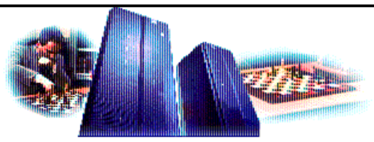
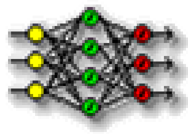




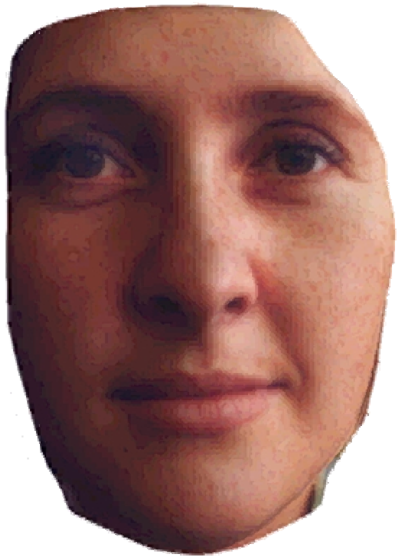
Introduzione alla Realtà Virtuale

Alberto Borghese

Sommario

- Introduzione
- Sistemi di Input
- Generatori di mondi
- Motore di calcolo
- Sistemi di Output
- Conclusioni

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.

• *Computational 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.

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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

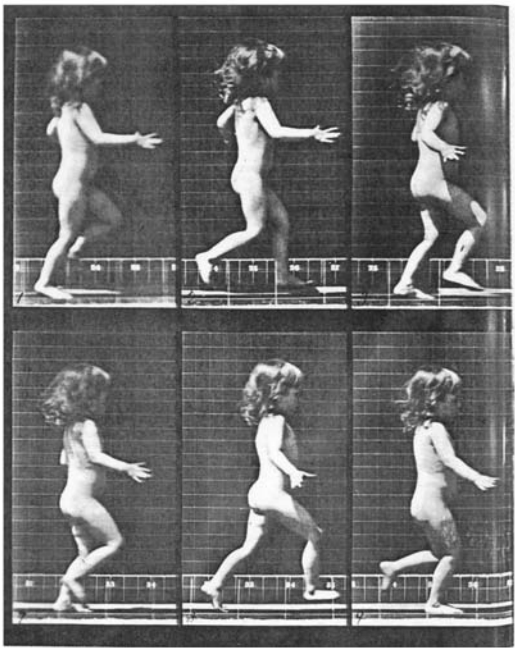
•Measure the position of the body segments inside the virtual environment.

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

<u>Adopted technology</u>

• Optoelectronics
    •Marker based
    •Computer vision.
• Magnetical
• Acoustical
• Mechanical

Edgar Muybridge (1896)



Optical systems (computer vision)

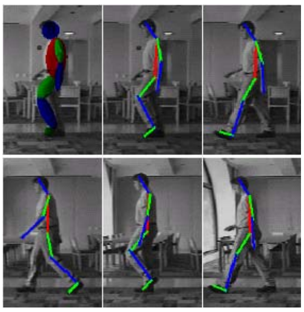
•**Advantage:** complete freedom of motion to the subjects. The scene is surveyed by standard videocameras.

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

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

Computer vision techniques

Silhouette (-> Skeleton)



Set of difficult problems:

2D Image processing (silhouette identification, optical flow detectors…)

Multi-view invariants.

Smooth motion -> temporal filtering.

Skeleton fitting (different rigid motion for different segments).

Pre-prototype research.

http://movement.stanford.edu/

The volumetric approach: a possible solution

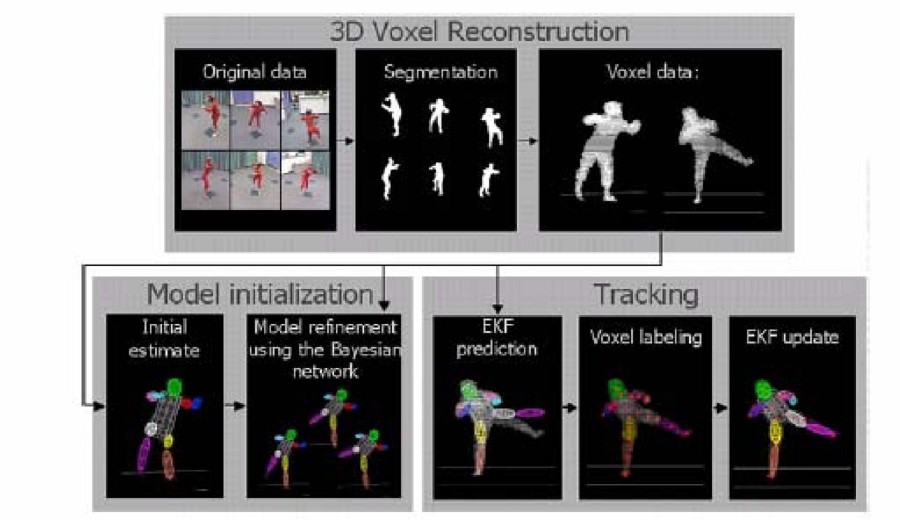
Mikic et al., Human Body Model Acquisition and Tracking Using Voxel Data, Int. J. Computer Vision, 53(3), 2003.

Cheung et al., A real time system for robust 3D voxel reconstruction of human motions. Proc. Ieee Conf. CVPR, 2000.

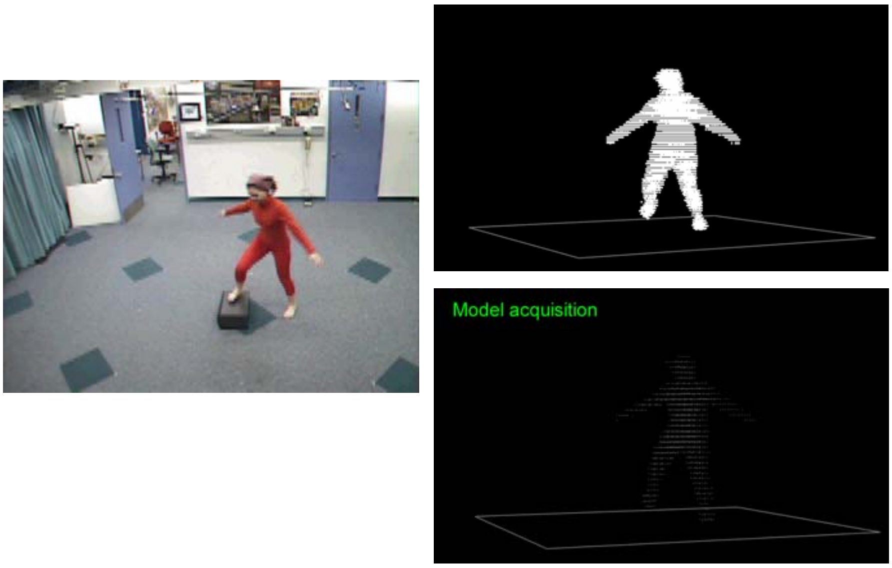
Jain et al., 3D video, Proc. VRAIS, 1994.

