

# Introduzione alla Realtà Virtuale Parte II

Alberto Borghese



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## Sommario



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

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## World generators



### Integrated systems for 3D CAD and Animation:

- Maya (ex-Alias/Wavefront)
- 3D Studio Max.

- Ogre3D
- Panda3D

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

Camera tracking, trasparencies....

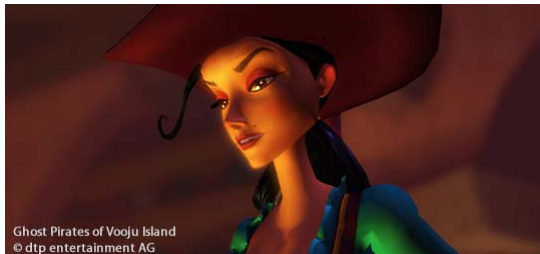
Specific CAD for mechanics: Katia, AutoCAD, Nastran SW....



## Panda3D - <http://www.panda3d.org/>



Panda3D is a game engine, a framework for 3D rendering and game development for Python and C++ programs. Panda3D is Open Source and free for any purpose, including commercial ventures, thanks to its [liberal license](#)





# OGRE3D - <http://www.ogre3d.org/>



Dynastica web browser gameplay trailer.flv



## Comparison



### Comparison OGRE3D – Panda3D

	OGRE3D	Panda3D
Type	3D rendering engine	3D game engine
Language(s)	C++	C++, Python
Bindings	Python, java	
License	MIT License	BSD license
Free for commercial application	Yes	Yes
Graphics subsystem	OpenGL and Direct3D support	OpenGL and Direct3D support
OS	Win, Linux, OSX	Win, Linux, OSX
Shader support	Yes	Yes
Audio	Using external libs	Embedded (OpenAL)
Collision detection	Using external libs	Embedded
Physics system	Using external libs	Embedded (ODE)
Keyboard and Mouse support	Using OIS	Embedded
Support for I/O devices	-	Embedded
Finite state machines	-	Embedded
GUI	Using external libs	Embedded
Skeletal animation	Yes	Yes
Particle Systems	Yes	Yes



## 3D structure



### Solid modeling

- 3D geometric solids: cubes, cylinders, cones...
- Revolution surfaces.
- Spline and NURBS (Piegle, 1993). CAD, high interactivity.
- Subdivision surfaces (Schroeder, 1999).
- Hierarchy of objects with heritage.

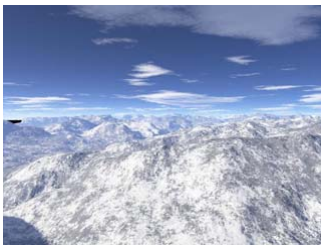
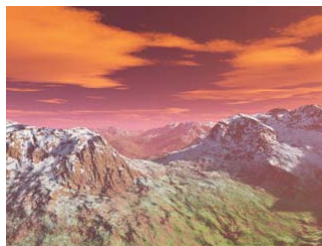
INSERIRE FIGURA

### Finite element models

- It is a class per sé. Local modeling. Mechanical modeling.
- Largely used for animation in medicine (facial animation, deformation of tissue during surgery). Multi-layer modeling.



## SW Specifico per modellazione terreni (Terragen)





## 3D structure from points



### 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 (median axis transform, 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; Ferrari et al. 2005, semi-parametric models).
- Support Vector Regression (SVR, A.Smola and B.Scholkopf)

.....

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## 3D Scanner: Autoscan - 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.*

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## Models from range data



Cyberware whole body scanner, WB4



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## Models from range data (II)



Cyberware smaller model  
3030



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### 3D structure from range data (III)



Polhemus hand held laser scanner





### Models from range data (IV)



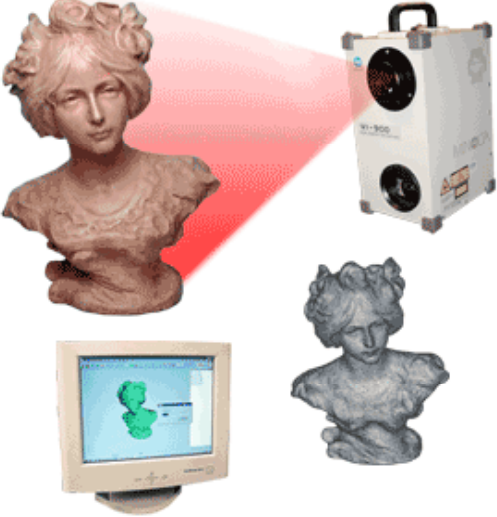
Digibot II.

