Virtual Reality (VR)
Augmented Reality (AR)

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Introduction

- Definition of VR/AR
- History of VR/AR
- Applications of VR/AR
- Components of VR/AR systems

Introduction

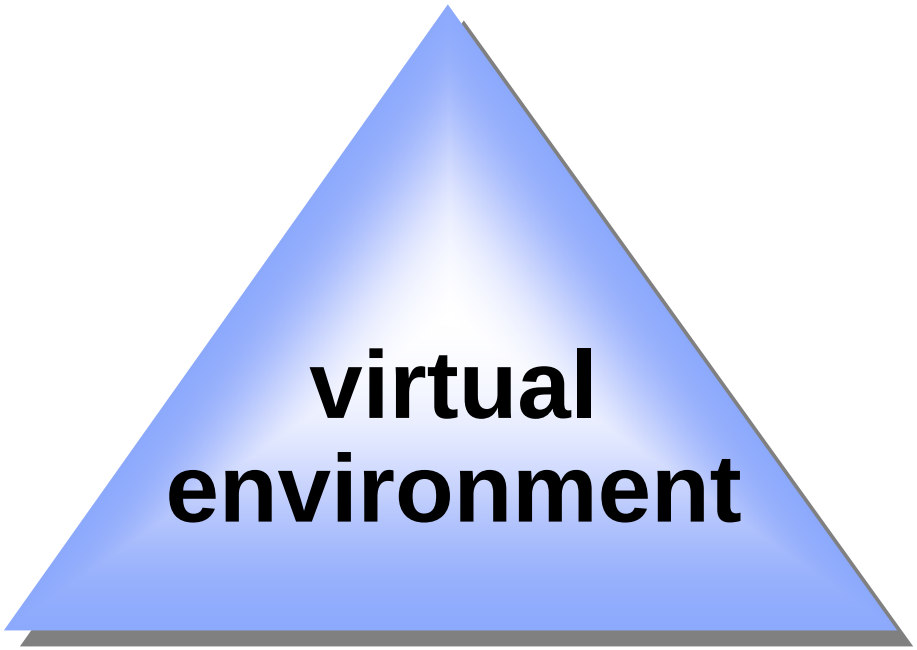
Literature:

1. D.A. Bowman, E. Kruijff, J.J. LaViola,Jr., I. Poupyrev, 3D User Interfaces, Theory and Practice, Addison-Wesley 2005.
2. R. Azuma, *A Survey of Augmented Reality* (http://www.cs.unc.edu/~azuma/ARpresence.pdf) Presence: Teleoperators and Virtual Environments, pp. 355–385, August 1997.
3. K. M. Stanney, Virtual Environments, in The Human-Computer Interaction Handbook, J.A. Jacko, A. Sears (eds.), Lawrence Erlbaum Associates, Inc. 2003.
4. T. Mazuryk, M. Gervautz, Virtual Reality: History, Applications, Technology and Future, TR-186-2-96-06, February 1996
5. W. Carlson, A Critical History of Computer Graphics and Animation, Section 17: Virtual Reality, The Ohio State University 2003, http://design.osu.edu/carlson/history/lesson17.html
6. E. Jacobson, A Virtually Realistic History of Virtual Reality, December 2009, http://www.highestfive.com/science/a-virtually-realistic-history-of-virtual-reality/
7. J. Strickland, How Virtual Reality Works, http://electronics.howstuffworks.com/gadgets/other-gadgets/virtual-reality8.htm
8. G. Klinker, Class notes, TU München, 2010.
9. P. Milgram, F. Kishino, A taxonomy of mixed reality visual displays, IEICE Transactions on Information Systems, Vol. E77-D, No. 12, December 1994.
10. T. Kuhlen, Class notes, RWTH Aachen, 2006.
11. J. Cohen, Class notes, John Hopkins Dept. Computer Science, University of Baltimore, 2000.
12. Jim Vallino, Introduction to Augmented Reality, http://www.se.rit.edu/~jrv/research/ar/introduction.html.
13. S. Müller, Class notes, FH Koblenz-Landau.
14. H. Kaufmann, Class notes, TU Wien, 2008.

What is Virtual Reality (VR) ?

Immersion

I3



Intuition:

- **3-D & multimodal**
  - **visual**
  - **acoustic**
  - **haptic/tactile**

Interaction in Real Time:

- **Navigation**
- **Manipulation**

Source: [10]

What is AR ?

- Real + virtual
- Interactive in real-time
- Registered in 3 Dimensions

Source: [2]

Reality-virtuality continuum [9]

Source: [8]

History

- 1956-1962: Sensorama
  (Morton Heilig)

5 "experiences" :
- motorcycle ride through New York
- bicycle ride
- ride on a dune buggy
- helicopter ride
- dance by a belly dancer

Source: [5]

History

- 1960: Head-Mounted Display Patent Proposal by M. Heilig

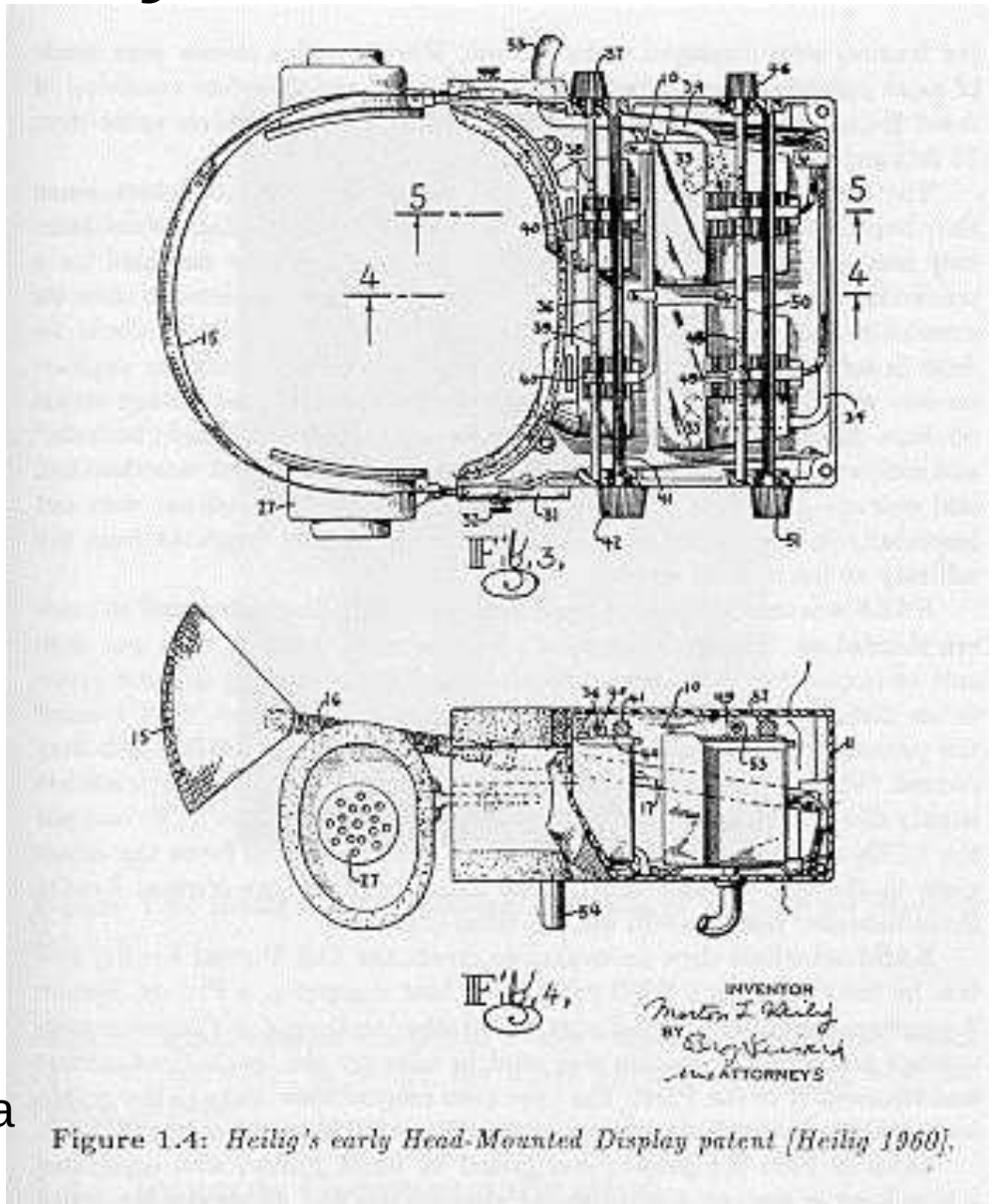


Figure 1.4: *Heilig's early Head-Mounted Display patent [Heilig 1960].*

from *Virtual Reality Technology*, Burdea & Coiffet

Source: [5]

History

- 1961: Headsight
  first fabricated Head-Mounted Display (by Comeau and Bryan of Philco Corporation)
  - single CRT element attached to the helmet
  - a magnetic tracking system to determine the direction of the head
  - to be used with a remote controlled closed circuit video system for remotely viewing dangerous situations.

History

- 1964: B. Polhemus starts company Polhemus Associates
  - develops electromagnetic tracking technology
  - system described in F. Raab, E. Blood, T. Steiner, and H. Jones, Magnetic position and orientation tracking system, IEEE Transactions on Aerospace and Electronic Systems, Vol. 15, No. 5, **1979**, pp. 709-718.

History

- 1964 - : B. Polhemus
  - electromagnetic tracking technology

Polhemus FASTrak and VISIONTrak tracking systems

Source: [5]

History

- 1965: « The Ultimate Display » (I. Sutherland)
  - “a room within which the computer can control the existence of matter”
  - an artificial world construction concept based on
    - interactive graphics
    - force-feedback
    - sound
    - smell
    - taste
  - "The Ultimate Display," Sutherland, I.E., Proceedings of IFIPS Congress 1965, New York, May 1965, Vol. 2, pp. 506-508.

History

- 1968: « The sword of Damocles »
  (I. Sutherland)
  - First Head-Mounted Display linked to a computer (and not cameras), driven by computer graphics
  - Sutherland, Ivan E. 1968. "A Head-Mounted Three Dimensional Display," pp. 757-764 in Proceedings of the Fall Joint Computer Conference. AFIPS Press, Montvale, N.J.

History

Source: [11]

1968: « The sword of Damocles »
(I. Sutherland)

- Wireframe images superimposed on world
- two separate systems for tracking:
  - Mechanical
  - Ultrasonic

