

# Introduction to Virtual Reality Part II

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## Content



- Introduction
- Input Systems
- **Virtual Reality Engine**
- World Generators
- Output Systems
- Applications

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## Sensorial stimulation



Vision -> Graphical rendering

Audio -> Audio rendering

Proprioception -> Vibrators, gloves,...

Olfactory

....



## Graphical representation



Graphical rendering is usually carried out on model represented by 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.
- RealTime application -> low poly



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



## VRML format -> X3D



```

#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
cex TRUE
solid TRUE
creaseAngle 8
}
translation 0 0 0
center 0 0 0
scale 1 1 1
}
}

```



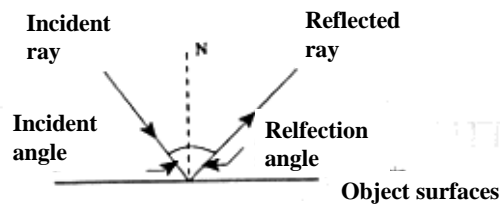
## Rendering



Preure that "renders", that is generates, an image starting from the Mathematical description of a 3D scene, through algorithms that define the color in each point of the digital image [Wikipedia].

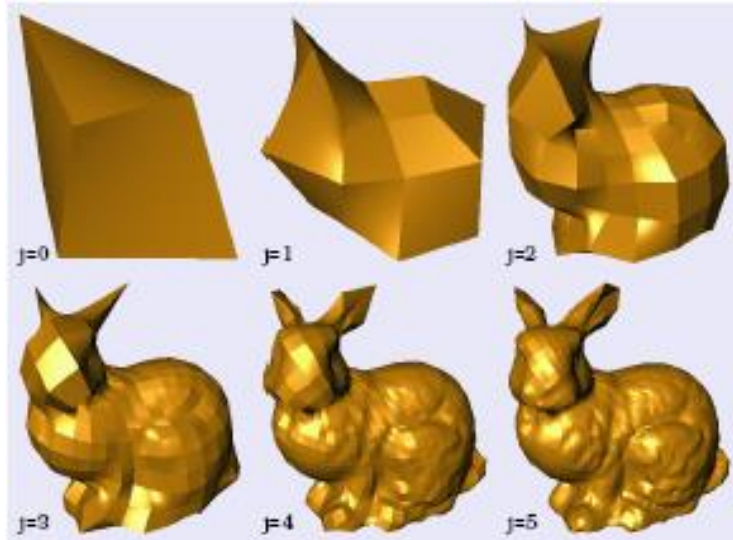
Rendering is based on the physics of the (electromagnetic) waves that describes the interaction between the waves and the interacting mean, causing reflections, refraction, scattering, tunnelling effects...).

We see what is **sent back (reflected)** by the scene => The scene is lit by one or more lights (not light, no image), that is reflected by objects and hits the image plane.





# LOD models



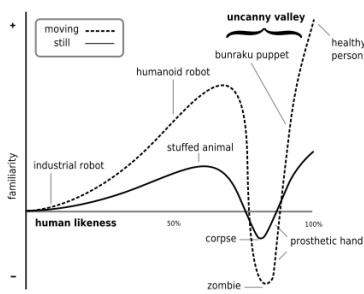
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# Avatar designed avoiding the "uncanny" valley



Mori, Masahiro (1970). Bukimi no tani The uncanny valley (K. F. MacDorman & T. Minato, Trans.). Energy, 7(4), 33-35. (Originally in Japanese)



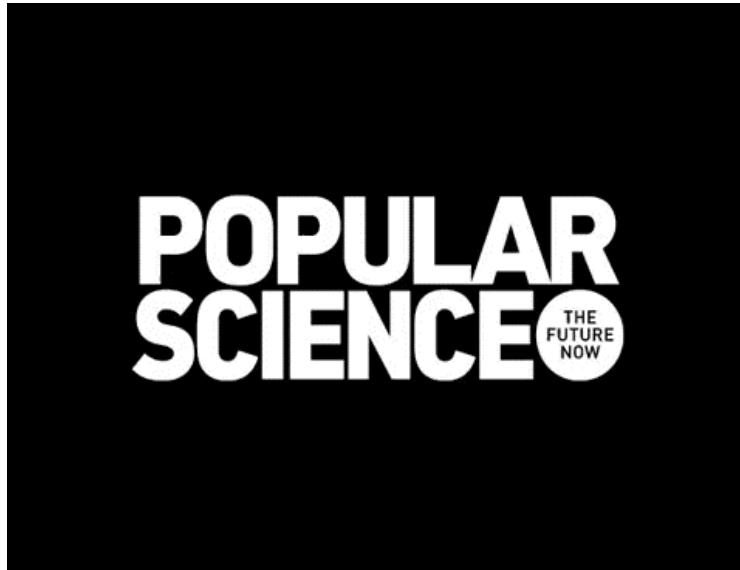
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## Uncanny Valley



## The graphical engine (visual computing)



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

Interpolation of normals direction among adjacent triangles (to create the appearance of a continuous curved surface)

Graphical pipelining (from 3D geometry to 2D images: projection, colour, texture, shadowing, ...).

