

# Virtual and Augmented Reality

Hannes Kaufmann

Interactive Media Systems Group (IMS)

Institute of Visual Computing &  
Human-Centered Technology

# Overview

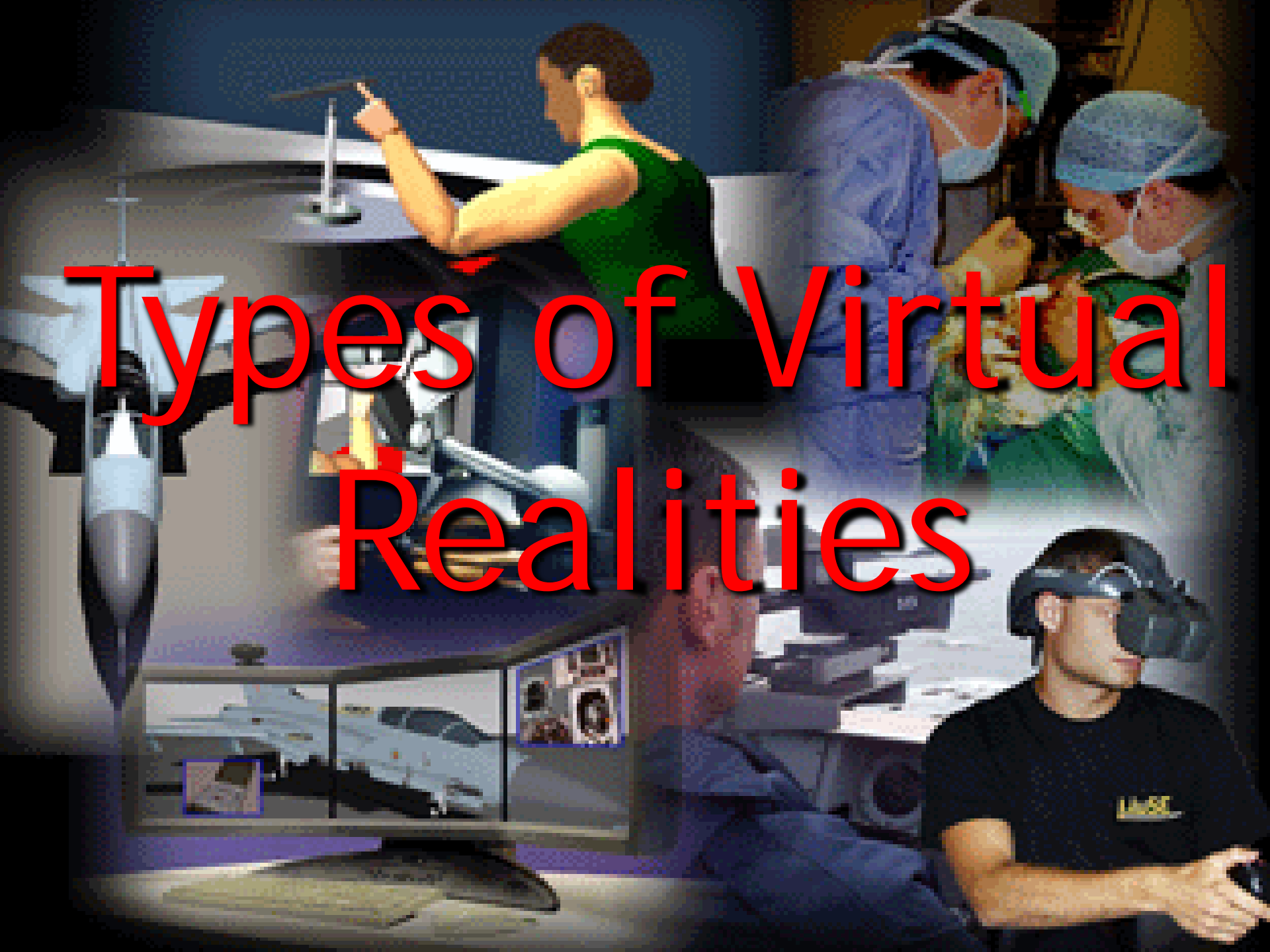
- Introduction, Applications
- Input Devices & Tracking
- Output Devices – Displays, Haptics,...
- 3D Graphics Hardware
- Scene graphs, AR/VR Framework,...
- 3D Interaction
- Usability, Evaluations
- Current Research



# Introduction - Overview

- Terms and Definitions
- History of VR
- Application areas and examples





# Types of Virtual Realities



Flatscreen VR



Gaming Applications



Multiple Flatscreens



18.1" LCD display,  
Resolution: 1280×1024



The DTI 2018XL Virtual Window™

Auto-stereoscopic 3-D Display (courtesy of Dimension Technologies Co.)



17" LCD display,  
Resolution: SXGA  
(1280×1024)

Virtual Window 3-D Display (courtesy of Virtual Research Co.)



FloStation



elumens

Mini-Workbench



The ImmersaDesk




CAVE 3-D large volume display (Fakespace Co.)



# Head Mounted Displays (HMD)...



Interactive Personal Display



- Fields for compact storage
- Completely Adjustable Fully Immersive Design

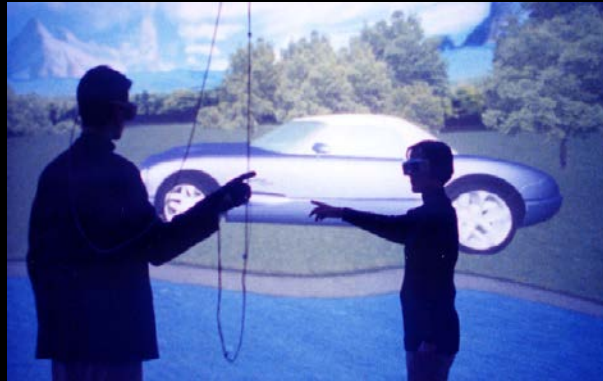
Advanced Concept Drawing 129T 00001  
CONFIDENTIAL

**IIS** Interactive Imaging Systems, Inc.



# KEY ELEMENTS

- Immersion
- Interactivity



# Virtual Reality – Definitions

„The **computer-generated simulation** of a three-dimensional image or environment that can be **interacted** with in a seemingly real or physical way by a person using special **electronic equipment**.”

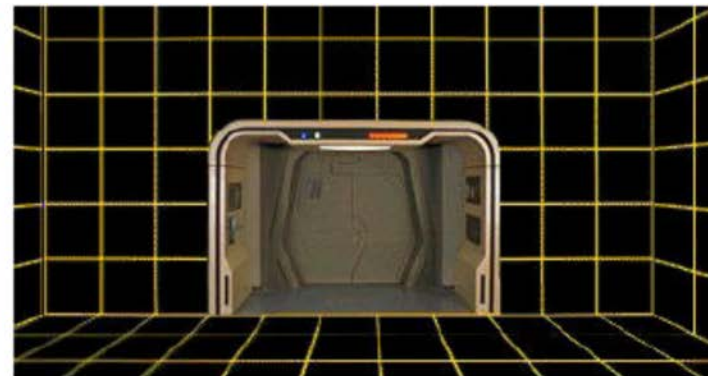
“Virtual reality is an **artificial environment** that is created with **software** and presented to the user in such a way that the **user suspends belief** and accepts it as a real environment.”

