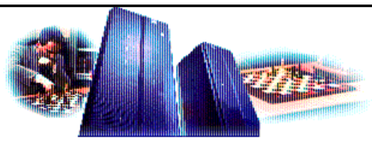
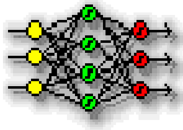




Introduction to Virtual Reality Part II

Alberto Borghese
Applied Intelligent Systems Laboratory (AIS-Lab)
Department of Computer Science
University of Milano

Content

- Introduction
- Input Systems
- World Generators
- Graphical Engine
- Output Systems
- Conclusions

VR - World generators

- Graphics Library:
  - •OpenGL
  - •DirectX
- 2D /3D Graphical Engines:
  - •Realtime
    - •Ogre3D
    - •Irrlicht
    - •SDL/SFML
  - •Non Realtime
    - •Renderman (PIXAR)
    - •Arnold
    - •Cycle (Blender)
- Software that useGraphialEngines:
  - 3D modeling
    - Blender
    - Maya
    - 3D Studio Max
  - Game Engines
    - Panda 3D
    - Unity 3D
    - Unreal

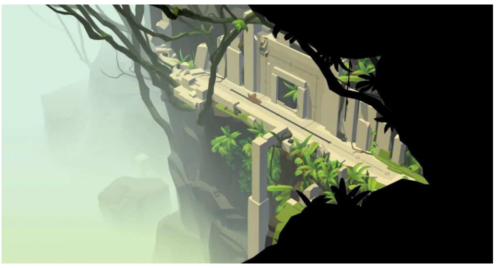
} realtime

Low level

↓

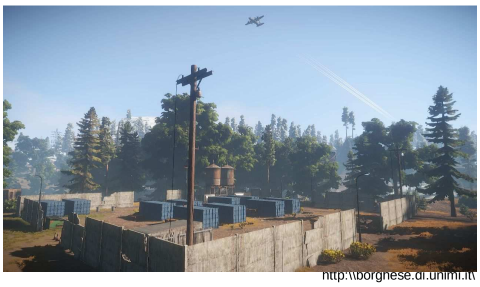
High Level

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 modelling

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.

Rendering
•Colour and Texture
• lights => shadows.

Animation
•Motion (animation)
•Camera tracking (for aumented reality), trasparencies….

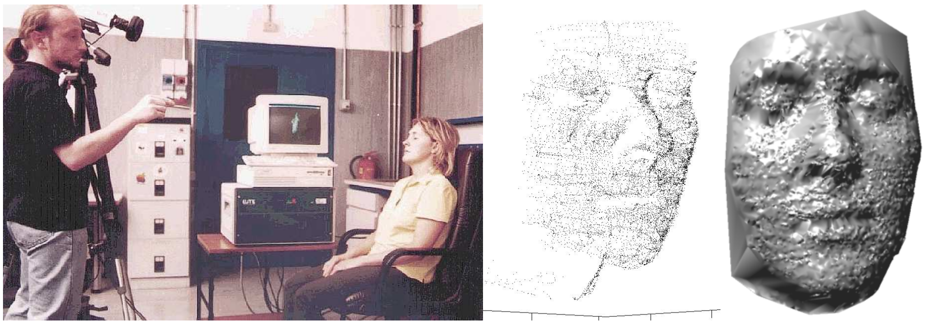
Specialized systems: Finite element models
• It is a class per sé. Local modeling. Mechnical modeling.
• Largely used for animation in medicine (facial animation, deformation of tissue during surgery). Multi-layer modeling.
• Specialized SW are usually associated: Katia, AutoCAD...
• 3D Structure.

Specific CAD for mechanics: Katia, AutoCAD, Nastran SW => **Visual Computing**

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.

Models from range data

Cyberware whole body scanner, WB4

Which problems do you envisage?