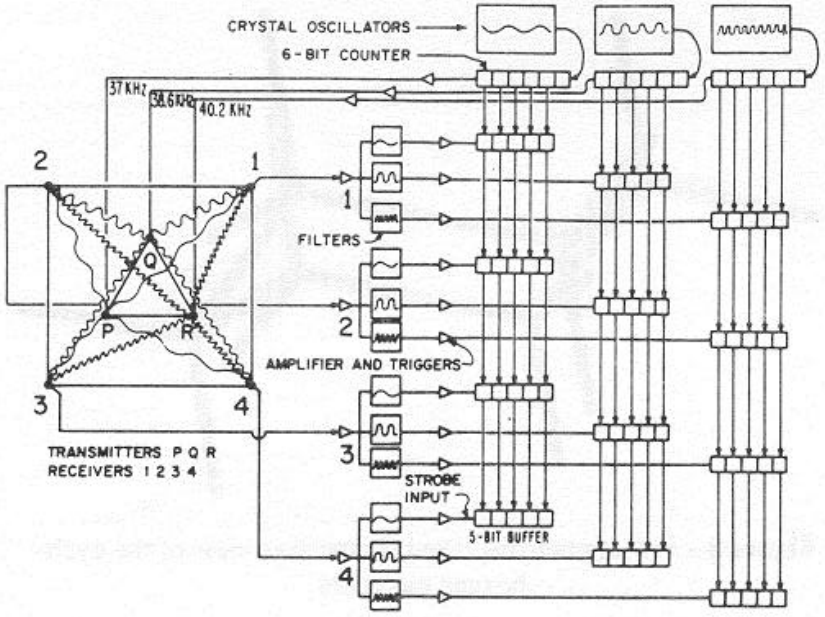


Figure 5 - The ultrasonic head position sensor logic

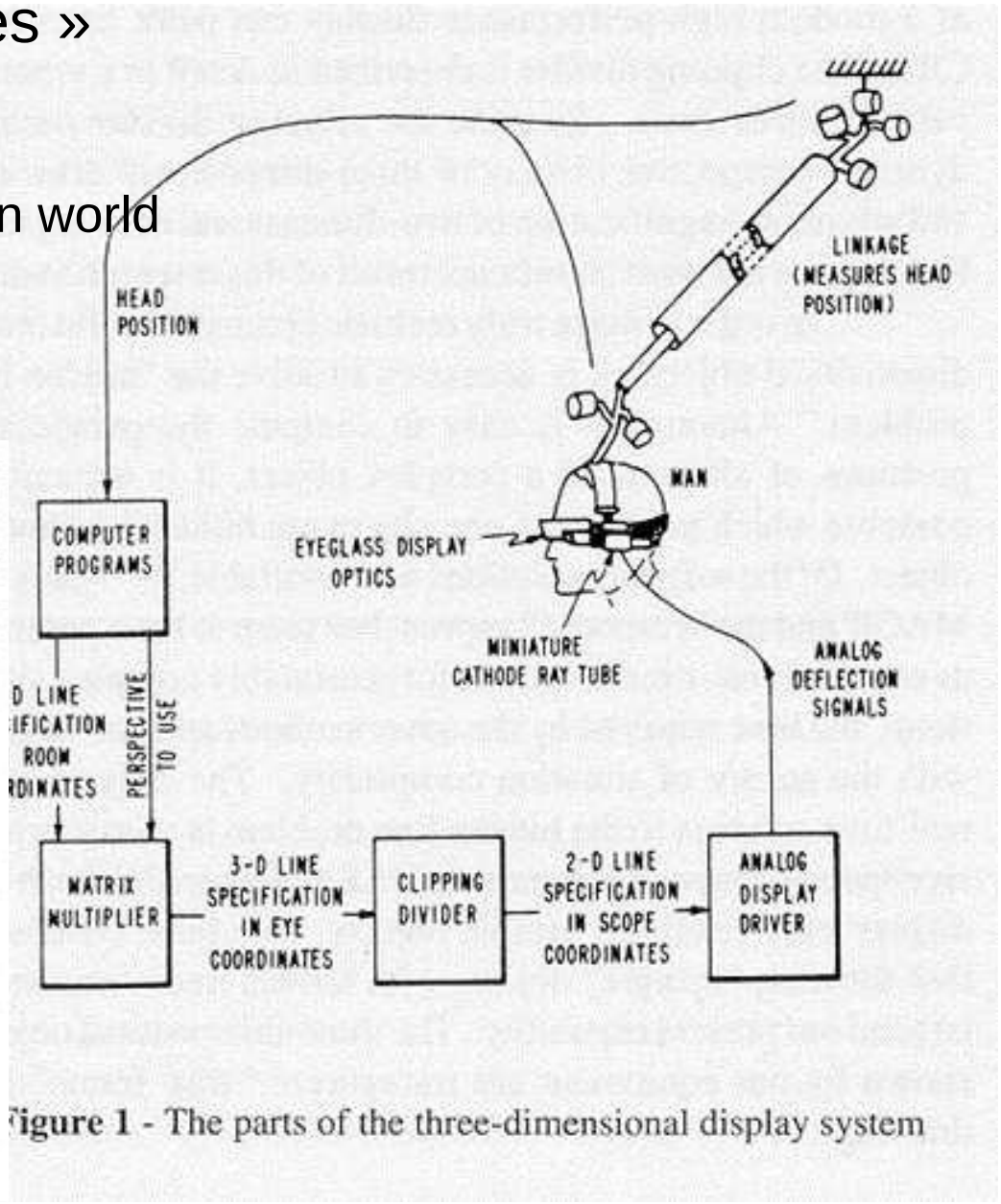
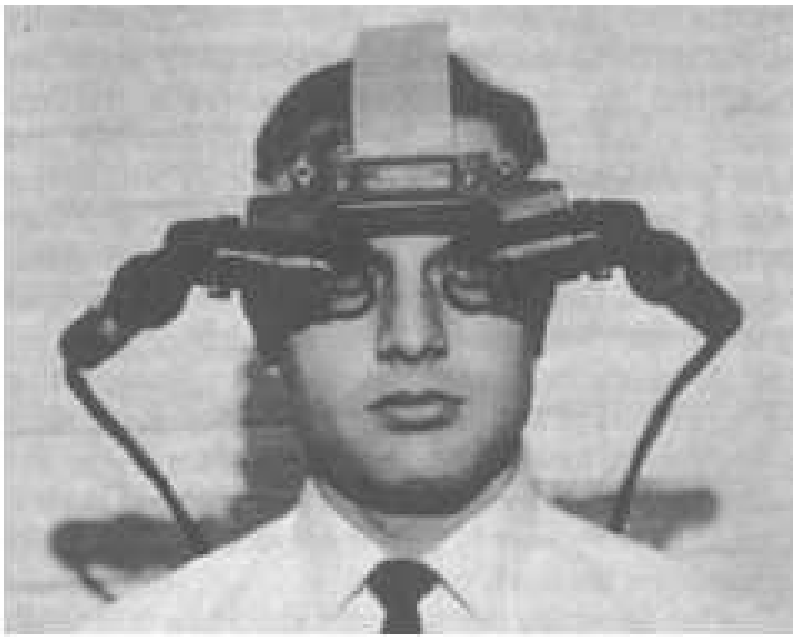


Figure 1 - The parts of the three-dimensional display system

History



1968: « The sword of Damocles »
(I. Sutherland)

Source: [5]

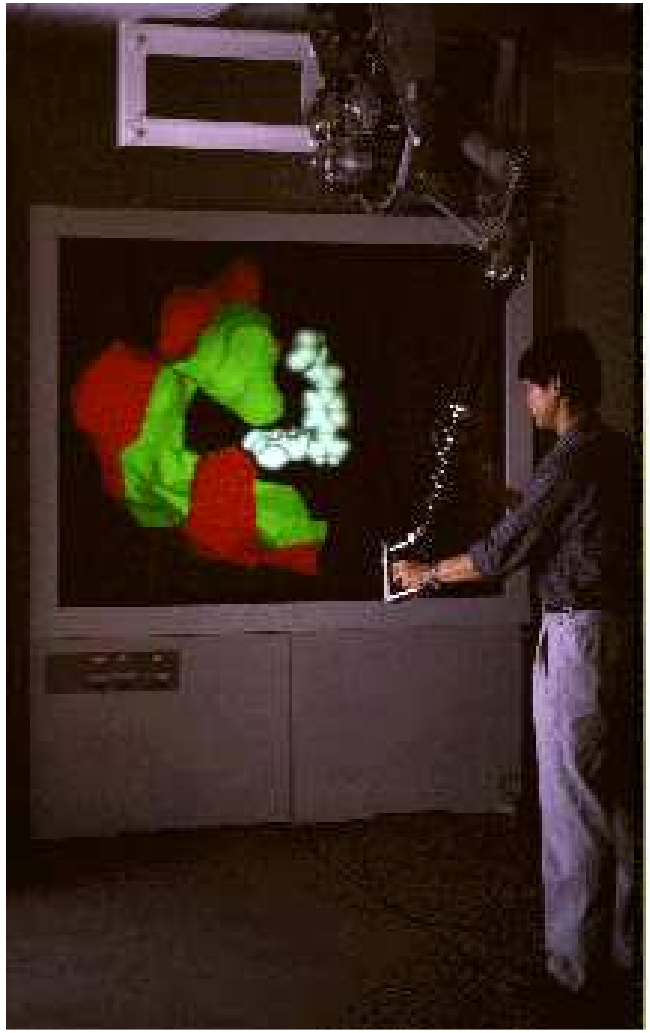
History

- 1971: GROPE (started by Brooks in 1967)
  - first prototype of a force-feedback system realized at the University of North Carolina (UNC)
  - Haptic/kinesthetic display system for molecular forces
  - Progression:
    - Grope I, 2D system for continuous force fields
    - Grope II, 1978, full six-dimensional (6D) system with three forces and three torques, but forces in real time only for very simple world models
    - Grope III, 1988, Argonne Remote Manipulator (ARM), full 6D system

History

- 1971: GROPE (started by Brooks in 1967)

GROPE III (UNC): Argonne Remote Manipulator (ARM)



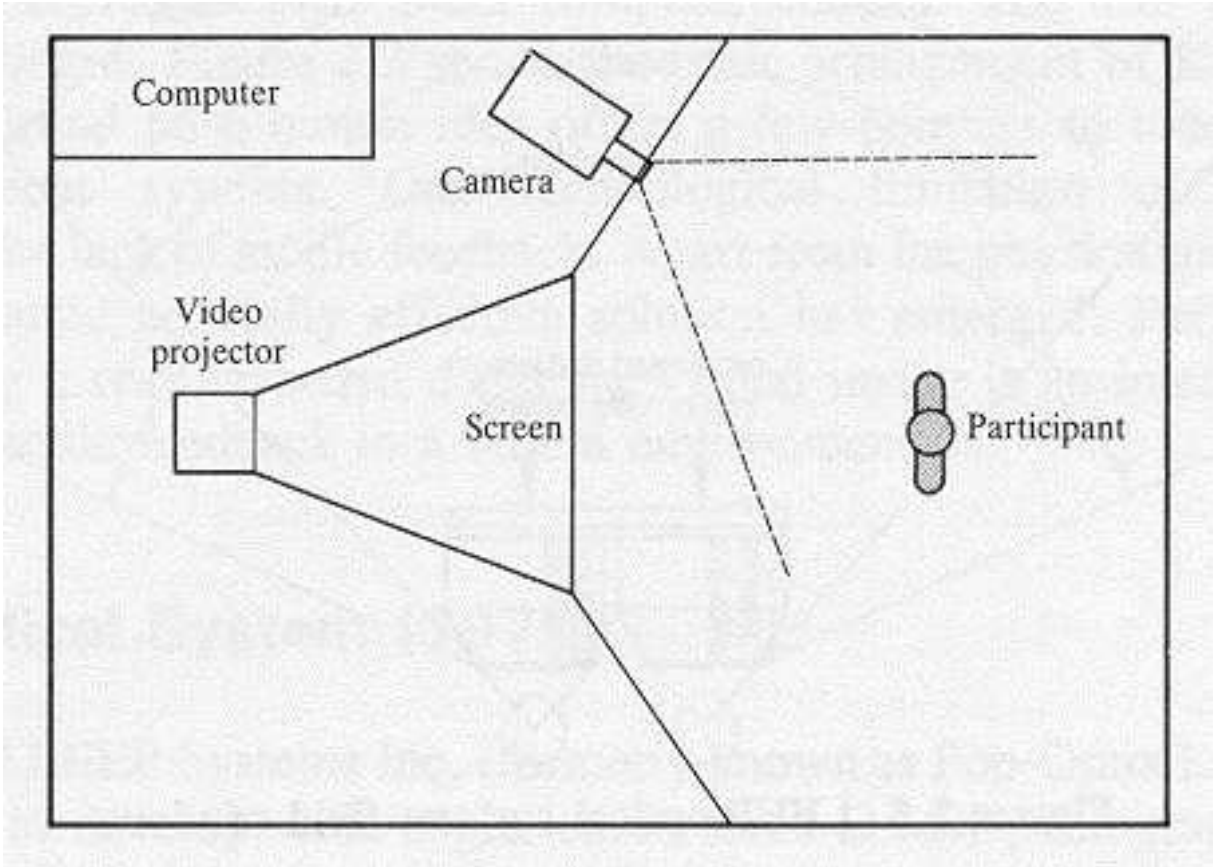
Source: [5]

History

- 1975: VIDEOPLACE (M.Krueger)
  - University of Connecticut
  - Graphics and gesture recognition
  - Interaction of real participants and graphics objects controled by the computer
  - Projection on a large screen of users' silhouettes grabbed by the cameras. Interaction of participants thanks to image processing techniques in 2D screen's space.
  - Krueger, M.W., "Artificial Reality". Reading, Mass., Addison Wesley, 1983

History

- 1975 - : VIDEOPLACE (M.Krueger)



History

- 1975 - : VIDEOPLACE (M.Krueger)

http://www.youtube.com/watch?v=d4DUIeXSEpk&feature=related

History

- 1975 - : VIDEOPLACE (M.Krueger)

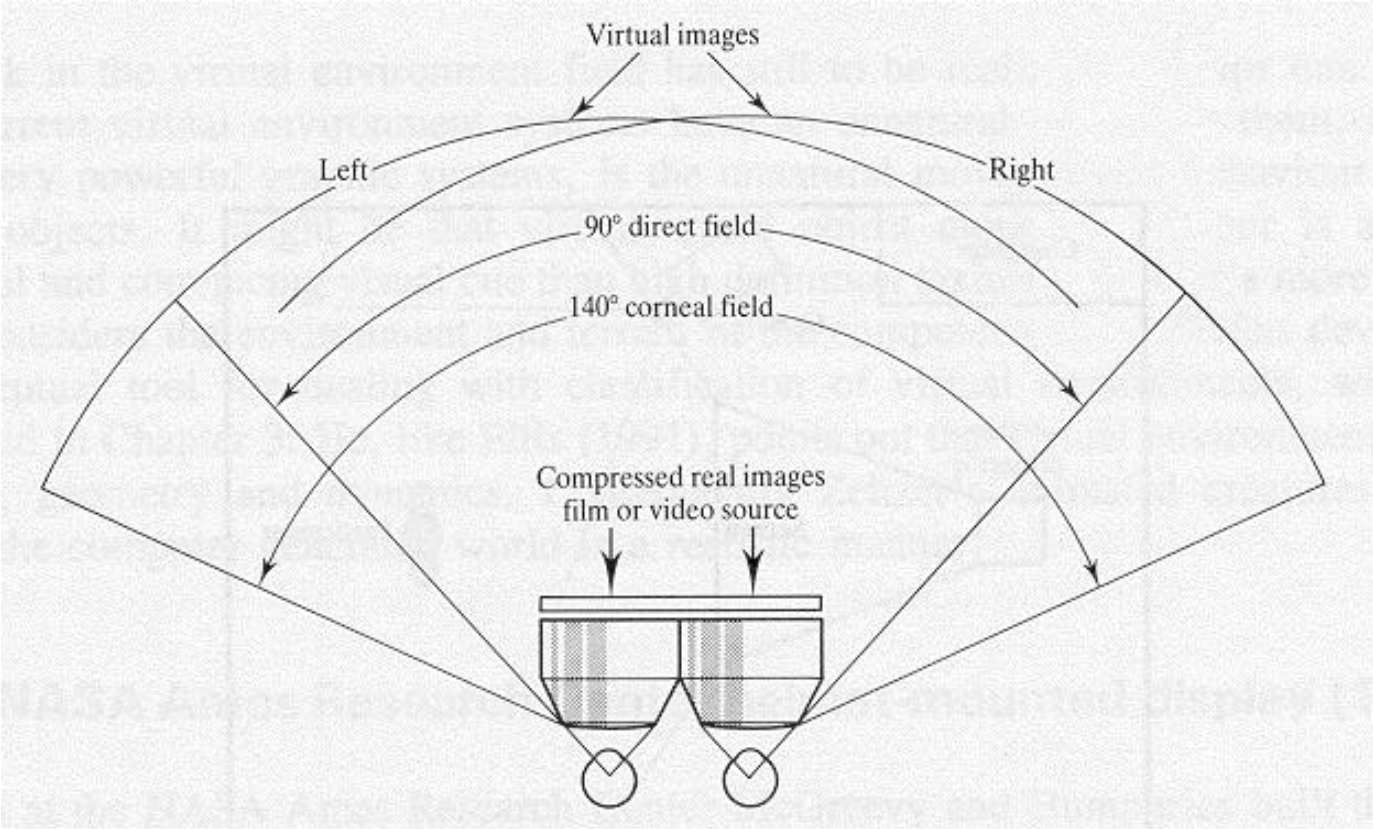
http://www.youtube.com/watch?v=dqZyZrN3Pl0&feature=player_embedded

History

- 1975: LEEP optical systems starts to develop wide angle lenses for 3-D still photography applications
  - Large Expanse, Extra Perspective (LEEP) optical system (Eric Howlett,1979)
  - LEEP is the basis for most of the current virtual reality helmets available today
  - very wide field of view stereoscopic image

History

- Since 1975: LEEP optical systems



Source: [11]

History

- 1977: Sayre Glove (T. Defanti, D. Sandin, R. Sayre) in a project for the National Endowment for the Arts
  - first instrumented glove described in literature
  - it monitors hand movements
  - finger flexion measured by light based sensors
  - Inexpensive
  - lightweight

History

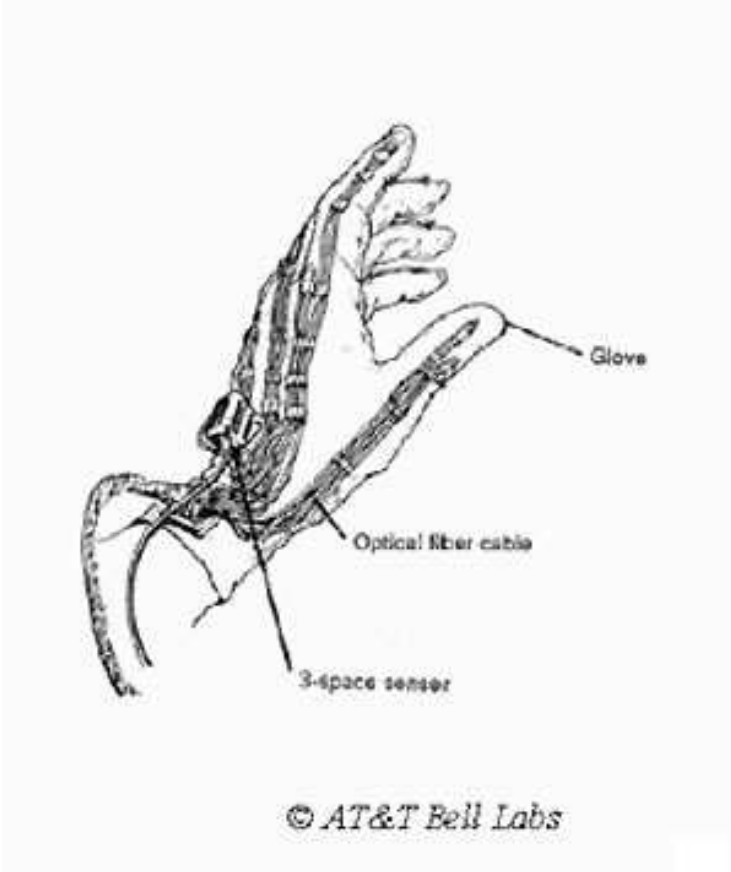
- 1982: VCASS = **V**isually **C**oupled **A**irborne **S**ystems **S**imulator (T. Furness, US Airforce Armstrong Medical Research Labs)
  - advanced flight simulator
  - Pilot wears HMD that augments the out-the window view by the graphics describing targeting or optimal flight path information
  - Furness, T. 1986. The super cockpit and its human factors challenges. Proceedings of the Human Factors Society. 30, 48-52.

