input Devices

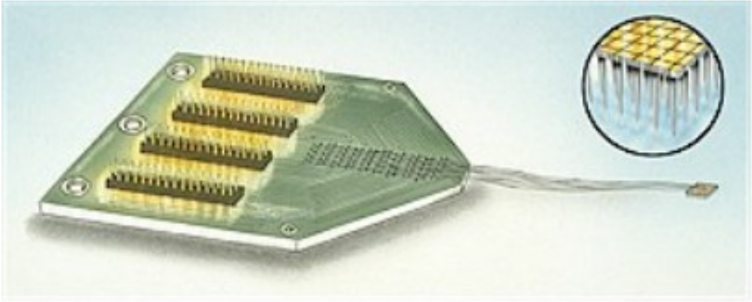


The Shape tape

Virtual Keyboard

Brain Computer Interfaces

- Idea: control the machine by your brain only (no intermediary devices)
  - So far: EEG
  - SciFi: implant

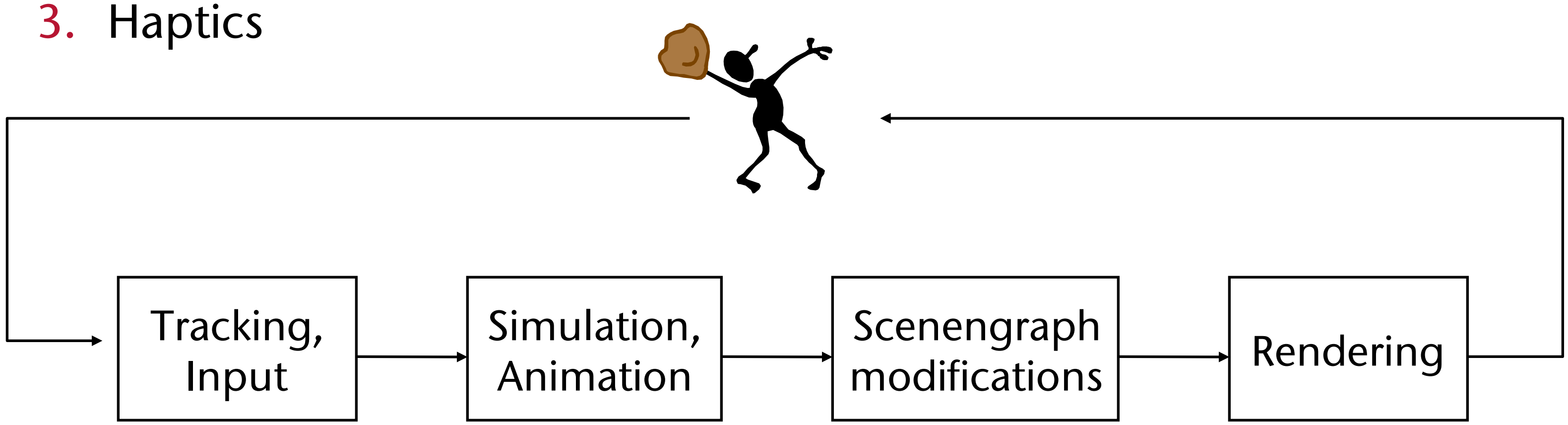


Digression: Affective Computing

- Idea: sense user's attention and emotions, then alter system behavior accordingly
- Parameters:
  - Gesture, posture
  - Voice
  - Eye gaze
  - Breathing
  - Pulse & blood pressure
  - Electrical activity of muscles
  - Skin conductance
- http://www.media.mit.edu/affect/
- Sense user's health: http://www.bodymedia.com, pilot in NRW(?) with patients with a heart condition

Software Architecture for Integrating Devices

1. Get *tracking data*
2. Transform geometry and viewpoint
3. Get "binary" input (gestures, spoken keywords)
4. Simulate and animate objects
5. Render …
    1. 2x image (stereo)
    2. Sound
    3. Haptics



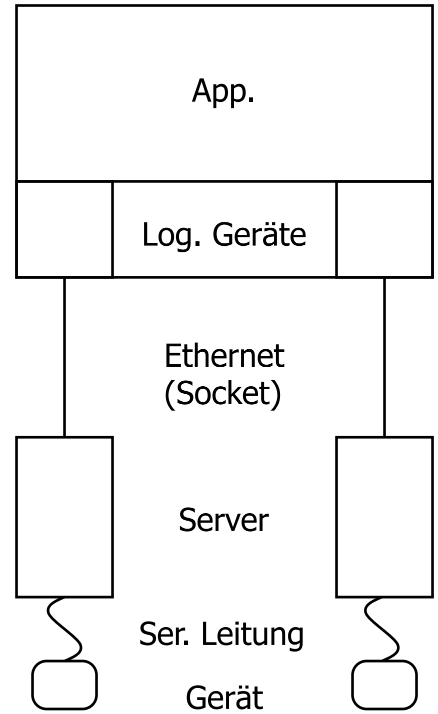
Logical Devices

- Problem:
  - Relative / absolute devices (e.g., spacemouse vs. optical tracker)
  - Different dimensionality
  - Different interfaces / APIs to devices
- Solution:
  - Abstract from physical devices → logical devices
  - Classify according to dimensinality of device input
  - Make all logical devices *absolute* devices (integrate relative ones)
- Logical devices [inspired by Wallace 1976]:
  - 0D = "Button" (boolean)
  - 1D = "Value" (float)
  - 6D = "Space" (matrix)
  - 1-out-of-n = "Choice" (integer)
  - Glove (float array)

- Mapping matrix:

	Maus	Space-mouse	Trak-ker	Spra-che	Tasten	Lauf-band	Glove	Dial
Button	x	x	(x)	x	x	(x)	x	
Value	(x)	(x)	(x)	(x)		x	x	x
Space	(x)	x	x					
Choice	x	x					x	

- Requirements on architecture:
  - Device could be at arbitrary host → client-server architecture
  - Lots of clients per server
  - Fault tolerant, in case of wrong parameters (e.g., wrong port), device switched off at init time, etc.
  - Ideal: substitute other physical device for logical device by config file (e.g., for driving the navigation)
- 2 kinds of quality of service (QoS): fast or reliable



Kind of data	Treatment of latency	Kind of transport	Data structure
continuously	"better never than late"	UDP	Shared memory
discrete	"better late than never"	TCP	Queue