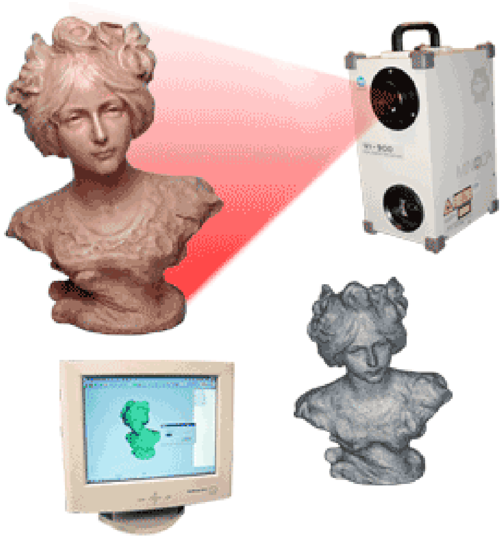
Models from range data (II)

Cyberware smaller model
3030

Models from range data (IV)

Digibot II.
•Platform rotates
•Scanner line translates.

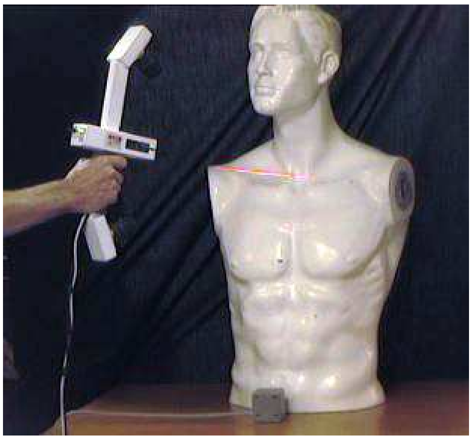
MINOLTA
Scanner Laser 3d



Minolta scanner 3D

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

3D structure from range data (III)



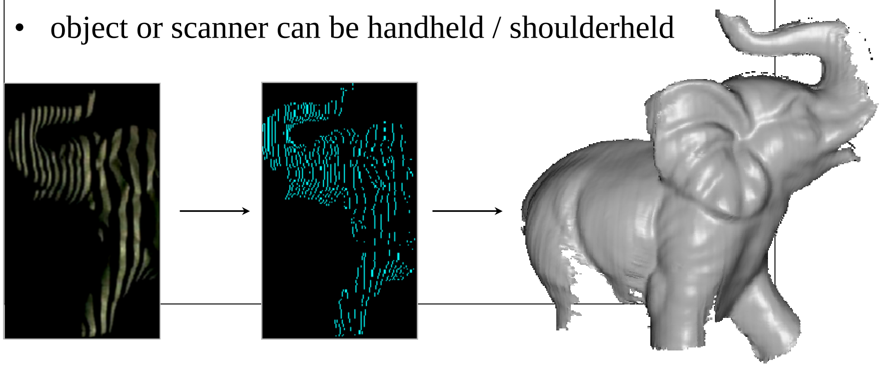
Polhemus hand held laser scanner

Research challenges
Digital Michelangelo project

- vision problems
  - aligning and merging scans
  - automatic hole filling
  - inverse color rendering
  - automated view planning
- 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)

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

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):

•Delauney triangulation (Watson, 1981; Fang and Piegl, 1992). Direct tessellation (no filtering).

• Alpha shapes, Ball Pivoting (Bernardini et al., 2000), Power Crust (median axis transoform, Amenta, 2002). Post processing to regularize a Delauney tessellation.

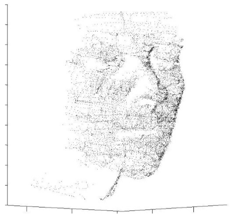
•**Surface fitting to range data**

• Snakes (Kass et al., 1988). Energy based approach. Best curves.

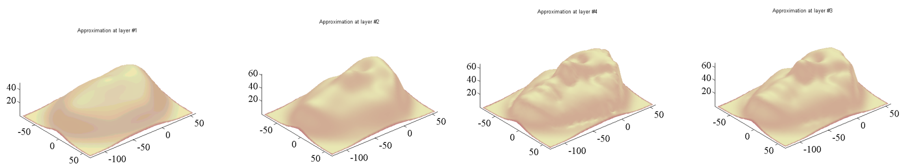
• Kohonen maps (1990).