Parallelization. GPU programming language (CUDA nVidia).

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

Multiple cache levels.

Look-ahead code optimization (compiler optimization).



## 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.



## 2D collision detection



- Collision detection with target can be checked by analyzing the overlapping between part of the motion mask only in particular regions.
- Identification of the motion mask as the outermost part of the body. Approximated collision detection defining general shapes.

Correct Hand collision area  
(most left pixel in the area around first top most high pixel)

- Collision with targets gives hit, collision with distractors gives a miss.
- Same principles implemented with Sony EyeToy Webcam (2003).





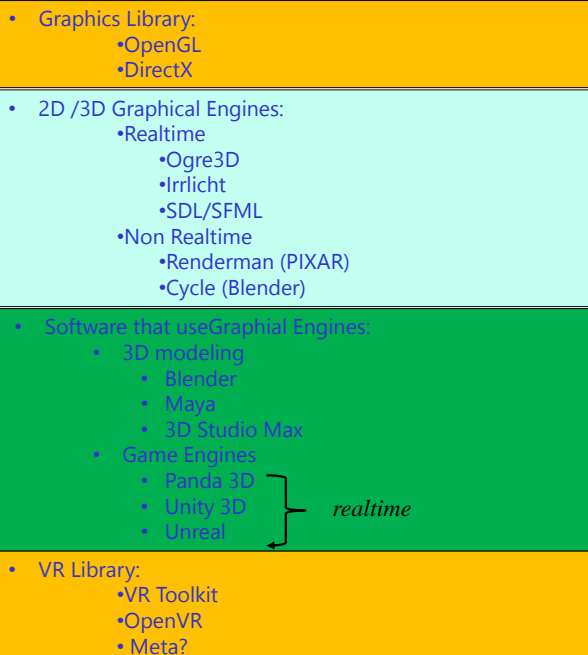
# Content



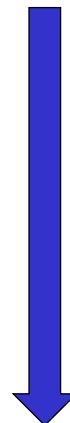
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# VR related engines



**Low level**



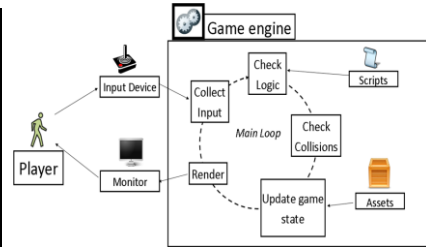
**High Level**



<http://unity3d.com>



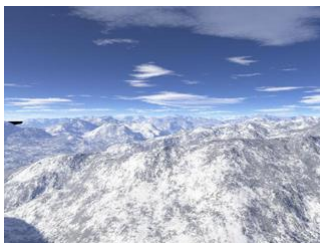
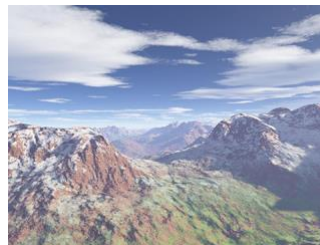
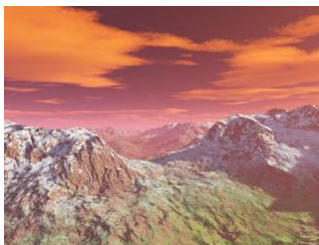
Lara Croft go puzzle adventure



Rush game



## Specific SW for terrain modelization (Terragen)

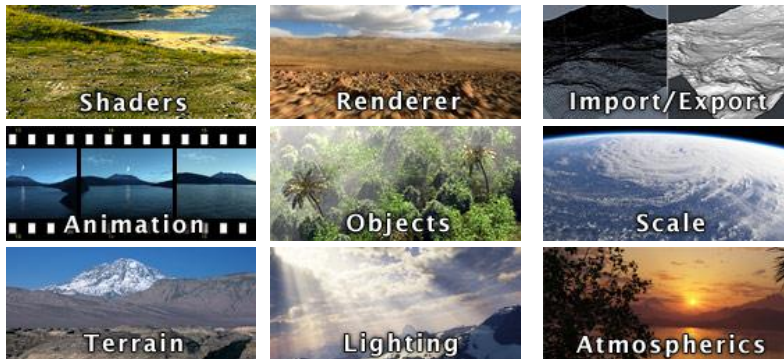






## Artificial landscape

<http://planetside.co.uk/products/terragen3>



Video on Vajont history

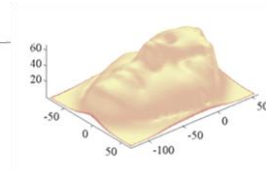


## 3D Assets making

- Scanners 3D (copying from reality)
  - Active (laser or unstructured light, sound)
  - Passive (video)
- Modelling
  - Organic
  - Non organic
- Procedural content generation



## 3D Scanner: Autoscan - 1997



- Manual scanning through a laser pointer,
- Real-time display feed-back to guide scanning.
- Flexible set-up and portability
- Acquisition of laser spot in real-time at 100 Hz. (max 100 points / sec)  
*3D reconstruction of the spot through triangulation poses problems due to noise on the measurement of position on the cameras.*

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## Models from range data



Cyberware whole body scanner, WB4



Which problems do you envisage?