History

- 1983: Grimes' Digital Data Entry Glove
  (G. Grimes, Bell Labs)
  - device for measuring hand positions
  - finger flex sensors, tactile sensors at the fingertips, orientation sensing and wrist-positioning sensors
  - changeable positions of the sensors
  - intended for creating "alpha-numeric" characters by examining hand positions
  - alternative to keyboards
  - possibility for non-vocal users to "finger-spell" words

History

- 1983: Grimes' Digital Data Entry Glove (G. Grimes, Bell Labs)



Source: [5]

History

- 1984: VIVED = **VI**rtual **V**isual **E**nvironment **D**isplay (McGreevy, NASA)
  - first low-cost, wide field-of-view, stereo, head-tracked, head-mounted display
  - integrated in the first of NASA's virtual environment workstations:
    - Digital Equipment Corporation PDP-11/40 computer
    - Evans and Sutherland Picture System 2 with two 19" monitors
    - Polhemus head and hand tracker
    - video cameras
    - custom video circuitry
    - VIVED system

History

1984: VIVED = **VI**rtual **V**isual **E**nvironment **D**isplay (McGreevy, NASA)

October 1987 Scientific American featured VIVED « a minimal system, but one which demonstrated that a cheap immersive system was possible »

Source: [5]

History

- 1985: VPL Research (founded by Jaron Lanier, Jean-Jacques Grimaud)
  - J. Lanier came up with term « virtual reality »
  - First commercially available VR devices: DataGlove (1985), Eyephone HMD (1988)
  - VPL DataGlove:
    - neoprene fabric glove with two fiber optic loops on each finger
    - at opposite ends of each loop : LED - photosensor
    - small cuts in fiber optic cable along its length: by bending a finger light escaped from the fiber optic cable through these cuts, amount of light reaching the photosensor = measure of bending
    - Problems:
      - recalibration for each user and even for same user
      - fatigue (because of the stiffness)
      - High price (9000$)

History

- 1985: VPL Research (founded by Jaron Lanier, Jean-Jacques Grimaud)
  - VPL DataGlove, Eyephone HMD

Source: [13]

Source: [5]

History

- 1985: VIEW = **Virtual I**nteractive **E**nvironment **W**orkstation (S. Fisher, NASA)
  - NASA's first virtual reality installation:
    - redesigned LEEP
    - Polhemus tracker
    - 3D audio output
    - gesture recognition using VPLs DataGlove
    - a remote camera
    - BOOM-mounted CRT display.

Source: [5]

History

- 1985: VIEW = **Virtual** **I**nteractive **E**nvironment **W**orkstation (S. Fisher, NASA)

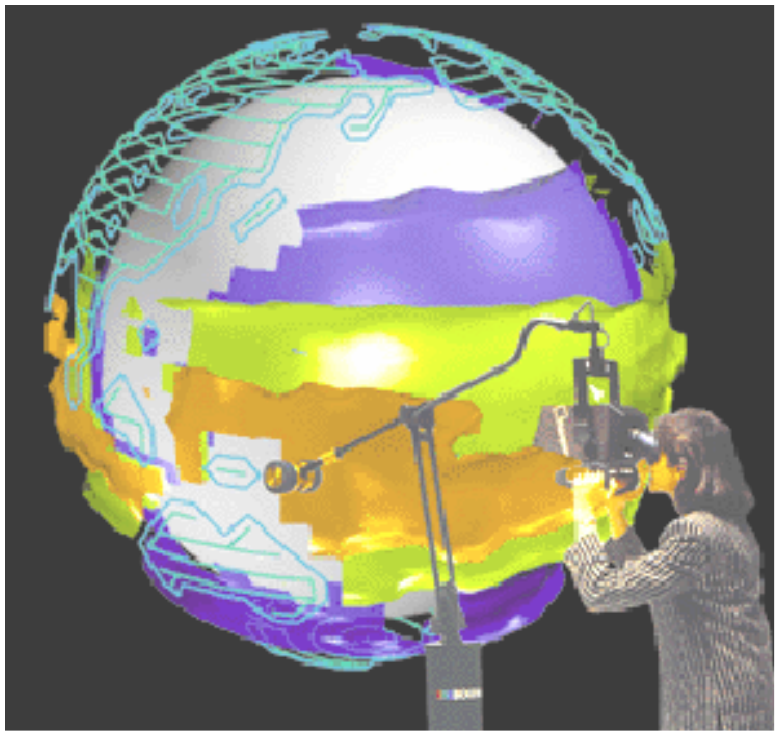
Source: [10]

1989

1992

History

- 1989: BOOM = **B**inocular **O**mni-**O**rientation **M**onitor (built by Fake Space Labs, initially for NASA's VIEW)
  - very small monitors mounted on a mechanical arm
  - monitors used like a pair of binoculars
  - tracking of mechanical arm changes perspective
  - easy to change users
  - high resolution



Source: [5]

History

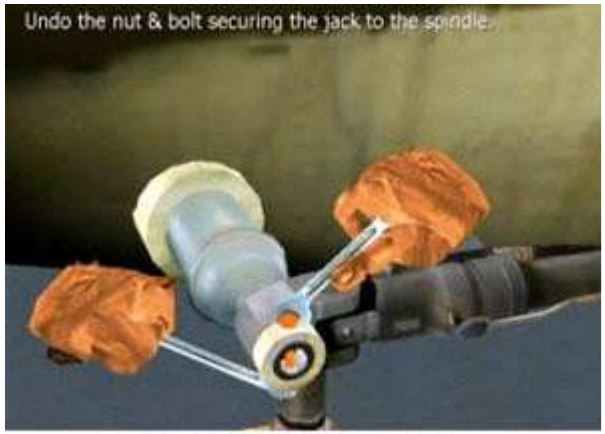
- 1985-1990: Pixel-Planes project (UNC)
  - image-generation system capable of rendering 1.8 million polygons per second
  - used in several UNC VR projects:
    - GROPE
    - architectural walkthrough project
    - planning of cancer therapy

History

- 1986: Ascension (founded by E. Blood, J. Scully, formerly with Polhemus)
  - Motion tracking technology (Flock of Birds)
  - application areas:
    - animation
    - medical imaging
    - biomechanics
    - virtual reality
    - simulation/training
    - military targeting systems
  - used technology:
    - DC magnetic and AC magnetic
    - infrared-optical
    - inertial and laser technologies

Source: [5]

3D-BIRD mounted on Sony LDI-100 HMD. Audi TT Coupe virtual interior and exterior environment courtesy Eon Reality, Sweden.

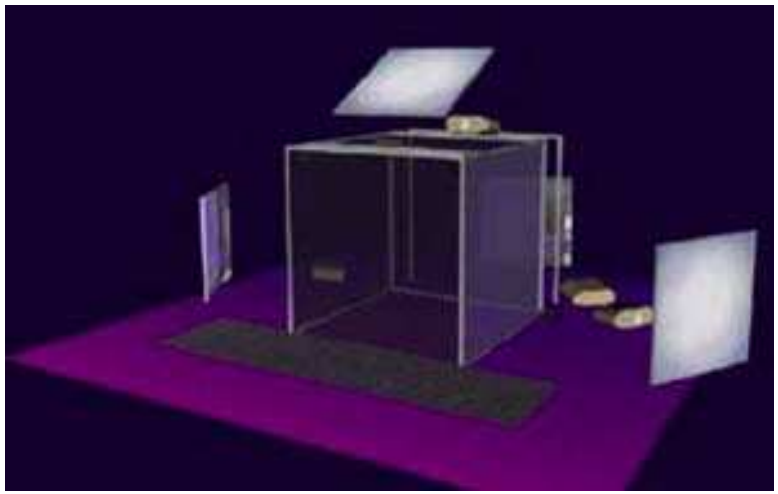


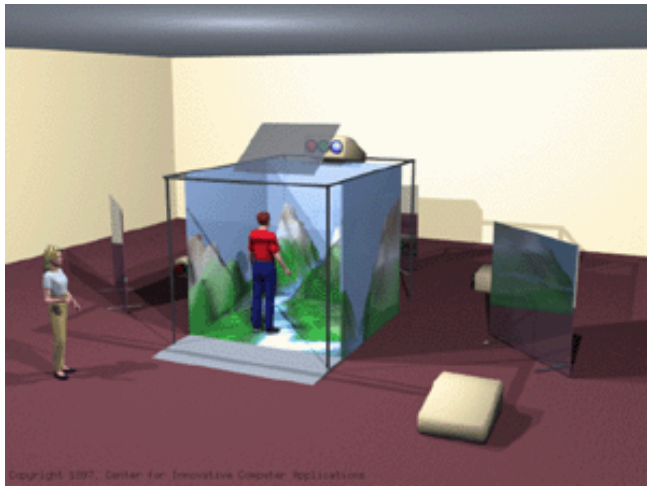
Maelstrom's virtual toolkit teaches technicians how to perform repairs to the Puma helicopter. Immersive tools – headset, cyber gloves, and Ascension's three sensor Flock of Birds – are used to simulate real-world conditions in which repairs often take place. Image courtesy Maelstrom Virtual Productions

Ascension's Flock of Birds motion tracker is used in a Puma helicopter repair training

History

- 1992: CAVE = CAVE Automatic Virtual Environment (C. Cruz-Neira, D. Sandin, T. DeFanti at Electronic Visualization Lab (EVL), University of Illinois Chicago)
  - surround-screen, surround-sound, projection-based virtual reality (VR) system
  - coupled with head and hand tracking systems to produce the correct stereo perspective





Source: [14]

History

- 1992: CAVE

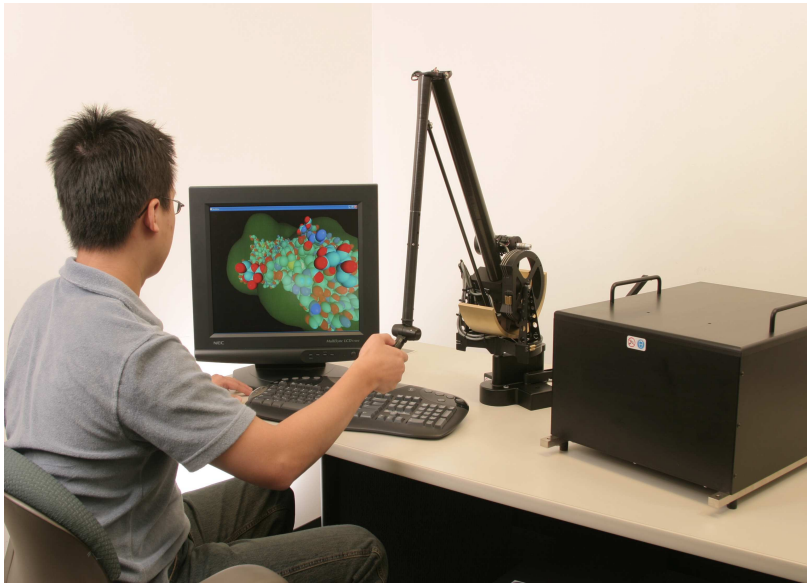
http://www.youtube.com/watch?v=-Sf6bJjwSCE&feature=related

History

- 1993: Silicon Graphics Reality Engine:

  Hardware-supported Gouraud Shading, Texture Mapping, Z-Buffering, Anti-Aliasing (approx. 200 000 Polygons/sec)

- 1993: OpenGL Standard (graphics library)
- 1993: PHANToM Haptic Device (T. Massie, K. Salisbury)



Pictures: Sensable Technologies

History

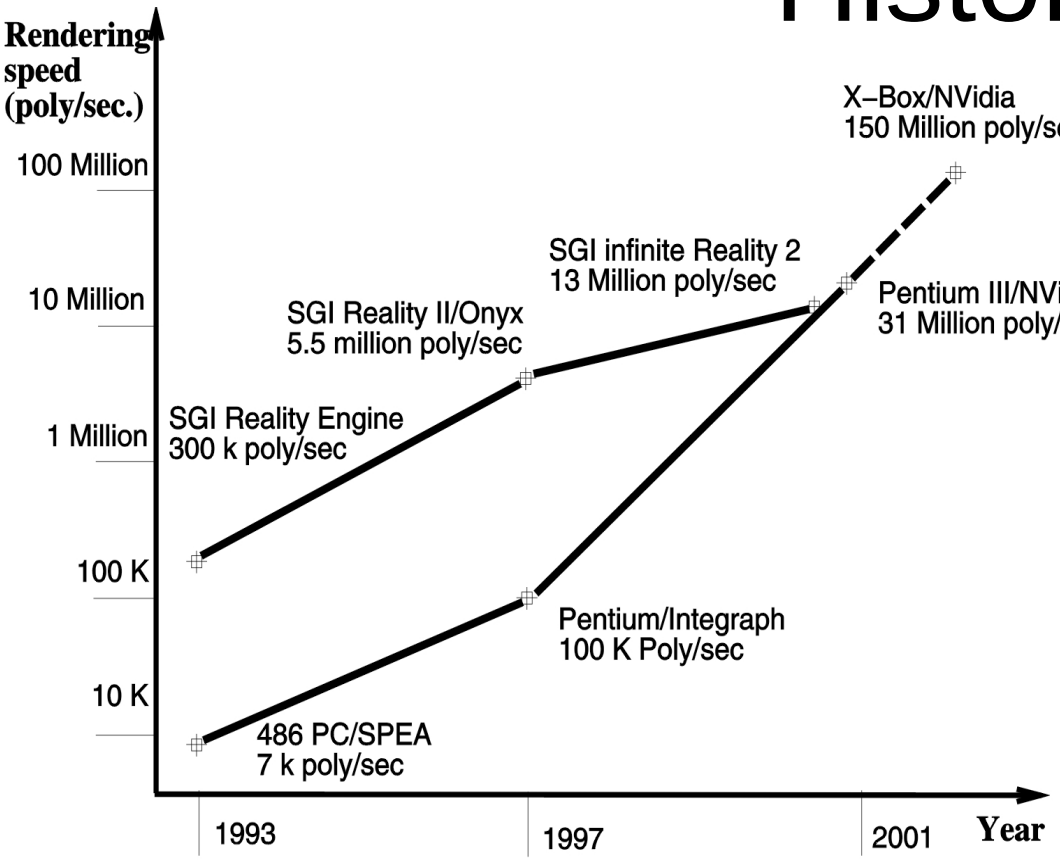
- 1995: VRML = **V**irtual **R**eality **M**odeling (or **M**arkup) **L**anguage (introduced by Silicon Graphics)
  - language used to create 3-D worlds
  - Web3D Consortium supervises development
  - international ISO standard
  - Successor: X3D (extensible 3D)

History

- 1996: Silicon Graphics Infinite Reality
- 1998: Silicon Graphics Infinite Reality2 (13 Mio Polygons/sec)
- 1998 until today: Development of VR applications in military, automotive industry, medicine, …

Picture: Silicon Graphics Inc.