• Radial Basis Functions Networks (Poggio and Girosi, 1995; Ferrari et al. 2005, semi-parametric models, incremental approach).

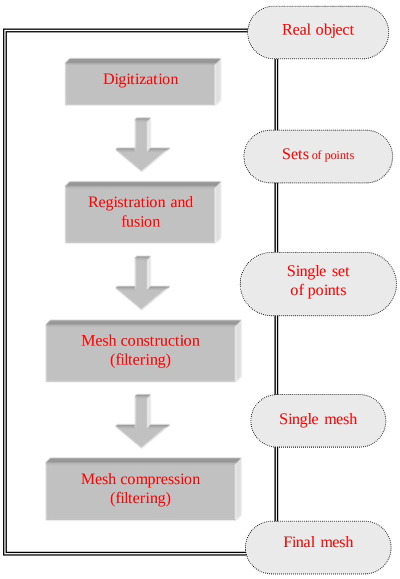
• Support Vector Regression (SVR, A.Smola and B.Scholkopf)



.....



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

Modelling

The most used techniques nowadays are:

- Polygonal modelling -> video-games

- Nurbs
- SubDivision

} Organic shapes, animation movies

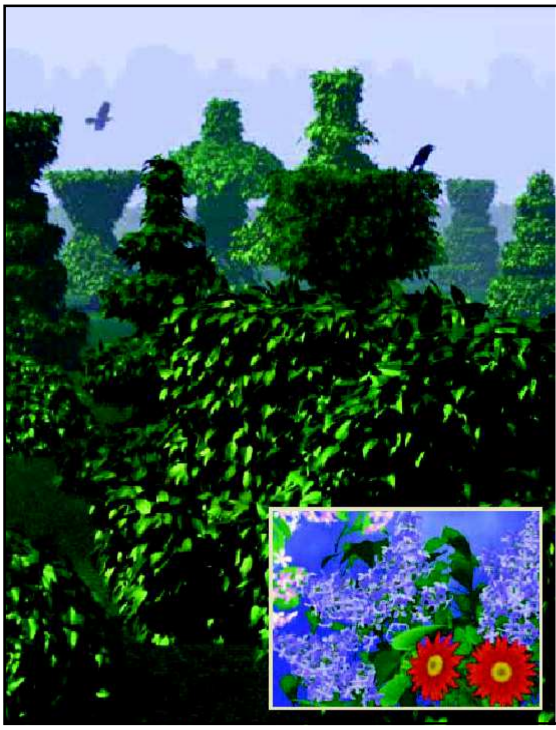
- CSG Boolean operations (e.g. estrusion) -> 3D Print

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. Měch, 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

L-systems

Realizing a plant

Lindenmayer example
variables : X F
constants : + − [ ]
start : X
rules : (X → F−[[X]+X]+F[+FX]−X), (F → FF)
angle : 25°

Here, F means "draw forward", − means "turn left 25°", and + means "turn right 25°". 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.

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    - Unreal

realtime

Low level

High Level

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.
•RealTime application -> low poly

