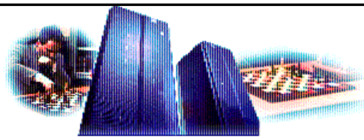
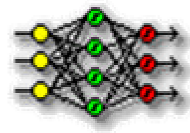

L'intelligenza robotica
Introduzione alla Realtà Virtuale

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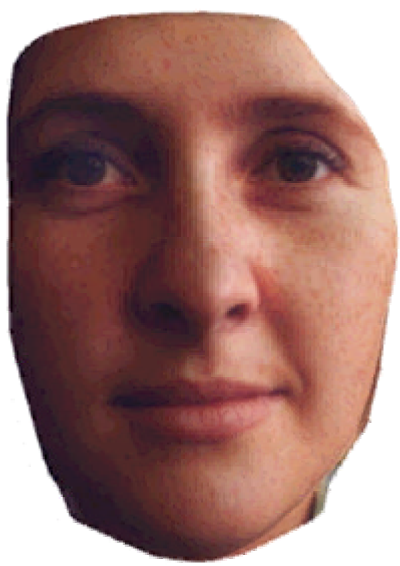
Which is real, which is virtual?

Historical Perspective

- *Virtual Worlds or Synthetic Environments*
- *Philosophical* and *Technologial* origin.

Philosophical background

Ontology and *Gnoseology*.

- Plato (world of the ideas) 428-348 a.C.
- Berkeley (sensorial experience is too limited) 1685-1753.
- Hegel ("what is rational is real..") 1770-1831.
- New age.

Historical Perspective (II)

Technological background

- *Philco HMD, 1961.*
- *"Ultimate display", Sutherland, 1970.*
- *Data Glove, VPL Research, 1988.*

Virtual Reality Systems

Key characteristics are:

Immersivity.

Interactivity.

VR should be able to stimulate the human sensorial systems
In a coordinated way.

A typical VR system

VR systems are constituted of:

• *Input systems* (measure the position *in* the environment and force *over* the environment.

• *World generators* (provides a realistic virtual world in which to act.

• *Graphical engine* (computes the output, given the input and the virtual world).

• *Output systems* (outputs sensorial stimuli *on* the subject. Vision, sound, force … are generated as if they were provided *by* the virtual environment.

Components of a VR system

- ***Input systems.***
- *World generators.*
- *Graphical engine.*
- *Output systems.*

Input systems

Measure human actions on the virtual environment.

- Position. Measure the position of the body segments inside the virtual environment.
- Force. Measure the force exerted by the body segments when in contact with a virtual object.

- Estimate the motor output of the human muscle-skeleton system.

Position systems

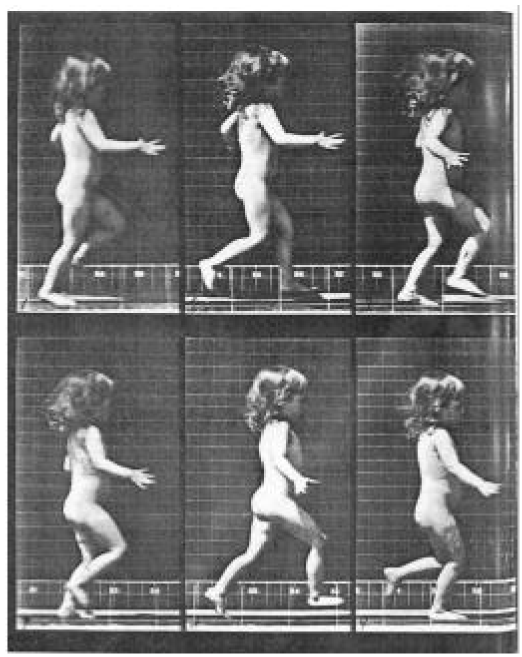
•Measure the position of the body segments inside the virtual environment.

- Motion capture (batch, complete information on the movement).
- Real-time trackers (real-time position).
- Gloves (specialized for hands).
- Gaze trackers.

Adopted technology

- Opteolectronics
  - •Marker based
  - •Computer vision.
- Magnetical
- Acoustical
- Mechanical

Edgar Muybridge (1896)



Optical systems (computer vision)

•**Advantage:** complete freedom of motion to the subjects. The scene is surveyed by standard videocameras.

•**Disadvantage:** ill-posed problems (high sensitivity to limited resolution, noise and lighting conditions).