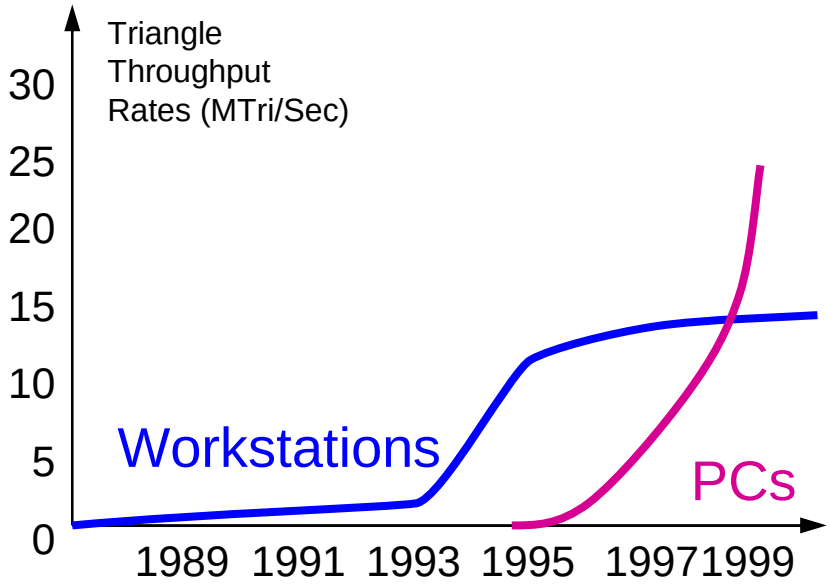
History



Source: [10]

Picture:Burdea et al.

Source: [13]

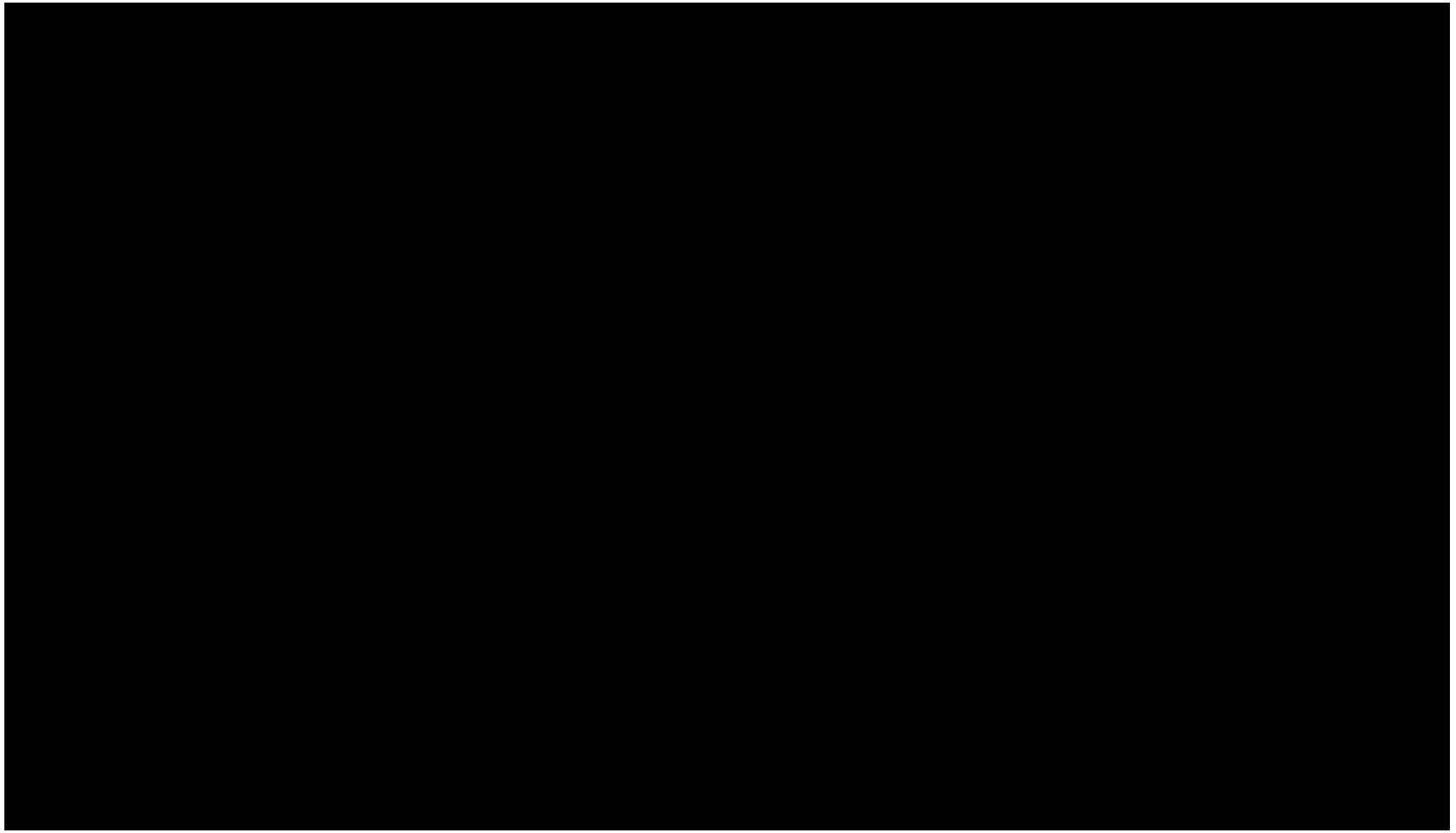


History

- Since 1990: Augmented Reality
  - technology that “presents a virtual world that enriches, rather than replaces the real world” (see S. Bryson et al.: Knowledge-Based Augmented Reality. Communications of the ACM, Vol. 26, No. 7, pp. 56-62 (1993))
  - see-through HMD that superimposes virtual three-dimensional objects on real ones
  - previously used to enrich fighter pilot’s view with additional flight information (VCASS)
  - great application potential in many areas:
    - Medicine
    - Entertainement
    - Automotive, airplane, ship industries
    - Architecture
    - Education
    - …

History

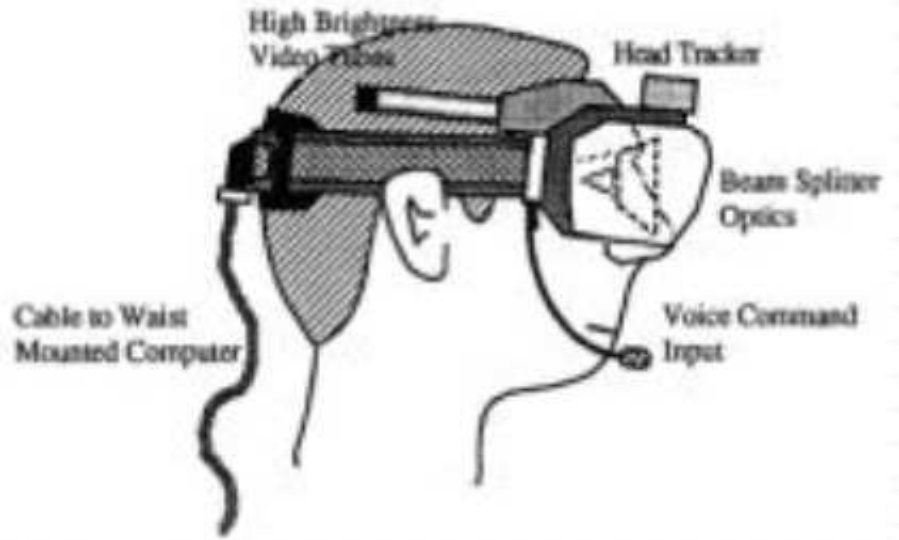
- Since 1990: Augmented Reality



http://www.youtube.com/watch?v=P9KPJlA5yds&feature=related

History

- 1992: Tom Caudell and D. W. Mizell coin the term « Augmented Reality » (at Boeing): T. P. Caudell, D. W. Mizell**, Augmented Reality: An Application of Heads-Up Display Technology to Manual Manufacturing Processes,** Proc. 1992 IEEE Hawaii Intl. Conf. on Sys. Sciences, 992, pp 659-669.

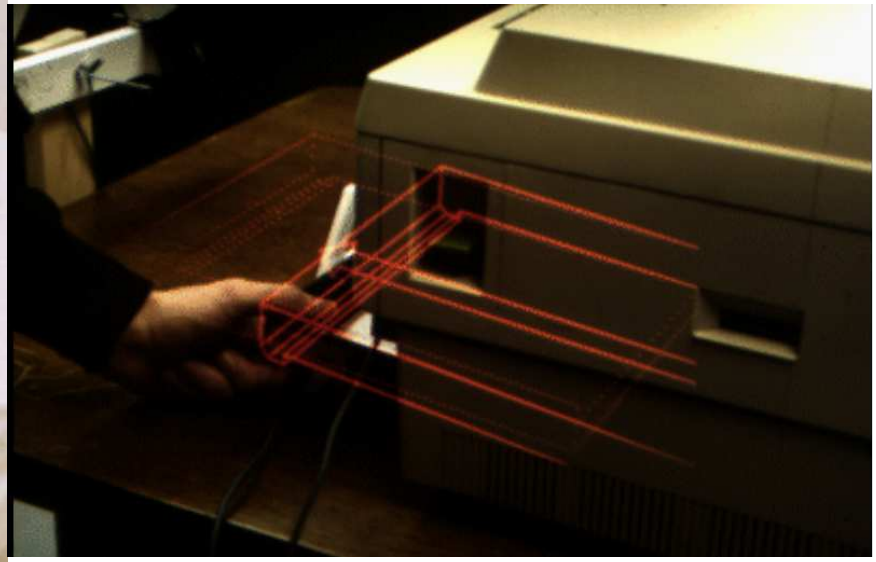


History

- 1992: L.B. Rosenberg develops one of the first functioning AR systems, called VIRTUAL FIXTURES, at the U.S. Air Force Research Laboratory—Armstrong, and demonstrates benefits to human performance:
  - L. B. Rosenberg, The Use of Virtual Fixtures As Perceptual Overlays to Enhance Operator Performance in Remote Environments, Technical Report AL-TR-0089, USAF Armstrong Laboratory, Wright-Patterson AFB OH, 1992.
  - L. B. Rosenberg, "The Use of Virtual Fixtures to Enhance Operator Performance in Telepresence Environments" SPIE Telemanipulator Technology, 1993.

History

- 1992: AR system prototype, KARMA, Columbia University, New York : Feiner, S., MacIntyre, B., and Seligmann, D. Knowledge-based augmented reality. *Communications of the ACM*, 36(7), July 1993, 52-62.



http://graphics.cs.columbia.edu/projects/karma/karma.html

History

- 1994: Julie Martin creates first 'Augmented Reality Theater production', Dancing In Cyberspace, funded by Australian Federal Government, Australia Council For The ArtsFeatures using Silicon Graphics computers and Polhemus sensing system


interactive virtual stage set


holographic illusion projected in tree

http://www.myspace.com/cyberengineer#!/cyberengineer

History

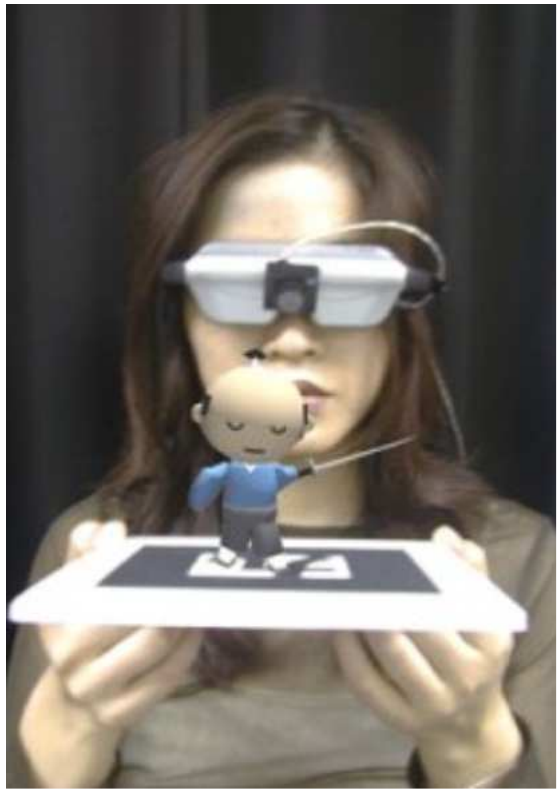
- 1998: Spatial Augmented Reality introduced by: Ramesh Raskar, Greg Welch, Matt Cutts, Adam Lake, Lev Stesin and Henry Fuchs,
  "**The Office of the Future : A Unified Approach to Image-Based Modeling and Spatially Immersive Displays**," ACM SIGGRAPH 1998, Orlando FL, July 19-24, 1998.