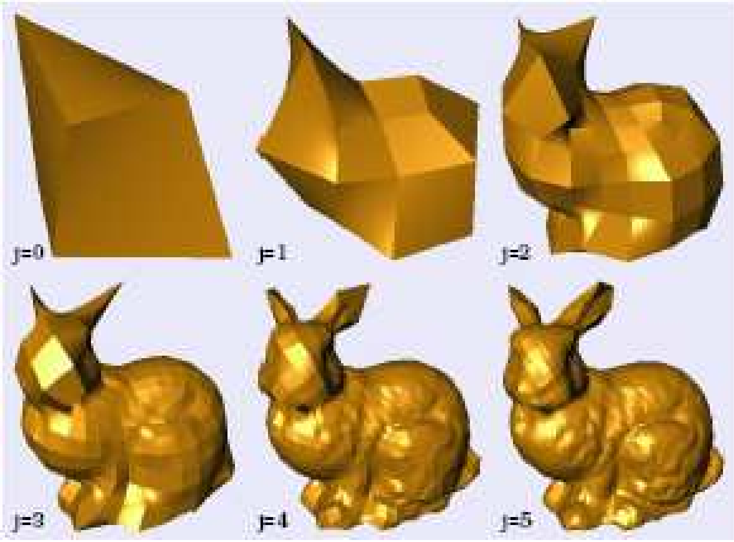
⇓

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
ccw TRUE
solid TRUE
creaseAngle 8
}
}
translation 0 0 0
center 0 0 0
scale 1 1 1
}
]
}
}
```

LOD models

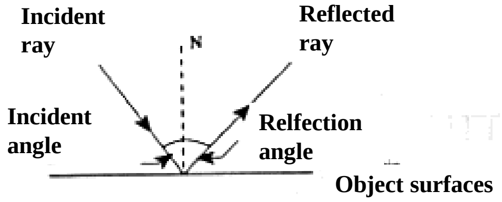


Rendering

Precure 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 relfections, refraction, scattering, tunnelling effects…).

We see what is **sent back (reflected)** by the scene.



The graphical engine (visual computing)

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

Interpolation of normals direction among adjacent triangles (to create the appearence of a continous 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 (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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Augmented Reality – Camera movement from video

Applications for smart phone (Vuforia)

Haptic displays

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