- Immersive
- Artificial
- Interactive

Vision: Holodeck



Star Trek's Holodeck



# Milgram's Reality-Virtuality Continuum (1994)



Mixed Reality

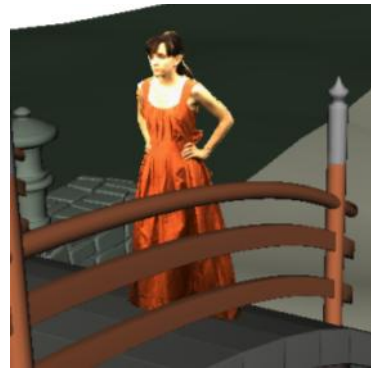
Real  
Environment



Augmented  
Reality (AR)



Augmented  
Virtuality (AV)

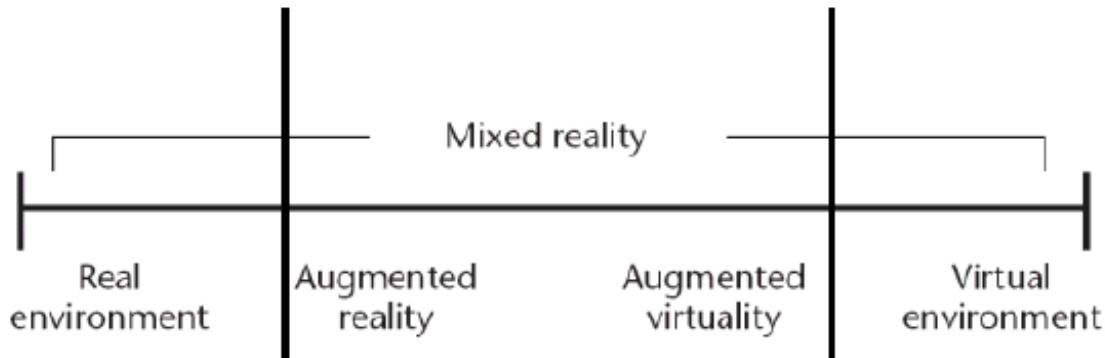


Virtual  
Environment



Adapted from Milgram, Takemura, Utsumi, Kishino. Augmented Reality: A class of displays on the reality-virtuality continuum

# Augmented Virtuality



Enhancing the virtual world by pictures/textures/models of the real world



# Augmented Reality (AR)



Definition (Azuma, 1997)

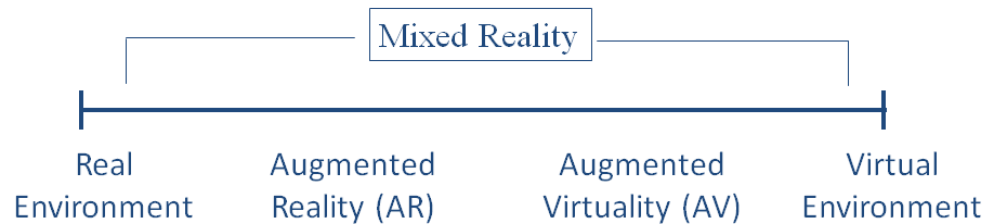
- 1) Combines real and virtual world
- 2) Interactive in real time
- 3) Registered in 3-D  
(real and virtual objects are in a 3D relation to each other)

# Augmented Reality (AR)

- Advanced technical requirements:
  - Accuracy of „Tracking“
  - „Registration“: Combining real and virtual world
- Precise, accurate, fast and robust tracking & registration



# Mixed Reality



- Any combination of real and virtual world

# Collaborative VR / AR / MR



- Users share the same virtual space
- Assists social interaction / cooperation
  - natural communication (language, gestures)
  - supports working in teams

# Distributed VR / AR

- Distributed collaboration over large distances possible
- Large number of users supported
- Flexible distribution of computing power & resources
- Flexible hardware setups



# History of VR

<https://web.archive.org/web/20181231092232/http://archive.ncsa.illinois.edu/Cyberia/VETopLevels/VR.History.html>  
<http://www.bilawchuk.com/mark/history.html>

# 1956 - Sensorama (Morton Heilig)



Introducing . . .

## sensorama

The Revolutionary Motion Picture System  
that takes you into another world  
with

- 3-D
- WIDE VISION
- MOTION
- COLOR
- STEREO-SOUND
- AROMAS
- WIND
- VIBRATIONS



SENSORAMA, INC., 855 GALLOWAY ST., PACIFIC PALISADES, CALIF. 90272  
TEL. (213) 459-2162

# Ivan Sutherland – Ultimate Display (1970)



"The ultimate display would be

- a room within which the computer can control the existence of matter.
- A chair displayed in such a room would be good enough to sit in.
- A bullet displayed in such room would be fatal.
- Such a display could literally be the Wonderland into which Alice walked.,,

Video

# 1970s – Interactive Works: *VideoPlace/VideoDesk* (by Myron Krueger)



“Artificial Reality”

# Jaron Lanier: Virtual Reality

- ~1980-82: first used the term „Virtual Reality“
- Founds the first company producing VR products (VPL Research) (dataglove, HMD,... used in Lawnmower Man)
- 1984: Neuromancer - William Gibson: „Cyberspace“
  - Visions for later developments e.g. VRML/Web3D standard or movies such as Matrix

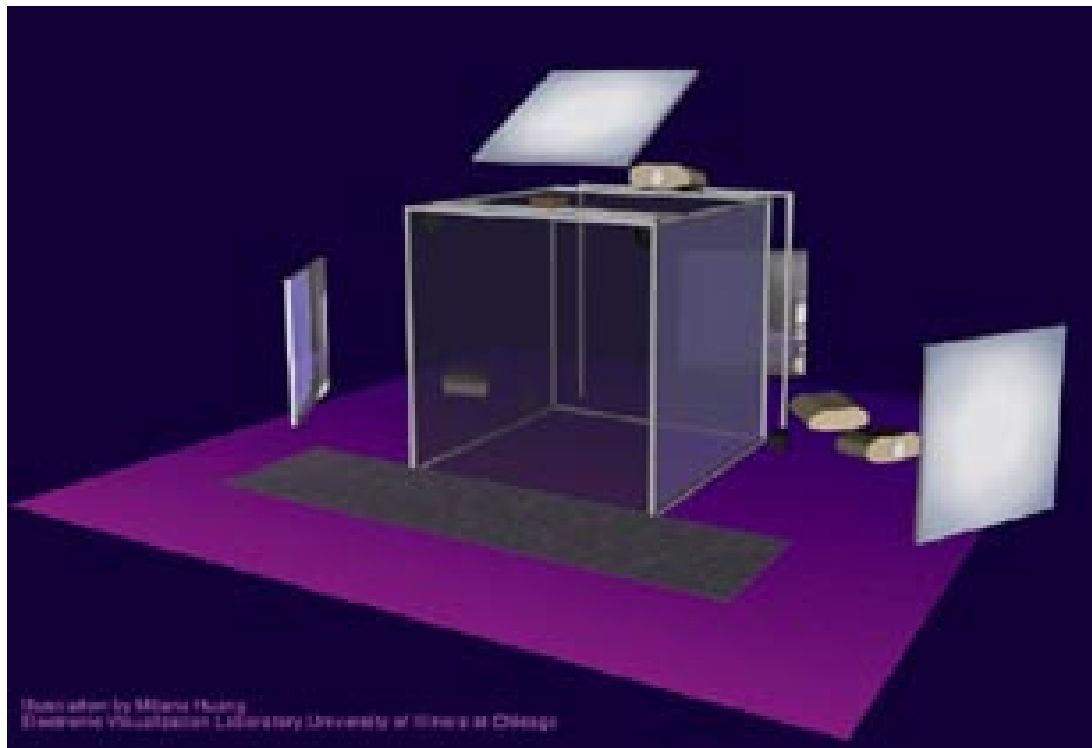


# Scott Fisher - VIEW (1985)

- NASA Ames Research: Telepresence
- Stereoscopic HMD, Headphones, Microphone, Datagloves