http://www.cs.unc.edu/~raskar/Office/

Sketch by Andrei State

History

- 1999: Hirokazu Kato created ARToolKit at University of Washington Human Interface Technology Laboratory (HIT Lab).
  - Ongoing development by HIT Lab , HIT Lab NZ at the University of Canterbury, New Zealand, and ARToolworks, Inc, Seattle.
  - Very widely used AR tracking library with over 160,000 downloads since 2004.



http://www.hitl.washington.edu/artoolkit/

History

- 2000: ARQuake, the first outdoor mobile AR game is developed by Prof. Bruce H. Thomas and 4 students at Wearable Computer Lab at the University of South Australia

http://wearables.unisa.edu.au/projects/arquake/

History

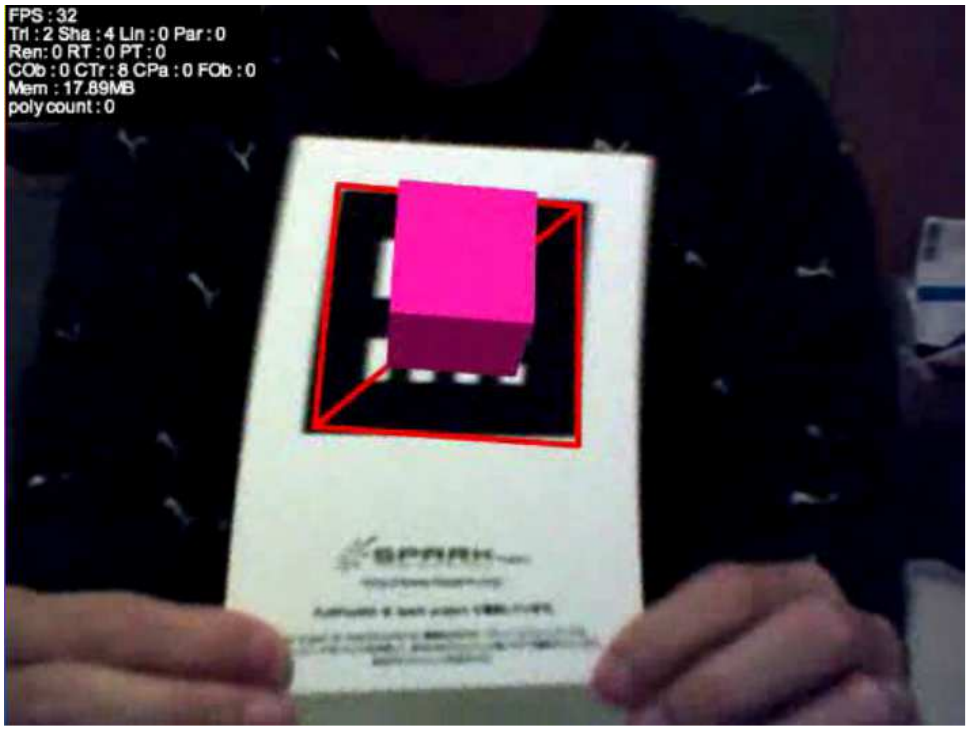
- 2008: Wikitude AR Travel Guide on Android, iPhone, Blackberry, Symbian and Bada.

http://www.wikitude.com/team

http://www.youtube.com/watch?v=8EA8xlicmT8

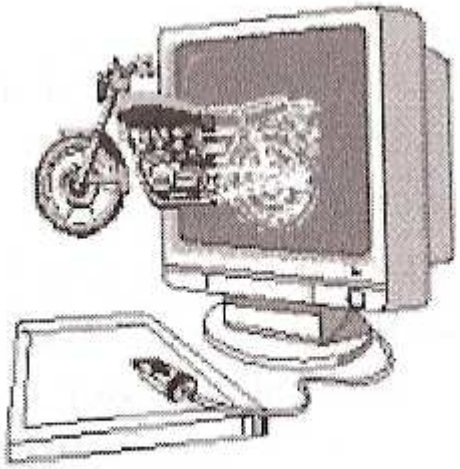
History

- 2009: AR Toolkit was ported to Adobe Flash (FLARToolkit) by Saqoosha, bringing augmented reality to the web browser:
  - FlarToolkit is an open source code library for **Augmented Reality in Flash**



http://saqoo.sh/a/en/flartoolkit/start-up-guide

Applications



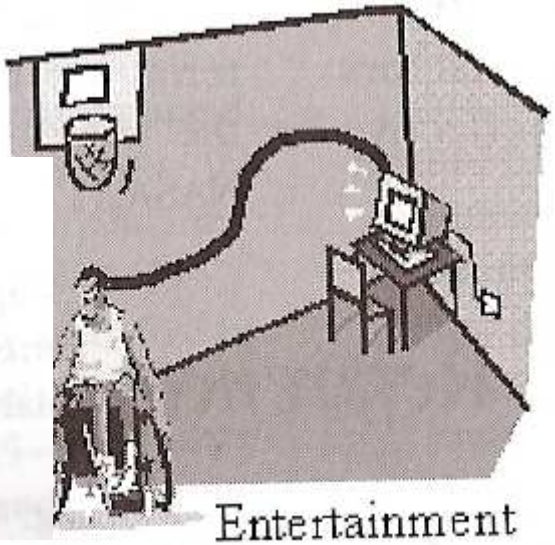
Engineering

Military Training

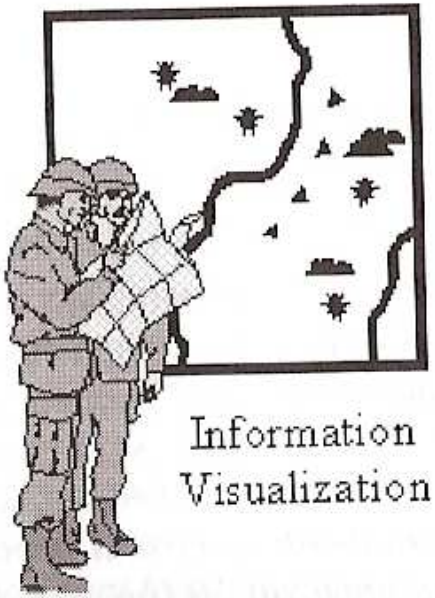
Education

Medical

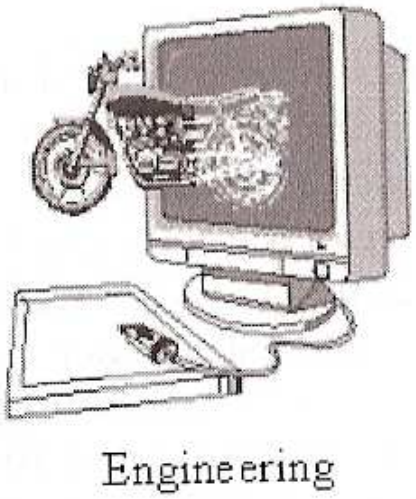
Psychotherapy



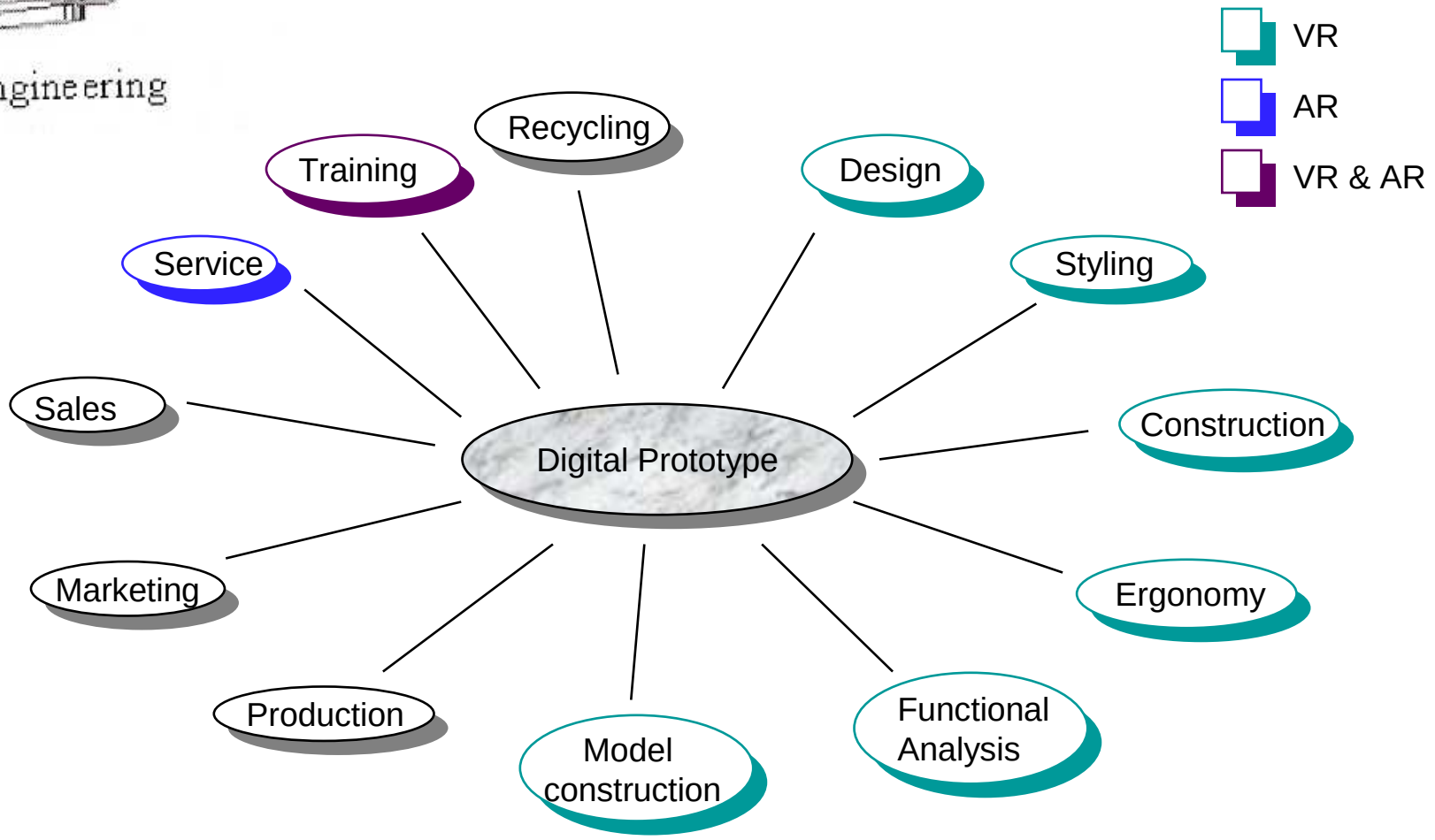
Entertainment



Information Visualization

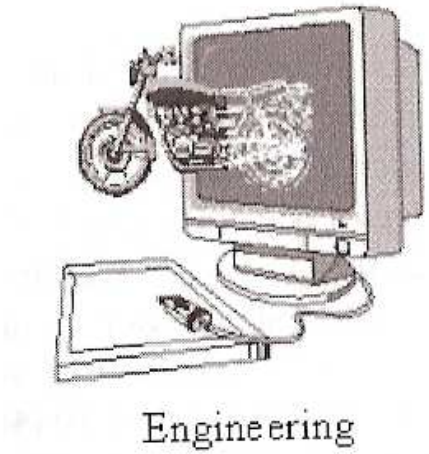


Applications of VR



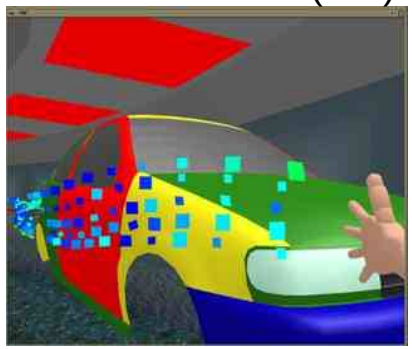
Digital Mock-Up (DMU)

Applications of VR

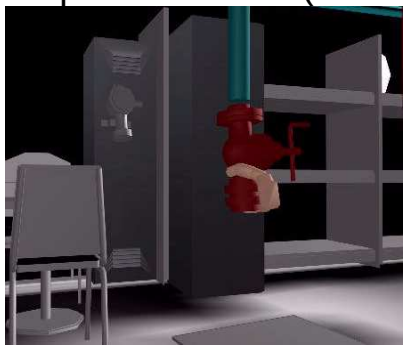


CAD & Design

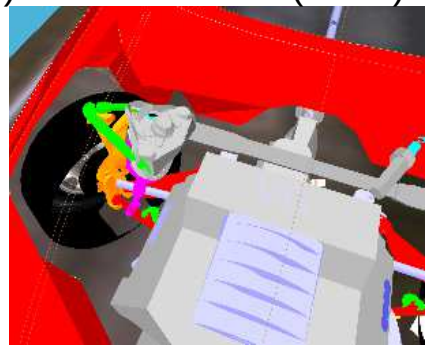
Virt. Wind Chanel (VW)



Ship construction (BloVo)



Mechanical Sim. (AUDI)

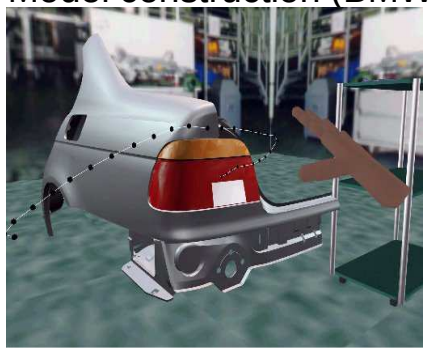


Architecture (Lufthansa)

Design Review (VW)

Ergonomy (BMW)

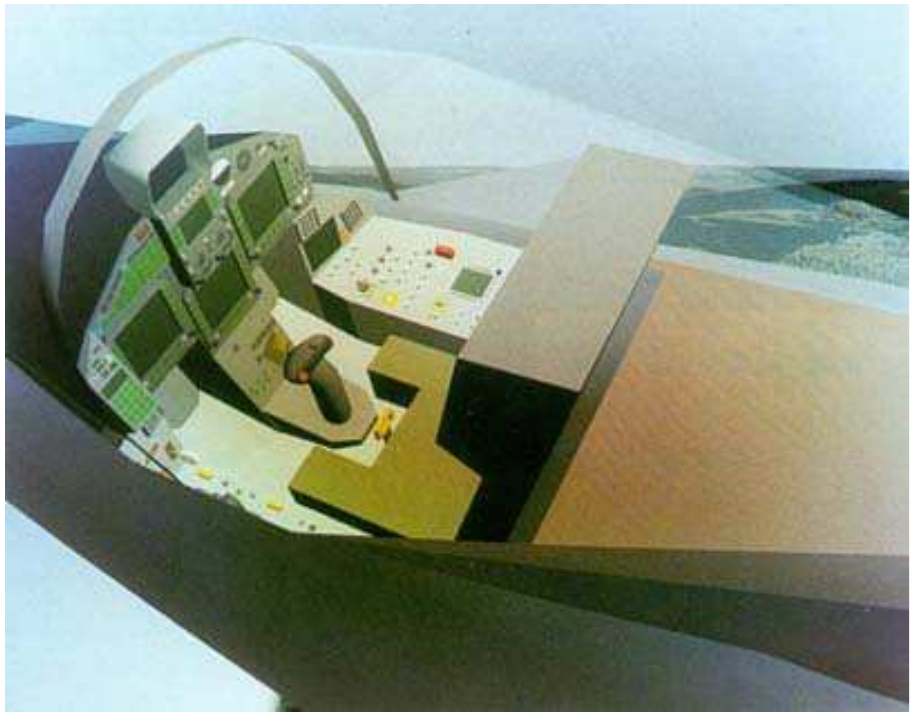
Model construction (BMW)