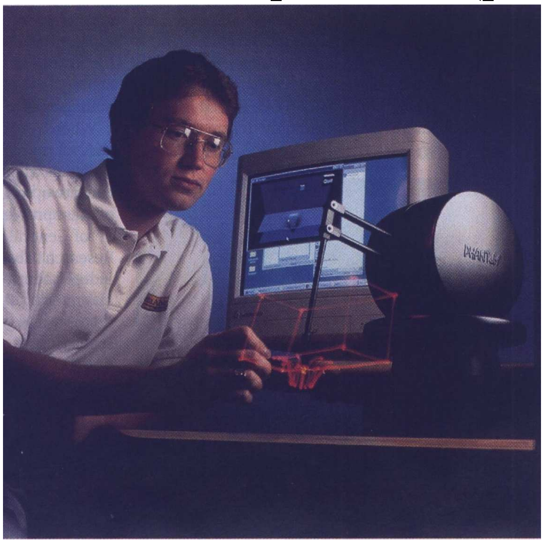
Measure the force exerted by the subject on the virtual environment.

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/

Direct drive manipulandum (phantom)



A similar device (Falcon) si available and used in our lab for rehabilitation

Haptics low cost

Omni Phantom

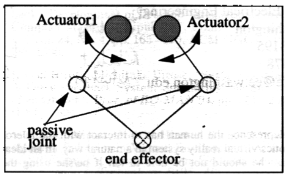
Novint Falcon

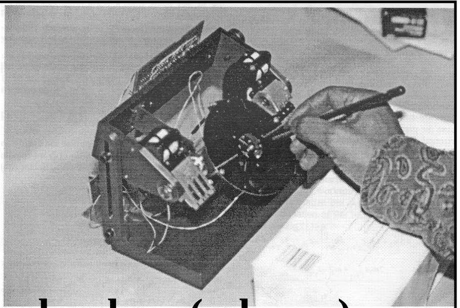
Requirements of Haptic displays

- Large bandwidth.
- Low intertial and viscosity.

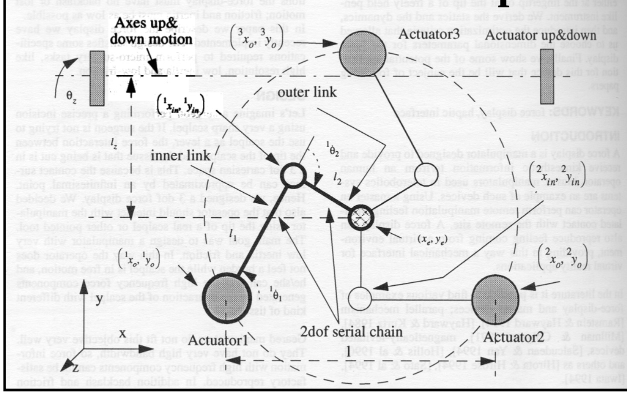
<u>Technological solutions (oggetto intermediario):</u>

- 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)

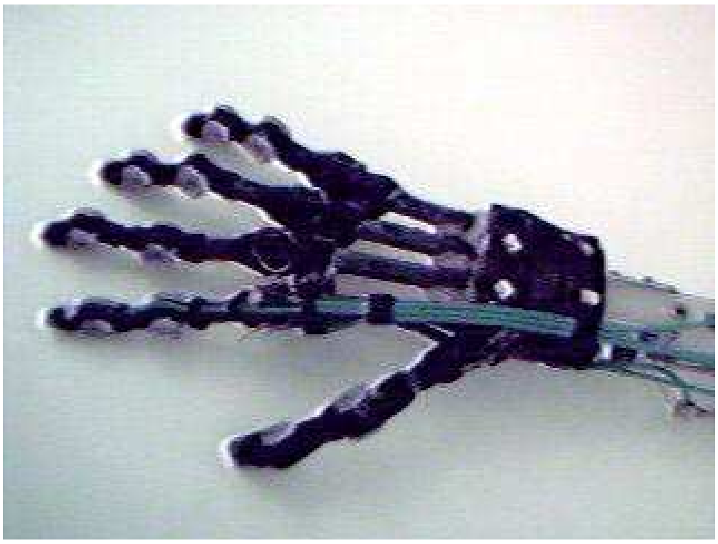


MIT-Manus, 2004

Braccio di ferro, 2010

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

Gloves (Blackfinger, 2000)

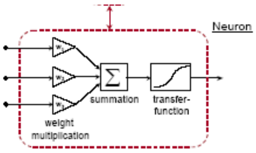


Percro glove (2002)

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

http://www.percro.org

Other output devices