# Cruz-Neira, Sandin & DeFanti (EVL) – CAVE (1992)

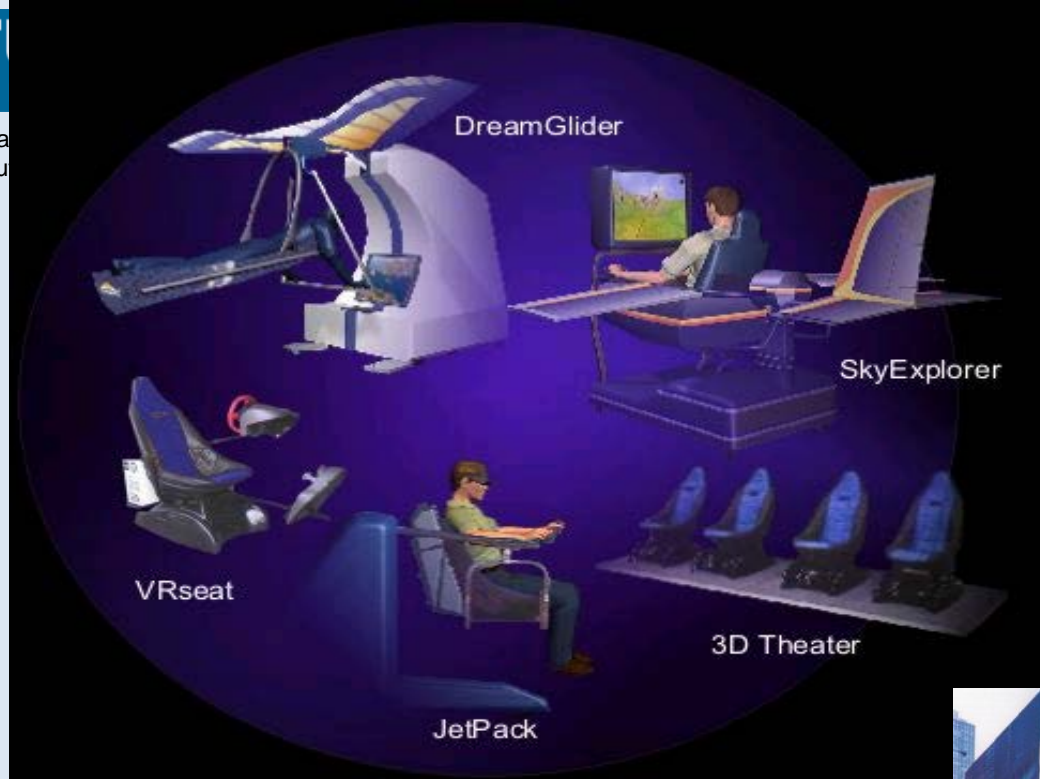


# VR Hype (mid 1990s)



## 26





Hype was too early.

Today the VR entertainment market is growing considerably.



Mixed reality, VR and 3D installations always very successful in theme parks

# Development of the Game Industry (since '90)

- 3D graphics and 3D sound
- Display technologies
- New user interfaces
- New Game Engines / Modeling Tools / Rendering Frameworks
- Easier content development / story telling

# Virtual Reality: To The Mass Market

## 2000's – Advances in other Technologies



*Galaxy S2*

The  
Smartphone  
Revolution

Thin, low cost displays

Advances in  
Computer  
Vision



*Microsoft Kinect 360*

- Natural Feature Tracking & Mapping
- Affordable 2D/3D cameras

Advances in  
Computing  
Power &  
Networking

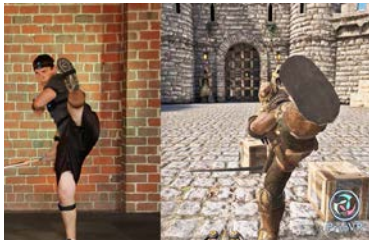
- CPU/GPU
- Highspeed networking

Emerge of  
Crowdfunding

## 2012's – The Kickstarter Revolution



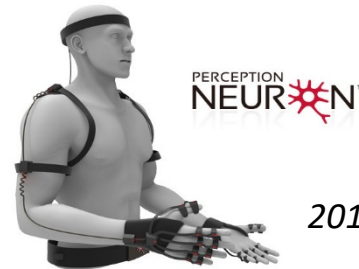
*2012 Oculus Rift*



*2013 PrioVR MoCap*



*2014 Cyberith Virtualizer*



*2015 Perception Neuron MoCap*

## 2016 – VR Displays for Mass Market



# The Kickstarter Revolution & Oculus Rift (2013 - ?)

- A new hype – but will it stay?

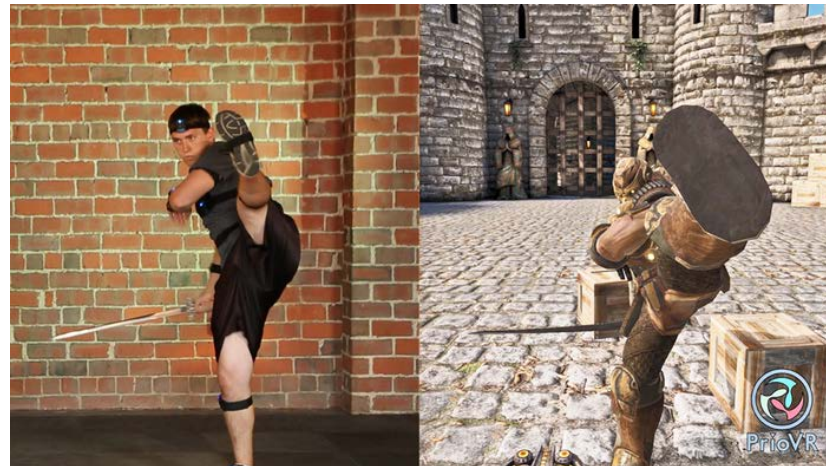


9,522 Backers  
**\$2,437,429**  
pledged  
of \$250,000 goal



577 Backers  
**\$361,452**  
pledged  
of \$250,000

Cyberith Virtualizer



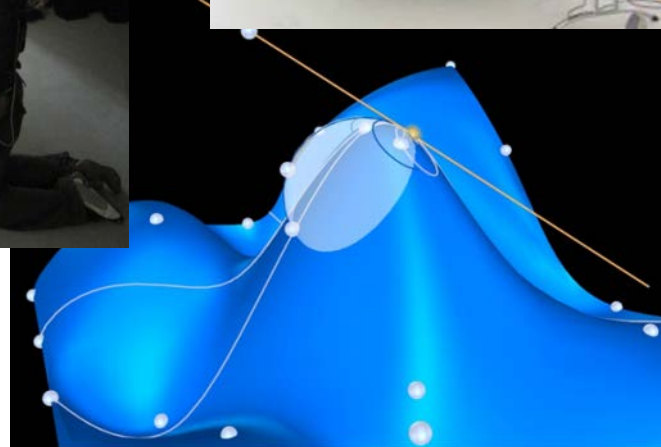
PrioVR Inertial Motion Capture

854 Backers  
**\$322,103**  
pledged  
of \$75,000 goal

# „Real“ VR/AR Application Areas

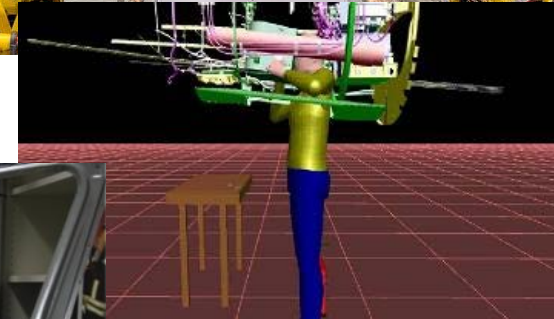
# Application Areas

- Industrial (real time simulation, ergonomics,...)
- Visualisation (scientific, medical, information vis.)
- Entertainment
- Training & Education
- Rehabilitation & Therapy
- Modeling & Design



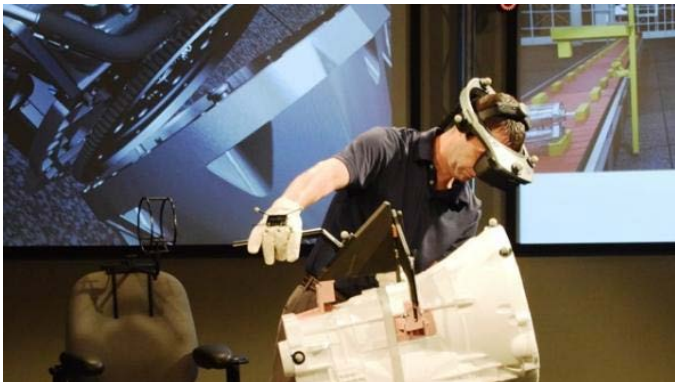
# Industrial Applications

- Design studies
- Production chain simulation (robot collisions, accessibility,...)
- Ergonomics (e.g. assembly)
- 3D Modeling
- Simulation
- Aiding workers (assembly, navigation, ...)



