

Virtual and Augmented Reality

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Interactive Systems

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

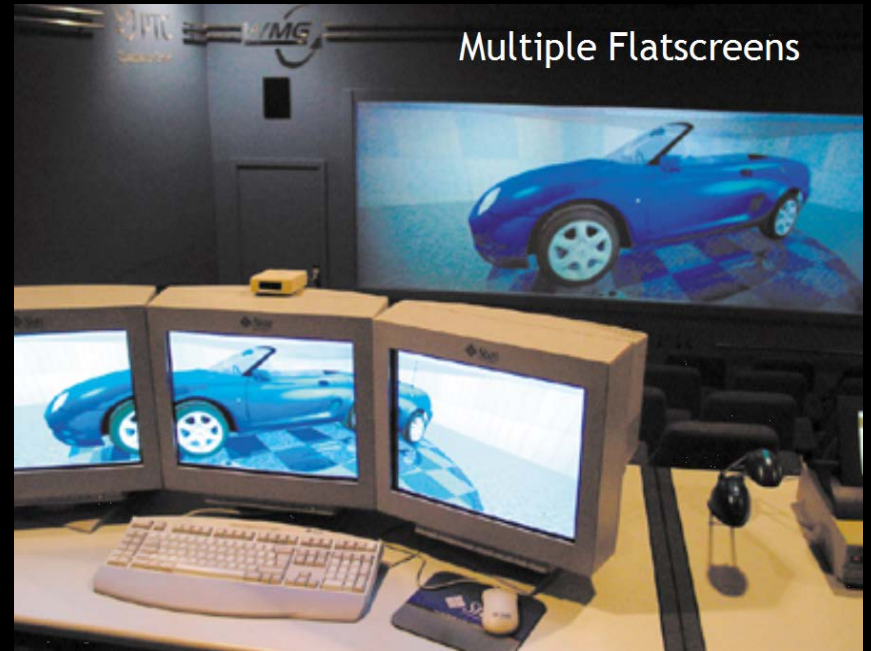




Flatscreen VR



Gaming Applications



Multiple Flatscreens



18.1" LCD display,
Resolution: 1280x1024



The DTI 2018XL Virtual Window™

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



17" LCD display,
Resolution: SXGA
(1280x1024)

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



FloStation



elumens

Mini-Workbench



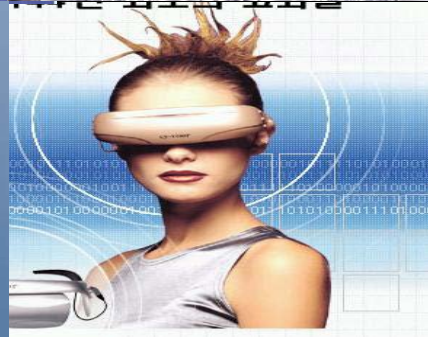
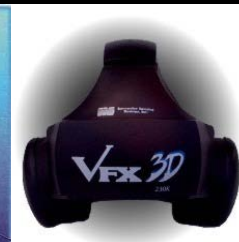
The ImmersaDesk




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



Head Mounted Displays (HMD)...




Interactive Personal Display



- Folds for compact storage
- Completely Adjustable Fully Immersive Design

Advanced Concept Drawing 129T 00001
CONFIDENTIAL



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**.”

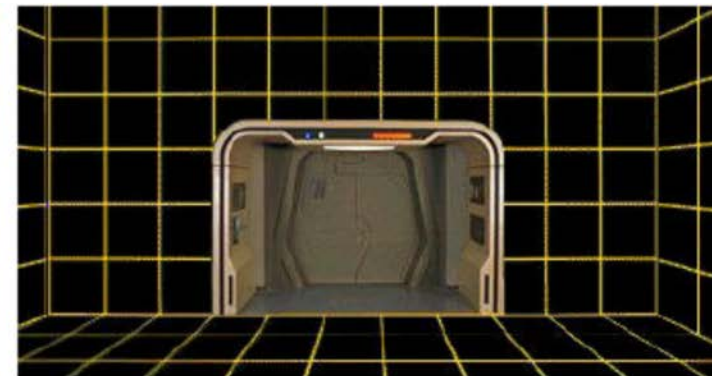
“Virtual reality is an **artificial environment** that is created with **software** and presented to the user in such a way that the **user suspends belief** and accepts it as a real environment.”

- Immersive
- Artificial
- Interactive

Vision: Holodeck



Star Trek's Holodeck



Milgram's Reality-Virtuality Continuum (1994)



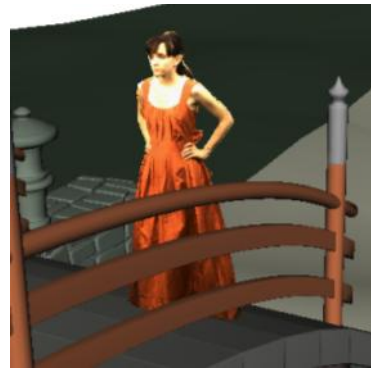
Mixed Reality

Real
Environment

Augmented
Reality (AR)

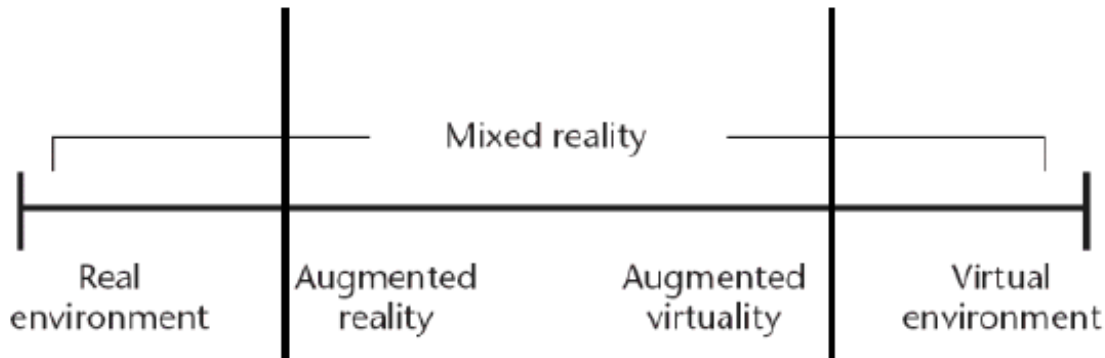
Augmented
Virtuality (AV)

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)

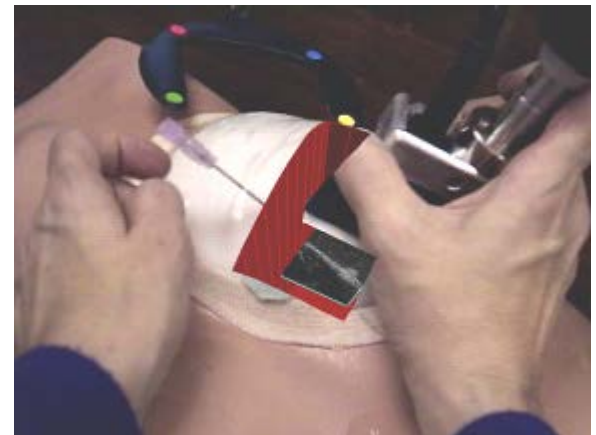


Definition (Azuma, 1997)