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## Models from range data (II)



Cyberware smaller model  
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## Models from range data (IV)



Digibot II.  
•Platform rotates  
•Scanner line translates.



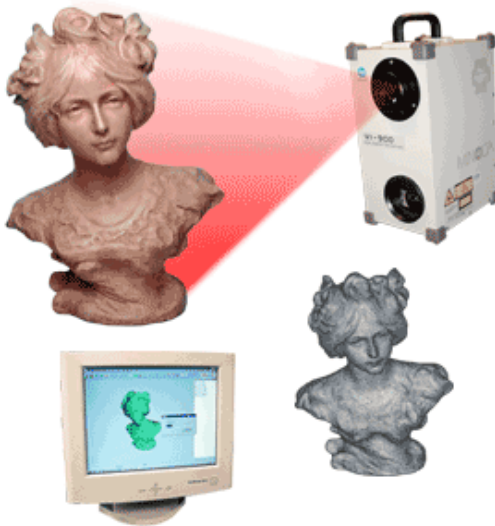
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**MINOLTA**  
Scanner Laser 3d



## Minolta scanner 3D

[https://www.konicaminolta.com/instruments/download/instruction\\_manual/3d/index.html](https://www.konicaminolta.com/instruments/download/instruction_manual/3d/index.html)



## 3D structure from range data (III)



Polhemus hand held laser scanner



# From Clouds to surfaces



Effect of measurement noise is clear with Delaunay triangulation.  
Need of filtering is evident.



# 3D structure from points

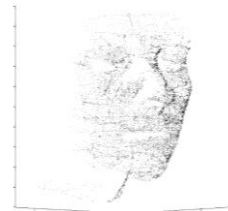


## Linear approximation (mesh):

- Delaunay 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 Delaunay tessellation.

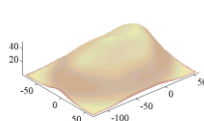
## Surface fitting to range data

- 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, incremental approach).
- Support Vector Regression (SVR, A.Smola and B.Scholkopf)

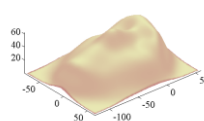


.....

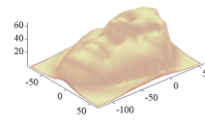
Approximation at layer #1



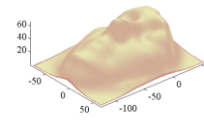
Approximation at layer #2



Approximation at layer #3

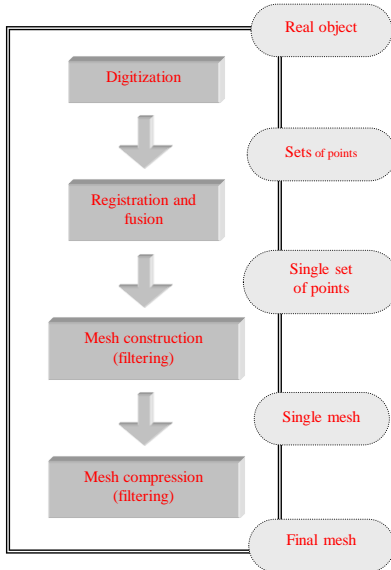


Approximation at layer #4





## 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 Digital Michelangelo project



- vision problems
  - aligning and merging scans
  - automatic hole filling
  - inverse color rendering
  - automated view planning
  - Interaction of laser with marble
- digital archiving problems
  - making the data last forever
  - robust 3D digital watermarking
  - indexing and searching 3D data
  - real-time viewing on low-cost PCs



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



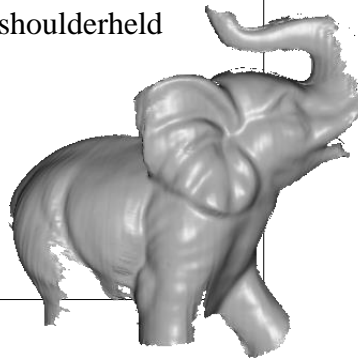
- A projector of stripes with pseudo-random width and a video camera
- holes can be found and filled on-the-fly
- object or scanner can be handheld / shoulderheld



video frame



range data



merged model  
(159 frames)

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## Kinect fusion



<http://blogs.msdn.com/b/kinectforwindows/archive/2012/11/05/kinect-fusion-coming-to-kinect-for-windows.aspx>



Low cost 3D modeling

**KinectFusion: Real-time 3D  
Reconstruction and Interaction  
Using a Moving Depth Camera, Izadi et al.,  
Proc. Siggraph 2011**

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## Procedural Modelling



Models generated through a procedure (a software program, an algorithm)

It is possible to construct a 3D mesh specifying parametric rules to create the objects.