Il motion capture verrà trattato in forma più dettagliata all'interno del corso di Animazione Digitale.

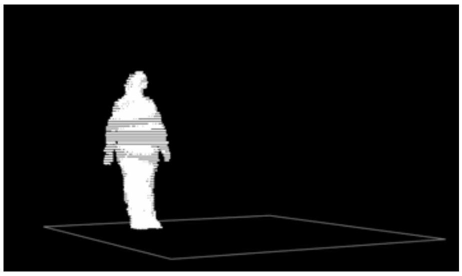
I passi di elaborazione (Mikic et al.)

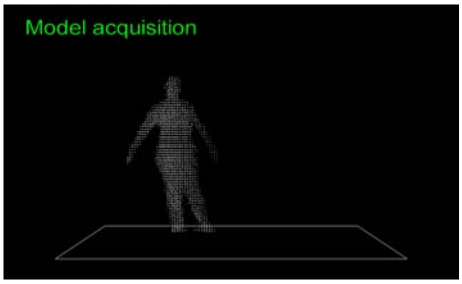


Results: stepping (640 x 480, 10Hz)

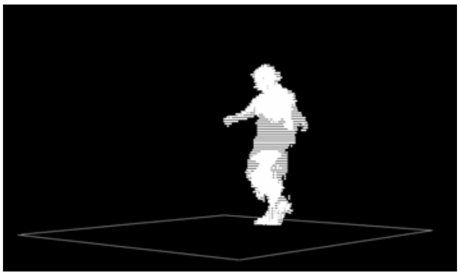


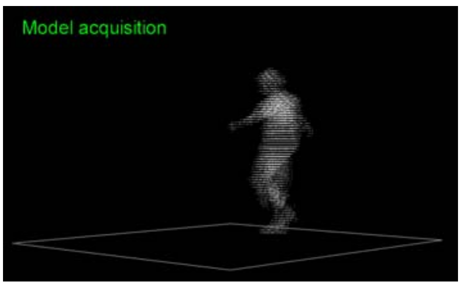
Results: dancing



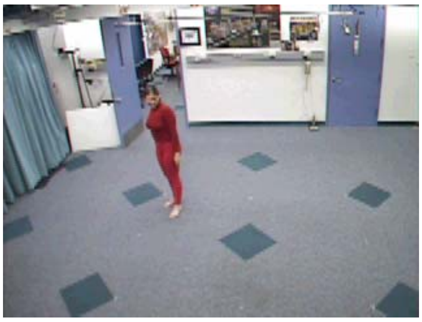


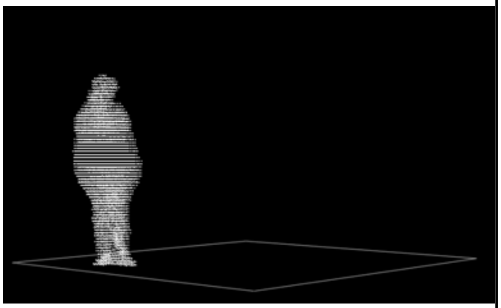
Results: jumping

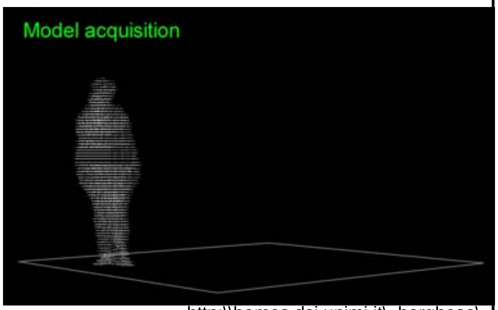




Results: cartwheel

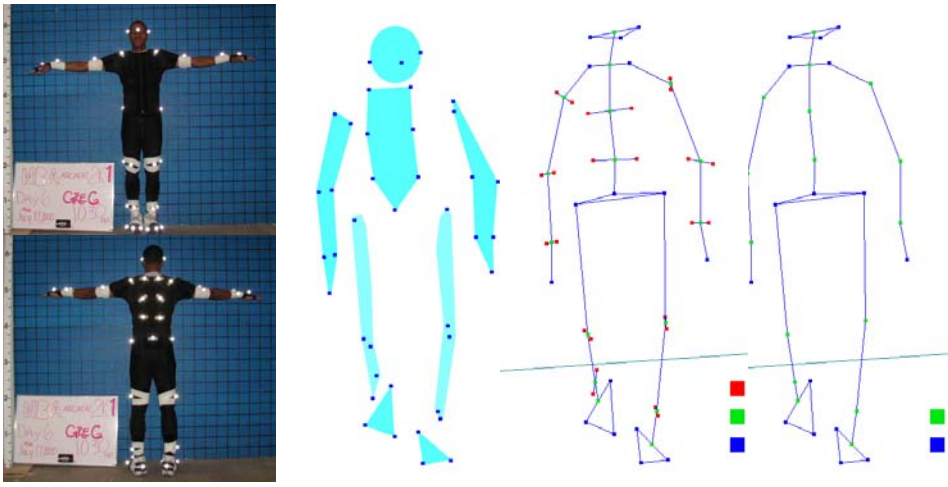






Optical systems – marker based

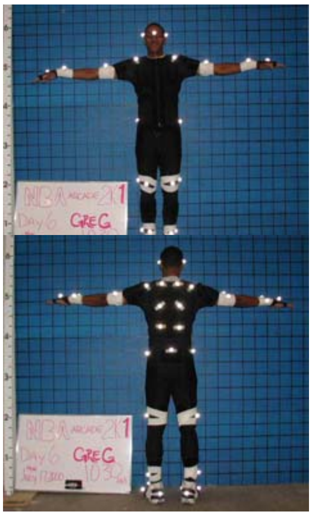
They are based on modeling human body as a skeleton (Pedotti, 1977).