- Platform rotates
- Scanner line translates.




**MINOLTA  
Scanner Laser 3d**



**Minolta scanner  
3D**

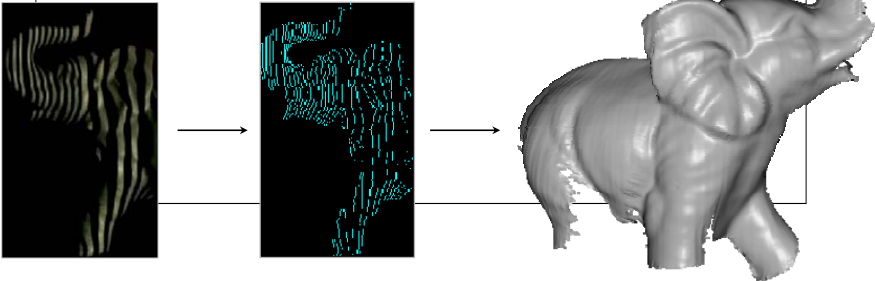
[http://kmpi.konicaminolta.us/eprise/main/kmpi/content/ISD/ISD\\_Category\\_Pages/3dscanners](http://kmpi.konicaminolta.us/eprise/main/kmpi/content/ISD/ISD_Category_Pages/3dscanners)

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**Video-based 3D scanner (Rusinkiewicz et al., 2002)**

- A projector of stripes with pseudo-random width and a video camera
- holes can be found and filled on-the-fly
- object or scanner can be handheld / shoulderheld



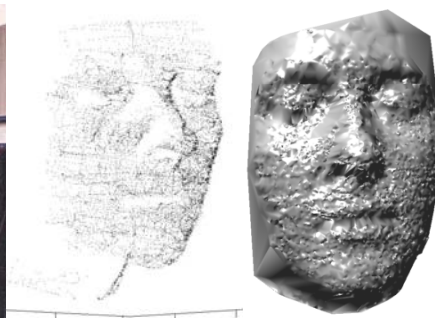
video frame      range data      merged model  
(159 frames)

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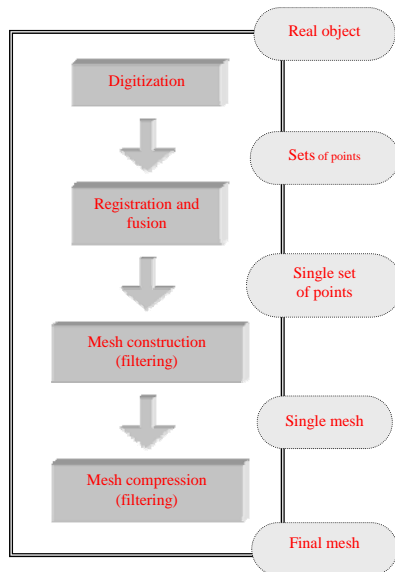
## Effect of measurement noise is clear with Delaunay triangulation



Need of filtering is evident.



## Scanner 3D modern pipeline



M. Levoy, S. Rusinkiewicz, M. Ginzton, J. Ginsberg, K. Pulli, D. Koller, S. Anderson, J. Shade, B. Curless, L. Pereira, J. Davis and D. Fulk, "The Digital Michelangelo Project: 3D Scanning of Large Statues," *Proc. Siggraph'99*, ACM Press, pp. 121-132, 1999



## Research challenges



- |  |  |
|--|--|
| <ul style="list-style-type: none"><li>• vision problems<ul style="list-style-type: none"><li>– aligning and merging scans</li><li>– automatic hole filling</li><li>– inverse color rendering</li><li>– automated view planning</li></ul></li></ul> | <ul style="list-style-type: none"><li>• digital archiving problems<ul style="list-style-type: none"><li>– making the data last forever</li><li>– robust 3D digital watermarking</li><li>– indexing and searching 3D data</li><li>– real-time viewing on low-cost PCs</li></ul></li></ul> |
|--|--|

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## Sommario



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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 (millions of).
- Much more than required by applications.