Examples: Trees, Cities, Mugs, ....



## Artificial plants



A synthetic model of the topiary garden at Levens Hall, England, by

R. Mëch, P. Prusinkiewicz, and M. James. "Garden of L" (inset) by P. Prusinkiewicz,

F. Fracchia, J. Hanan, and D. Fowler; see [www.cpsc.ucalgary.ca/~pwp](http://www.cpsc.ucalgary.ca/~pwp)

L-systems





## Realizing a plant



### Lindenmayer example

**variables** : X F

**constants** : + - [ ]

**start** : X

**rules** :  $(X \rightarrow F - [[X] + X] + F [+FX] - X), (F \rightarrow FF)$

**angle** :  $25^\circ$

Here, F means "draw forward", - means "turn left  $25^\circ$ ", and + means "turn right  $25^\circ$ ". X does not correspond to any drawing action and is used to control the evolution of the curve.

[ corresponds to saving the current values for position and angle, which are restored when the corresponding ] is executed.



## Content



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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.

Haptic 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/>



## Direct drive manipulandum (phantom)



Geomagic® Phantom® Premium  
(ex Sensable Techn. 1993-2012) Now 3D Systems  
A similar device (Falcon) is available and used in our lab for rehabilitation



## Haptics low cost



Omni Phantom



Novint Falcon

**Experience in the lab**


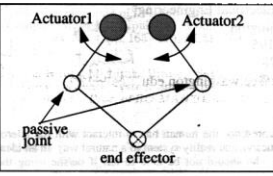
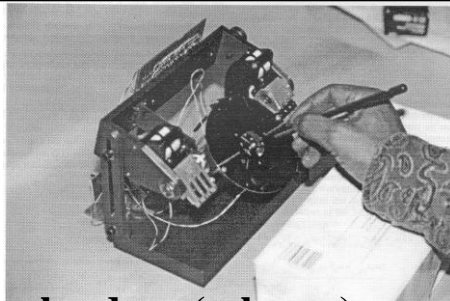


## Requirements of Haptic displays

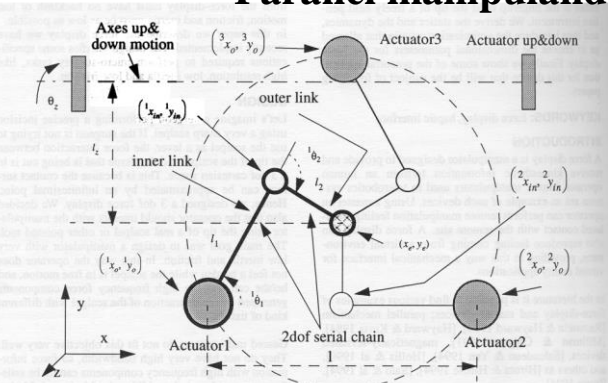
- Large bandwidth.
- Low inertial and viscosity.

### **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).


### Parallel manipulandum (schema)




<http://borghese.di.unimi.it>

## MIT-Manus, 2004



## Braccio di ferro, 2010

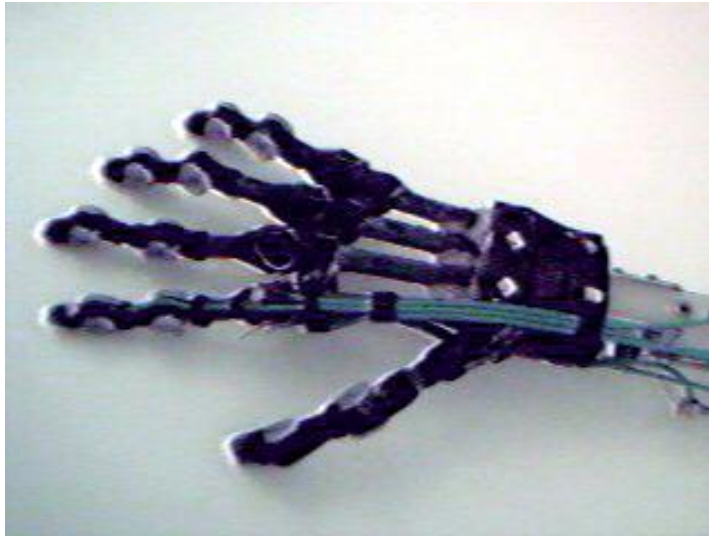


Support for the fore-arm, and generation of a force field.

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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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# Tactile Stimulators



Cyber touch:

- 6 vibrators, 1 for each finger + 1 on palm
- Vibration frequency: 0-125 Hz.
- Vibration amplitude: 1.2 N @ 125 Hz (max).