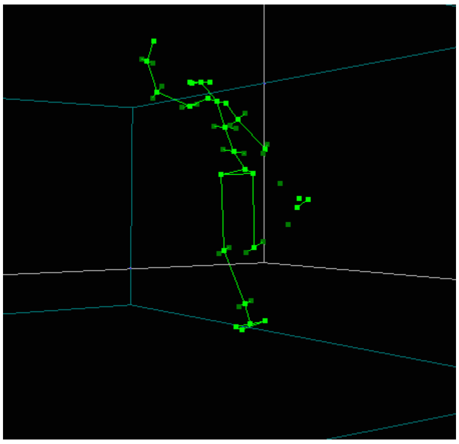


Markered subject 3D model Stick diagram Hidden model

Motion Capture with passive markers

Goal: reconstruction of the 3D motion of a set of markers





How passive markers work?

Passive markers are constituted of a small plastic support covered with retro-reflecting material (3M^{TM}). It marks a certain repere point.

Video-cameras are equipped with a co-axial flash.

Markers appear much brighter than the background making their detection, on the video images, easier.

Passive optical markers - processing

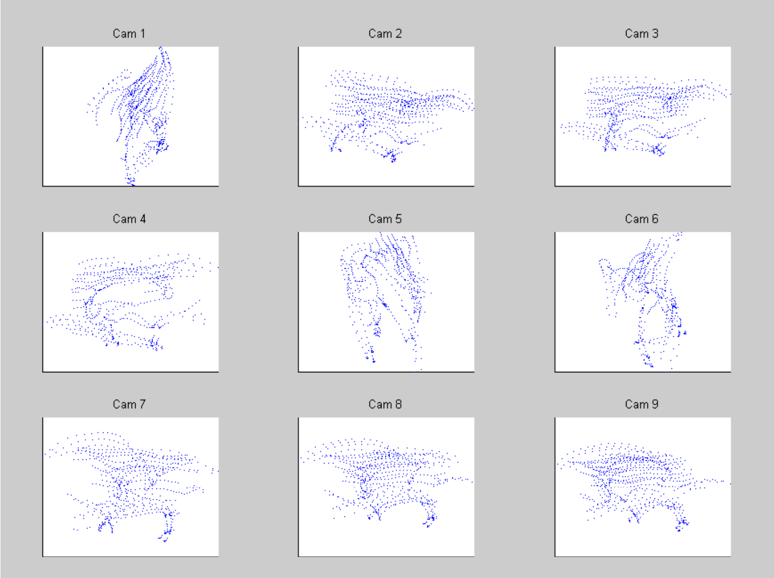
First step. Detection of the 2D position of the markers.
Thresholding (Vicon, Motion Analysis, MacReflex)
Correlation (Elite)

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

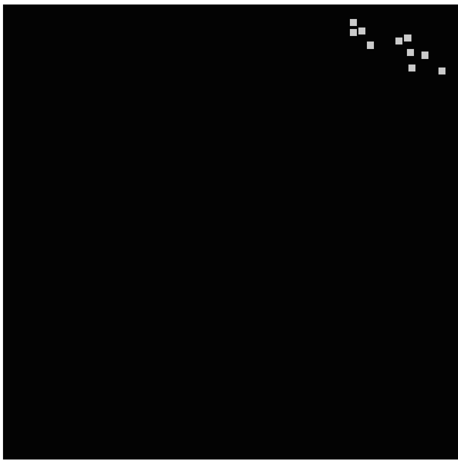
Third step. Reconstruction of the 3D position of the marker.

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

2D tracking



Tracking difficulties



It is a complex problem because:

• Dense set of markers. These may come very close one to the other in certain instants.

• Motion can be easily complex, as it involves rotation and twists of the different body parts (thing at a gymnastic movement).

•Multi-camera information and temporal information is required to achieve a robust tracking.

3D strings

3D strings already contain motion 3D information

The difficulties in data processing

1. Twists and rotations make the movement of the human body fully three-dimensional.
2. Each body part continuously moves in and out occlusion from the view of the cameras, such that each of them can see only a chunk of the whole trajectory.
3. Some body parts can be hidden to the view by other parts. Whenever it happens, the system should be able to correctly recognize the hidden markers as soon as they reappear without any intervention by the operator.
4. Chunks from the different cameras have to be correctly matched and integrated to obtain a complete motion description.
5. Each trajectory has to be associated with the corresponding body marker (labeling).
6. Reflexes, which do appear in natural environment and are erroneously detected as markers, have to be automatically identified and discarded.

A motion capture system

Motion capture for animation

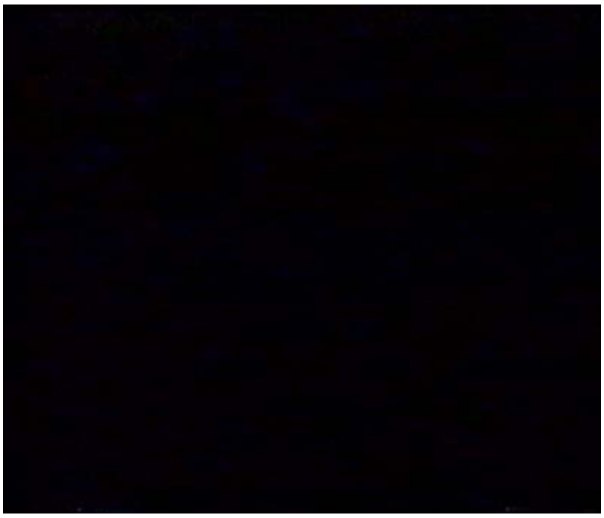
•Motion capture

•Definition of a 3D model.

•Mapping of the motion onto the 3D model.

•Animation.

Video by Superfluo

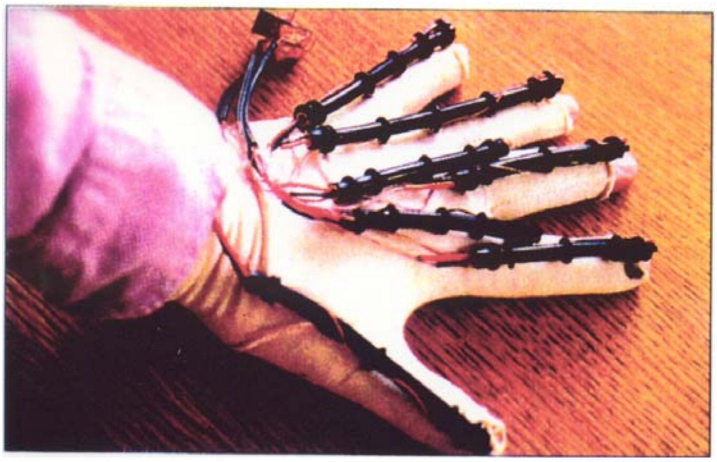


Gloves

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)