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



## VRML format



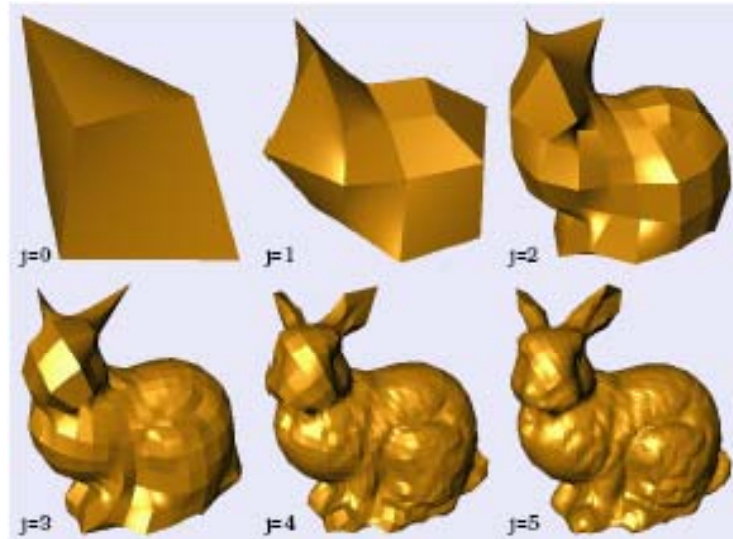
```

#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 models



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## The graphical engine (visual computing)



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

Interpolation of normals direction among adjacent triangles.

Graphical pipelining (geometry, colour, texture, shadowing, rendering...).

GPU programming language (CUDA nVidia).

Parallelization.

Hierarchy of structures (objects, collision detection...)

Multiple cache levels.

Look-ahead code optimization (compiler optimization).

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## Collision detection



Computational demanding ( $O(n^2EF)$ ).

Use of multiresolution models.

Hierarchical detection.

Geometry simplification (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.

International Haptic society - <http://www.isfh.org/>



## Requirements of Haptic displays



- Large bandwidth.
- Low inertial 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 and esoskeleta (Bergamasco, 1993, MITmanus, 2000, Braccio di ferro, 2007).



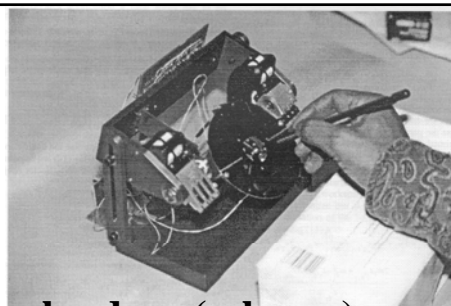
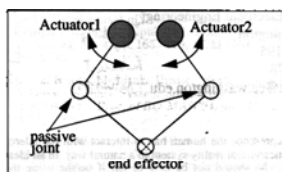
## Direct drive manipulandum (phantom)



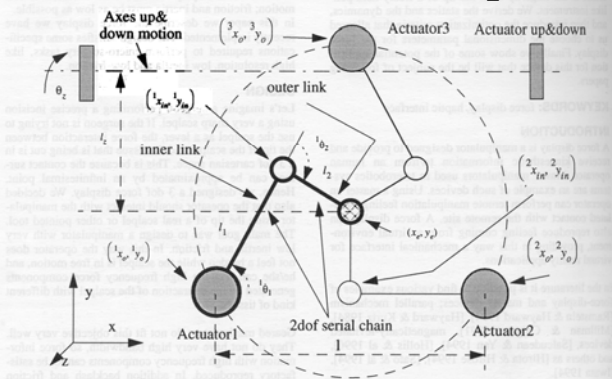
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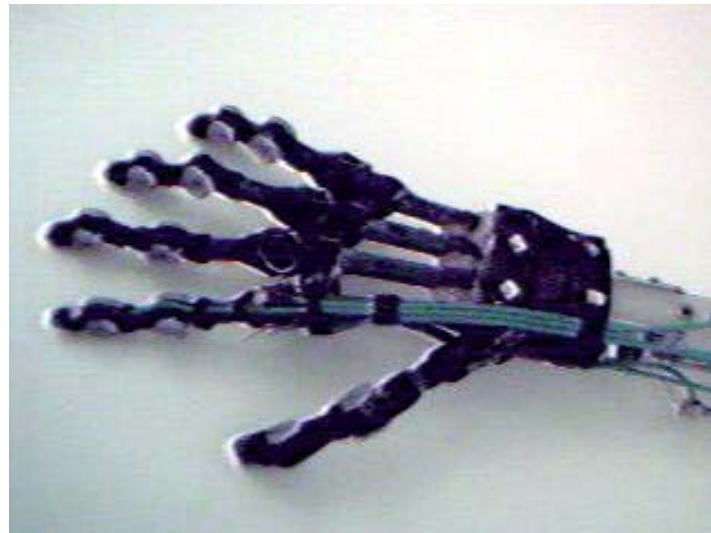