Audio – Stereo, sound spatialization.

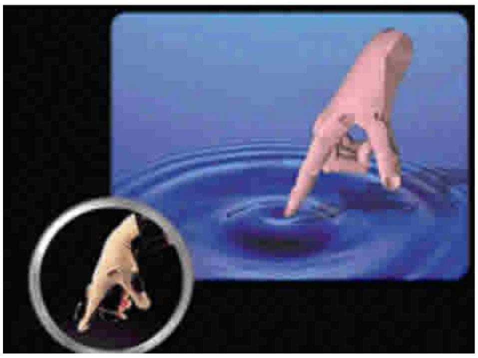
Olfactory – Virtual nose

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

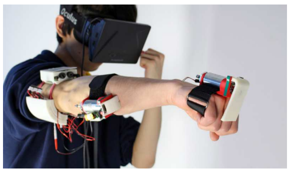
Tactile Stinulators

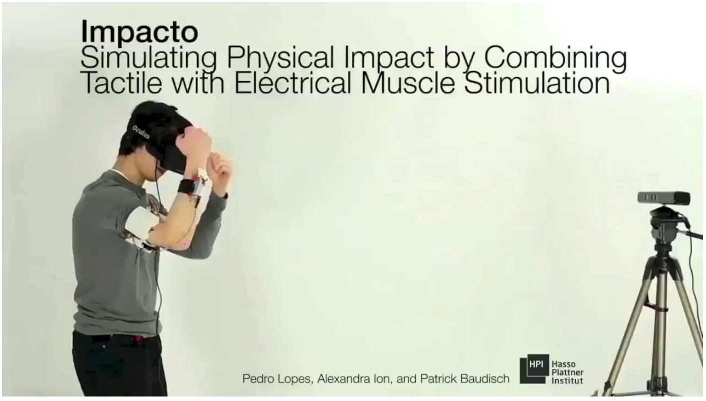
Cyber touch:
- 6 vibrators, 1 for each finger + 1 on palm
- Vibration frequency: 0-125 Hz.
- Vibration amplitude: 1.2 N @ 125 Hz (max).

Iwamoto & Shinoda
University of Tokio



The future?





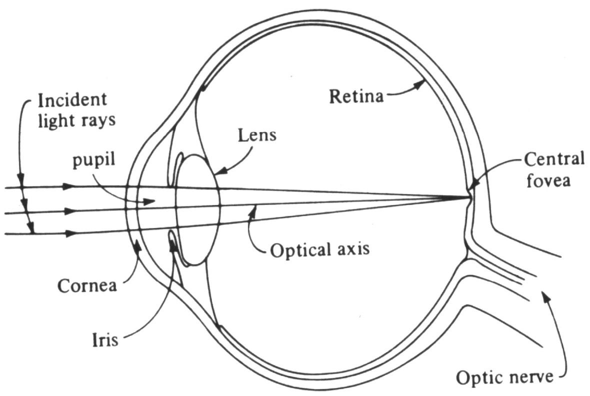
Sistemi di Output::visione

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).

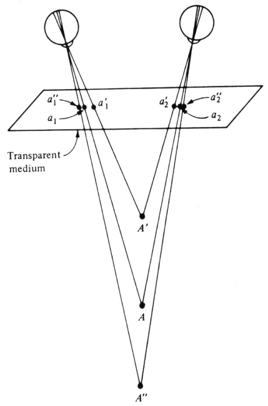
Requirements for the world generator:
•Stereoscopic vision for objects with D < 10m.
•Monocular cues for objects with D > 10m.
- - Occlusions.
- - Geometrical perspective and a-priori model knowledge.
- - Shading.
- - Motion.

Human eye



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

Stereo-disparity

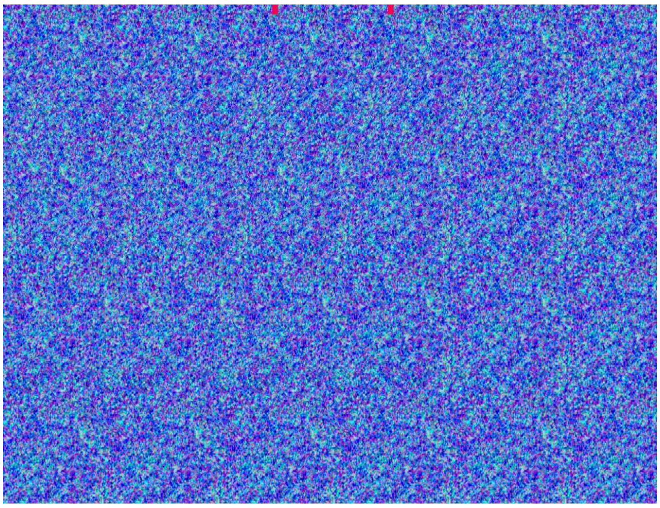