# Case Studies

## Ford Virtual Factory & Ergonomics (2012)



## BP Igloo Training (2015)



# Industrial Example Applications

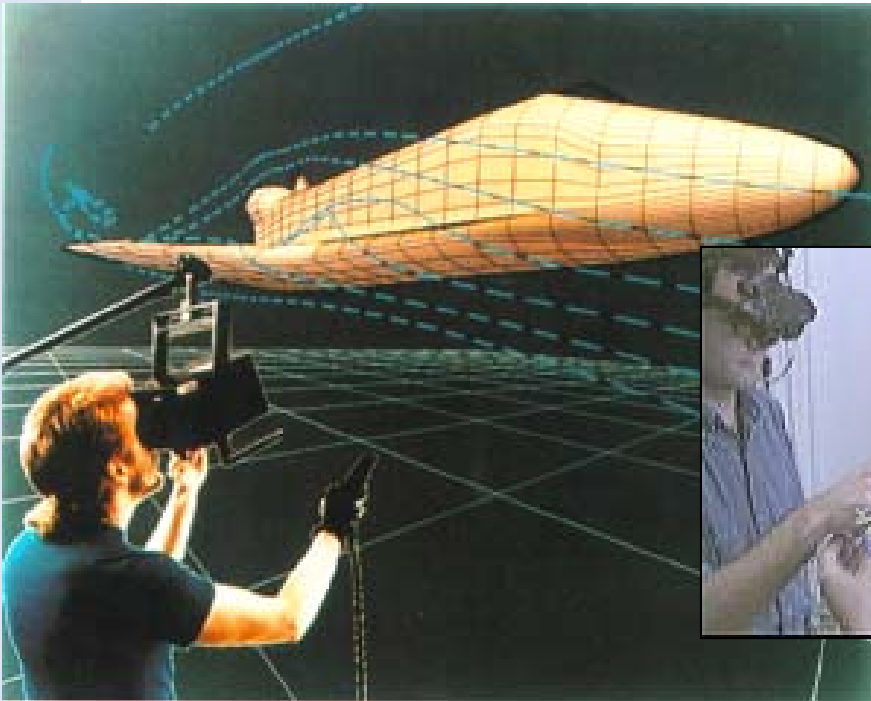
- AR in the welding shop



- Pick by Vision



# Scientific Visualisation

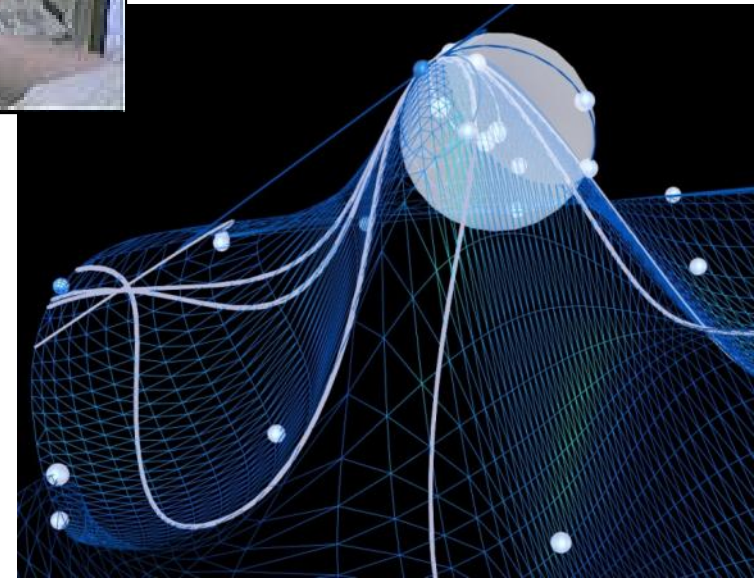


Volume Visualisation

Video

NASA - Virtual Wind Tunnel

Construct3D:  
Meusnier Point



# Visualisation in VR/AR – Why?

- Simulation und presentation of scientific data/experiments that would be too expensive, dangerous, big/small or impossible to do in real world
- Abstract content can be visualised in an understandable way
- Collaboration on complex 3D data possible
- Multiple and different forms of presentations (3D views)

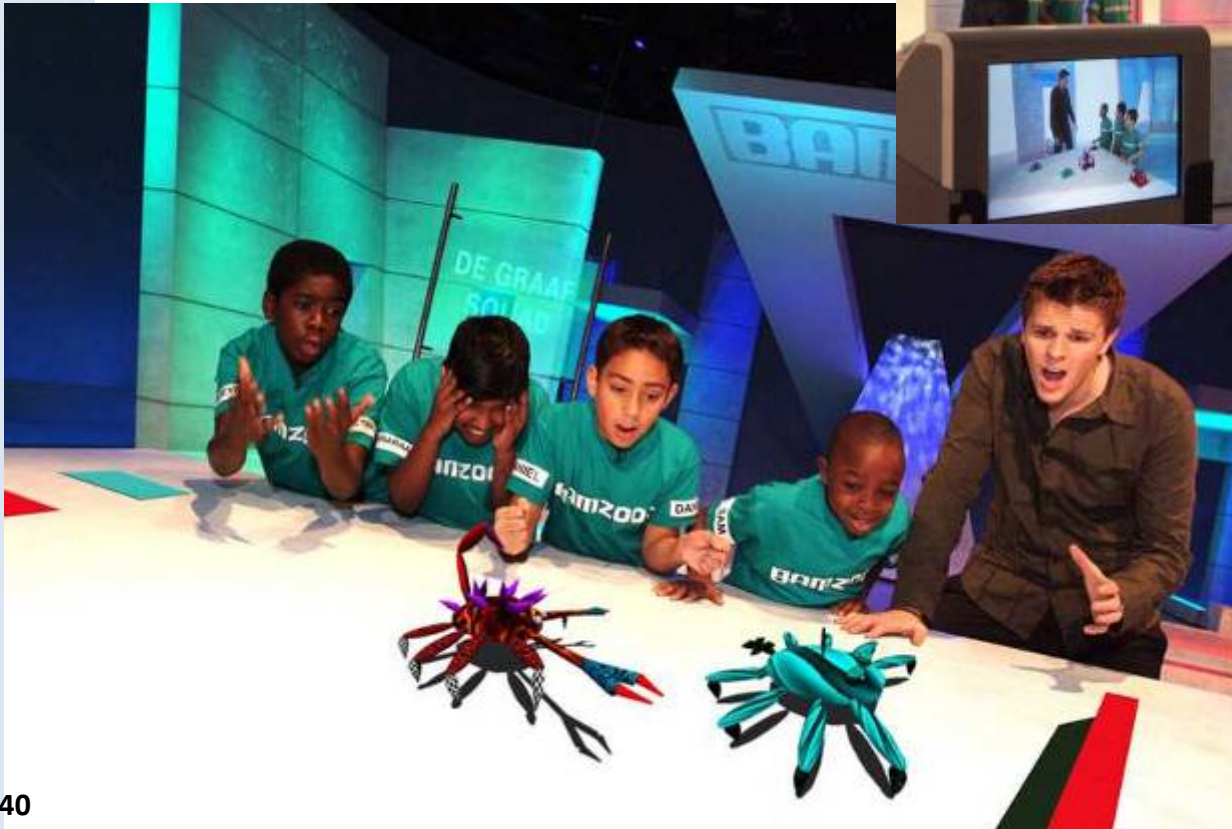
# Entertainment

- Complete immersion into the game possible
- Distributed collaboration
- Coolness & Fun factor



# Edutainment

- BAMZOOKI



# Edutainment in Museums



Virtual Showcase (Video)

# Training & Education

- Unlimited possibilities to re-try/learn
- Supports active participation – active learning!  
(in contrast to educational video)
- Increased interest and motivation of students
- New, better ways of training and learning
- New learning medium
- New, innovative learning content possible



# Medical Training

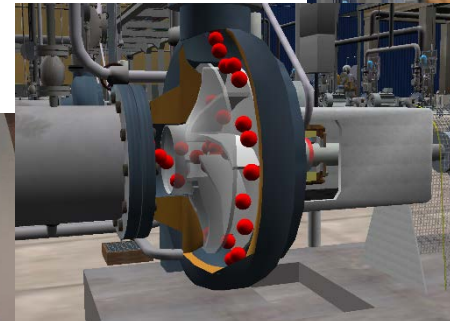
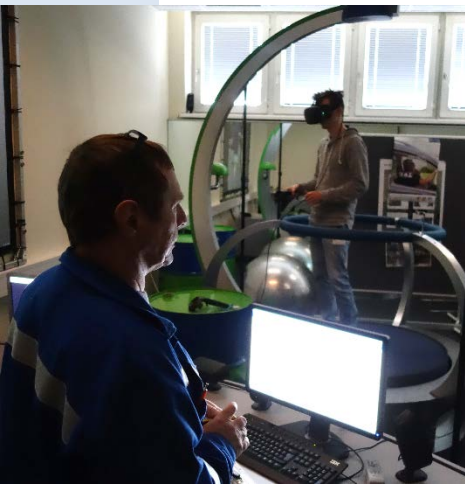
- Difficult steps in surgery
- Not enough training opportunities in real world e.g.: surgery in the auditory canal