## Parallel manipulandum (schema)



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## Gloves (Blackfinger, 2000)



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## Percro glove (2002)



Sensori goniometrici – non devono essere calibrati sulla lunghezza delle falangi.

<http://www.percro.org>

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## MIT-Manus, 2004



## Braccio di ferro, 2010



Support for the fore-arm, and generation of a force field.

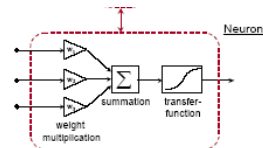


## Other output devices



**Audio** – Stereo, sound spatialization.

**Olfactory** – Virtual nose



Type	Sensitive material	Detection principle
semiconducting metal oxides (M.O.S., Taguchi)	doped semiconducting metal oxides (SnO <sub>2</sub> , GaO)	resistance change
quartz crystal microbalance, QMB	organic or inorganic layers (gas chromatography)	frequency change due to mass change
surface acoustic wave, SAW		
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).

Iwamoto & Shinoda  
University of Tokio



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## Sistemi di Output::display



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## Optical Output systems



### Requirements for the monitor:

- Large field of view ( $180^\circ \times 150^\circ$ ).
- 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.

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## La camera come strumento di ripresa



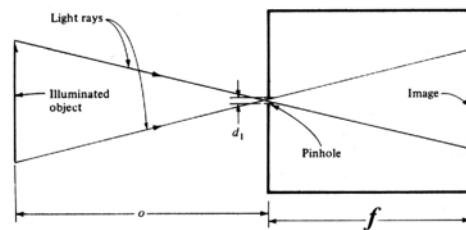
Come si forma un'immagine?

- Scena con oggetti riflettenti.
- Sorgente di illuminazione
- Piano di rilevazione della luce riflessa.



Modello pin-hole

Il motore di questa trasformazione è la **proiezione prospettica**.



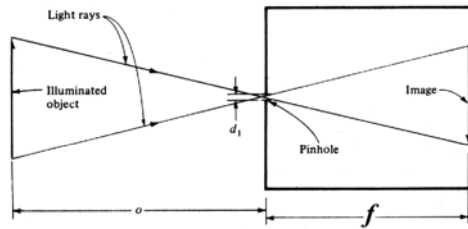
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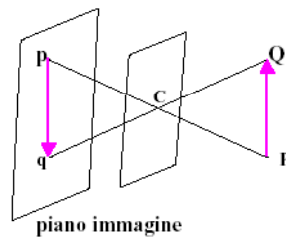
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## La pin-hole camera



**Proiezione prospettica:**  
tutti i raggi di proiezione  
passano per un unico punto,  
detto **centro di proiezione**.



Pinhole camera

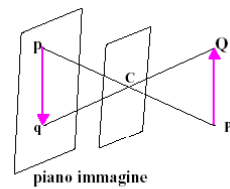
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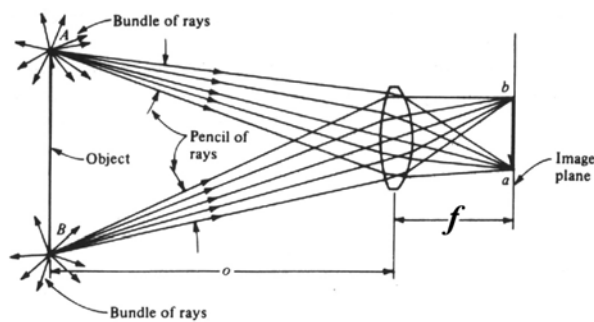
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## La lente



Pinhole camera



Lente convergente

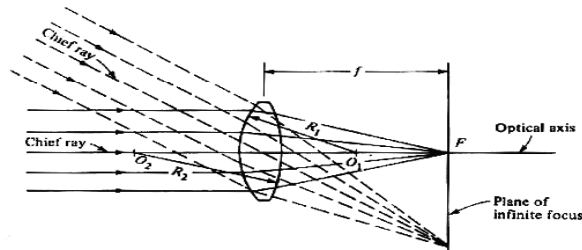
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## Geometria dell'ottica



Oggetti all'infinito

- **Distanza focale:** distanza del piano immagine quando un oggetto si trova all'infinito.
- **Asse ottico:** raggio che non viene deviato dalla lente.
- **Intersezione dell'asse ottico con il piano immagine dà il punto principale (F).**

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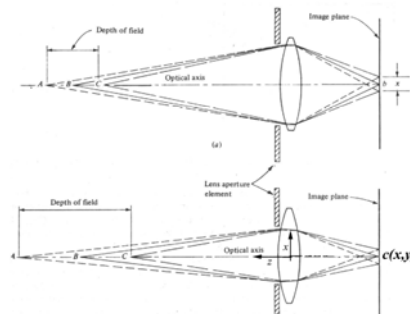
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## Messa a fuoco



Problema della messa a fuoco