Points further away are projected on points closer to the image center.

Vergence and focusing are strictly connected.

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

Autostereogram



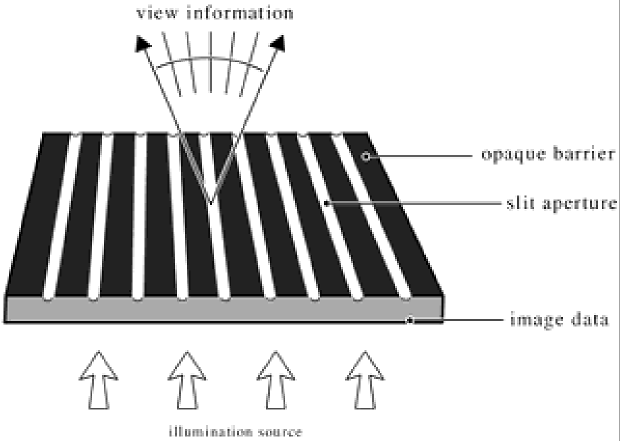
To see the 3D image, you need to relax and to try to view "through" the image (focusing at infinity)

Passive stereo

Stereo image for passive stereo

Stereogram through parallax

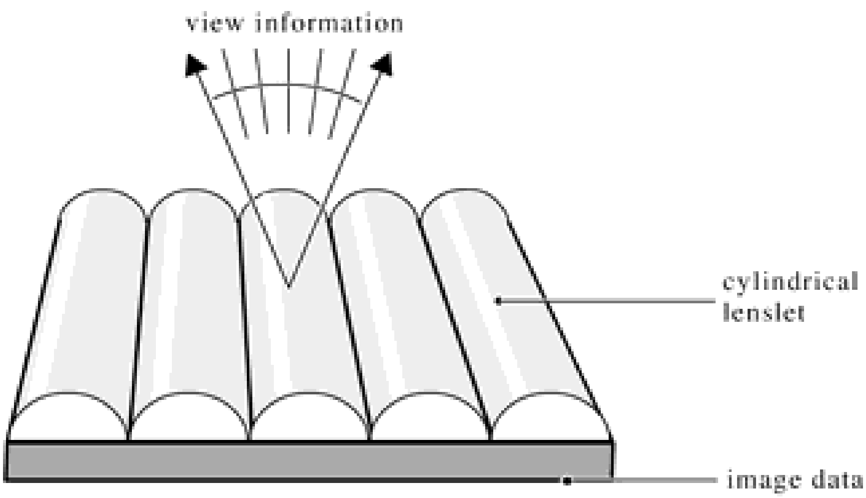
Patent of 1903



The image is subdivided into vertical stripes.

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

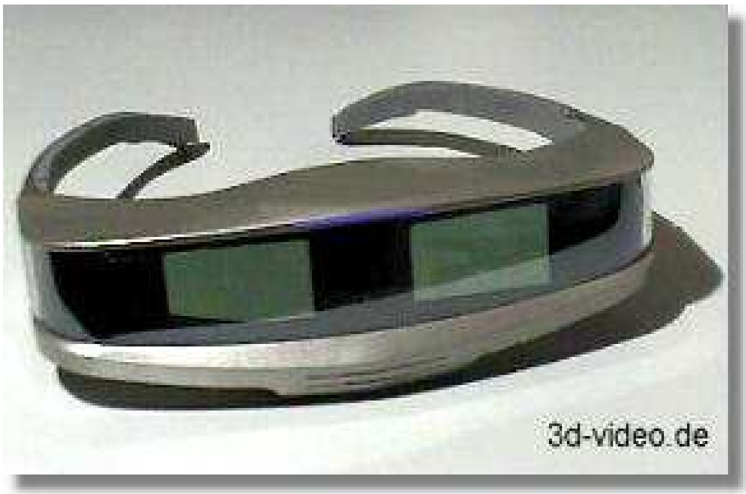
Display Autostereoscopici



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.

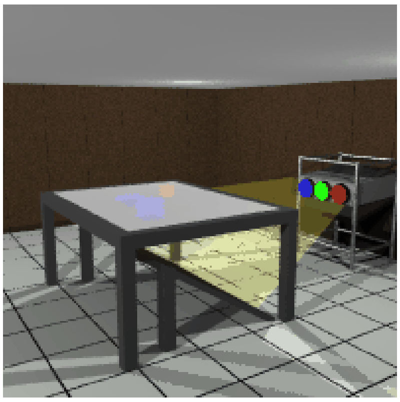
Oculus Rift novel HMD: a new hype

Thesis
Available

http://www.oculusvr.com/

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 (with or without stereo – see Graphics Lab in Celoria)

Workwall

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VR