[Birth forceps - Video](#)

# Training: OMV Refinery Simulator for Trainees

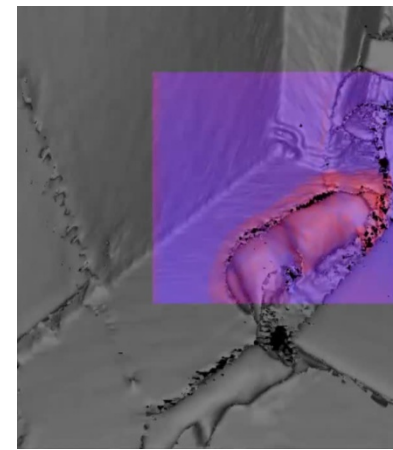
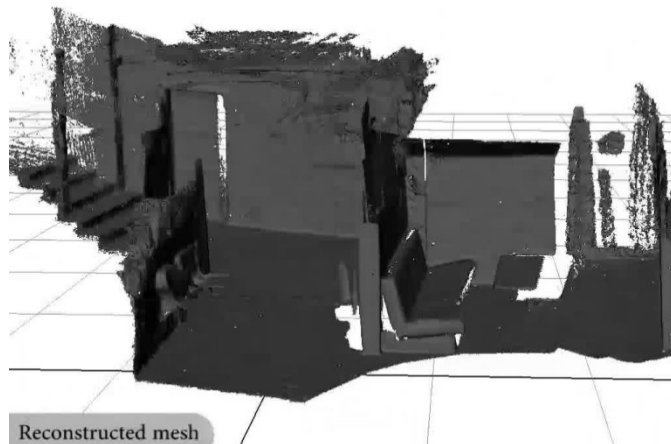
- SAVE safety trainer of the OMV refinery by Phenomatics
  - Simulation of industrial environment & processes
  - Fixed integration in employee training



# Training & Support of Fire Fighters

- Virtual Simulation and On-Site Training for First Responders
  - Mobile immersive VR training simulation
  - For on-site squad leaders
    - Plan-Do-Act-Check command cycle
    - Parameters: perspective, time, locomotion, exhaustion
- ProFiTex

## Support fire fighters with mission-relevant information based on various sensor data



# VR Education: NICE (Roussos et al., 1999)



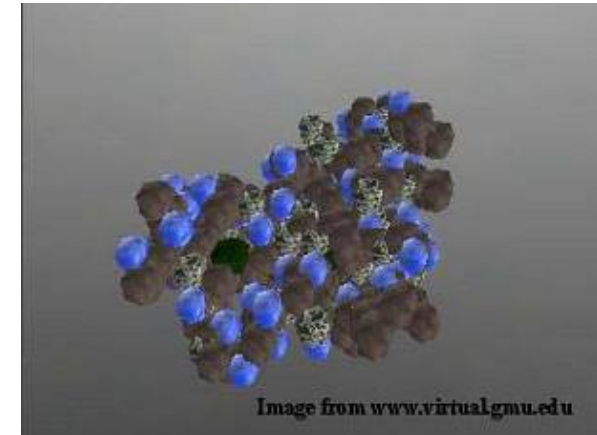
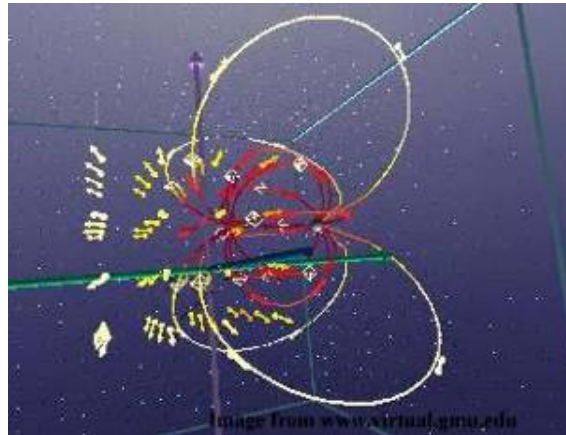
Courtesy Maria Roussos, EVL, UIC.

Area: Biology, especially for children (age 6-10)

Goal: Testbed for the exploration of virtual reality as a learning medium

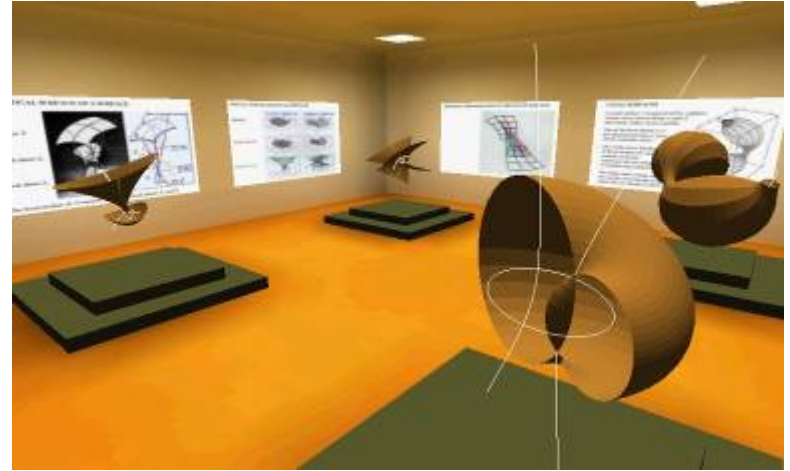
# ScienceSpace (Dede C. et al., 1996)

## NewtonWorld, MaxwellWorld, PaulingWorld



- NewtonWorld: Kinematics and dynamics of one dimensional motion
- MaxwellWorld: Electrostatics
- PaulingWorld: study of molecular structures
- Evaluation studies: Learners' engagement, usability issues

# CyberMath (Taxen G. et al., 2000)



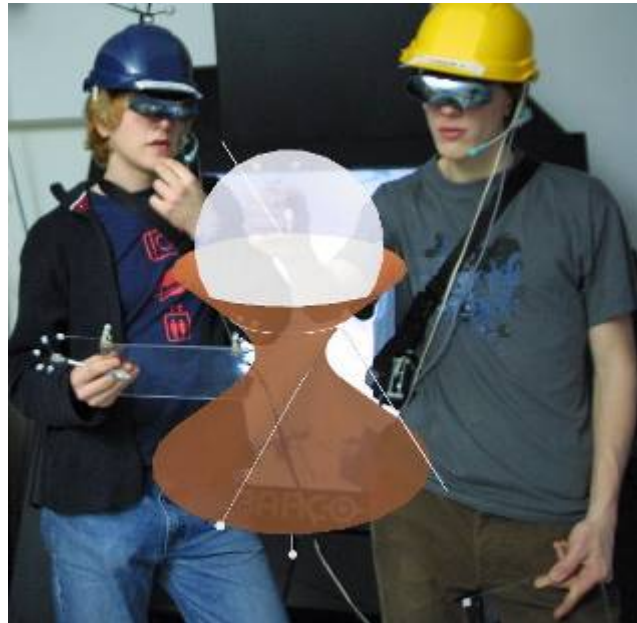
Courtesy Gustav Taxen, Center for User Oriented IT Design, Sweden.