Iwamoto & Shinoda  
University of Tokio

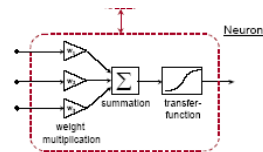


# Other output devices



**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



# The future?



**Impacto**  
Simulating Physical Impact by Combining  
Tactile with Electrical Muscle Stimulation



Pedro Lopes, Alexandra Ion, and Patrick Baudisch  
HPI Hans Plattner Institut

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# Sistemi di Output::visione



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## Optical Output systems



### Requirements for the monitor:

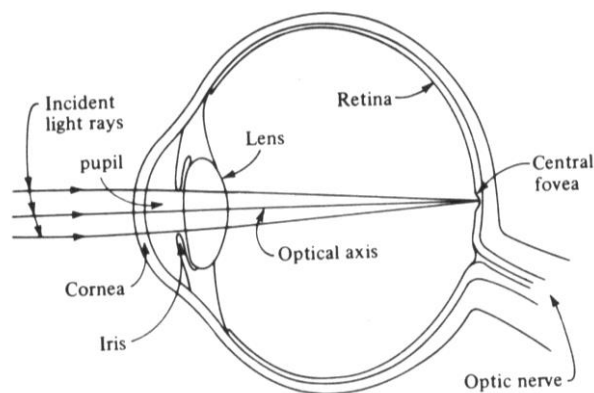
- Large field of view ( $180^\circ \times 150^\circ$ ).
- High spatial resolution (35 pixels/degree, equivalent to 12,000x12,000 pixels for a 19" display positioned at 70cm from the viewer).

### 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.



## Human eye

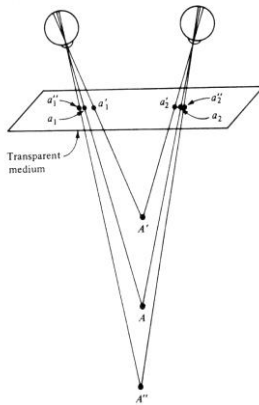


Its behavior is very similar to that of a camera  
Lens focuses the image, vergence movement orients the eye.





## Vergence



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

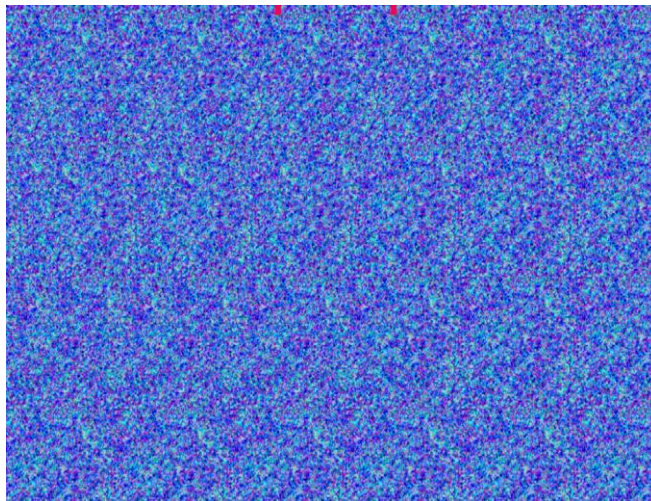
The sum of these distances is called stereo-disparity and depends on distance.

Vergence and focusing are strictly connected.

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



## Autostereogram



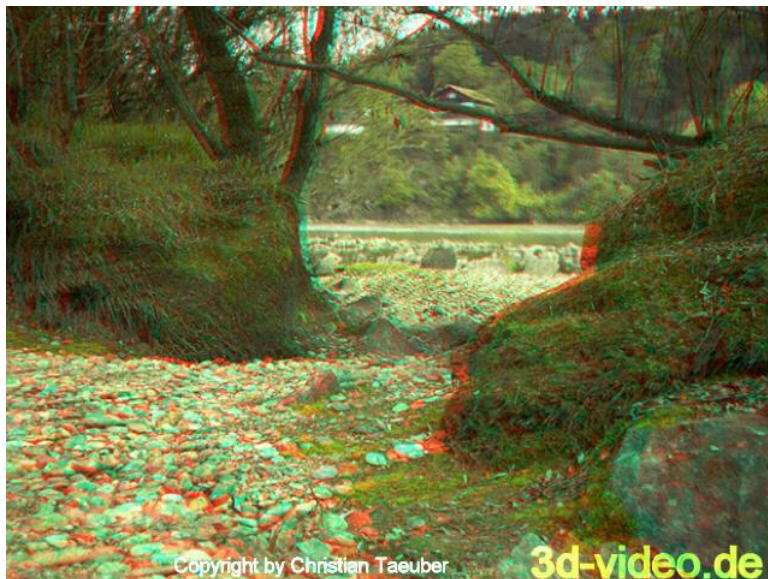
To see the 3D image, you need to relax and to try to view "through" the image (focusing at infinity)