- 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



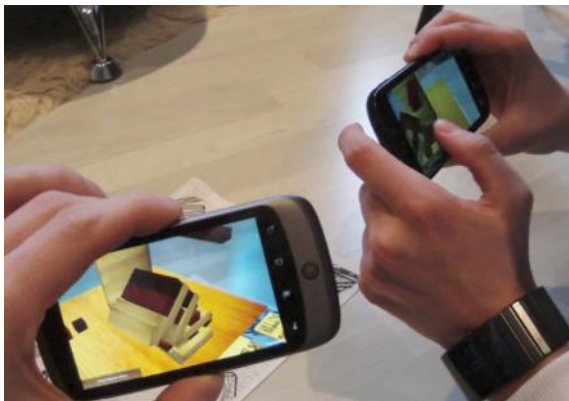
Collaborative VR / AR



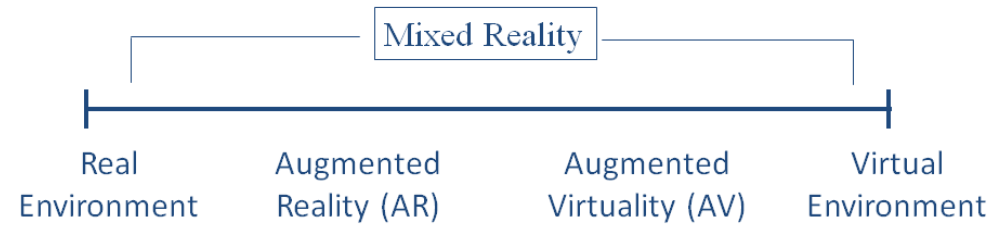
- Users share the same virtual space
- Assists social interaction / cooperation
 - natural communication (language, gestures)
 - supports working in teams

Distributed VR / AR

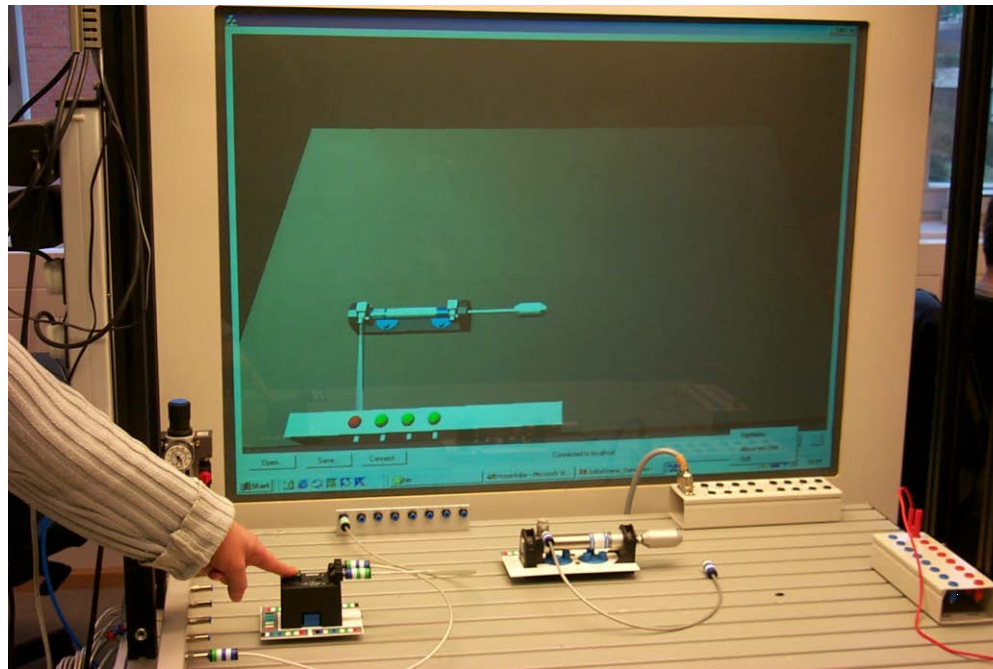
- Distributed collaboration over large distances possible
- Large number of users supported
- Flexible distribution of computing power & resources
- Flexible hardware setups



Mixed Reality



- Any combination of real and virtual world
- Sometimes also meant: Coupling of real with virtual world



History of VR

<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



© PATENTED

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“
- Finds 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

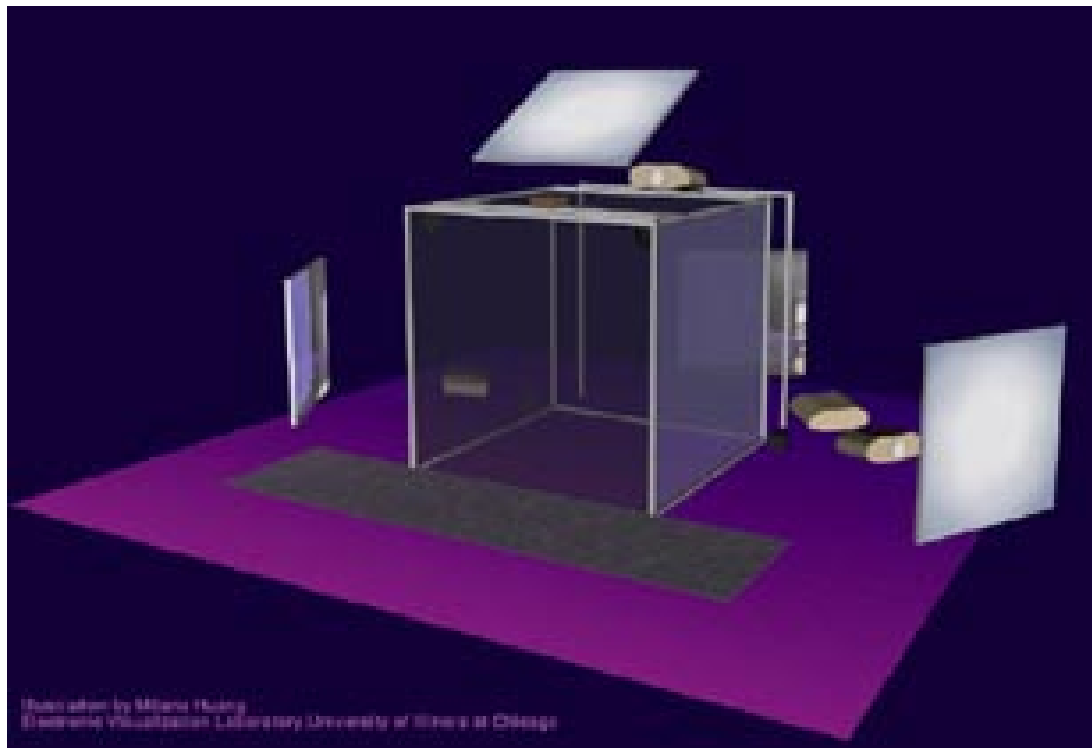


Scott Fisher - VIEW (1985)