Area: Mathematics education

Goal: Exploring open issues in VR education

- 4 exhibitions on geometry and calculus
- Remote collaboration (CAVE, desktop)
- Supports teaching styles

# Construct3D – Geometry Education in AR



Video

- Free movement around geometrical objects (Locomotion)
- Collaboration in geometry education

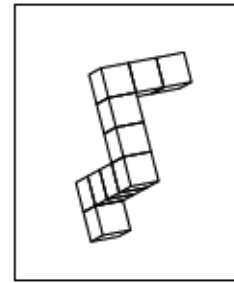
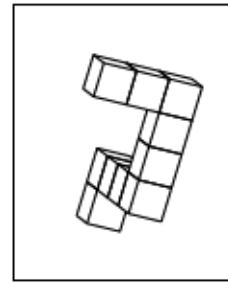
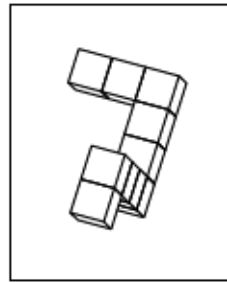
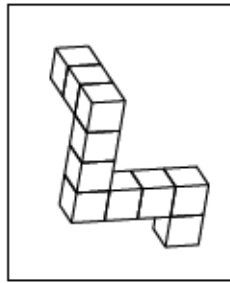
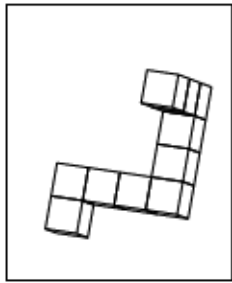
# Construct3D Setup

- High quality optical tracking for 2 users
- User Interface: Personal Interaction Panel (PIP)
- Key features:
  - Students work directly on geometric objects
  - „walk around“ objects
  - **direct manipulation** only



# Psychological Testing

e.g. spatial abilities

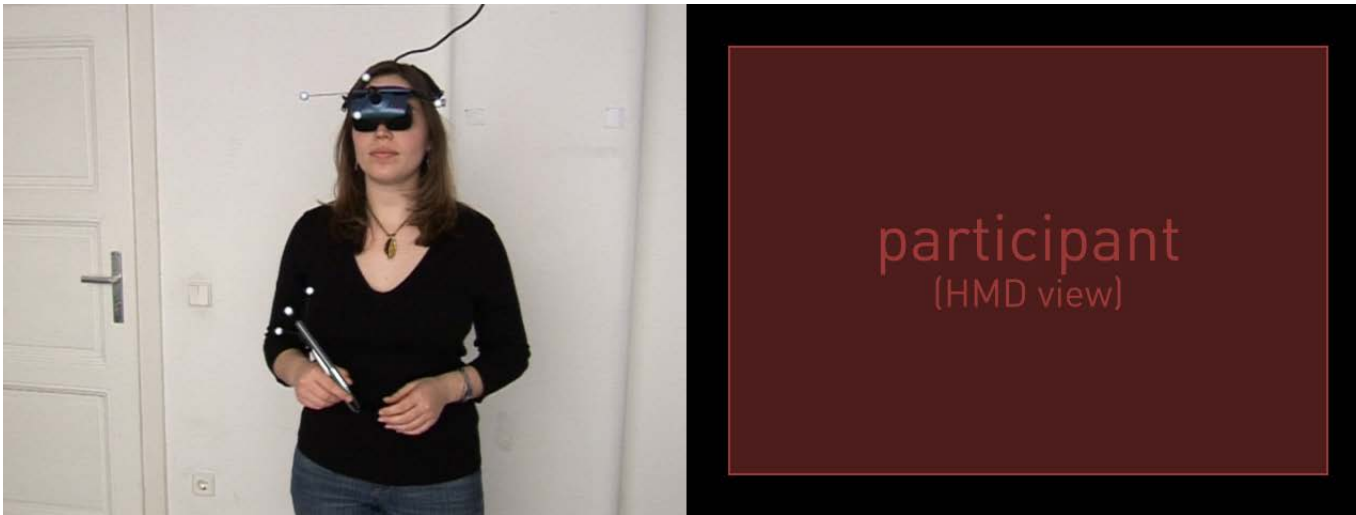


VR Mental Rotation Test

- Completely controllable test conditions
- Dynamic testing possible
- Exact monitoring (time, movement,...)

# d\*star: Dynamic Spatial Test in AR

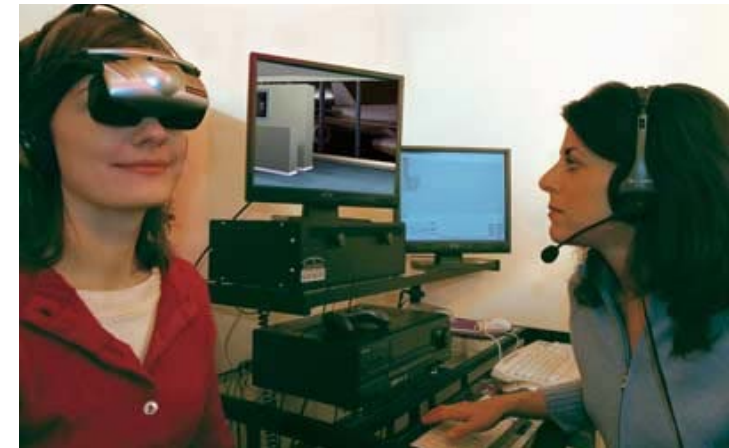
## Features



- Textual and aural assistance
- Online computation of item solution & item correctness
- Data recording
- Very intuitive interaction (focus on item)
- Optional visual assistance (tutorial mode)
  - Animated rotations of shape elements
  - Visualization of preceding elements
- Additional modes: Result inspection; God mode

# Rehabilitation & Therapy

- Rehabilitation e.g. stroke patients; elderly people (aging society)
- Therapy:
  - Anxiety e.g. fear of flight, heights (acrophobia), public speaking, arachnophobia (spiders), ...
  - Post-Traumatic Stress Disorder (PTSD)
  - Reduce Pain
  - Attention Deficit Hyperactivity Disorder (ADHD)
  - Coping with crimes ([Policelineup](#)-Video)



# Rehabilitation



Playmancer  
EU FP7 Project

- Improve mobility
- Reduce pain
- Increase motivation



Stroke rehabilitation (Crosbie et al.)

# Studies with burn patients

- Distraction when changing bandages
- Reduction of pain



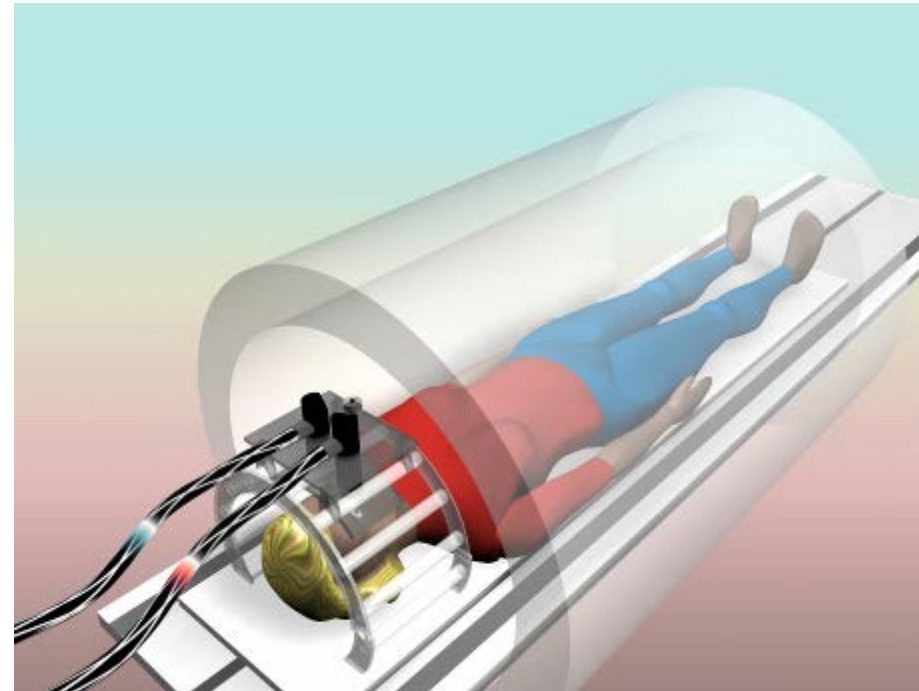
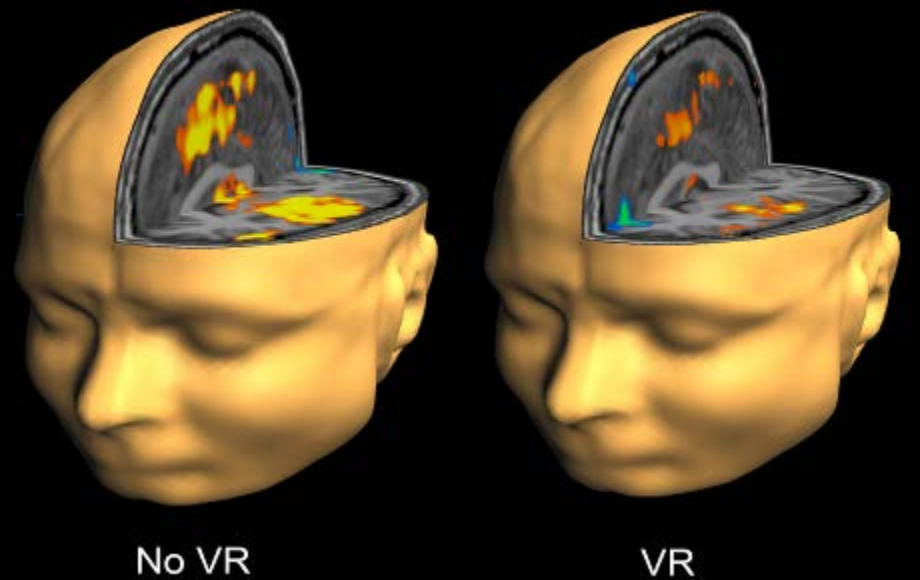
# Burn victims: South Pole Fantasy

Hunter Hoffmann et al.