# Passive stereo



# Stereo image for passive stereo

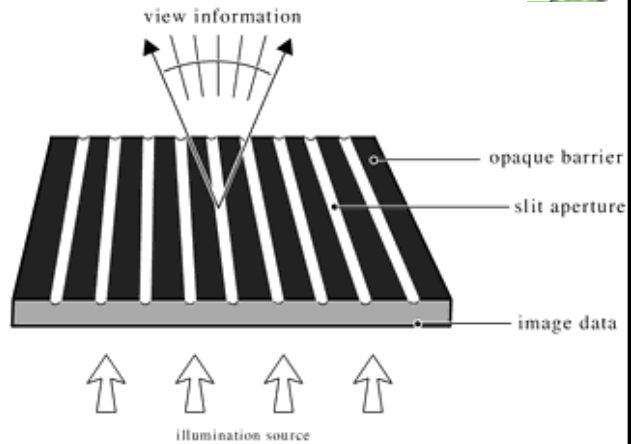




## Stereogram through parallax



Patent of 1903



The image is subdivided into vertical stripes.

Pairs of stripes congruent with a given angle of view are positioned in the proper columns under the lens.

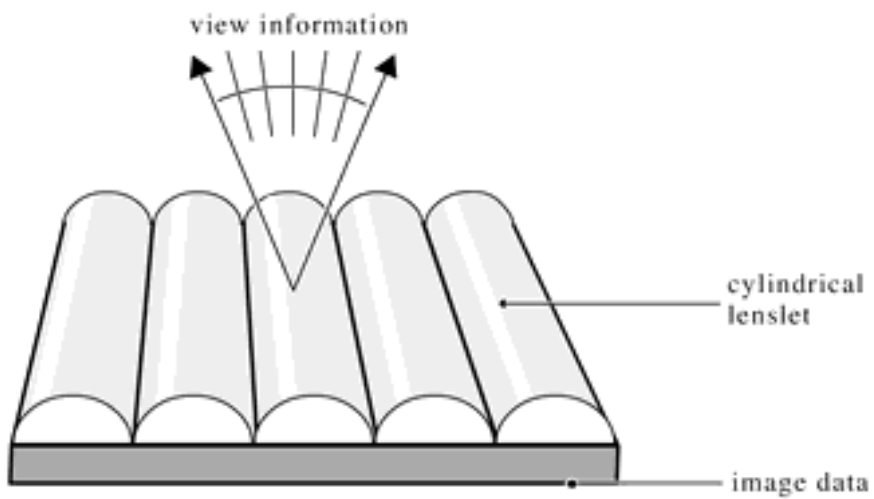
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## Display Autostereoscopici



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## Output devices (eye-glasses)



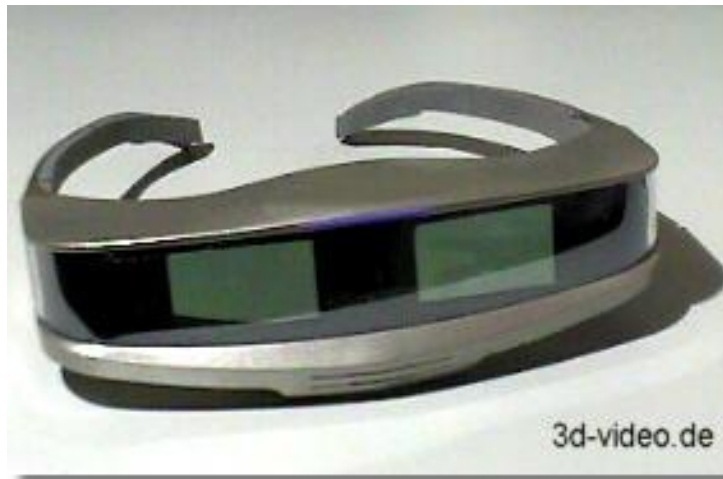
**Semi-immersive:** Eye-glasses (video accuracy, but user is not allowed to move, lateral vision is permitted, which limits virtual realism).



Images are generated multiplexed in time for the two eyes.  
Quad-buffering is used (a pair of double buffers).



## I-glasses (games)





## 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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## Oculus Rift novel HMD: a new hype



Thesis  
Available



**Experience in the lab**

<http://www.oculusvr.com/>

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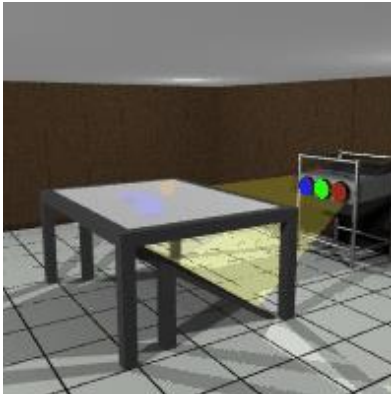
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## Responsive work-bench (Strauss et al., 1995)



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



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## Large screen displays (with or without stereo – see Graphics Lab in Celoria)



### Workwall



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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.