**Parametri di camera (o intrinseci):**

- **Punto principale  $c(x,y)$  + lunghezza focale,  $f$  (3 parametri).**
- **Occorre conoscere anche il fattore di forma dei pixel nel caso di immagini digitali (è una costante, non un parametro).**
- **(Distorsioni).**

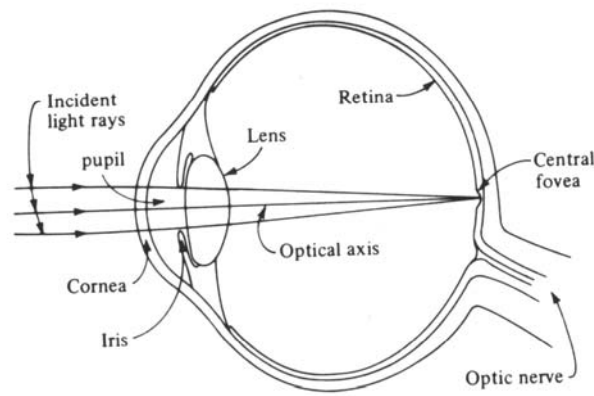
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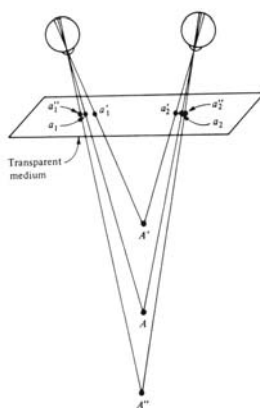
# L'occhio umano



Its behavior is very similar to that of a camera



# Stereo-disparity



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

Vergence and focusing are strictly connected.

Also monocular cues: shading, apparent size, .....



## Passive stereo



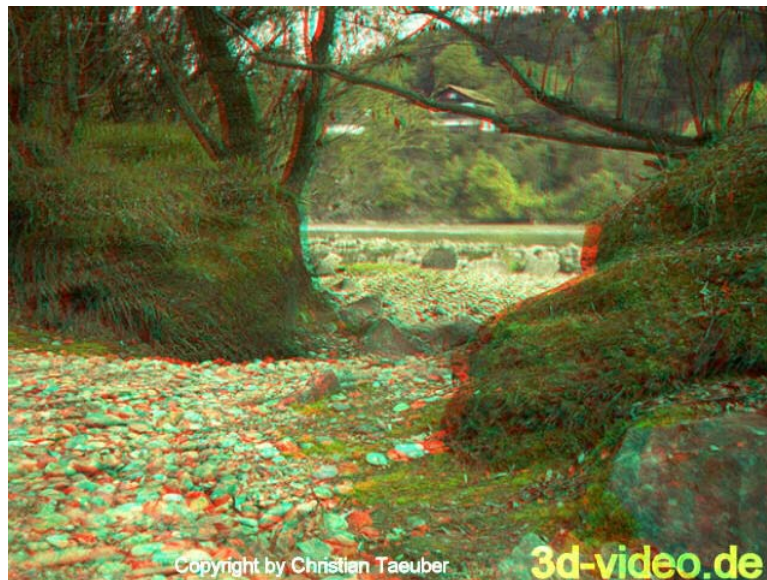
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## Stereo image for passive stereo



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## Stereogramma con parallasse



Brevetto del 1903

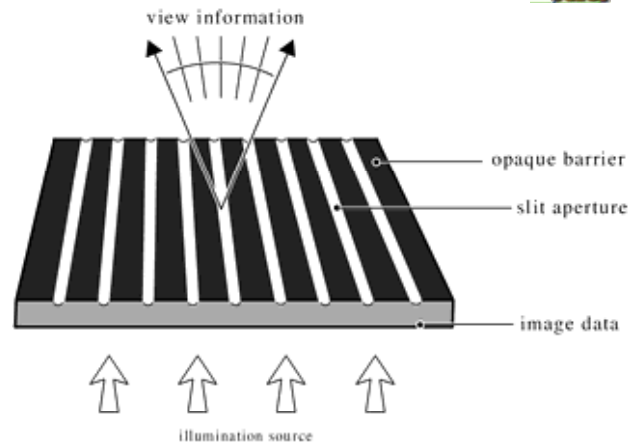


Immagine suddivisa in strisce verticali.

Coppie di strisce, associate alla parallasse orizzontale, sono posizionate in funzione dell'angolo.

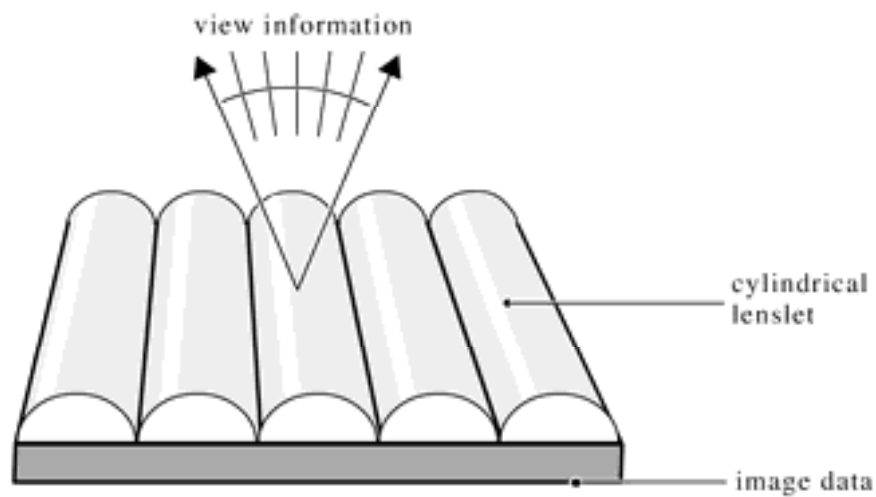
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## Display Autostereoscopici



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## 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).



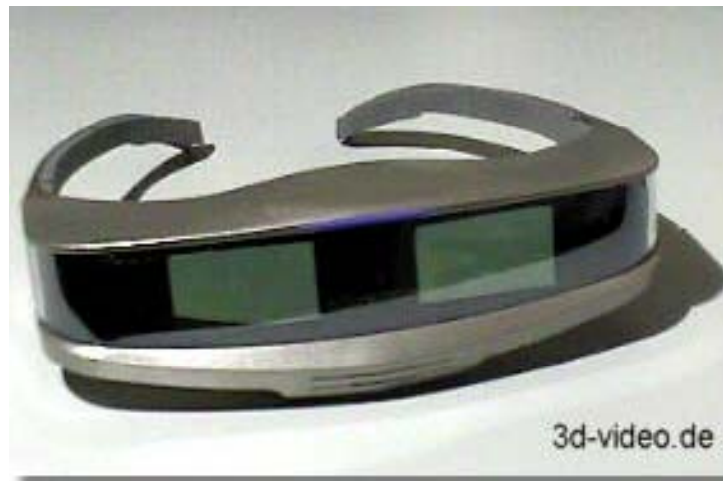
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## I-glasses (games)