# fMRI VR Pain Distraction (Hoffman et al.)

Pain Related Brain Activity is reduced during VR



# Attention Deficit Hyperactivity Disorder

## Virtual Classroom

(Rizzo et al.)



# 425 Patients in Clinical Database: Anxiety Disorders, Phobias, and Panic Disorders

- Aviophobia: 48.7%
- Driving: 13.4%
- Public Speaking: 7.3%
- Fear of Heights: 4.5%
- General Anxiety Disorder: 4.0%
- Claustrophobia: 3.1%
- Panic w/Agora: 2.6%
- Social Phobia: 2.4%
- Panic Disorder: 1.4%
- Agoraphobia: 0.9%
- Arachnophobia: 0.5%
- Needle Phobia: 0.2%
- Multiple Phobias: 8.9%
- Other Specific Phobias: 1.6%

Source: Brenda Wiederhold, VRMC

# Exposure Therapy Development

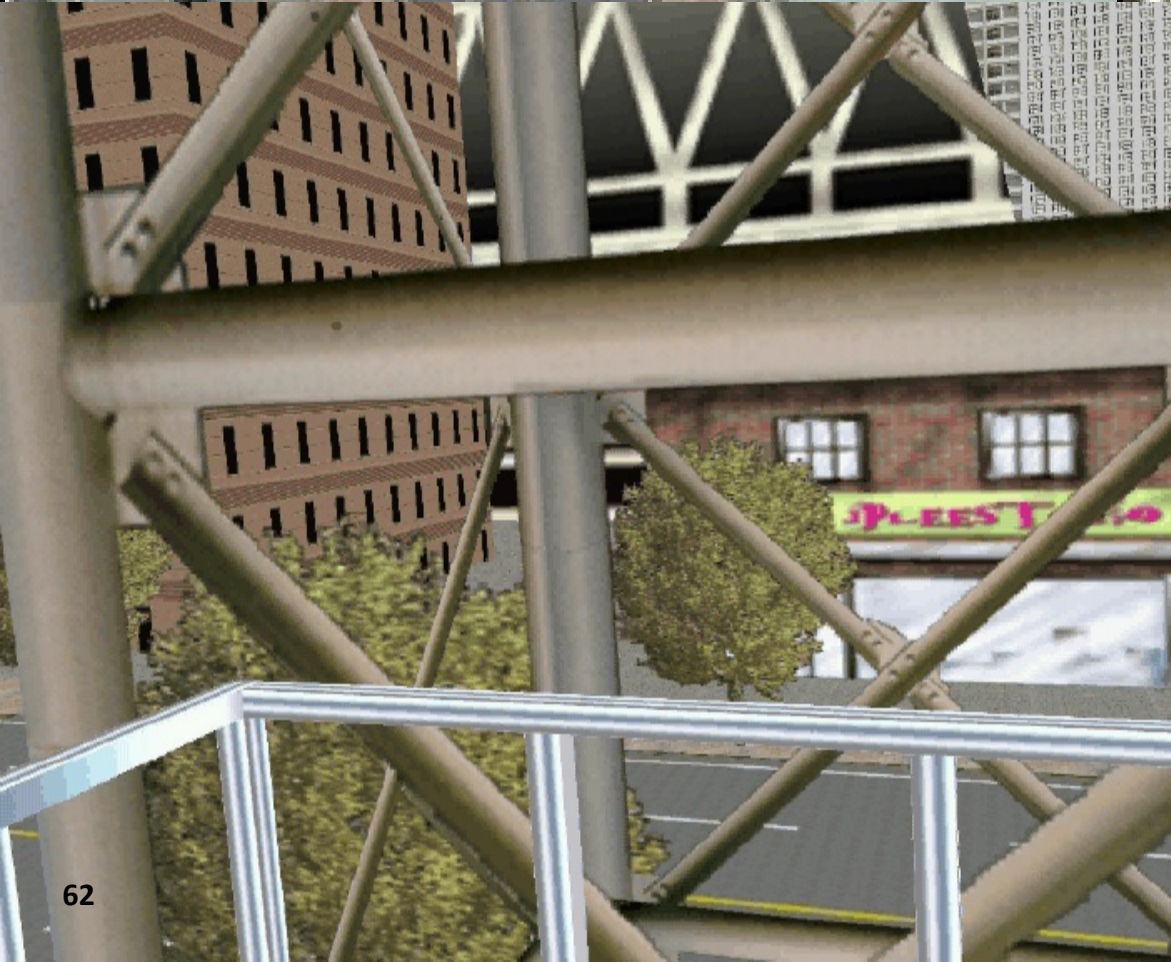
- Gradual confrontation (exposure) with the problem
- **Controlled** increase of the stimuli – controllable for therapist via interface
- Only works if patient feels **present** in the virtual world (4 stages)
- Additional measurement of biological parameters (pulse, skin conductivity and skin temperatur,...)

# Fear of flight: gradually increasing





Fear of heights



# Public Speaking Virtual Environment



# Arachnophobia



# Post Traumatic Stress Disorder (PTSD)

- Exposure therapy:  
Gradual controlled exposure to the problem
- Re-living and processing of traumatic experiences
- Similar therapy: Help after the death of a loved person

# World Trade Center Video Clip



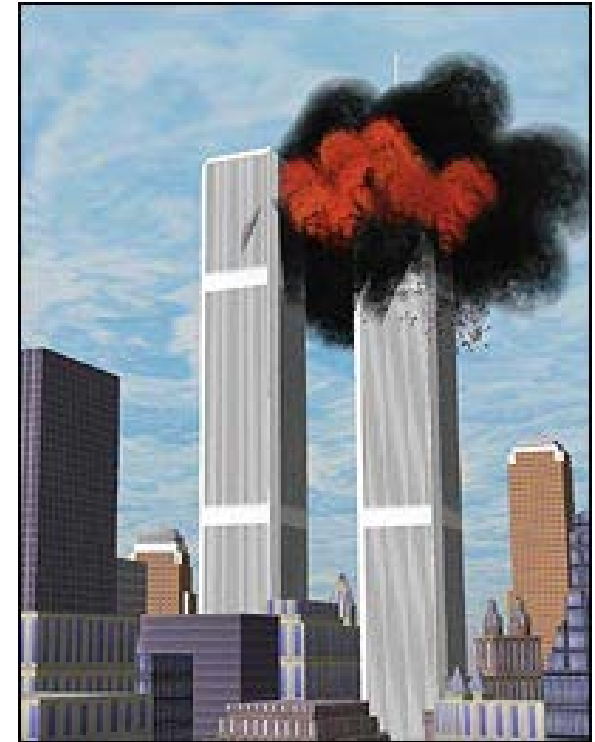
# World Trade Center PTSD (Difede & Hoffman)

## • Environment:

- 11 Graded Levels of Exposure
- 1<sup>st</sup> Stage: Normal day in NYC with view of WTC towers
- Final Stage: Entire re-enactment of 9/11

## Results:

- Participant showed decrease in SUDs (Subjective Units of Discomfort) rating over time
- 83% decrease in depression levels
- 90% reduction PTSD symptoms
- Patient no longer met criteria for PTSD