• **Solution**: hierarchical multi-stage processing.

Pipe-line of processing in CV systems

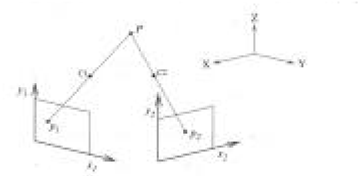
Reference: Cipolla and Pentland eds., Computer Vision for Human-Machine Interaction, Cambridge University Press, 1998.

•**First level:** Features detection.
• Background subtraction (Sturman and Zelter, 1994; Di Bernardo et al., 1995);
• Optical flow (Barron et al., 1995);
• Template matching (Borghese et al., 1990; Tomasi and Kanade, 1991);

Second level: Features matching.
(Xu and Ahuja, 1994; Shashua, 1999, Weng, 2000, Gruen, 1985);

Pipe-line of processing in CV systems (II)

•**<u>Third level:</u>** 3D Reconstruction.

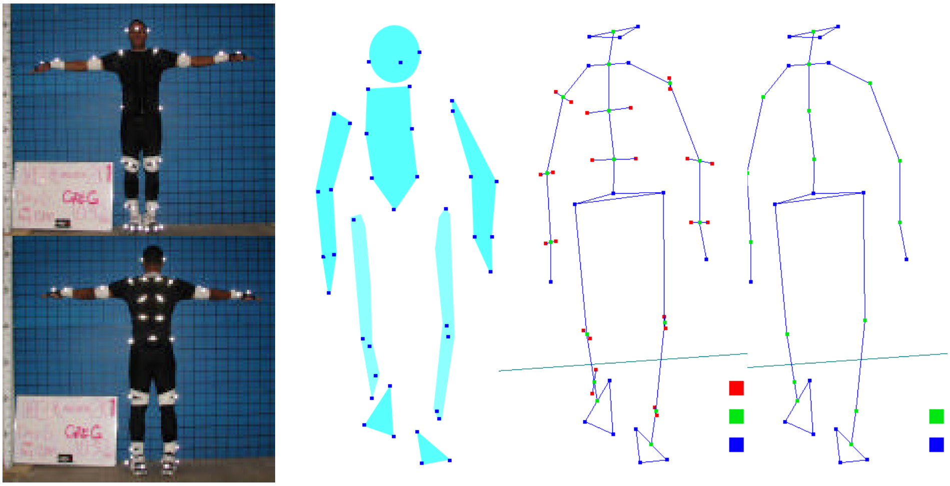


<u>Fourth level:</u> Model matching.
- Silhouette matching (Moezzi et al., 1996);
- 3D polygonal structures
  - Marching cube (Lorensen and Cline, 1987);
  - Snakes (Kass et al., 1988);
- Matching 3D structures
  - Facial models (Parke, 1996);
  - Superquadrics (Metaxis and Terzopoulos, 1991);

Motion Capture live (Jain et al.)

Optical systems – marker based

They are based on modeling human body as a skeleton (Pedotti, 1977).



Markered subject 3D model Stick diagram Hidden model

Passive optical markers - processing

First step. Detection of the 2D position of the markers.

Thresholding (Vicon, Motion Analysis, MacReflex)

Correlation (Elite)

Second step. Matching the same marker on the different cameras.

Third step. Reconstruction of the 3D position of the marker.

Fourth step. Classification of the markers according to the model of the subject.

Motion capture based on markers

Optical systems – marker based (II)

Advantage: High reliability in the identification of the markers (joints).
Disadvantages: Markers have to be attached to the subject before the motion. Wires carried by the subject in case of active markers.

Active vs. Passive markers technology

•Active markers – LED, or magnets, with wires, time multiplexing, high sampling frequency, with few markers, minimal processing.
•Passive markers – Small pieces of retro-reflective paper, Videocameras (video rates), complex data processing from image processing to 3D reconstruction.

Active markers

Magnetic trackers

• Electromagnetic induction. Magnetic material which is moved inside an electric field, with variable frequency. Isotrack, FastTrack and Flock of birds.
• A DSP is incorporated for time filtering.
• Maximum range: 1m.

Problems

• Distortions and linearity.
• Interference of metallic materials.

Optoelectronics active markers

• LED – Selspot, Watsmart, Optotrack.

Motion capture for animation

•Motion capture
•Definition of a 3D model.
•Mapping of the motion onto the 3D model.
•Animation.