## Nefertari



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## Virtual mannequin



Amazon virtual dressing room: <https://www.youtube.com/watch?v=X3ghb6atM2o>

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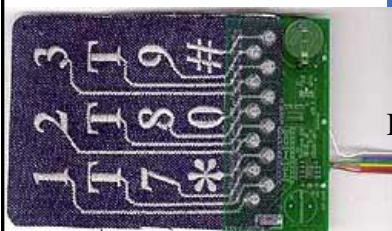
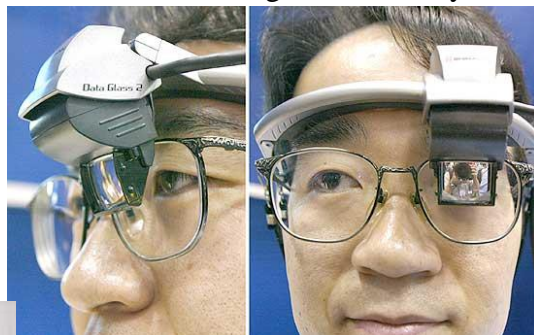
# Virtual mannequin



# Wearable devices – input / output



**Characteristics:** mobile, context sensitive, augmented reality.





## Design: virtual industrial plans



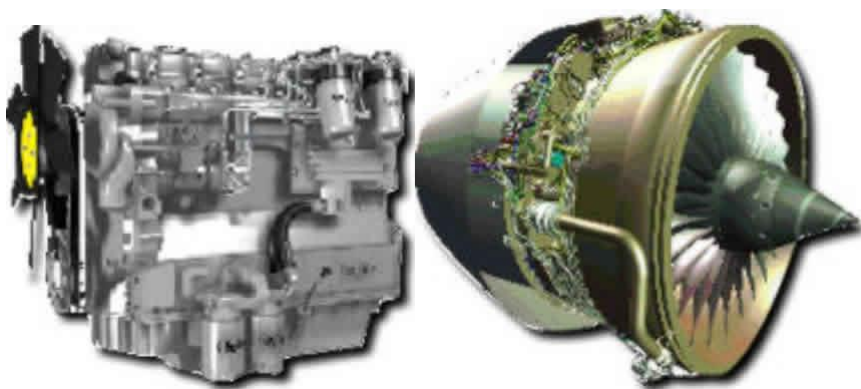
A.A. 2021-2022

70/85

<http://borghese.di.unimi.it>



## Design: virtual engines



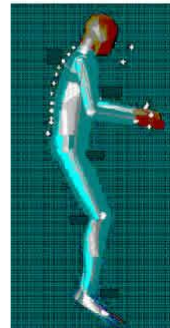
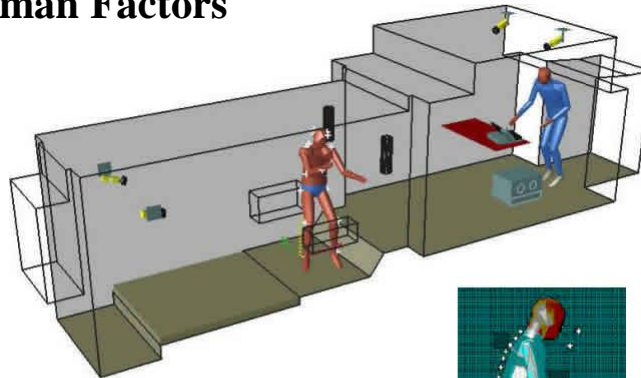
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# Human Factors



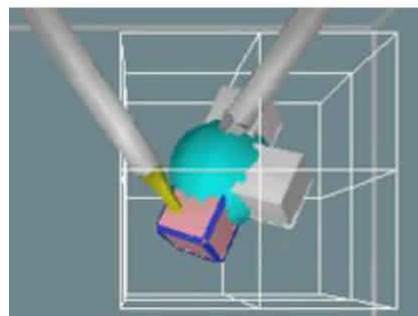
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# Assisted surgery



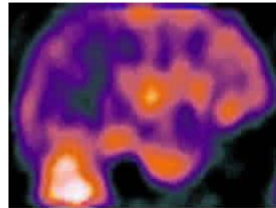
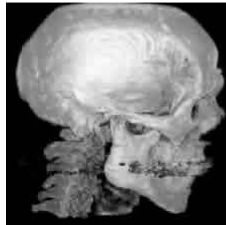
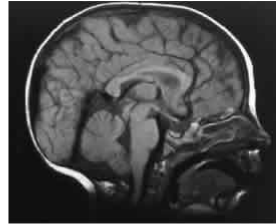
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## Surgery planning through imaging