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Digital Data Entry Glove (1983)

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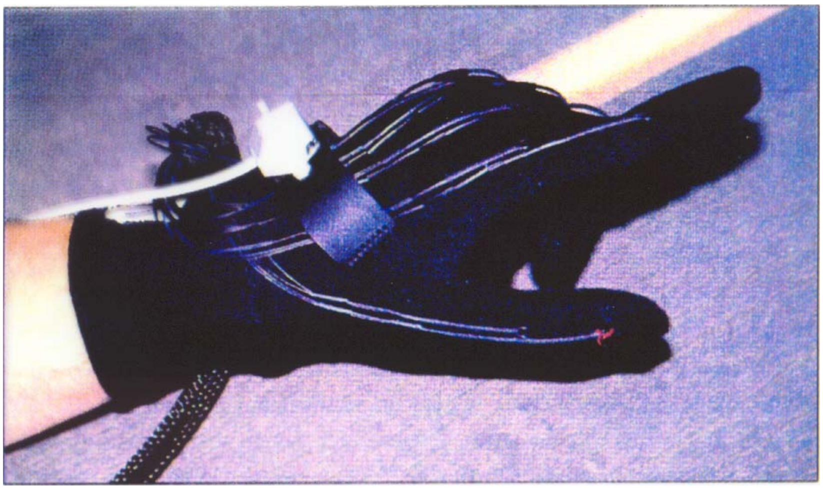
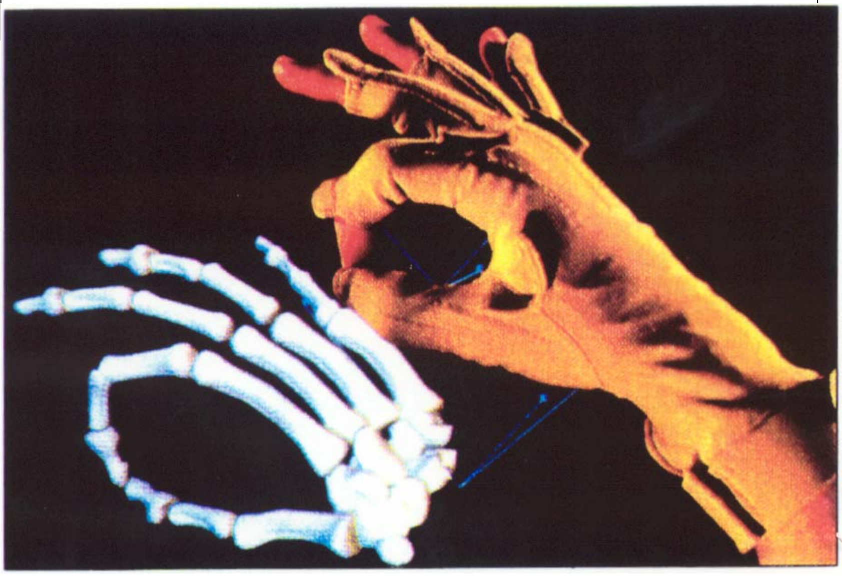
Data Glove (1987)



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.

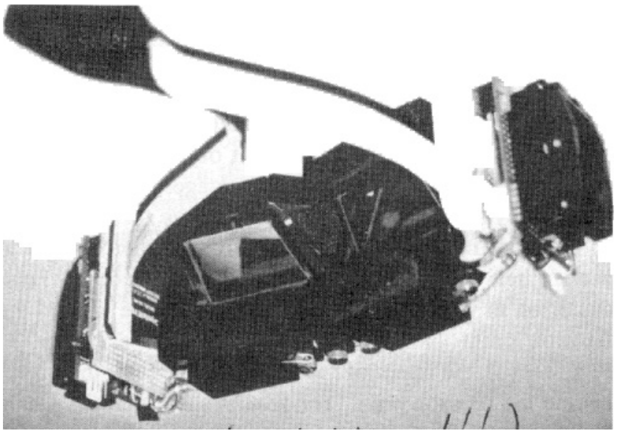
Measurement of a known pattern. From its distortion, the parameters can be computed.

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

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).



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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)

Camera motion, trasparencies….

3D structure

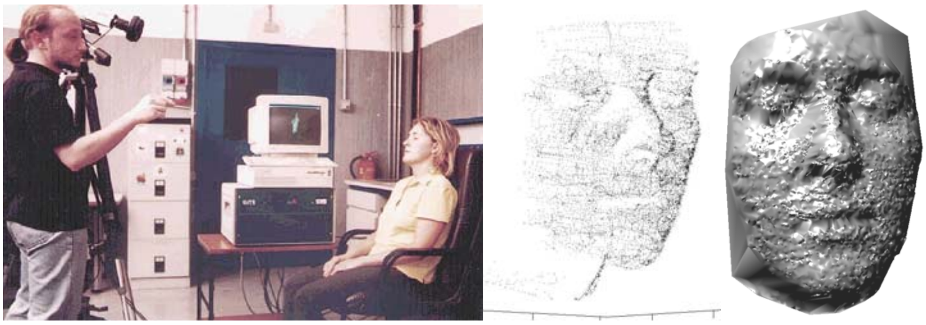
Solid modeling

•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).

Finite element models

• 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.

Autoscan (Borghese et al., 1997)



•Scansione manuale attraverso puntatore laser.
•Guida alla scansione dal feed-back su monitor.
•Flessibilità nel set-up e portabilità.
• Acquisizione spot laser in tempo reale a 100 Hz. (max 100 punti /sec)
La triangolazione diretta dei punti pone dei problemi per la presenza di rumore.

3D structure from data

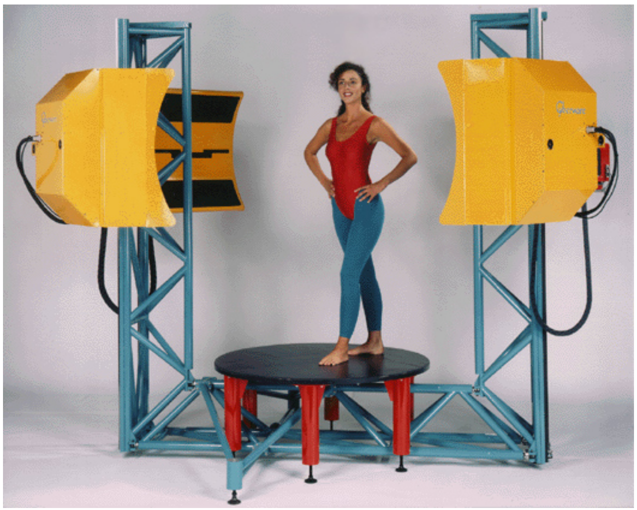
Linear approximation (mesh):
•Delauney triangulation (Watson, 1981; Fang and Piegl, 1992). Direct tessellation (no filtering).
• Alpha shapes, Ball Pivoting (Bernardini et al., 2000), Power Crust (Amenta, 2002). Post processing to regularize a Delauney tessellation.