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



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

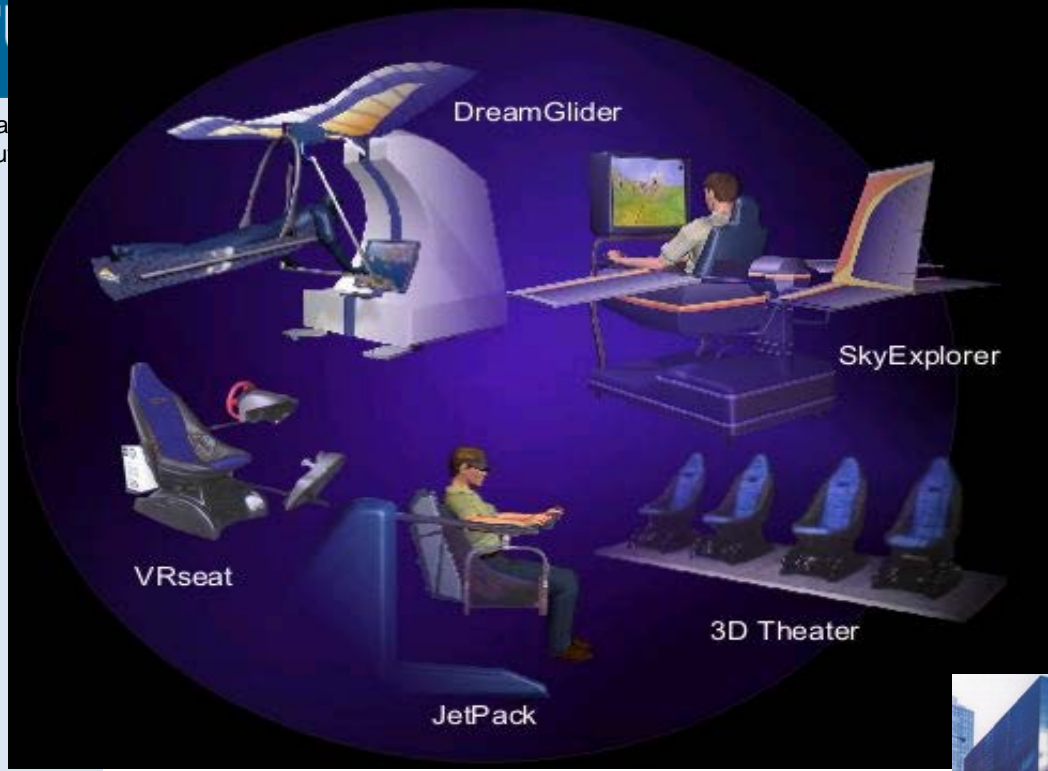


VR Hype (mid 1990s)



Experience The Thrills of An Alternative Reality!





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

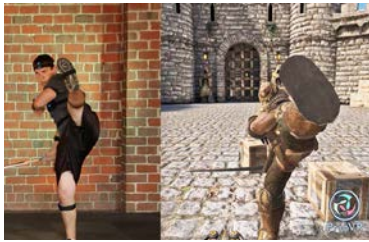
- CPU/GPU
- Highspeed networking

Emerge of Crowdfunding

2012's – The Kickstarter Revolution



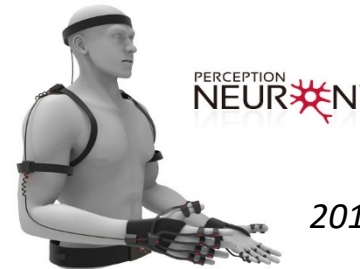
2012 Oculus Rift



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

HDMI



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

Cyberith Virtualizer



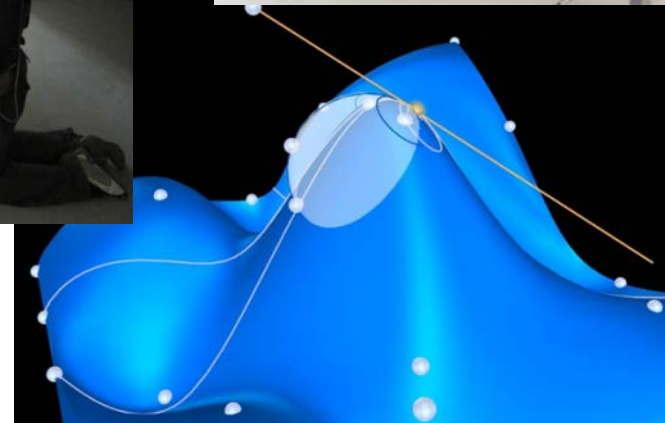
854 Backers
\$322,103
 pledged
 of \$75,000 goal