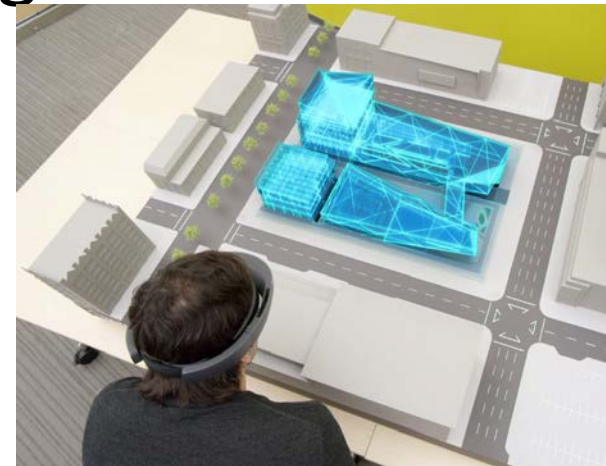
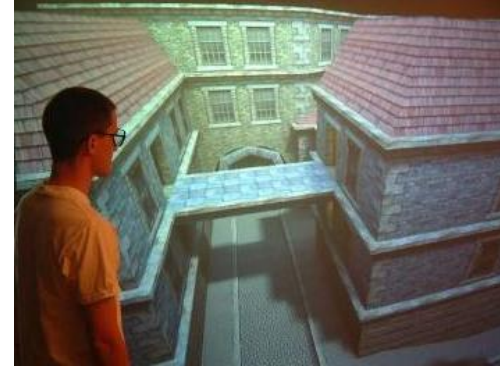
# PTSD: Iraq Veterans

(Rizzo et al.)



# Architectural Visualisation

- Visualising non-existing buildings and their environment
- Free navigation
- Visualisation of historical towns or non-real buildings
- Showing GIS Data (cables, lines,...)
- City planning

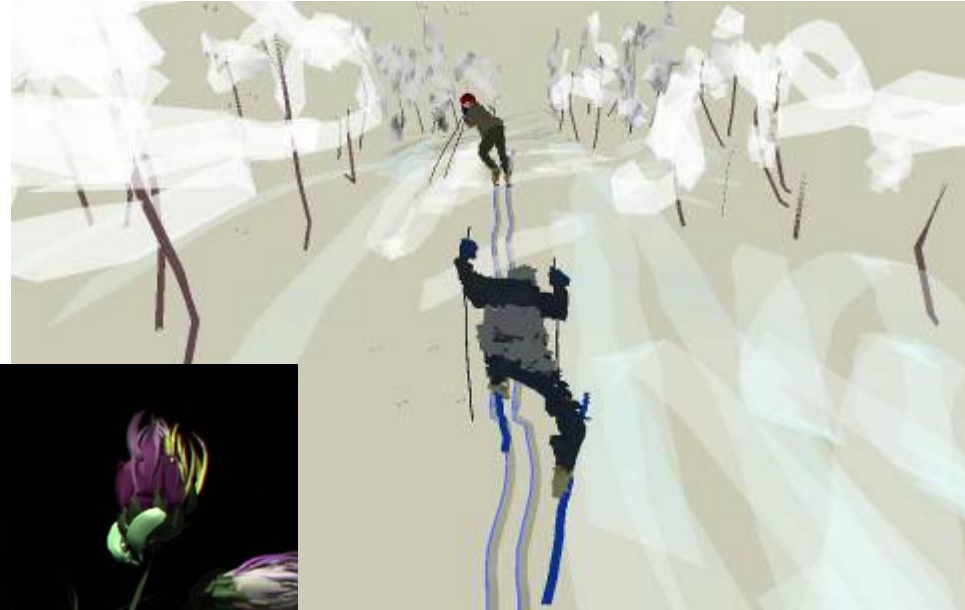


# CAD & Design



SpaceDesign (Video)

# VR & Kunst

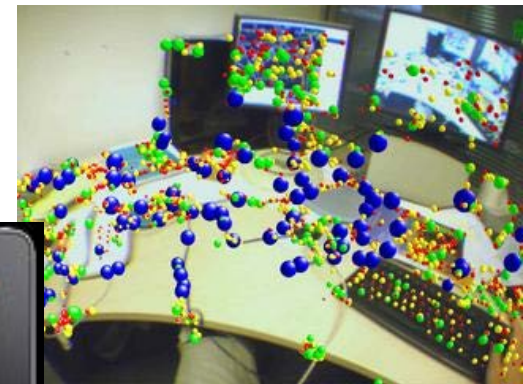


© Google / Tilt Brush

CAVE Painting - Helma  
Video

# Augmented Reality

- Large variety of AR applications nowadays
- Dynamic augmentation of location specific information
- Additional virtual information by interaction with the real world

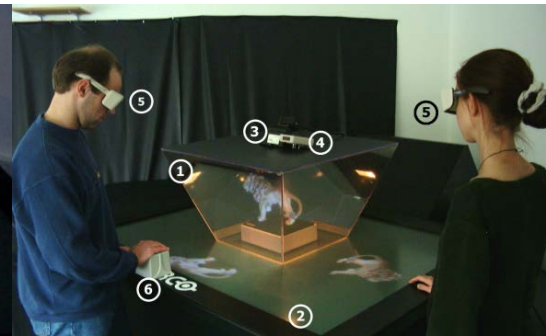


PTAM (2007)

13th Lab – SLAM(2011)

# AR in Museums

- Museums have artefacts that cannot be presented (or only rarely)
  - -> AR/VR exhibitions
- AR Museumguides
  - Tests with smartphones und smart glasses



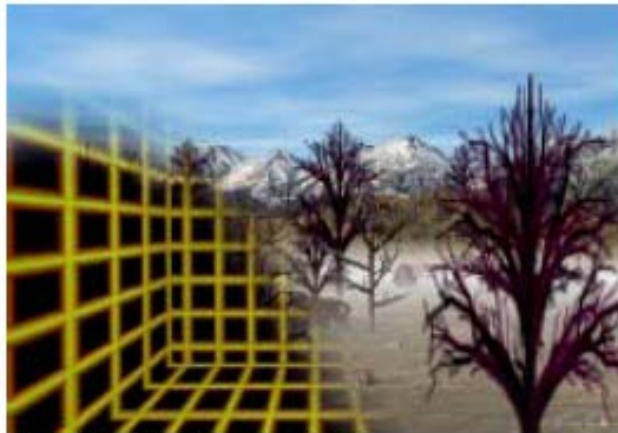
# Established Application Areas

- Very good reasons why VR/AR/MR established in these application areas
  1. New possibilities due to new technology
  2. New/Better solutions to existing problems
  3. Good usability and robust technology are an absolute requirement for wide distribution and public acceptance!
  4. Reasonable use of resources must be given. Use of expensive equipment must be justified.

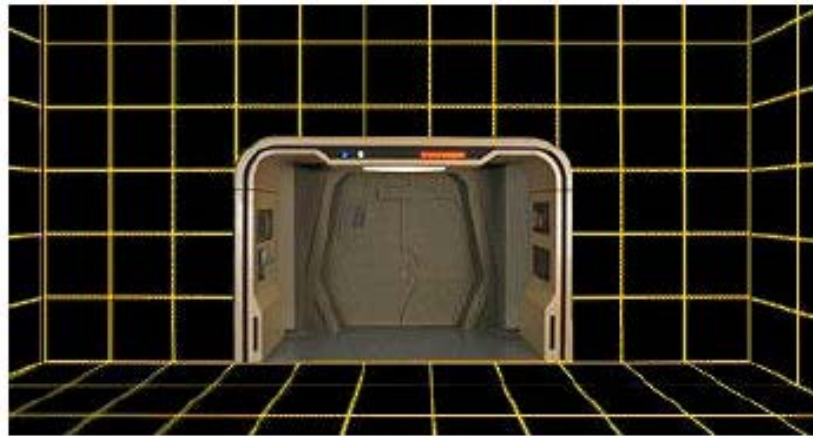
**Benefits must justify costs**

# All Problems Solved?

- We're far from it!



Star Trek's Holodeck



- More in the next lectures

# Overview



- Input Devices & Tracking
- Output Devices – Displays, Haptics,...
- 3D Graphics Hardware
- High Level Graphics Programming, Scene Graphs, VR/AR Framework,...
- 3D Interaction
- Usability, Evaluations
- Current Research

# Questions?

All VO slides in TISS!

Does it come on disk?