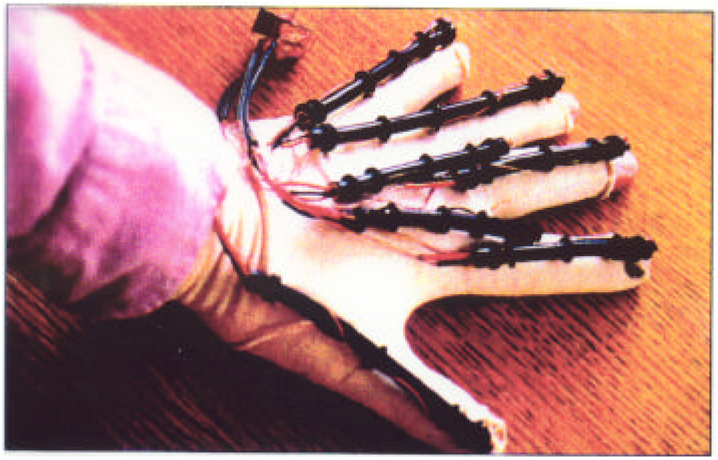
Video by Superfluo

Gloves

Monitor fingers position and force.

Problems with the motion of the fingers:
- overlap.
- fine movements.
- fast movements.
- rich repertoire.

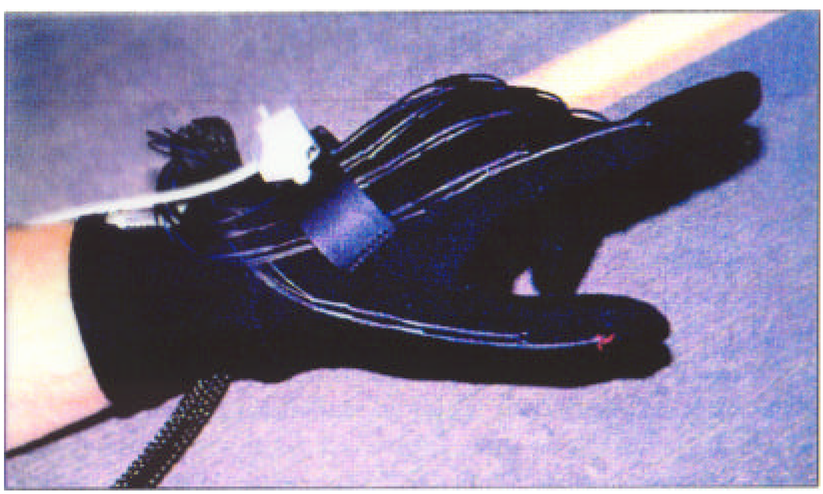
Sayre glove (1976)



MIT glove (1977)

Digital Data Entry Glove (1983)

Data Glove (1987)



Power Glove (1990)

Cyber Glove (1995)

Calibration

Estimate of the geometrical parameters in the transformation operated by the sensors (e.g. the perspective transformation operated by a video-camera).

Estimate of the parameters, which describe distortions introduced by the measurement system.

Measurement of a known pattern. From its distortion, the parameters can be computed.

Algorithms adopted: polynomial, local correction (neural networks, fuzzy).

Haptic displays

Convey to the subject the sensorial information generated in the interaction with the virtual objects: force, material texture…

Measure the force exerted by the subject on the virtual environment.

Aptic displays provide a mechanical interface for Virtual Reality applications.

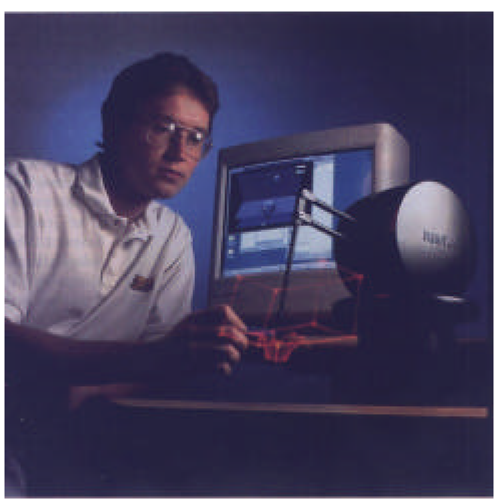
Most important developments have been made in the robotics field.