•**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).

.....

Models from range data

Cyberware whole body scanner, WB4



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Models from range data (II)

Cyberware smaller model 3030

A.A. 2004-2005 46/98 http:\\homes.dsi.unimi.it\~borghese\

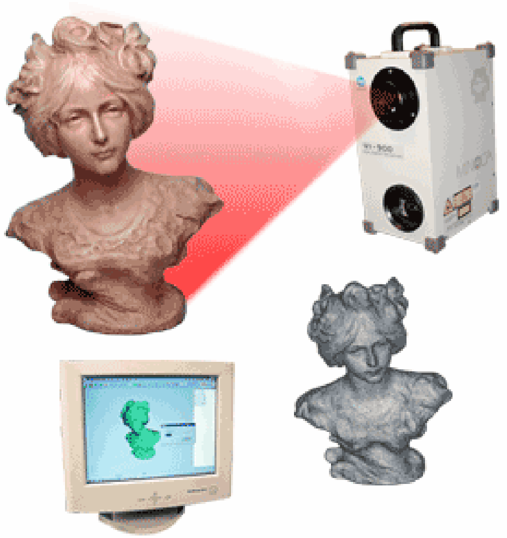
3D structure from range data (III)

Polhemus hand held laser scanner

Models from range data (IV)

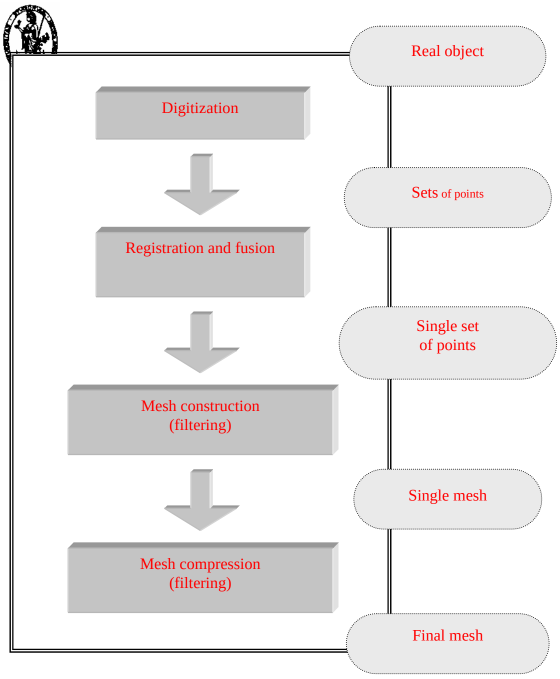
Digibot II.
•Platform rotates
•Scanner line translates.

MINOLTA
Scanner Laser 3d



Minolta scanner 3D

http://kmpi.konicaminolta.us/eprise/main/kmpi/content/ISD/ISD_Category_Pages/3dscanners



Scanner 3D Modern pipe-line

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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.

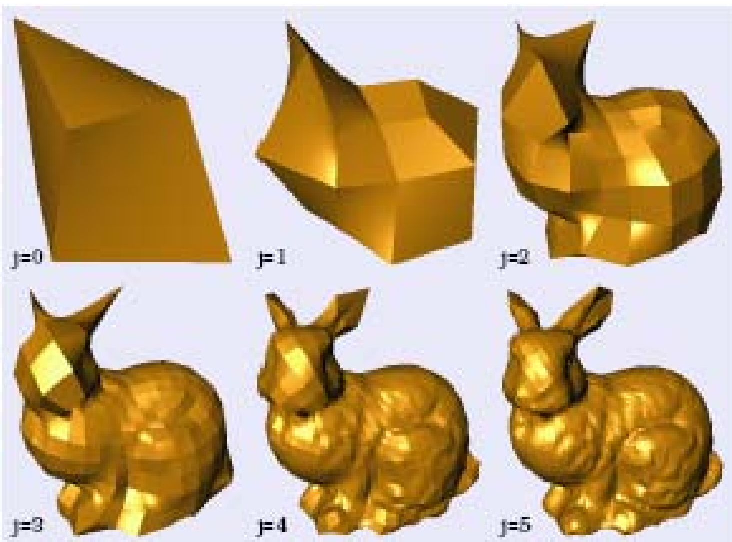
LOD Modelli a dettaglio e risoluzione diversi.

.

VRML format

```
#VRML V2.0 utf8
Viewpoint {
      position 0 0 3
      orientation 0 0 1 0
      fieldOfView 0
}
DirectionalLight {
      intensity 0.2
      ambientIntensity 0.2
      color 0.9 0.9 0.9
      direction 0 -1 -1
}
Group {
children Group{
children [
Transform {
children Shape {
appearance Appearance {
material Material {
ambientIntensity 1
diffuseColor 0.9 0.9 0.9
specularColor 0 0 0
emissiveColor 0 0 0
shininess 0
transparency 0
}
}
geometry IndexedFaceSet {
coord Coordinate {
point [
       -30.180237 -231.844711 -101.136322,
       -9.759983 -198.816086 -112.282883,
...
       41.981602 -72.366501 -38.740982,
       33.281391 -76.643936 -48.074211,
]
}
color Color {
color [
   0.9 0.9 0.9,
   0.9 0.9 0.9,
...
   0.9 0.9 0.9,
   0.9 0.9 0.9,
]
}
coordIndex [
      10, 685, 970, -1,
      0, 1133, 1162, -1,
…
      263, 472, 1176, -1,
      263, 666, 1176, -1,
]
colorPerVertex TRUE
ccw TRUE
solid TRUE
creaseAngle 8
}
}
translation 0 0 0
center 0 0 0
scale 1 1 1
}
]
}
}
```


LOD model



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…). GPU.

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.

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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.