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## HMD (n-vision)



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

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## Output devices (BOOM HMD)



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



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## CAVE



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

More people and  
Complete immersivity.



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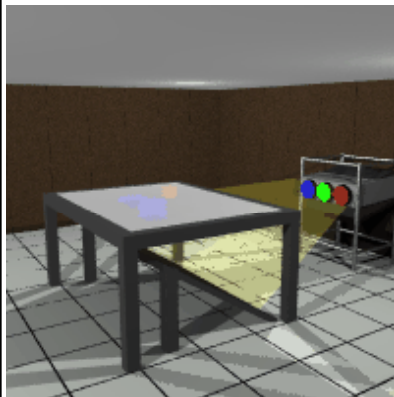
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## Responsive work-bench (Strauss et al., 1995)



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



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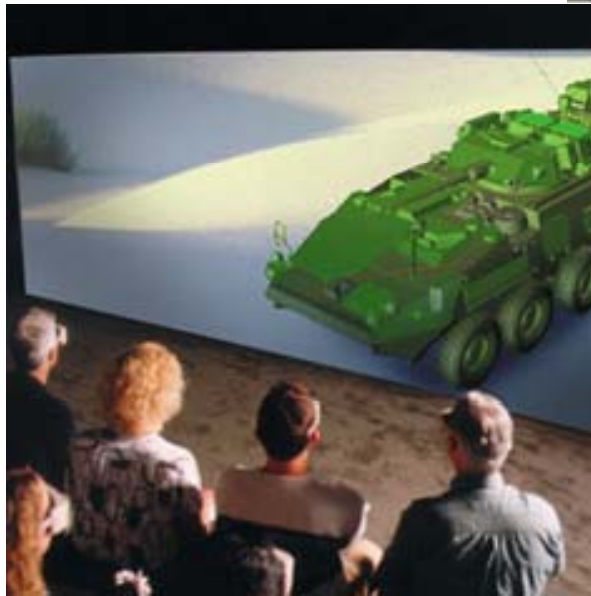
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## Large screen displays



### Workwall



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- **Conclusioni**

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## Applications



- Army
- Medicine
- Industry (inspection, virtual prototyping)
- Chemistry and Physics
- Virtual theaters and theme parks
- Entertainment
- Communication
- Engineering, Ergonomics and Architecture (Visual computing).
- History.

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## Indossatrice Virtuale



Cf. Politecnico di Losanna

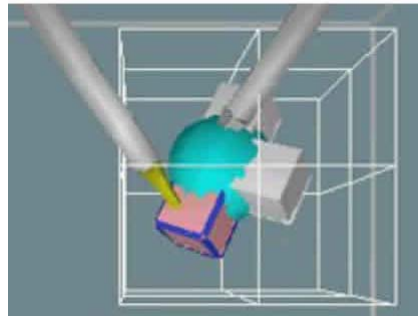
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## Simulazione di interventi di chirurgia mininvasiva