PrioVR Inertial Motion Capture

„Real“ VR/AR Application Areas

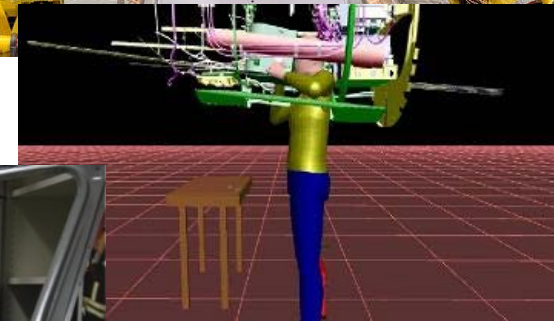
Application Areas

- 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

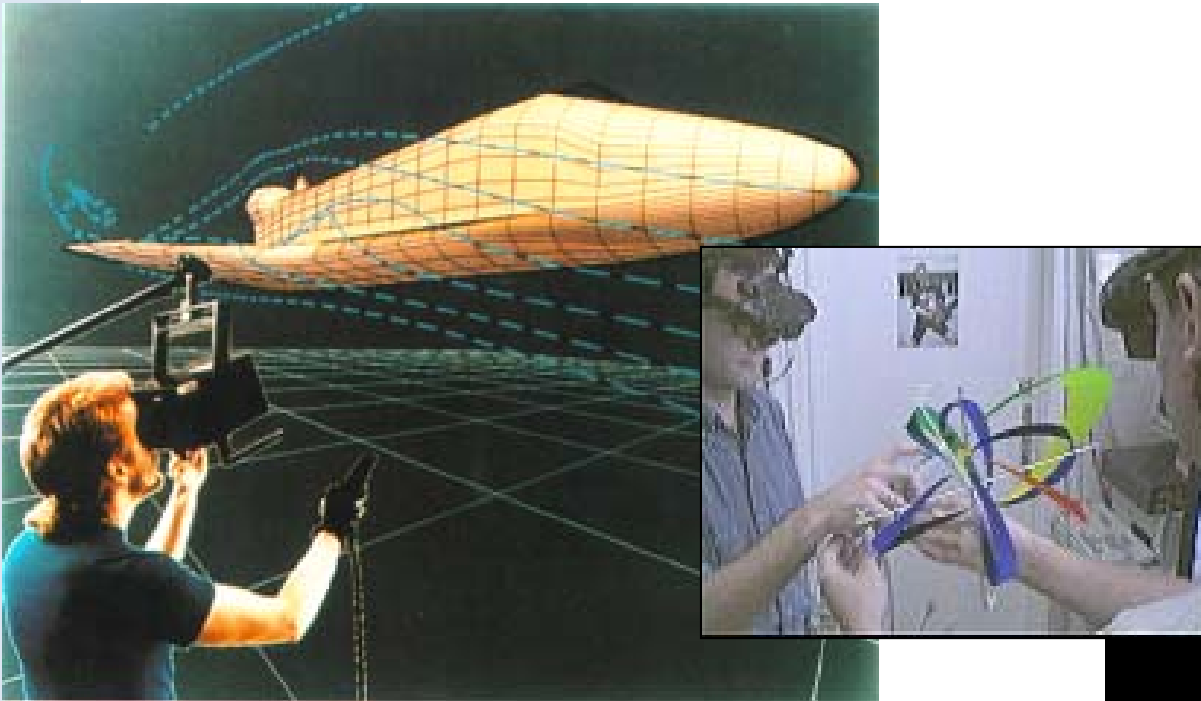
- AR in the welding shop



- Pick by Vision



Scientific Visualisation

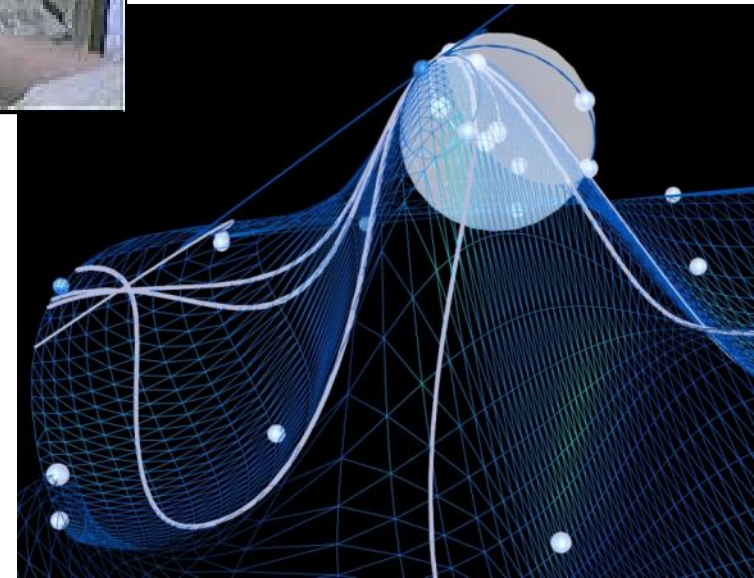


Volume Visualisation

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)

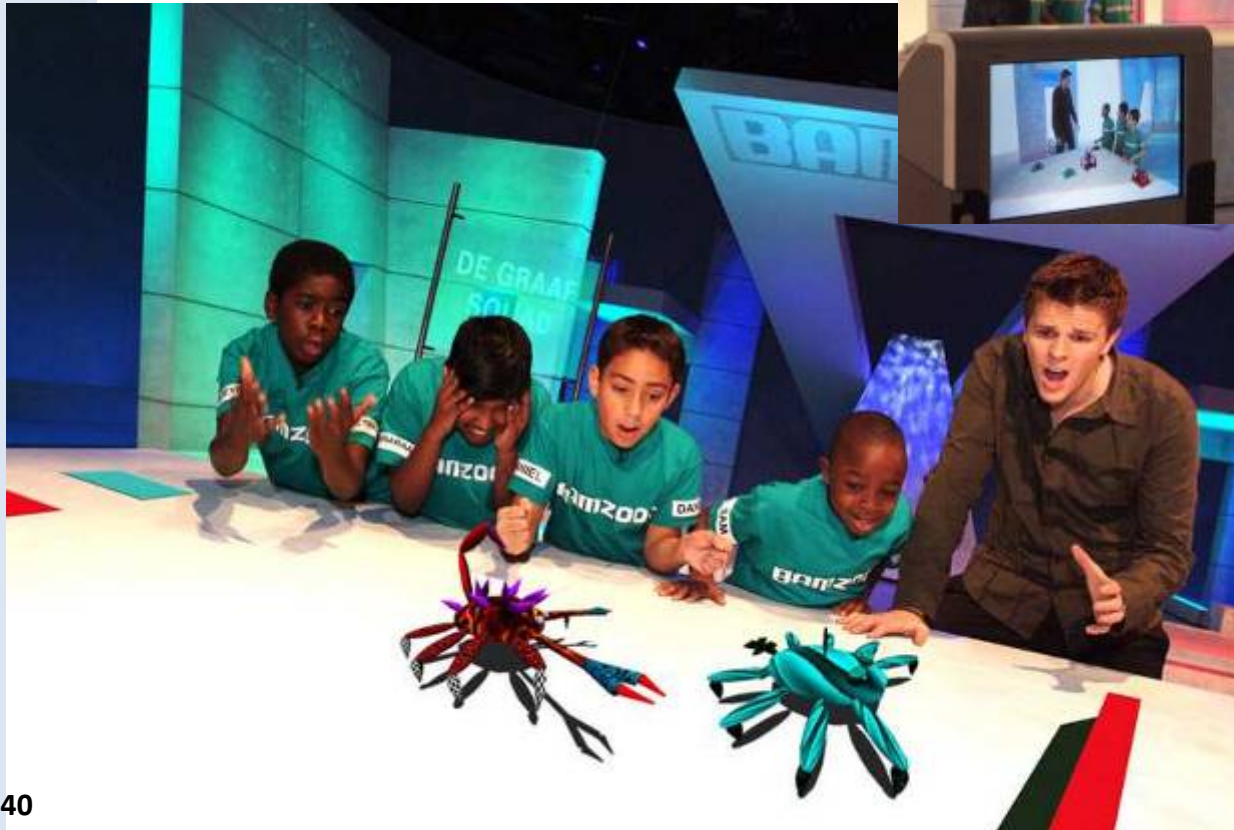
Entertainment

- 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

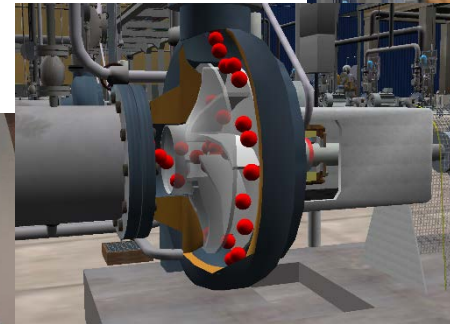
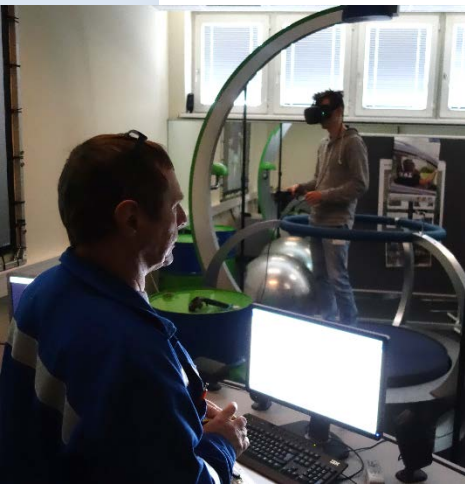
- Difficult steps in surgery
- Not enough training opportunities in real world e.g.: surgery in the auditory canal