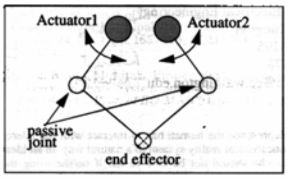
Requirements of Haptic displays

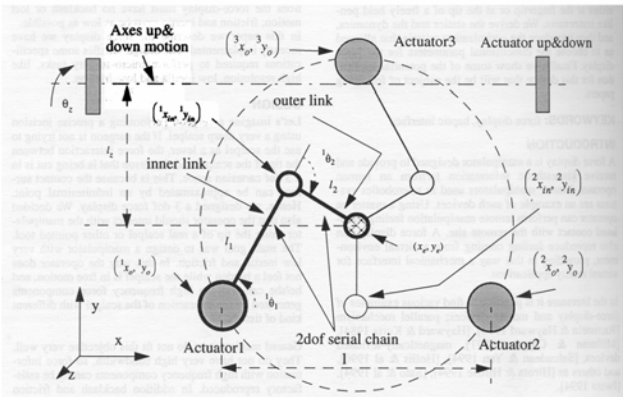
• Large bandwidth.
• Low intertial and viscosity.

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).

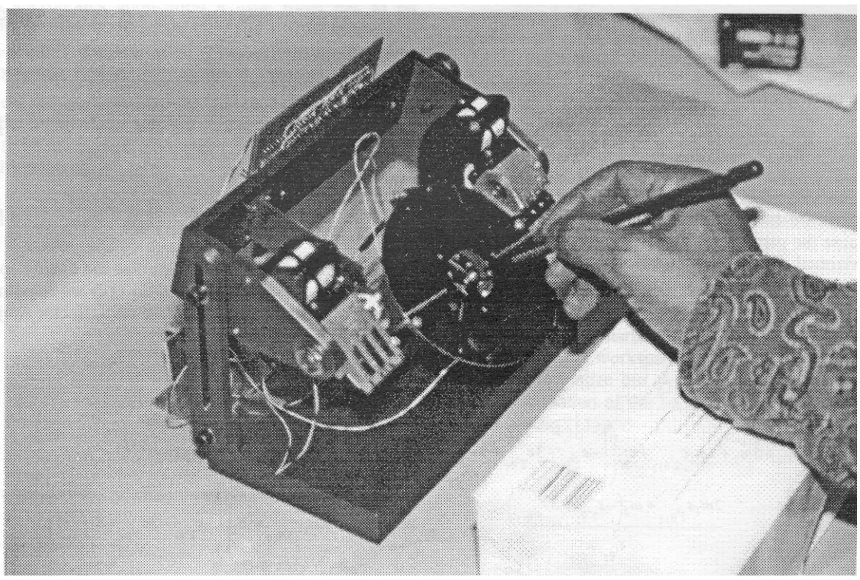
Direct drive manipulandum (phantom)

Parallel manipulandum (schema)

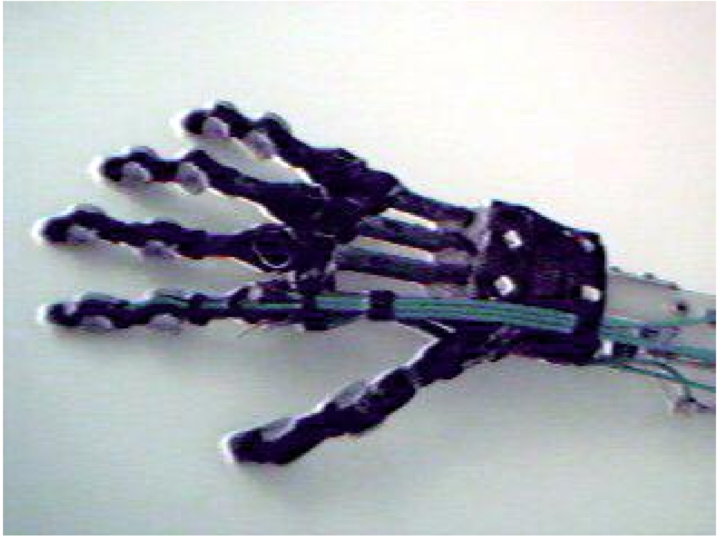




Pen Haptic display



Gloves (Blackfinger, 2000)



Cyber grasp

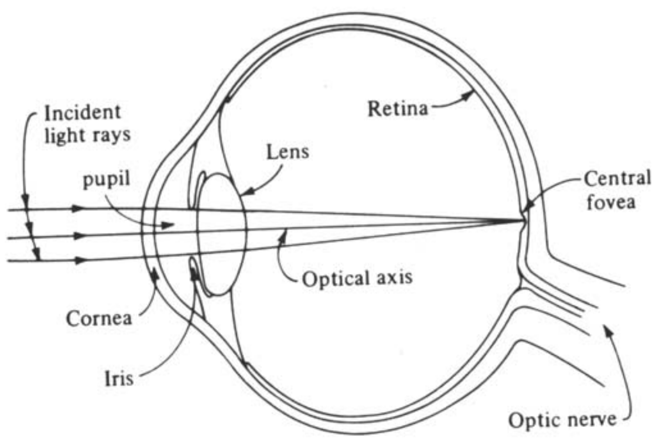
Cyber Grasp:
- max 12 N per dito
- Peso 350 grammi

Optical 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).

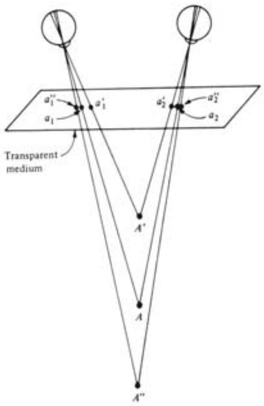
Requirements for the world generator:
•Stereoscopic vision for objects with D < 10m.
•Monocular cues for objects with D > 10m.
- - Occlusions.
- - Geometrical perspective and a-priori model knowledge.
- - Shading.
- - Motion.

The human eye



Its behavior is very similar to that of a photocamera

Stereo-disparity



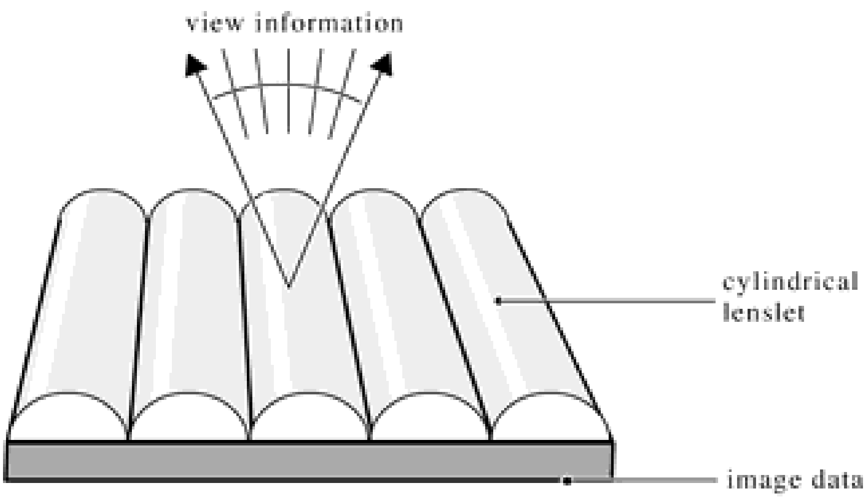
Points further away are projected on points closer to the image center.