Requirements of Haptic displays

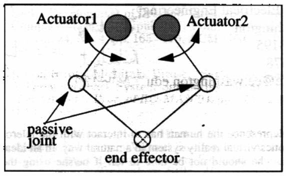
• Large bandwidth.
• Low intertial and viscosity.

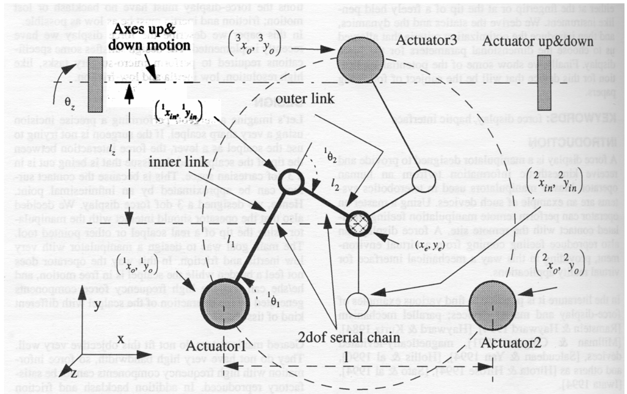
Technological solutions (oggetto intermediario):
• Direct drive manipulandum (Yoshikawa, 1990), Phantom (2000).
• Parallel manipulandum (Millman and Colgate, 1991; Buttolo and Hannaford, 1995).
• Magnetic levitation devices (Salcudean and Yan, 1994; Gomi and Kawato, 1996).
• Gloves (Bergamasco, 1993).

Direct drive manipulandum (phantom)

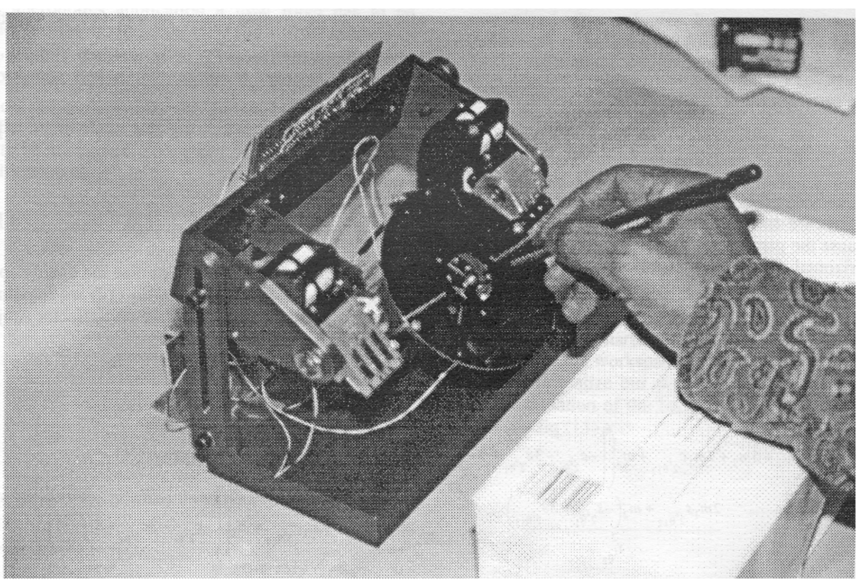


Parallel manipulandum (schema)