[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



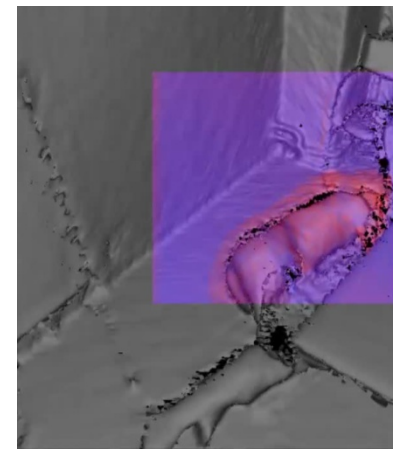
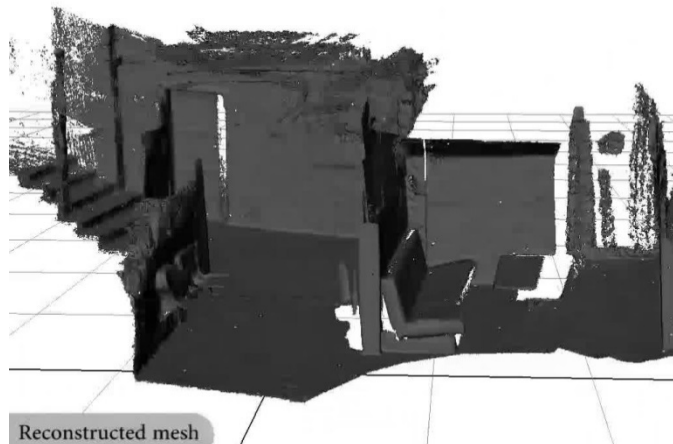
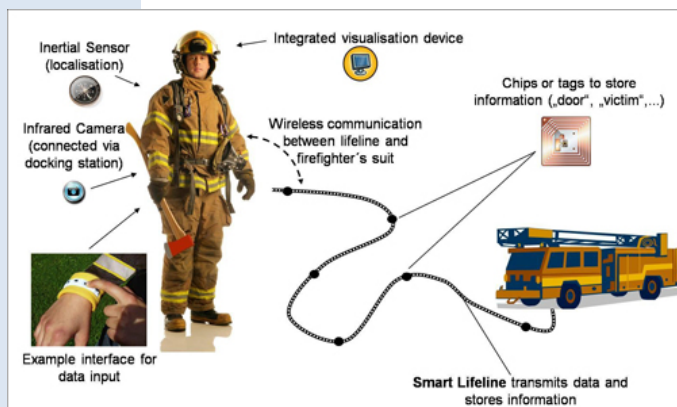
Training & Support of Fire Fighters

- 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)



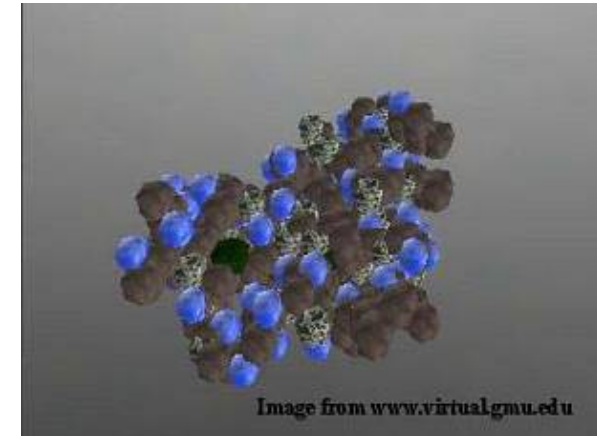
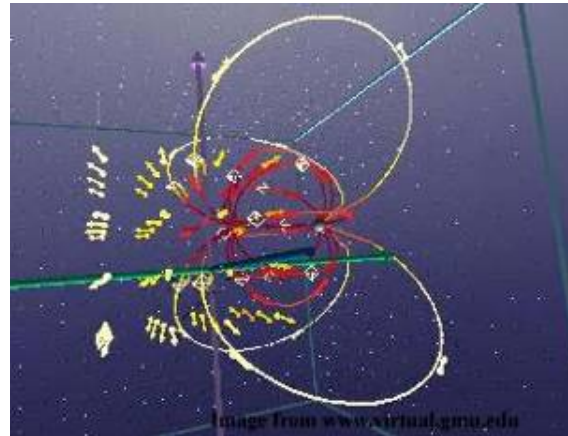
Courtesy Maria Roussos, EVL, UIC.

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

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

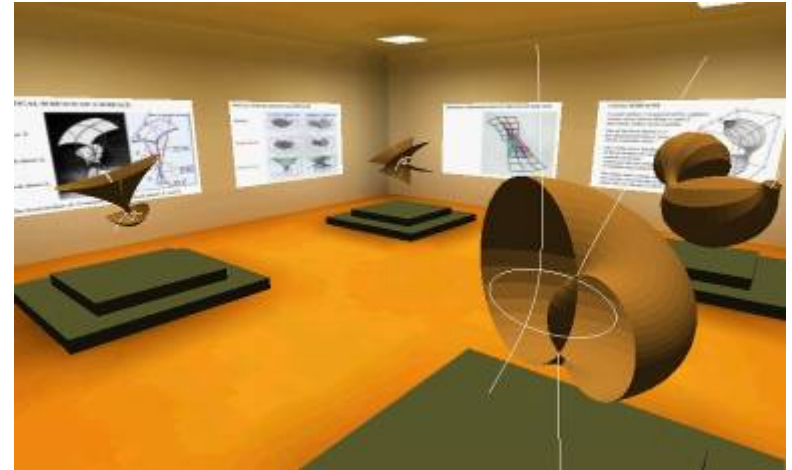
ScienceSpace (Dede C. et al., 1996)

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)



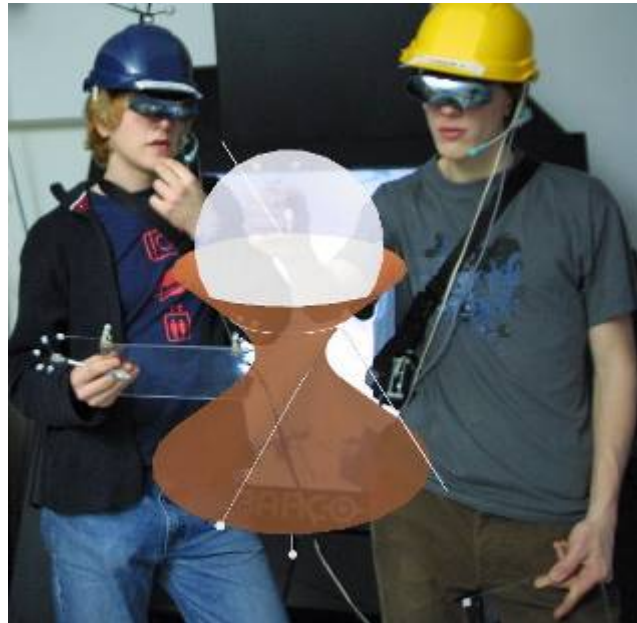
Courtesy Gustav Taxen, Center for User Oriented IT Design, Sweden.