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## Imaging and 3D printing



Acrylic mandible realized with CAD-CAM technology from CAT images

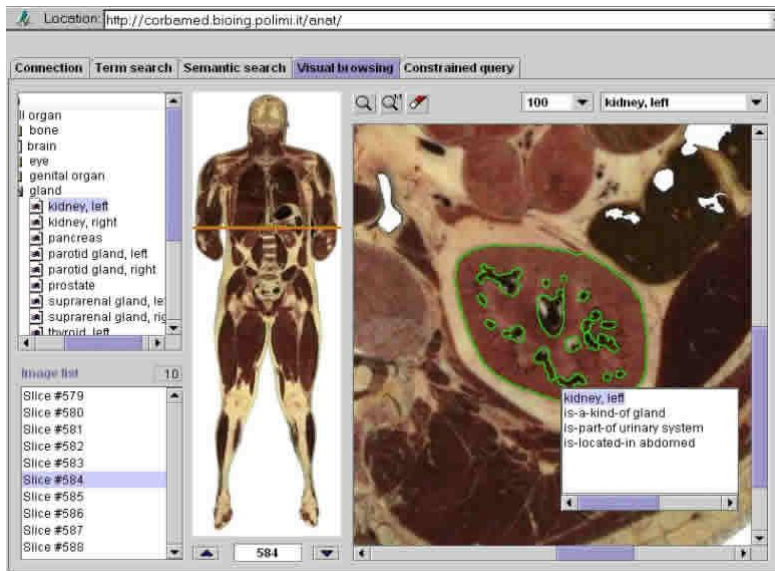
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# Virtual anatomy



# Augmented Reality – Camera movement from video



Applications for smart phone (Vuforia)



# Augmented Reality through Hololens



A new vision for computing, built on a history of innovation

<https://www.microsoft.com/da-DK/hololens>

**Experience in the lab**



# Clinical Motion Analysis

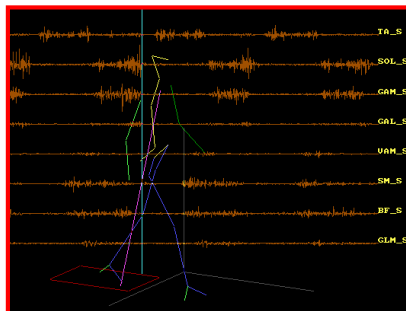


MOTION ANALYSER

FORCE TRANSDUCER

MATHEMATICAL MODELS

EMG



JOINT KINEMATICS

JOINT KINETICS

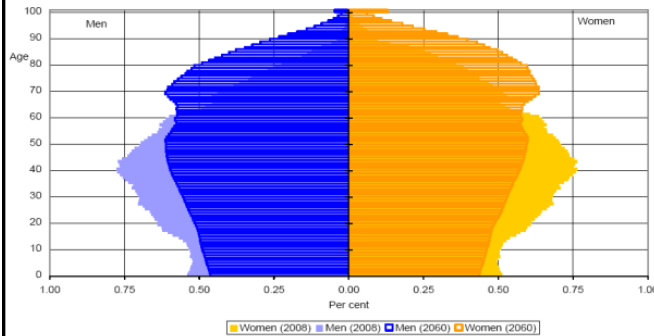
EXTERNAL FORCES

PLANTAR PRESSION

MUSCLE ACTIVATION AND FORCE



# Rehabilitation through VR: Rewire project



Source: Eurostat, EUROPOP2008 convergence scenario

- Increase of rehabilitation need.
- National health providers are facing budget cuts.
- Prolonged intensive rehabilitation allows recovering and/or maintaining health conditions.
- Remote patients can be addressed

ICT recent developments have made possible facing the challenge

<http://www.rewire-project.eu>

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# REWIRE's 3-levels platform



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# IGER – Intelligent Game Engine for rehabilitation



Adaptation



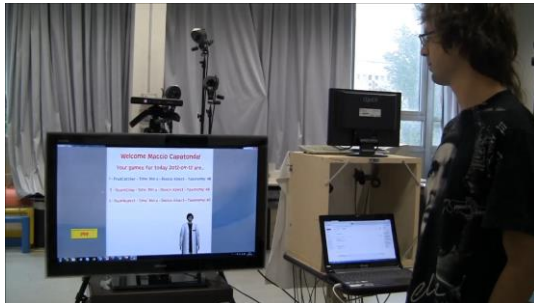
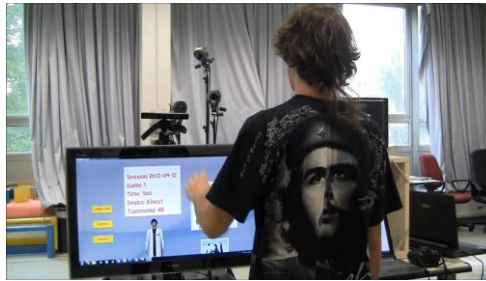
Monitoring



# IGER – NUI interfacing



NUI interfacing



NUI interfacing  
Speech recognition



## Virtual Tosca



## Content



- Introduction
- Input Systems
- World Generators
- Virtual Reality Engine
- Output Systems
- Conclusions