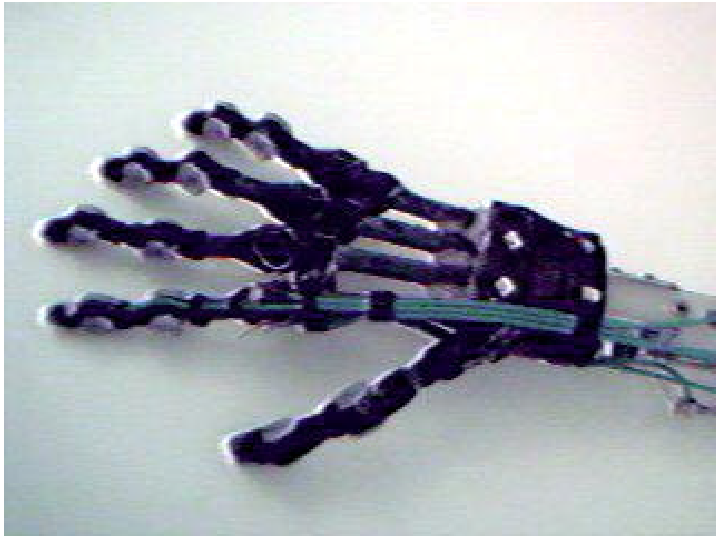




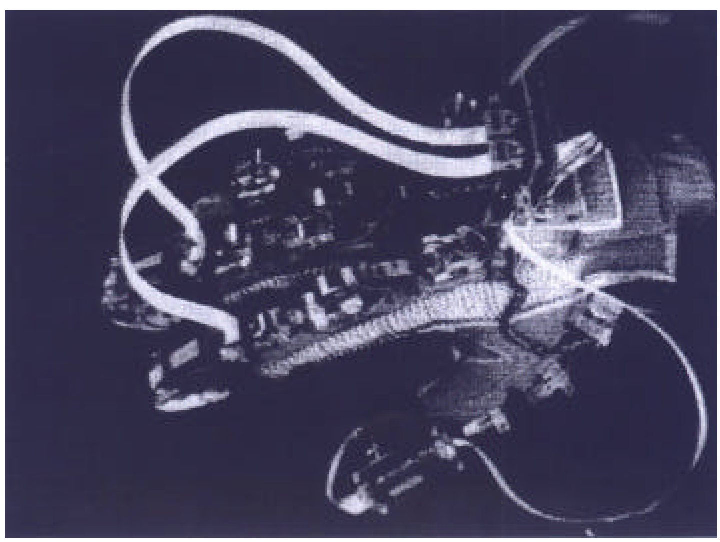
Pen Haptic display



Gloves (Blackfinger, 2000)

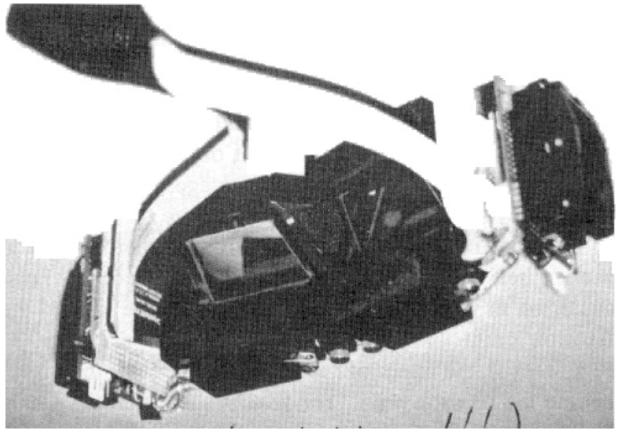


Percro gloves (Begamasco, 1993)



Gaze input

- Contact lenses carrying magnetic coils.
- Tvcameras aligned with an IR LED source.
- Stereoscopic eye-wear.
  - The direction of gaze is decided by measuring the shape of the spot reflected by the frontal portion of the cornea (Ohshima et al., 1996).



Components of a VR system

- *Input systems.*
- ***World generators*.**
- *Graphical engine.*
- *Output systems.*

World generators

Integrated systems for 3D CAD and Animation:
•Maya (ex-Alias/Wavefront)
•XSI (ex-Softimage)
•3D Studio Max.

• 3D Structure.
• Colour and Texture
• Motion (animation)
• Rendering (lights, shadows)

3D structure

Solid modeling

•3D geometric solids: cubes, cylinders, cones…
• Superquadrics (Terzopoulos and Metaxas, 1991): global parameters + local parameters.
• Revolution surfaces.
• NURBS (Piegle, 1993). CAD, high interactivity.
•Subdivision surfaces (Schroeder, 1999).

Surface fitting to range data

• Snakes (Kass et al., 1988). Energy based approach. Best curves.
• Kohonen maps (1990).
• Radial Basis Functions Networks (Poggio and Girosi, 1995; Borghese and Ferrari, 1998).

3D structure (II)

<u>Linear approximation (mesh):</u>

•Delauney triangulation (Watson, 1981; Fang and Piegl, 1992). Direct tessellation.

• Alpha shapes, ball pivoting (Bernardini et al., 2000). Post processing to regularize a Delauney tessellation.

• Polymesh models (Singh et al., 1995).

<u>Finite element models</u>

• It is a class per sé. Local modeling. Mechnical modeling.

• Largely used for animation in medicine (facial animation, deformation of tissue during surgery). Multi-layer modeling.

<u>LOD</u>

Modelli a dettaglio e risoluzione diversi.