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

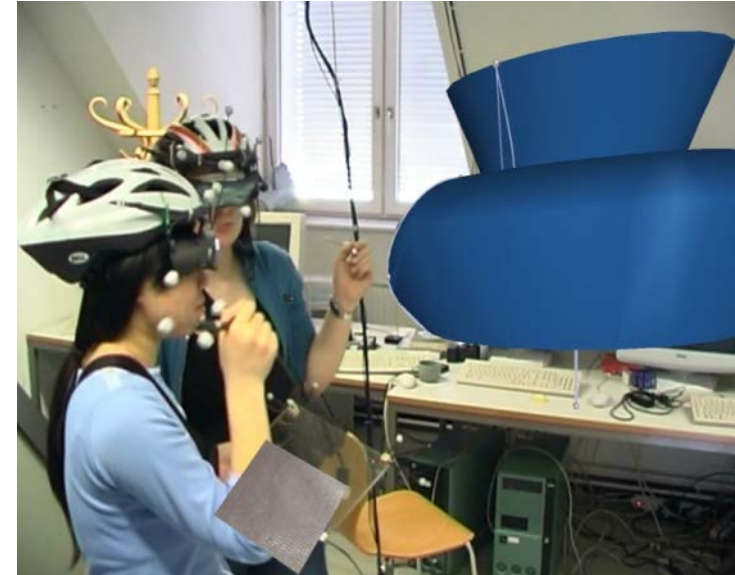


Video

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

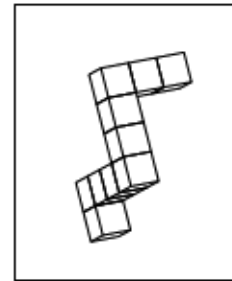
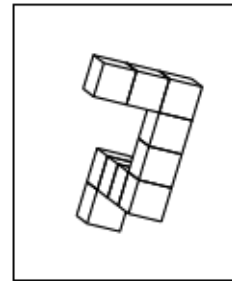
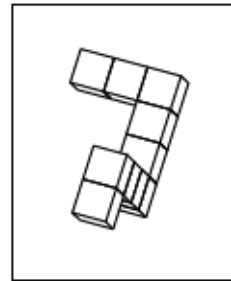
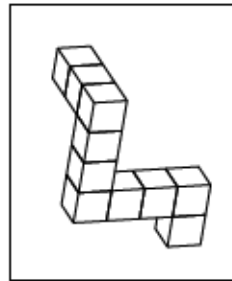
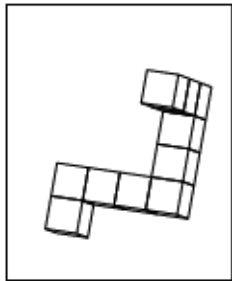
Construct3D Setup

- 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

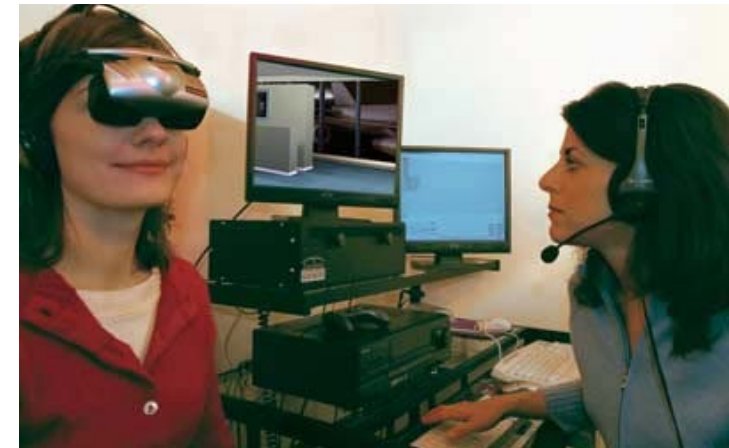
Features



- 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

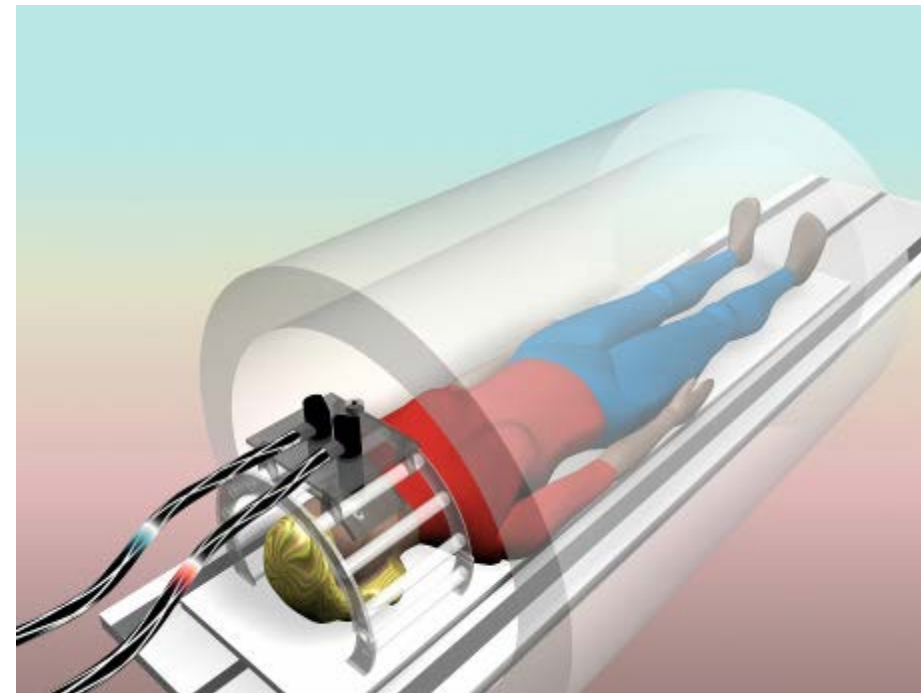
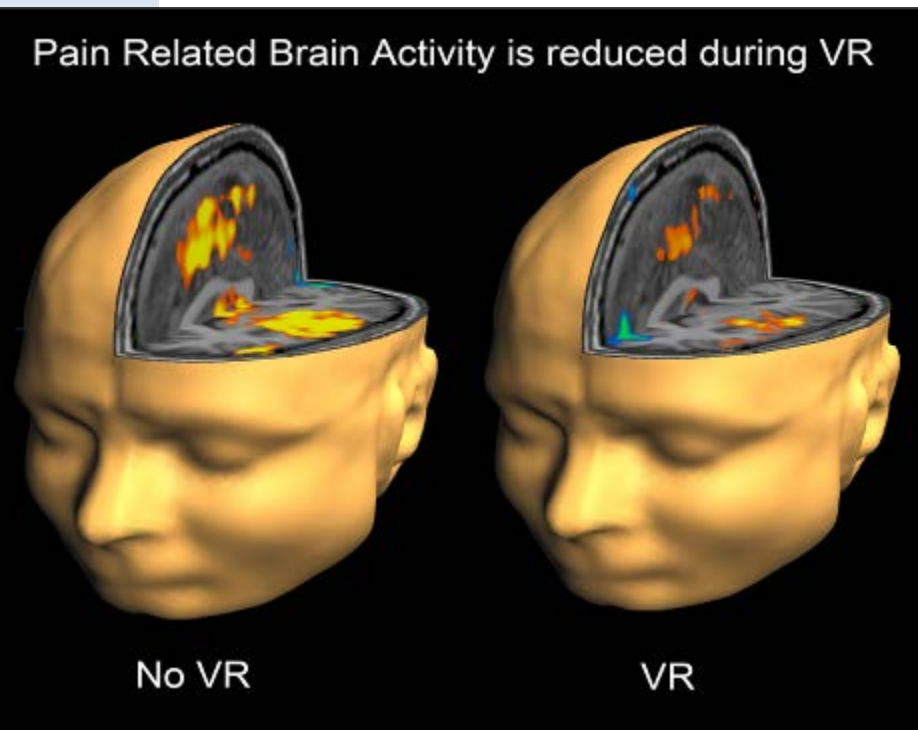


Burn victims: South Pole Fantasy

Hunter Hoffmann et al.



fMRI VR Pain Distraction (Hoffman et al.)