Vergence and focusing are strictly connected.

Passive stereo

Stereo image for passive stereo

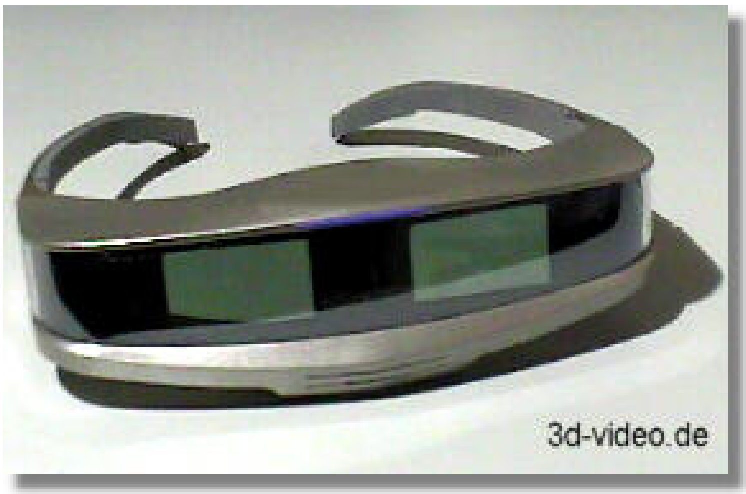
Display Autostereoscopici



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).

I-glasses (games)



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.

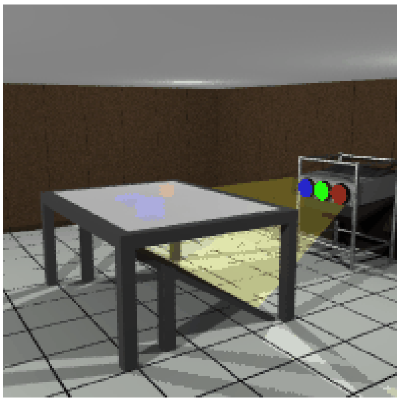
CAVE

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

More people and Complete immersivity.

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.



Large screen displays

Workwall

Physiological problems

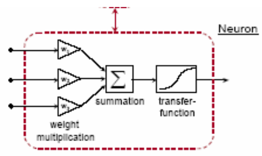
- SIMM and VR sickness limit the exposure time.
- Size and distances misperception.
- Limited range in extrapersonal space.

Other output devices

Audio – Stereo, sound spatialization.

Olfactory – Virtual nose

Type	Sensitive material	Detection principle
semiconducting metal oxides (M.O.S., Taguchi)	doped semiconducting metal oxides (SnO_2, GaO)	resistance change
quartz crystal microbalance, QMB surface acoustic wave, SAW	organic or inorganic layers (gas chromatography)	frequency change due to mass change
conducting polymers	modified conducting polymers	resistance change
catalytic field-effect sensors (MOSFET)	catalytic metals	workfunction change
pellistor	catalysts	temperature change due to chemical reactions
fluorescence sensors	organic dyes	light intensity changes
electrochemical cells	solid or liquid electrolytes	current or voltage change
infra red sensors	-	IR absorption



Stimolatori tattili

Cyber touch:

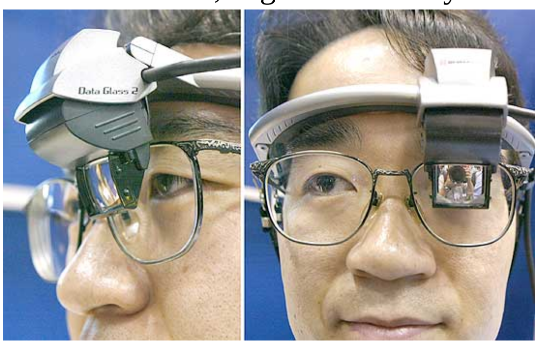
- 6 vibratori, uno per dito più 1 sul palmo
- Frequenza di vibrazione: 0-125 Hz.
- Ampiezza di vibrazione: 1.2 N @ 125 Hz (max).

Wearable devices - I

Xelibrì – Orologio/telefonino
(come digitare un numero?)

Wearable devices - II

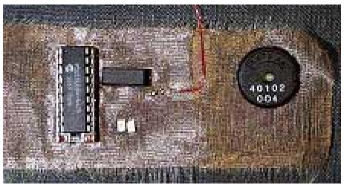
Characteristics: mobile, context sensitive, augmented reality.



Ciondolo contenente dati personali

Wearable devices - III

E-textile

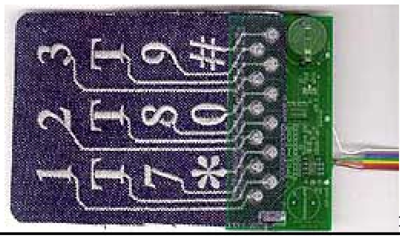


Circuito stampato su stoffa

Wrist-net

N3

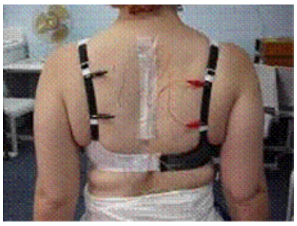
Interfaccia su stoffa.