Models from range data

Cyberware whole body scanner, WB4

Models from range data (II)

Cyberware smaller model
3030

3D structure from range data (III)

Polhemus hand held laser scanner

Models from range data (IV)

Digibot II.
•Platform rotates
•Scanner line translates.

Components of a VR system

- *Input systems.*
- *World generators.*
- ***Graphical engine.***
- *Output systems.*

Graphical representation

Graphical engines represent triangles => Every shape is transformed into triangles.

•The models created by the scanners are ensembles of triangles (milions of).
•Much more than required by applications.

⇓

Mesh compression. Representation of the same geometry/pictorial attributes, with a reduced set of triangles.

Gaze directed rendering

The graphical engine (visual computing)

Parallelization (graphical boards, SIMD architectures on Pentium IV).

Multiple cache levels.

Pipelining (graphical and computational).

Look-ahead code optimization (compiler optimization).

Hardware acceleration of graphical operations (OpenGL, texture mapping…).

Double buffering (for real-time visualization of 3D models).

Collision detection

Computational demanding (On^2EF).
Use of multiresolution models.
Hierarchical detection.
- Geometry semplification (axes aligned faces).
- Check for common volumes.
- Extraction of the faces belonging to these volumes.
- Octree of the pairs of candidate faces.
- Check for intersection.

Animation

- Key-frame animation.
- Motion capture.
- Dynamic animation.

Components of a VR system

- *Input systems.*
- *World generators.*
- *Graphical engine.*
- ***Output systems.***

Output systems

Requirements for the monitor:

• Large field of view (180º x 150º).

•High spatial resolution (35 pixels/degree, equivalent to 12,000x12,000 pixels for a 19" display positioned at 70cm from the viewer).

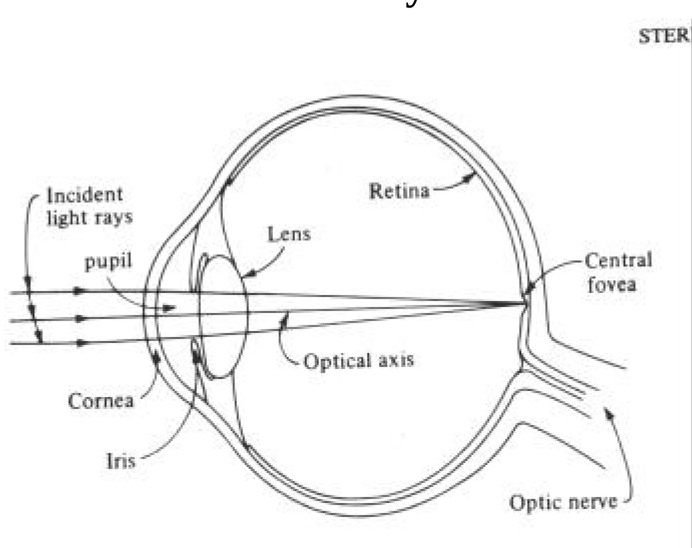
Requirements for the world generator:

•Stereoscopic vision for objects with D < 10m.

•Monocular cues for objects with D > 10m.

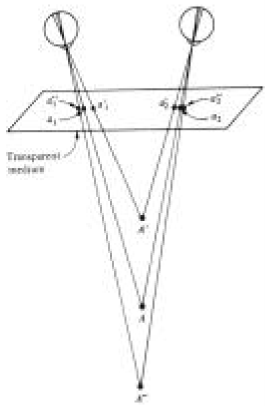
- - Occlusions.
- - Geometrical perspective and a-priori model knowledge.
- - Shading.
- - Motion.

The human eye



Its behavior is very similar to that of a photocamera

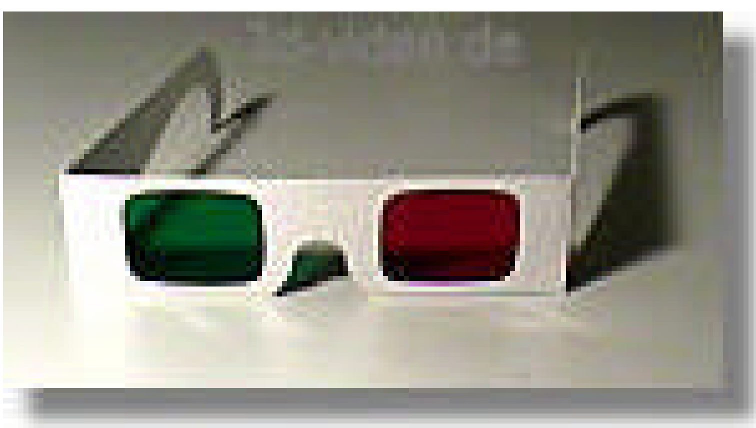
Stereo-disparity



Points further away are projected on points closer to the image center.