Cockpit Layout (CAVOK)

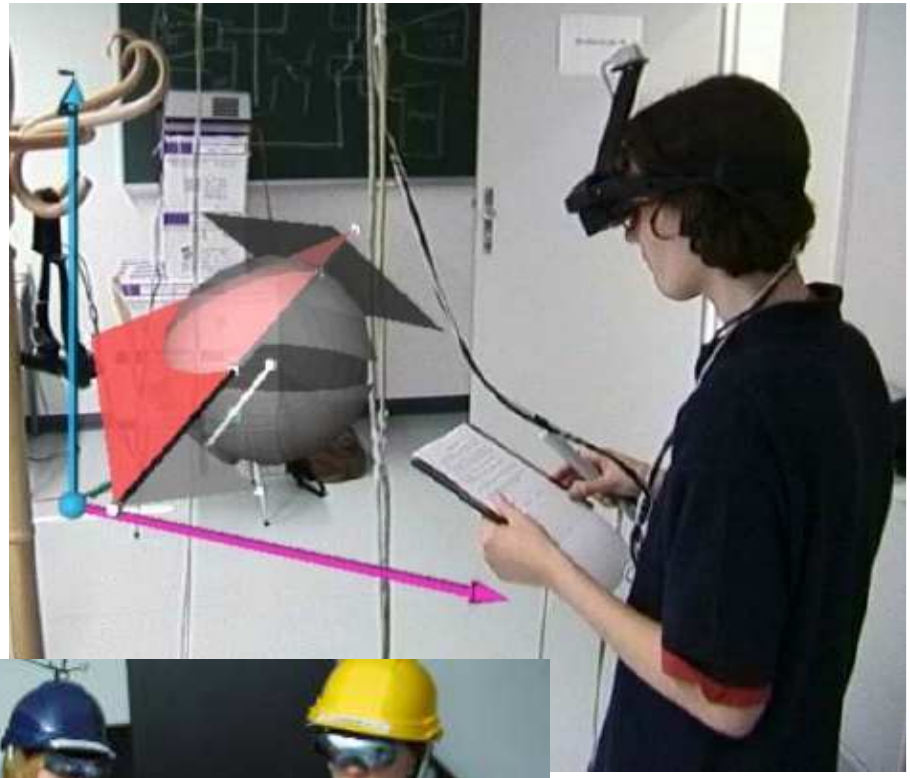
Applications of VR

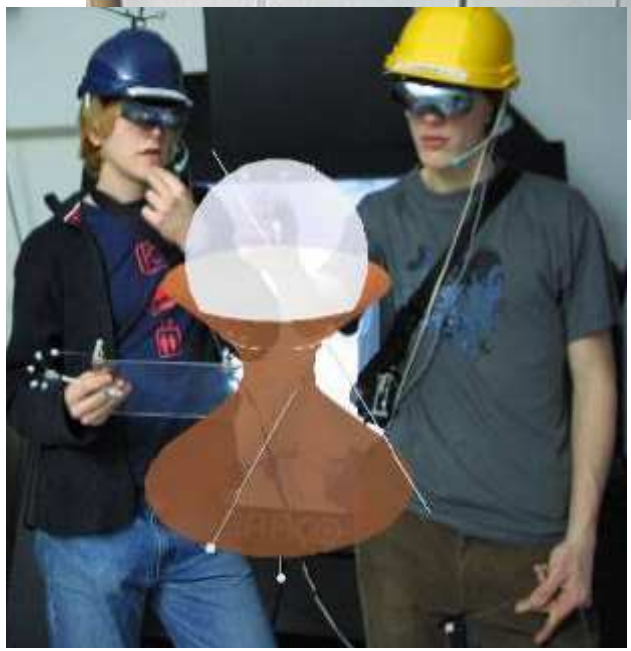
Military Training



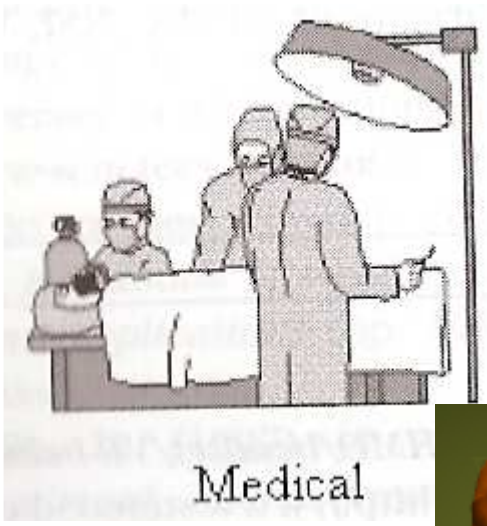
Applications of VR

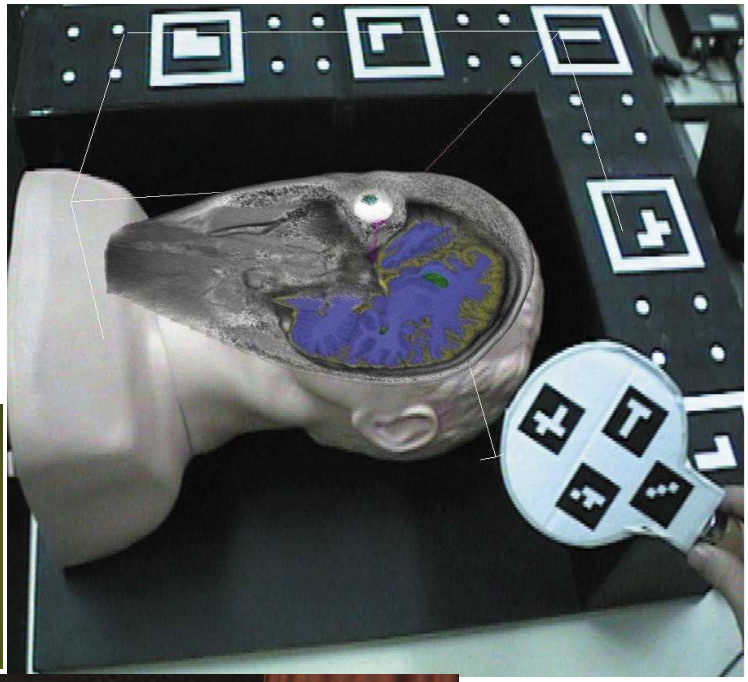
Education

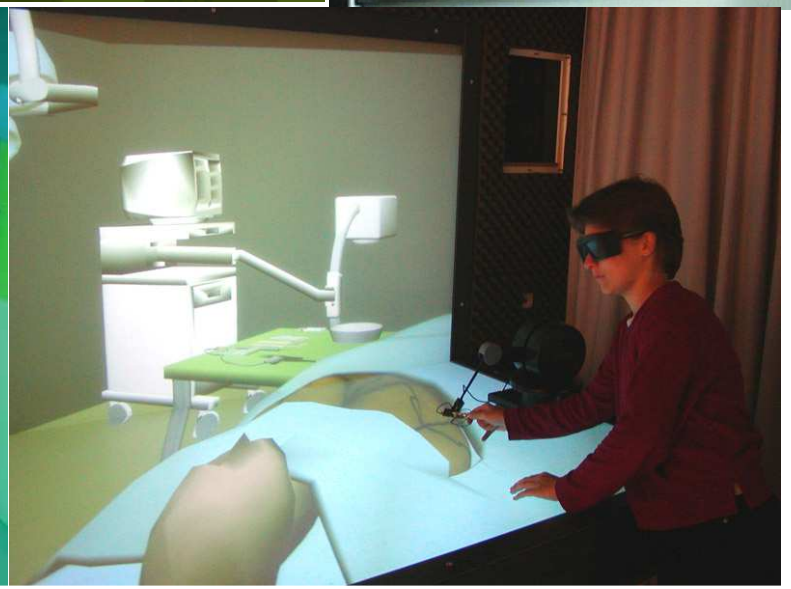




Applications of VR







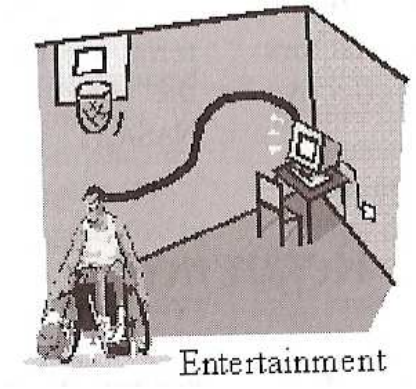
Virtual Surgery

Applications of VR

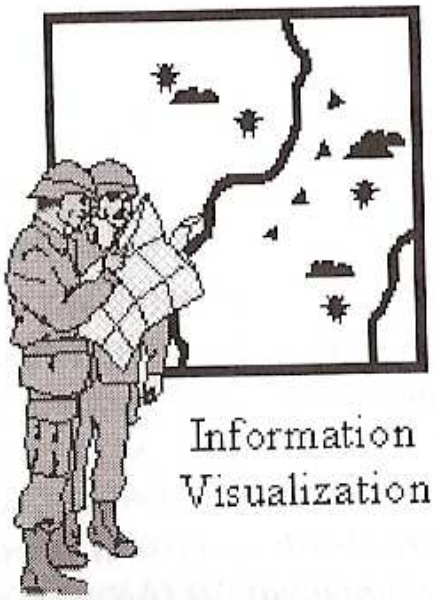
Arachnophobia

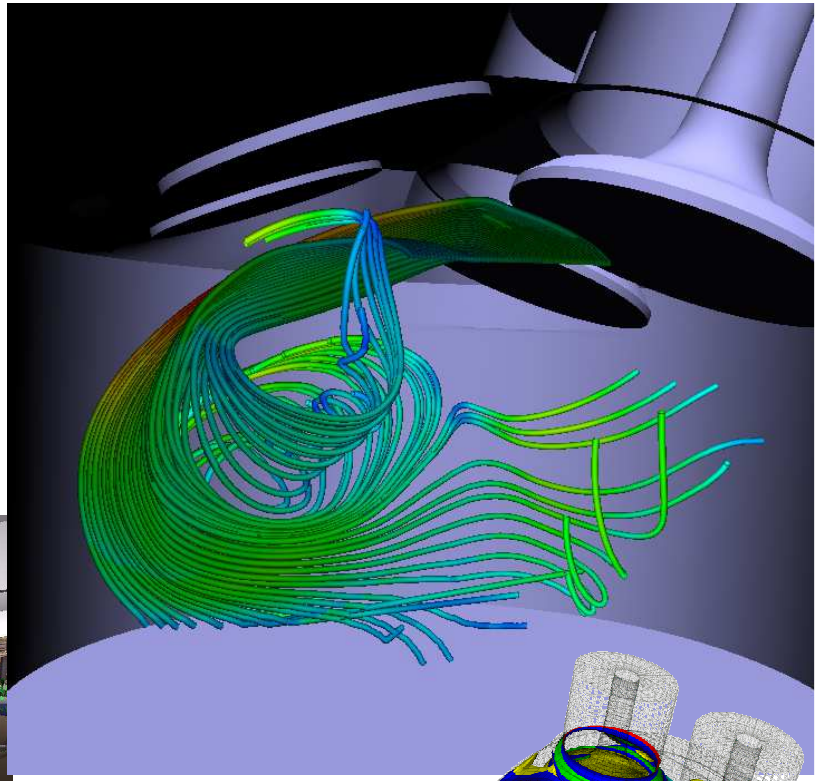
Public Speaking VE

Applications of VR

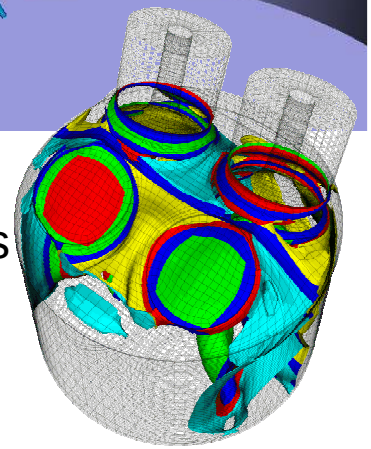


Applications of VR



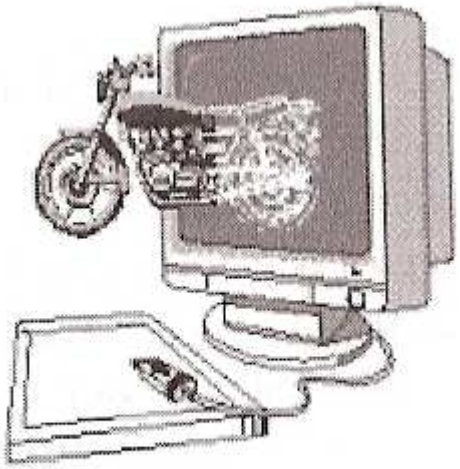


Computational
Fluid Dynamics



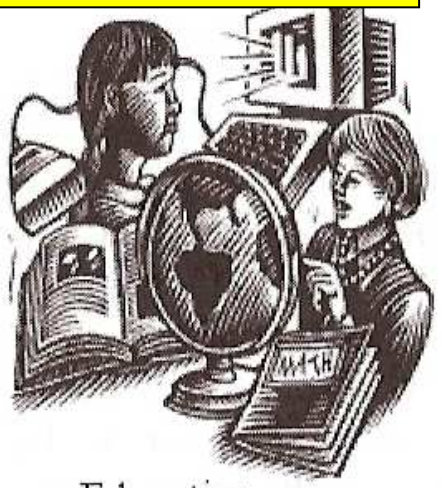