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%

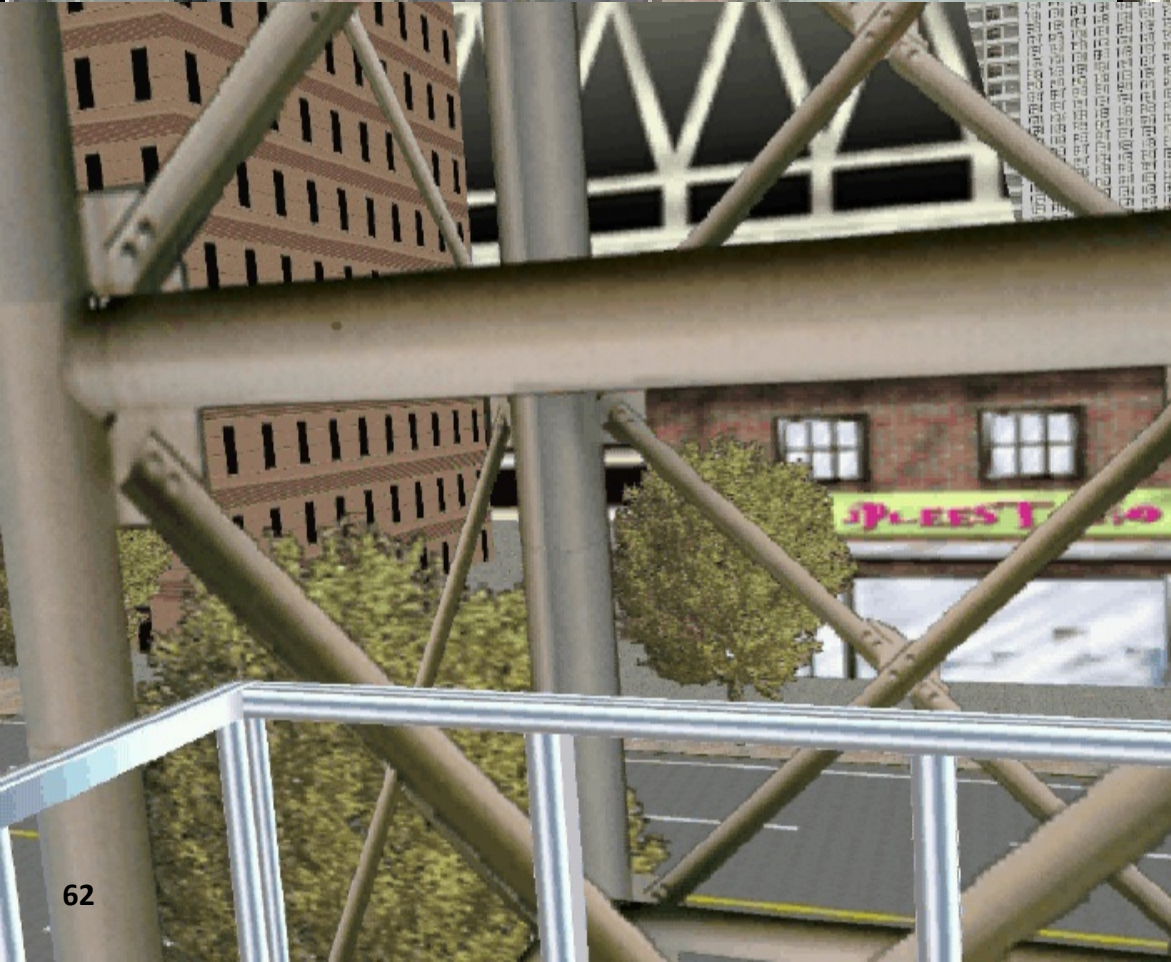
Source: Brenda Wiederhold, VRMC

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

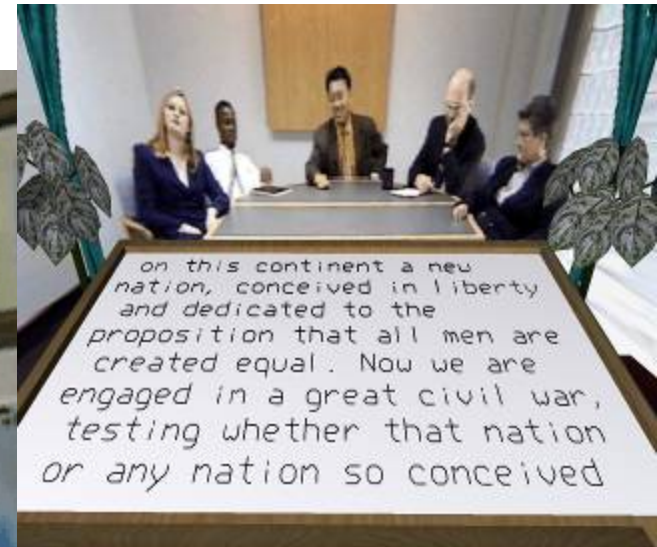




Fear of heights



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



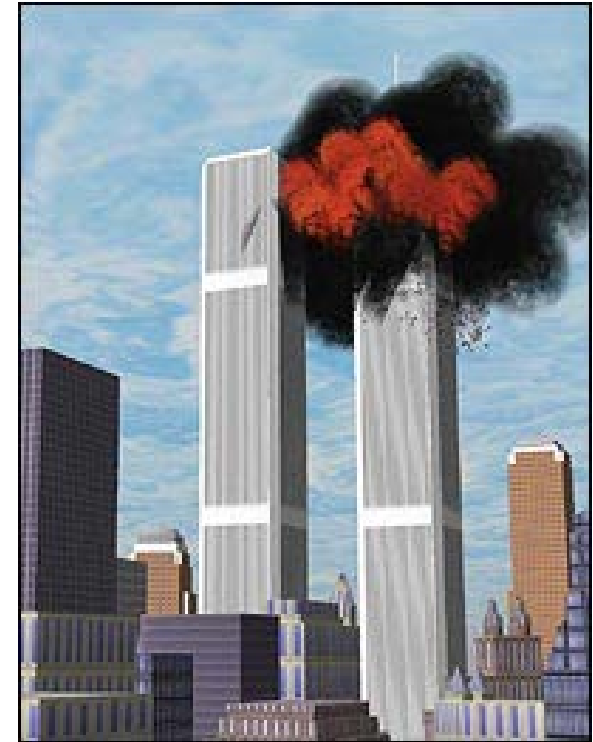
World Trade Center PTSD (Difede & Hoffman)

• Environment:

- 11 Graded Levels of Exposure
- 1st 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

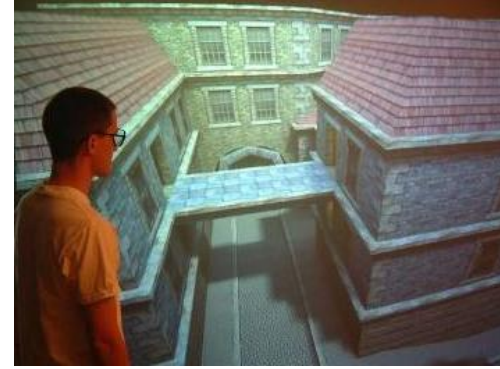


PTSD: Iraq Veterans

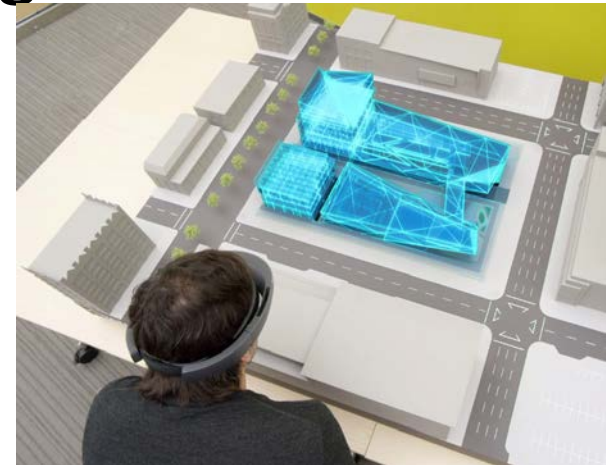
(Rizzo et al.)