Vergence and focusing are strictly connected.

Passive stereo



Stereo image for passive stereo

Output devices (eye-glasses)

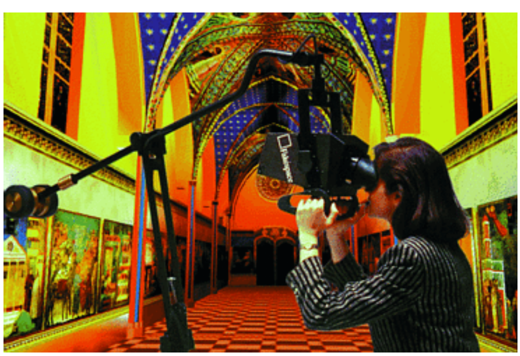
Semi-immersive: Eye-glasses (video accuracy, but user is not allowed to move, lateral vision is permitted, which limits virtual realism).

HMD (n-vision)

Up to 1280 x 1024, 180Hz.
Time multiplexing.

Output devices (BOOM HMD)

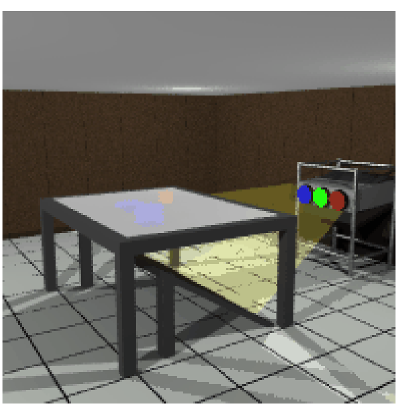
Up to 1280 x 1024 pixels / eye
CRT Technology
Head tracking is integrated.



I-glasses (games)

Responsive work-bench (Strauss et al., 1995)

Virtual 3D objects are positioned on a working table. They are created projecting the stereo images over the table surface.



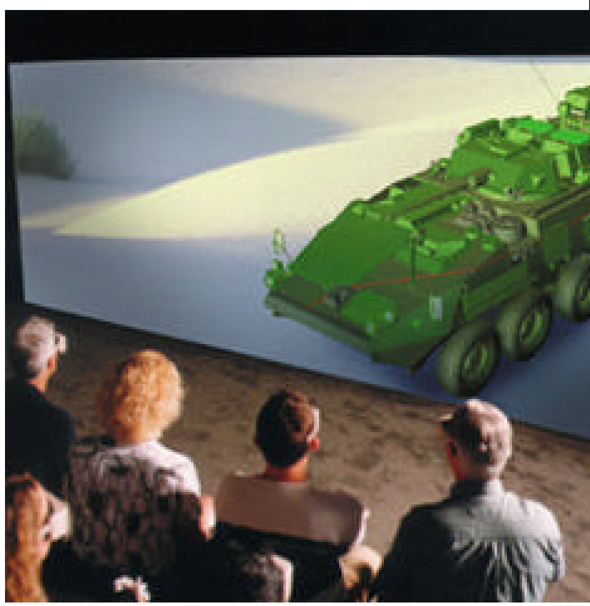
CAVE

Room 2.5m x 2.5m with Virtual images (steoscopic) projected onto its walls.

More people and Complete immersivity.

Large screen displays

Workwall



Wearable devices

(a) HMD – 320x240 VGA (b) Keyboard on cloth

Characteristics: mobile, context sensitive, augmented reality.

Physiological problems

- SIMM and VR sickness limit the exposure time.
- Size and distances misperception.
- Limited range in extrapersonal space.

Other output devices

Audio – Stereo, sound spatialization.

Force – Same devices which measure the force exerted by the subject.

Applications

- Army
- Medicine
- Industry (inspection, virtual prototyping)
- Chemistry and Physics
- Virtual theaters and theme parks
- Enterteinment
- Comunication
- Engineering, Ergonomics and Architecture.
- History.

La città di Giotto

La tomba di Nefertari