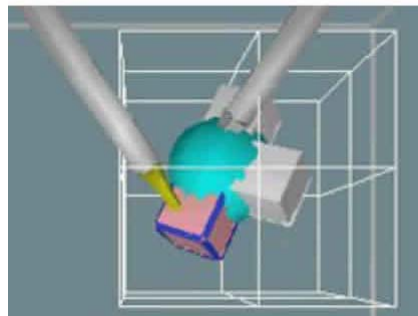
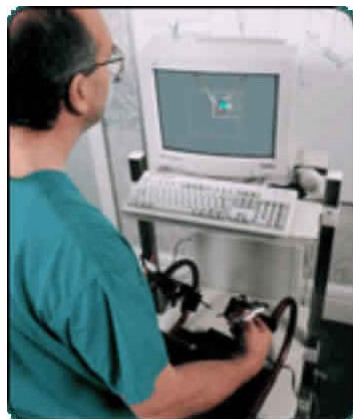
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## Simulazione di interventi di chirurgia mininvasiva



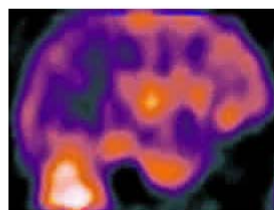
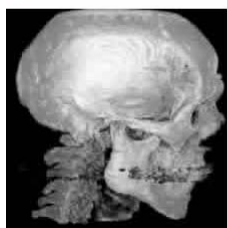
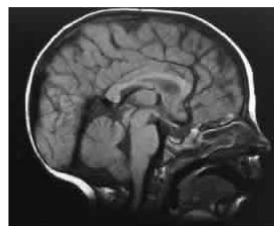
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## Fusione di immagini pre e intra operatorie



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## Imaging e stampanti 3D



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

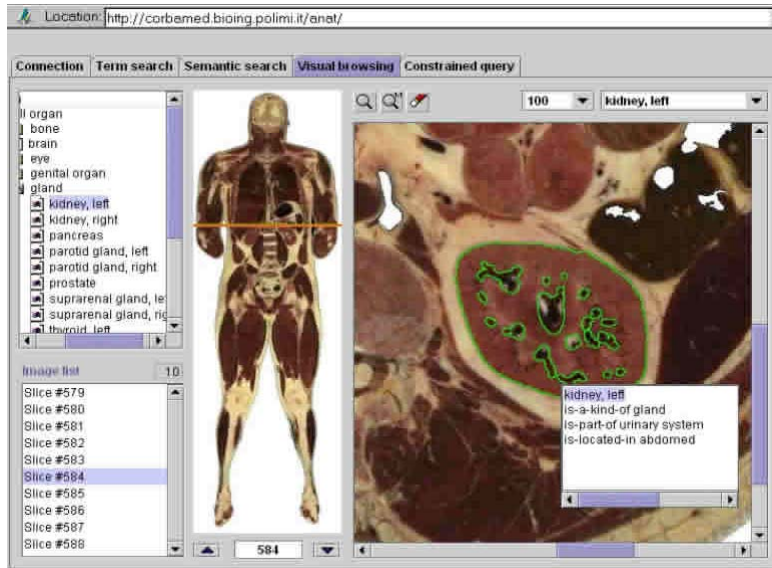
A.A. 2010-2011

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## Anatomia virtuale



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## Progettazione: impianti virtuali



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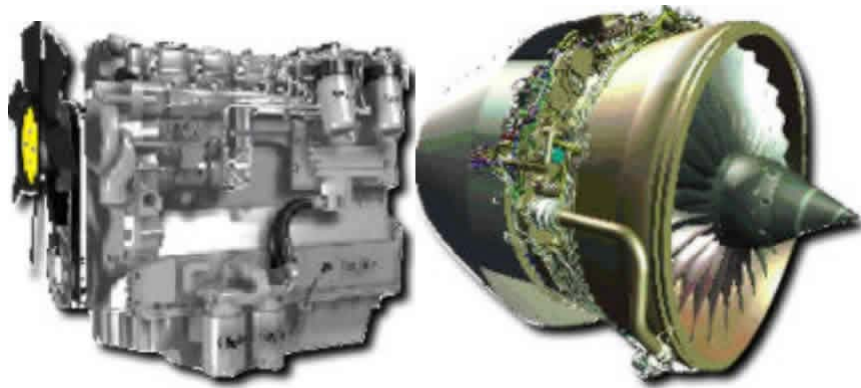
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## Progettazione: motori virtuali



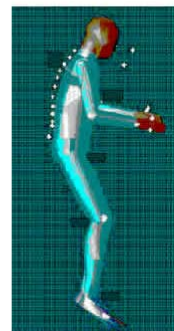
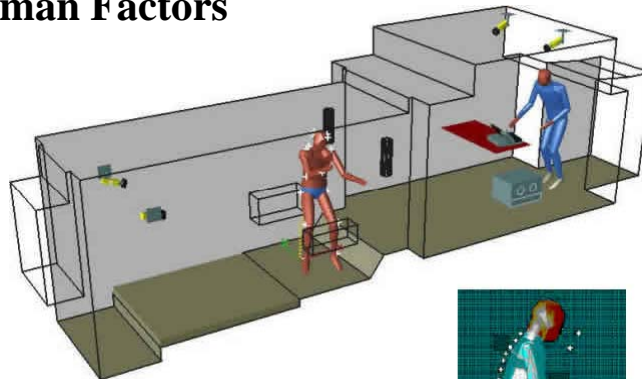
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## Human Factors



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## La tomba di Nefertari



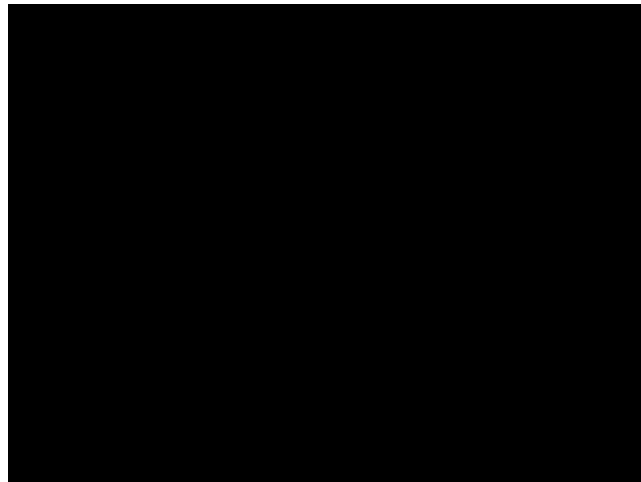
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## Virtual Tosca



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## Sommario



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