Architecture

Applications



Engineering

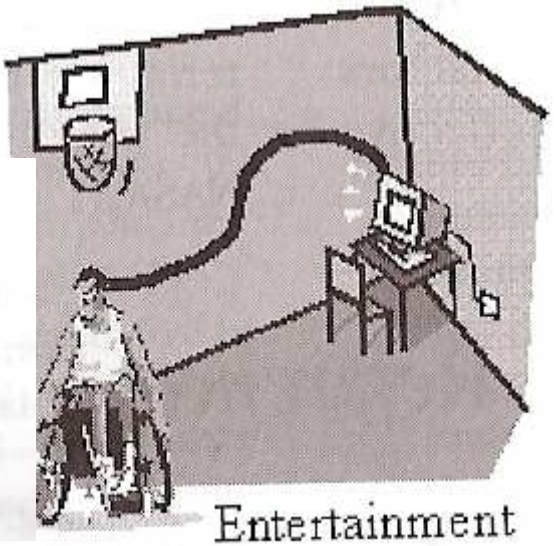
Military Training



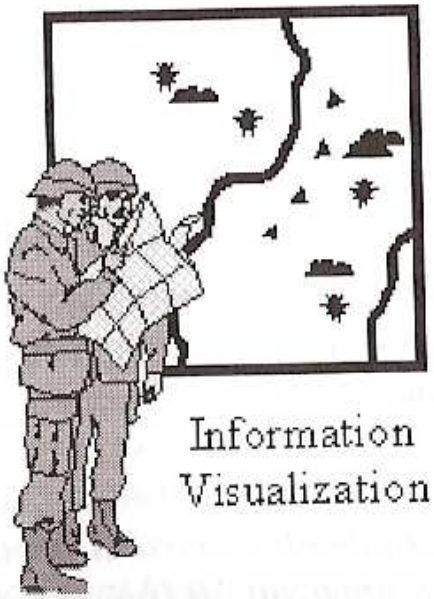
Education

Medical

Psychotherapy

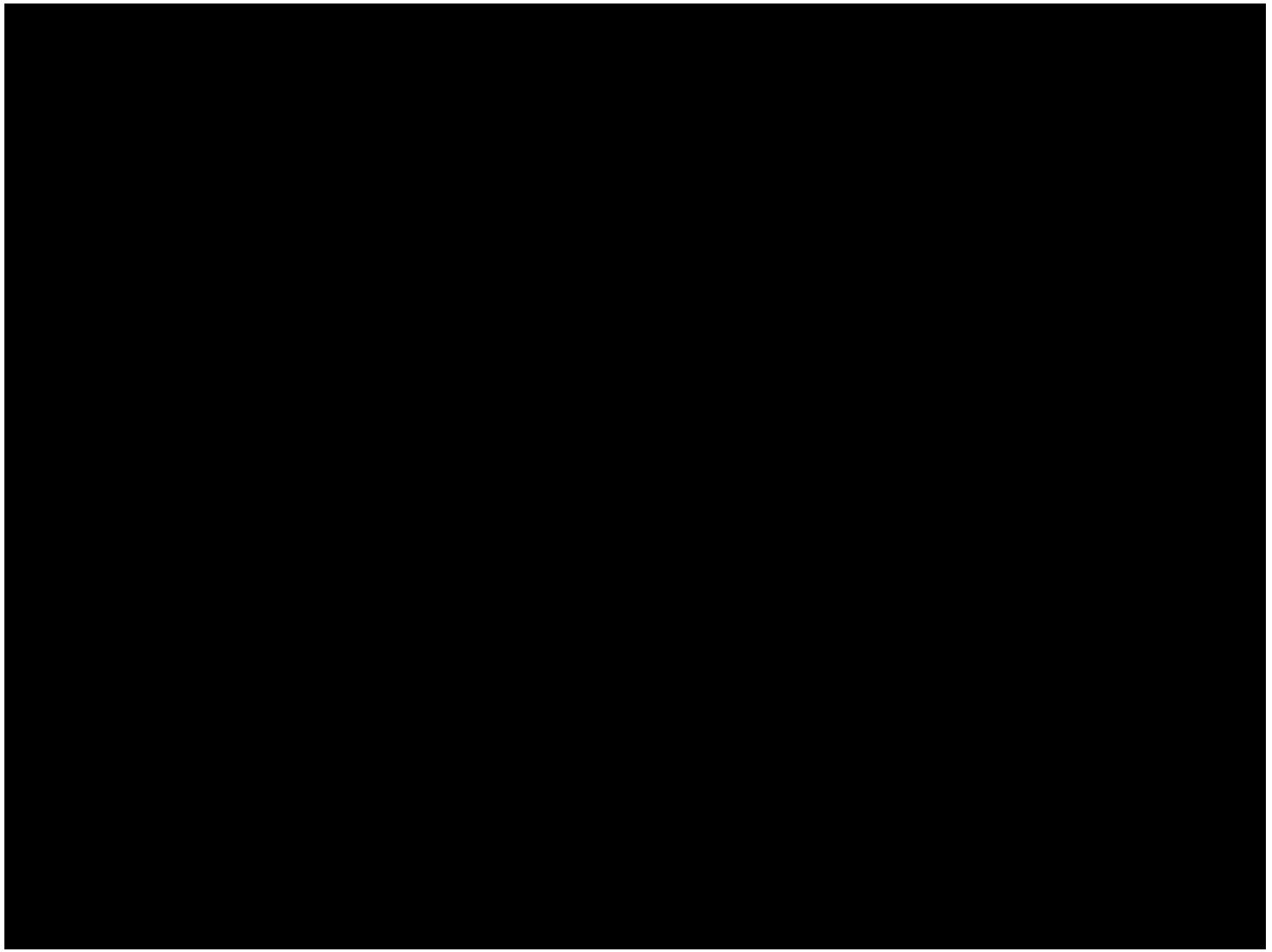


Entertainment



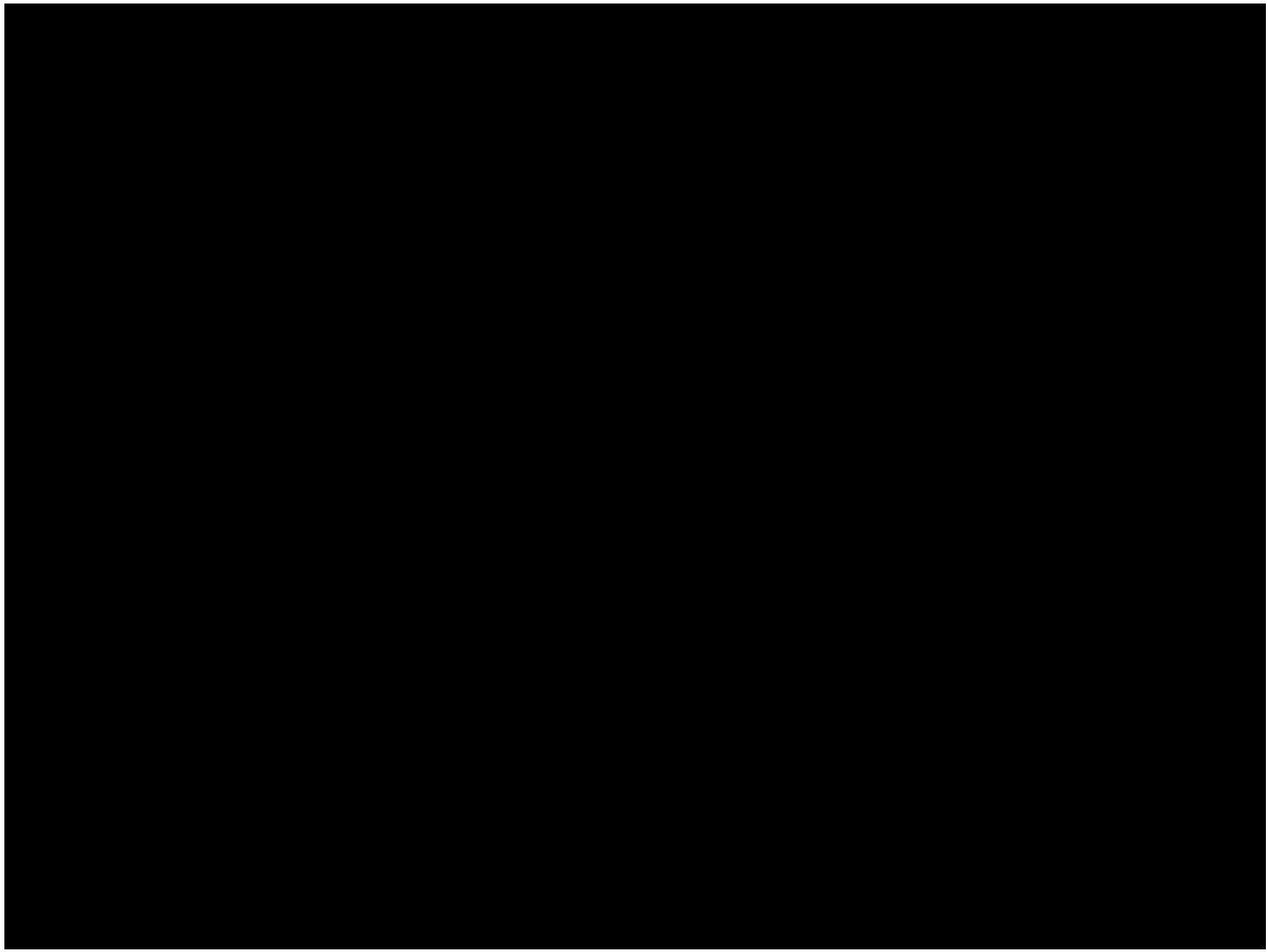
Information Visualization

Applications



http://il.youtube.com/watch?v=GAZwBM1kUqQ&feature=related

Applications

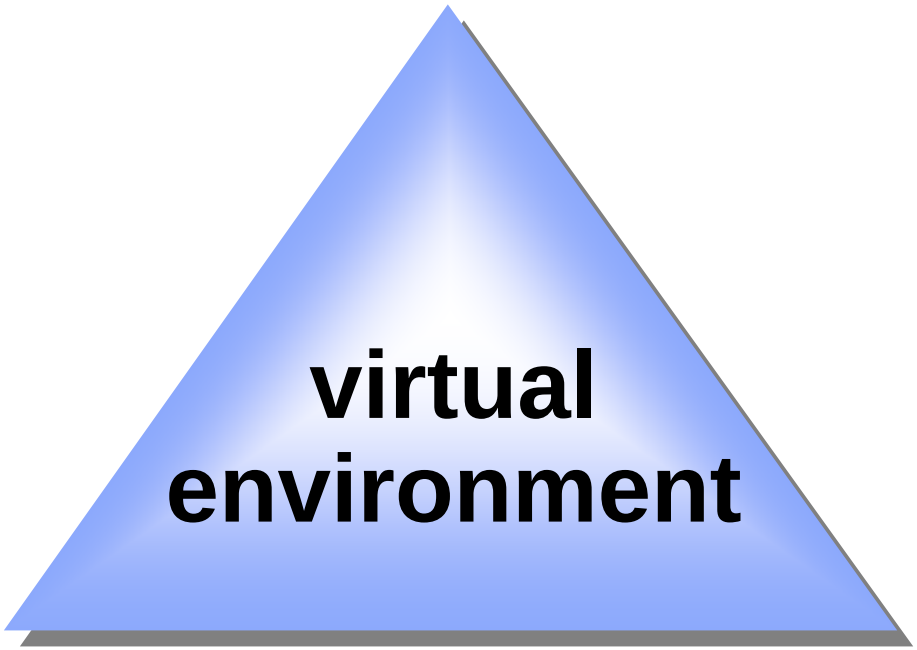


http://il.youtube.com/watch?v=5XRuTmRstIg&feature=channel

What is Virtual Reality (VR) ?

Immersion

I3



Intuition:

- **3-D & multimodal**
  - **visual**
  - **acoustic**
  - **haptic/tactile**

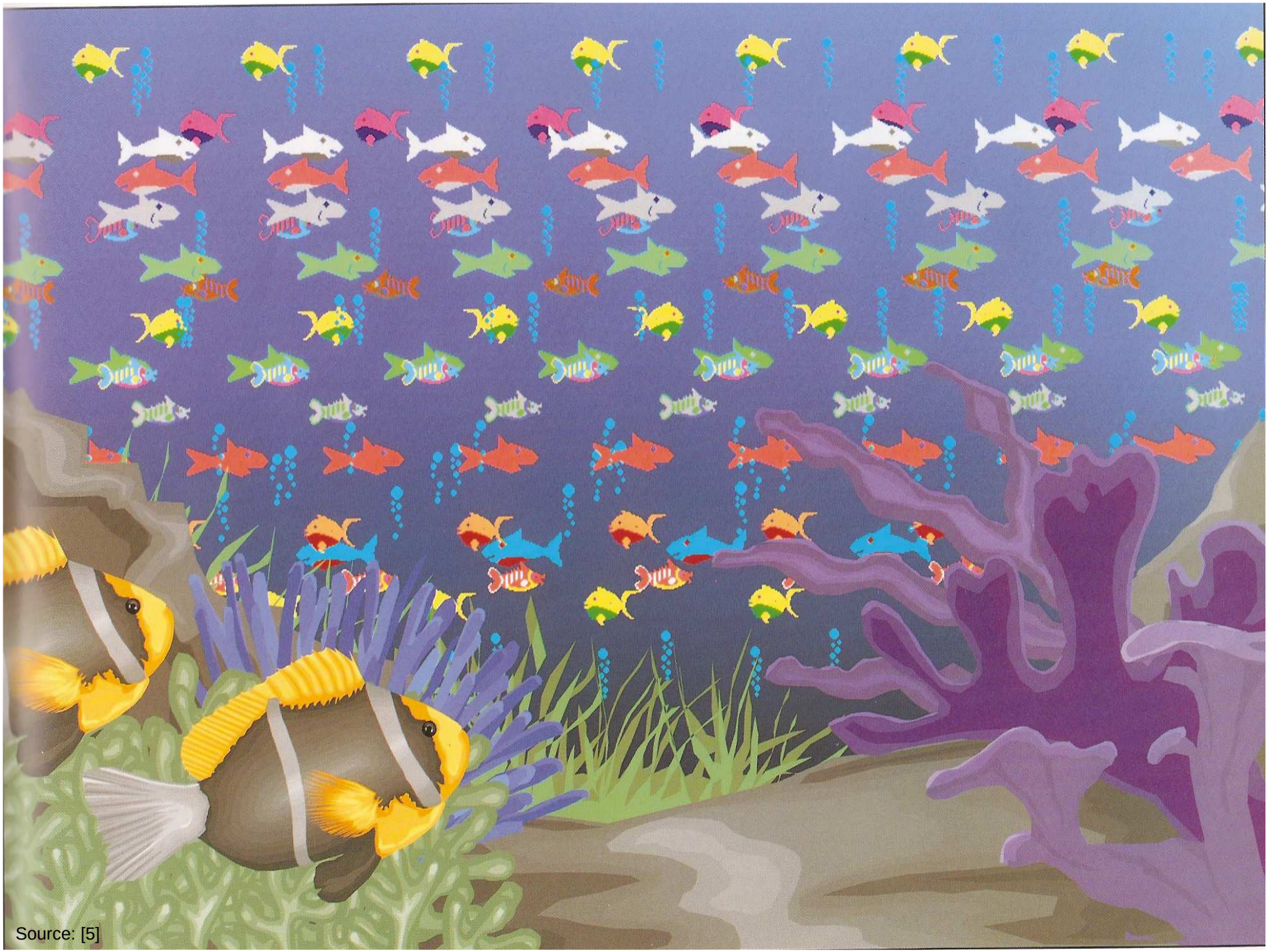
Interaction in Real Time:

- **Navigation**
- **Manipulation**

Source: [10]

3D Viewing

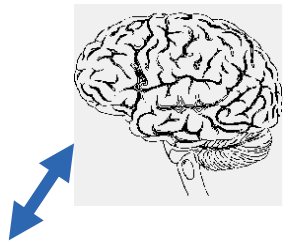
- Physiological Basics
- Concepts of Stereovision
  - Human Depth Perception and Stereoscopy
    - Monoscopic depth cues
    - Motion-based depth cues
    - Stereoscopic depth cues
    - Proprioception and depth perception
    - Range limits of stereoscopic depth perception
  - Problems in Stereoscopic Vision
- Technical Systems
  - Autostereoscopy
  - Nonautostereoscopic Displays



Source: [5]

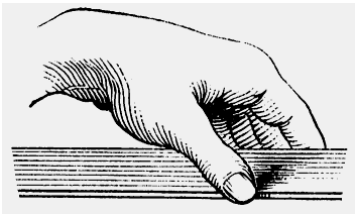
Haptics

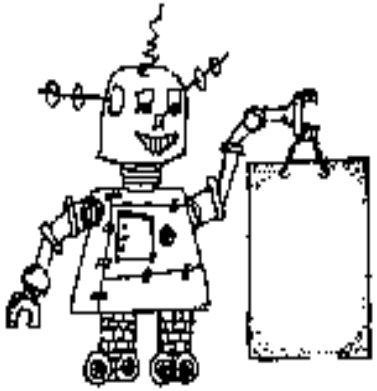
haptesthai (greek) = « to touch »



Overview:

- Physiological Basics (« Human Haptics »)
- Haptic Displays (« Machine Haptics »)
  - Haptic Displays Characteristics
    - Haptic Presentation Capability
    - Resolution
    - Ergonomics
  - Haptic Display Types
    - Ground-Referenced Haptic Devices
    - Body-Referenced Haptic Devices
    - Tactile Devices
    - Combination Devices
- Haptic Rendering (« Computer Haptics »)
- Applications and Advantages of Haptic Interfaces





What is AR ?

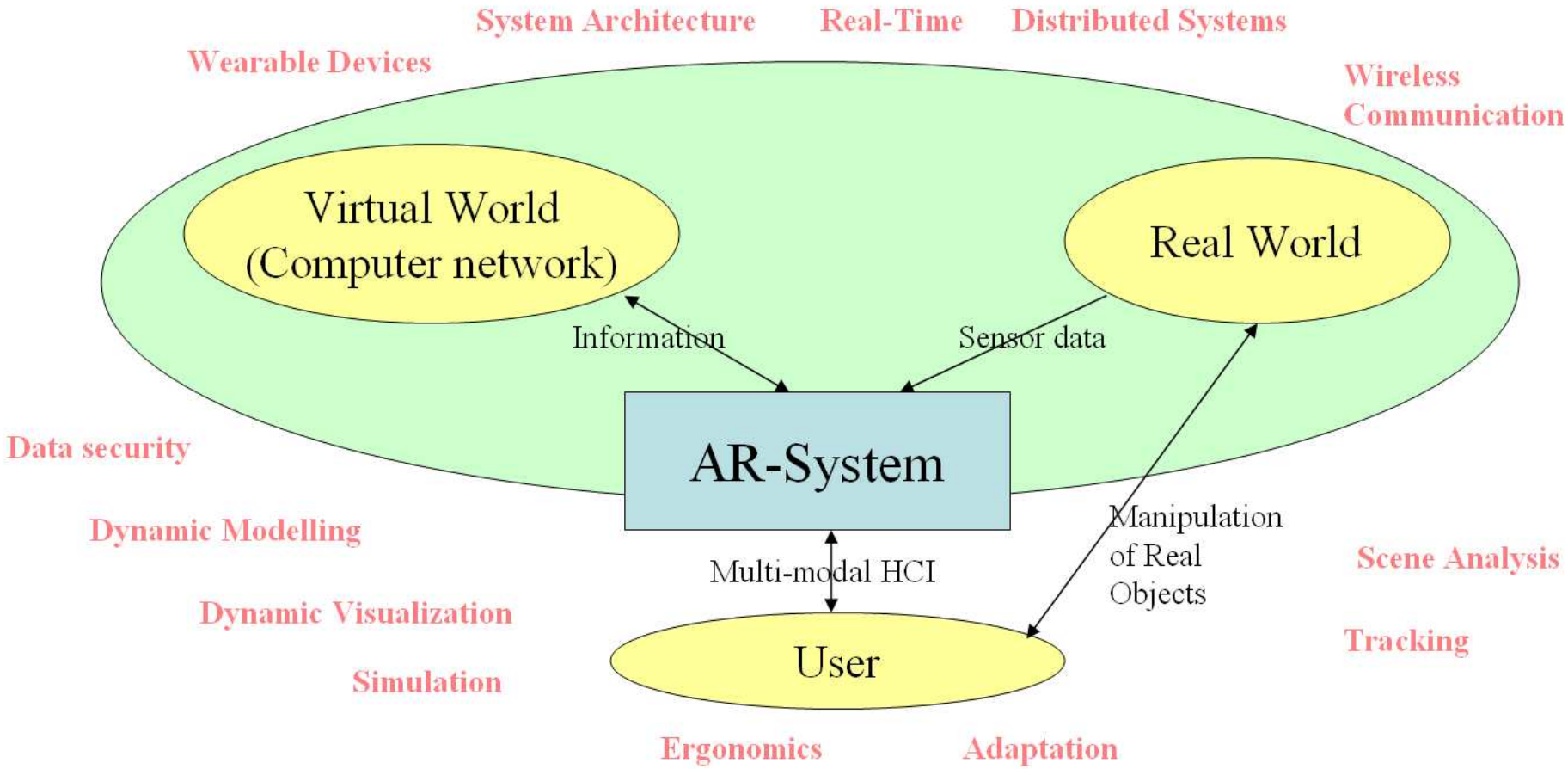
- Real + virtual
- Interactive in real-time
- Registered in 3 Dimensions

Source: [2]

Reality-virtuality continuum [9]

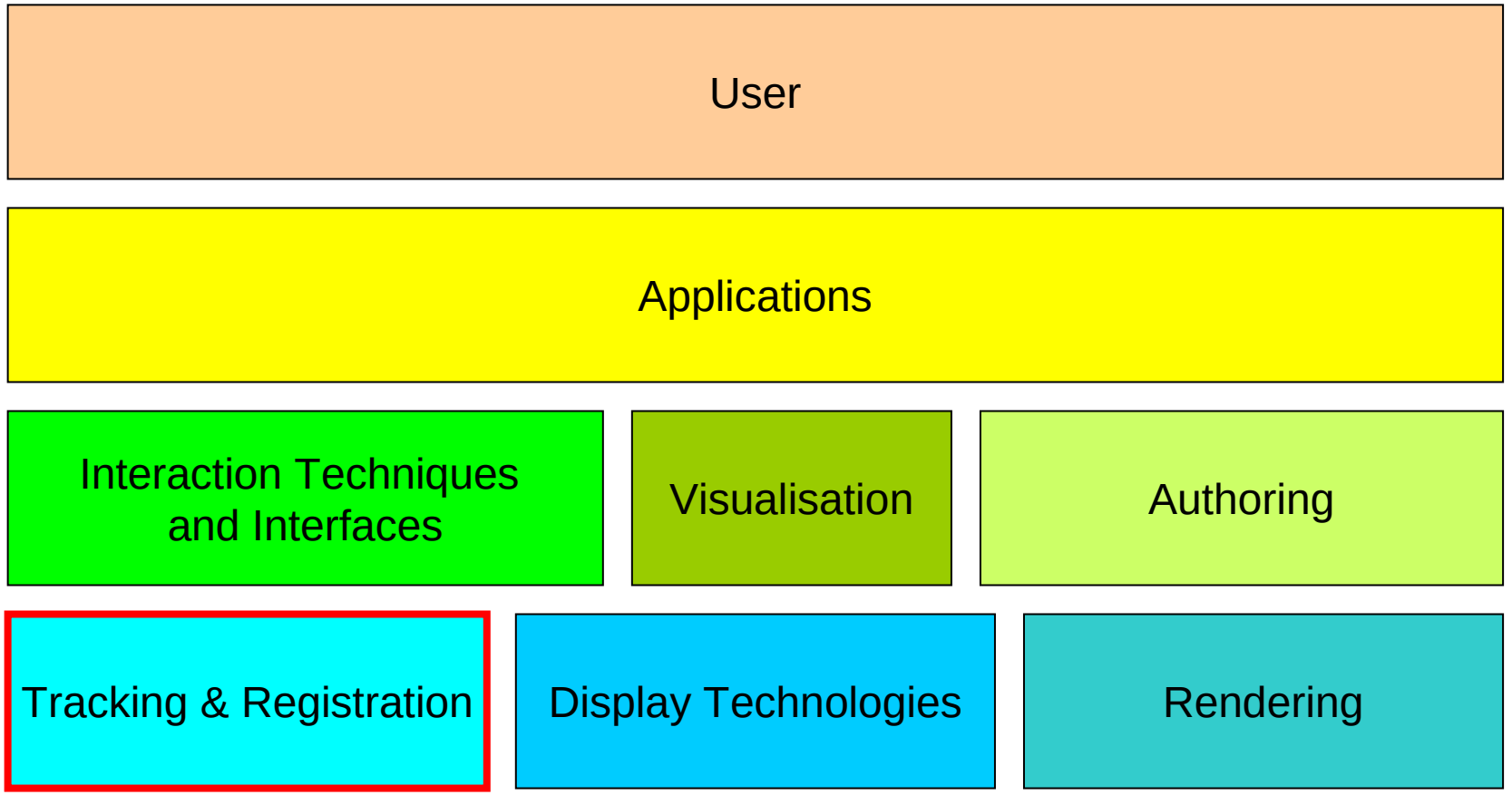
Source: [8]

Multimedia Combination of Reality and „Virtuality“



Source: [8]

Components of an AR system

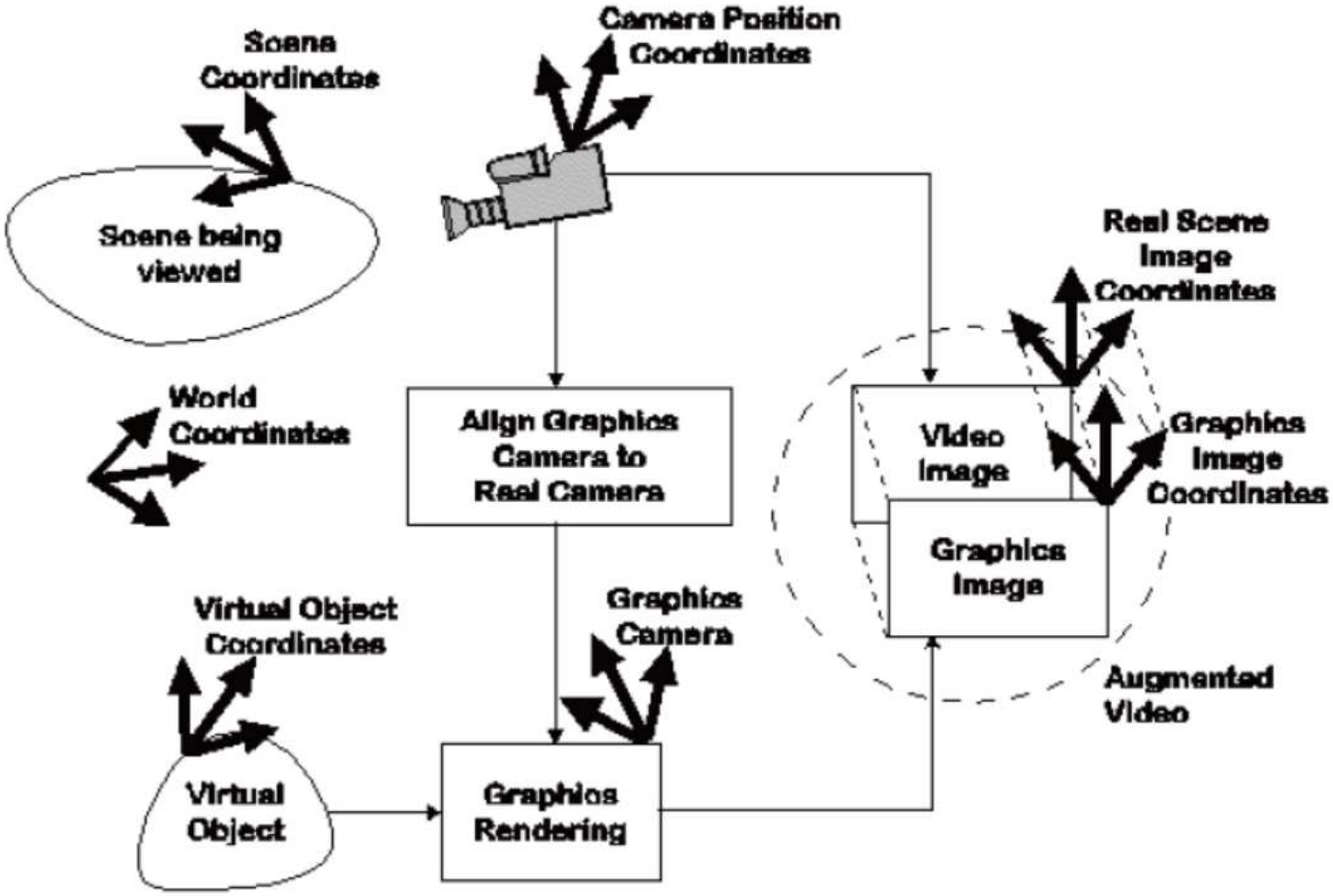


Performance of an AR system

Criteria:

- Update rate for generating the augmented image → at least 10 fps
- Accuracy of the registration of the real and virtual image

Tracking & Registration



Source: [1]

Tracking & Registration

Goal of AR system: continuously match virtual objects and real world in real time

→ registration

Requires:

- accurate knowledge of the relative positions of camera and scene
- continuous and precise computation of objects' positions with respect to camera
- correspondance of visual primitives from one image to the next

→ Tracking