Siemens
penna.-telefono

Wearable devices - IV

Electronical cloths - Sony



Smart cloths

Sommario

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- Sistemi di Input
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- Motore di calcolo
- Sistemi di Output
- Conclusioni

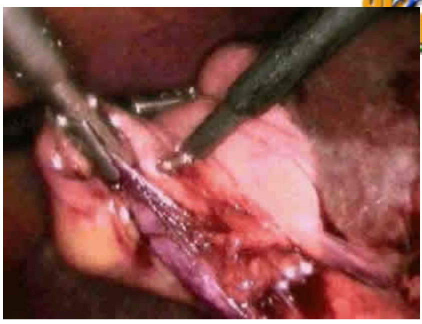
Applications

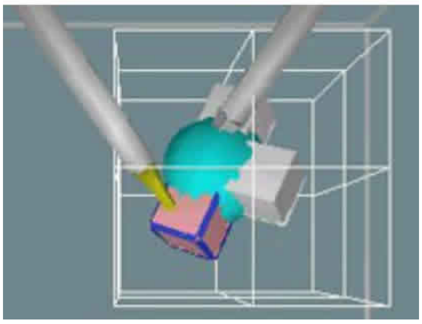
- Army
- Medicine
- Industry (inspection, virtual prototyping)
- Chemistry and Physics
- Virtual theaters and theme parks
- Enterteinment
- Comunication
- Engineering, Ergonomics and Architecture.
- History.

Indossatrice Virtuale

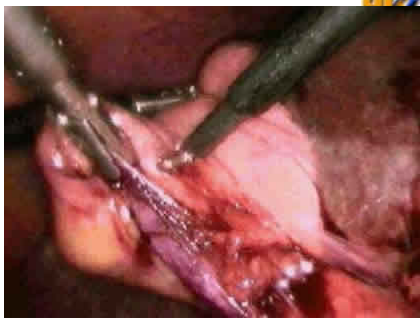
Cf. Politecnico di Losanna

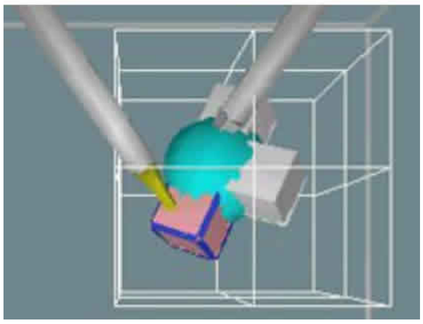
Simulazione di interventi di chirurgia mininvasiva



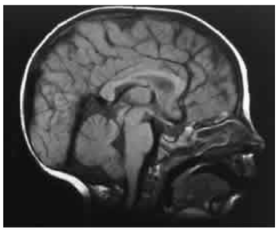


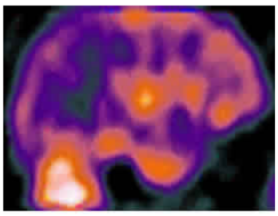
Simulazione di interventi di chirurgia mininvasiva





Fusione di immagini pre e intra operatorie

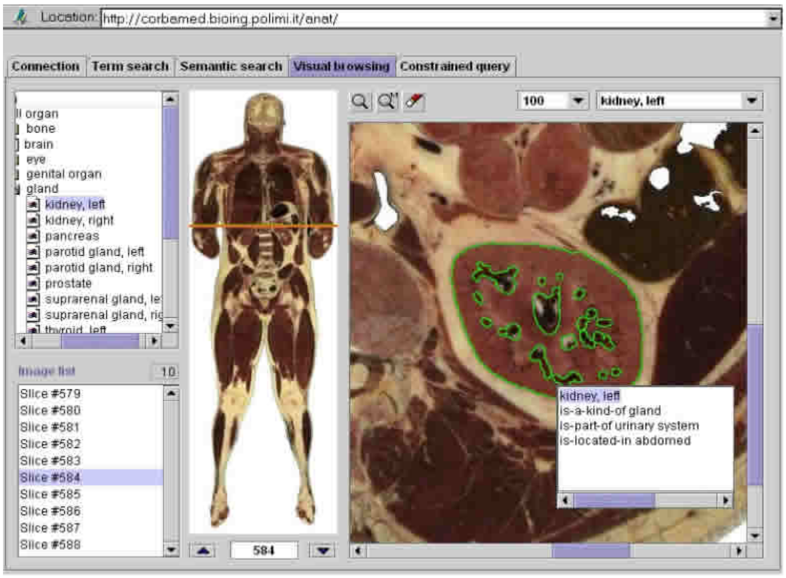




Realizzazione di oggetti 3D

Mandibola acrilica realizzata con tecnologia CAD-CAM a partire da scansioni TAC

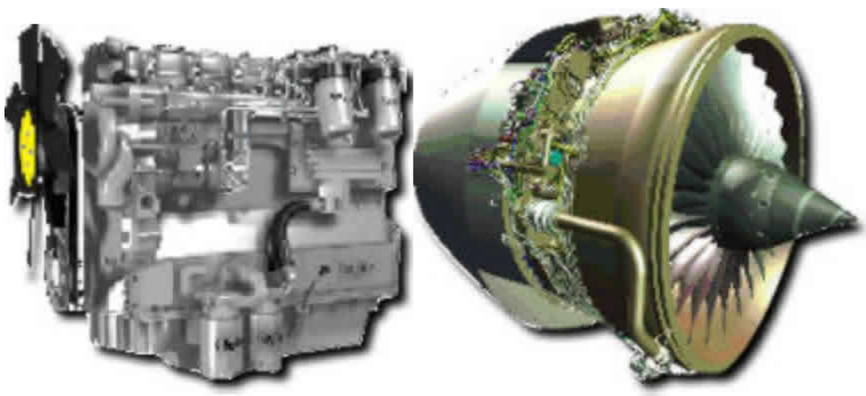
Anatomia virtuale



Progettazione: impianti virtuali

A.A. 2004-2005 93/98 http:\\homes.dsi.unimi.it\~borghese\

Progettazione: motori virtuali



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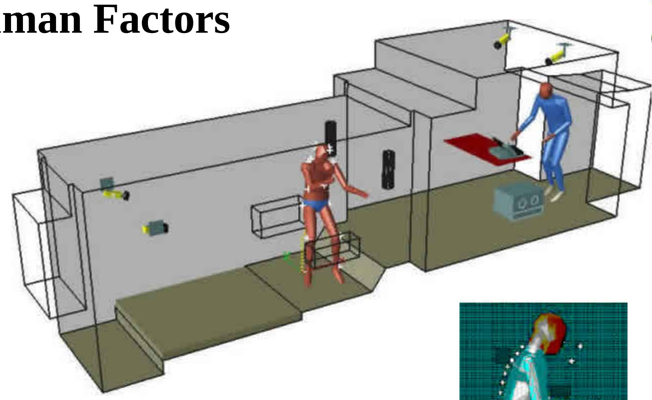
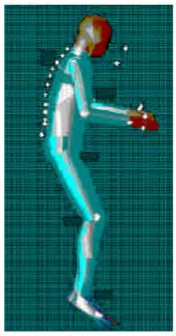
Human Factors





La città di Giotto

La tomba di Nefertari

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