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

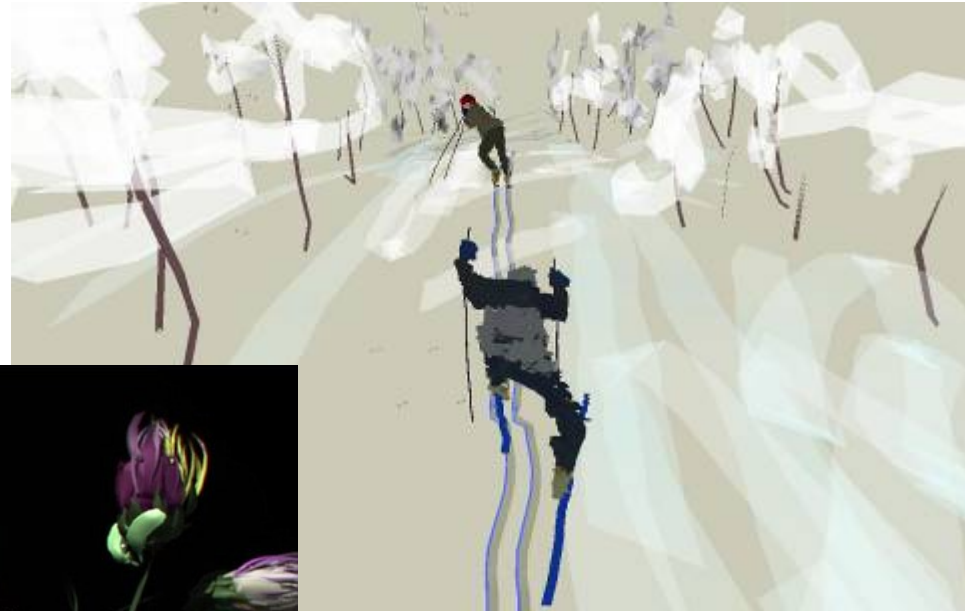


CAD & Design



SpaceDesign (Video)

VR & Kunst

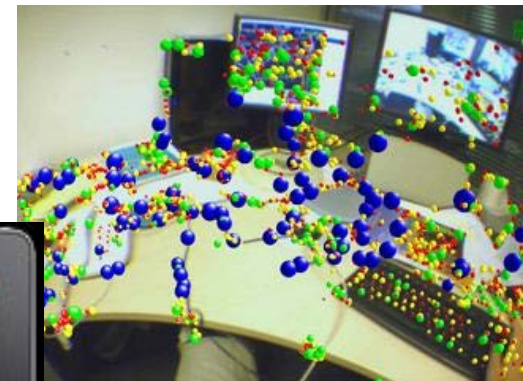


© Google / Tilt Brush

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

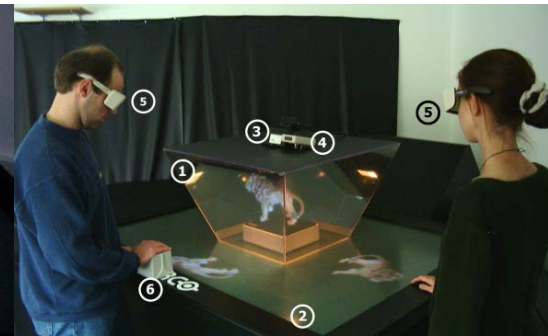
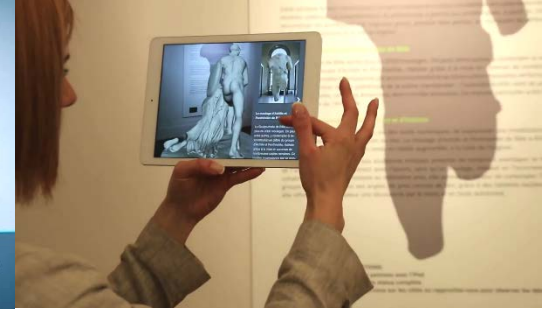


PTAM (2007)

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

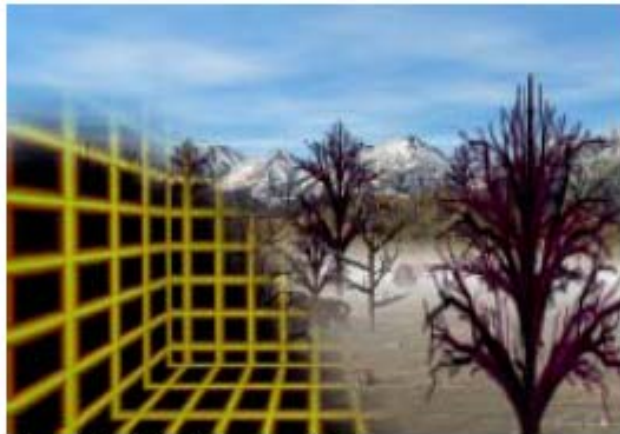


Established Application Areas

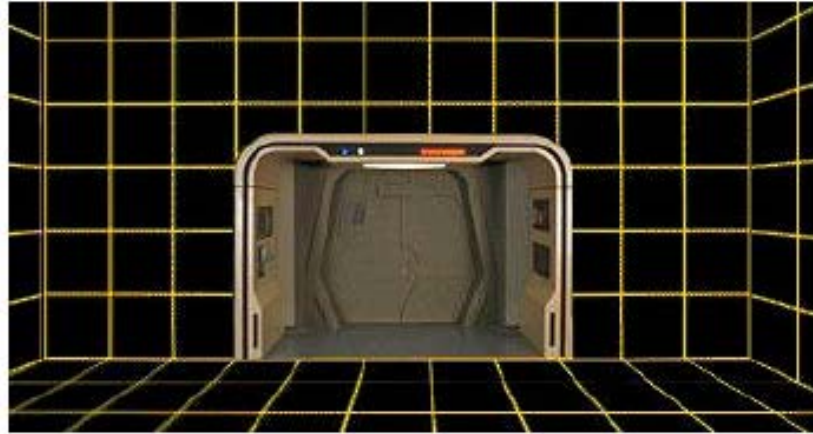
- Very good reasons why VR/AR/MR established in these application areas
 1. New possibilities due to new technology
 2. New/Better solutions to existing problems
 3. Good usability and robust technology are an absolute requirement for wide distribution and public acceptance!
 4. Reasonable use of resources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