Immersion and interaction
(deceive our sensorial systems)

User input to interact
Simulation of the Virtual World
Output adequate to feel immersed

Applications

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

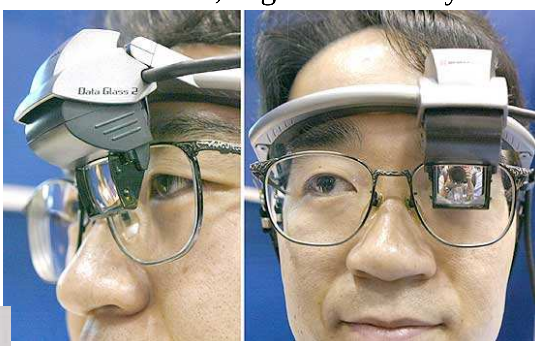
Nefertari

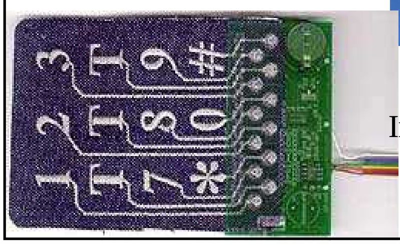
Virtual mannequin

Cf. EPFL

Wearable devices – input / output

Characteristics: mobile, context sensitive, augmented reality.



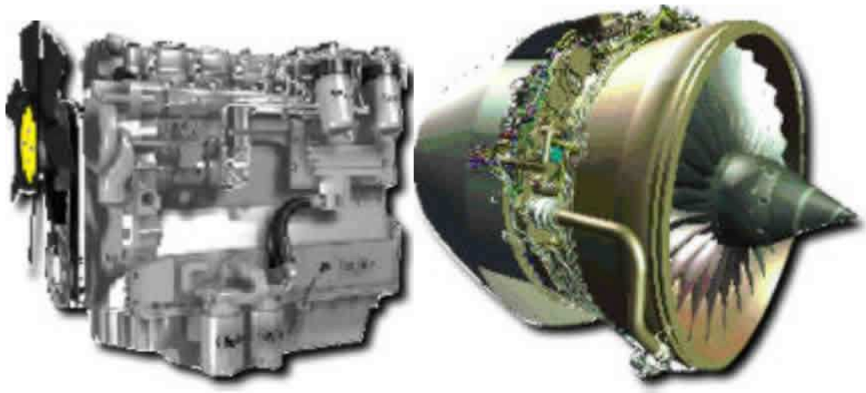


Interface on cloth

Design: virtual industrial plans

A.A. 2016-2017 69/82 http:\\borghese.di.unimi.it\

Design: virtual engines



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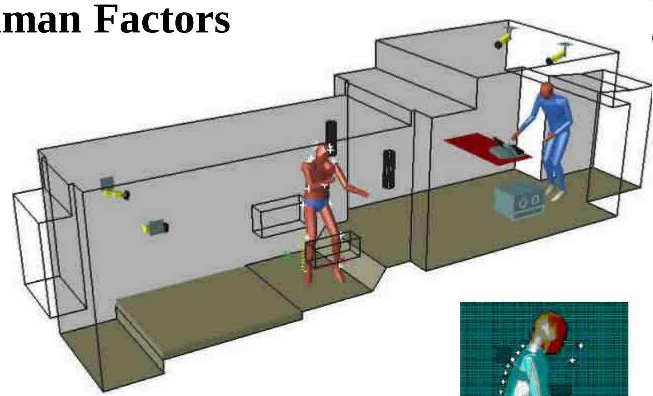
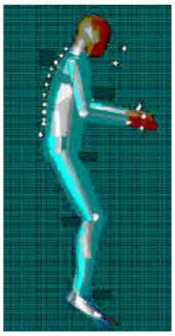
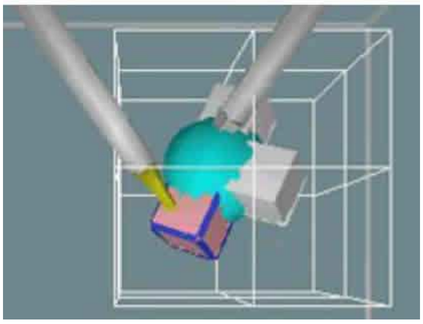
Human Factors

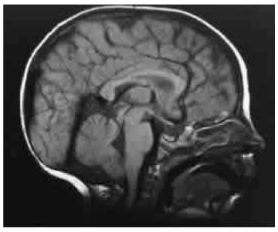


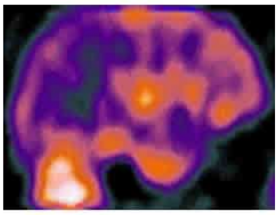


Assisted surgery



Surgery planning through imaging

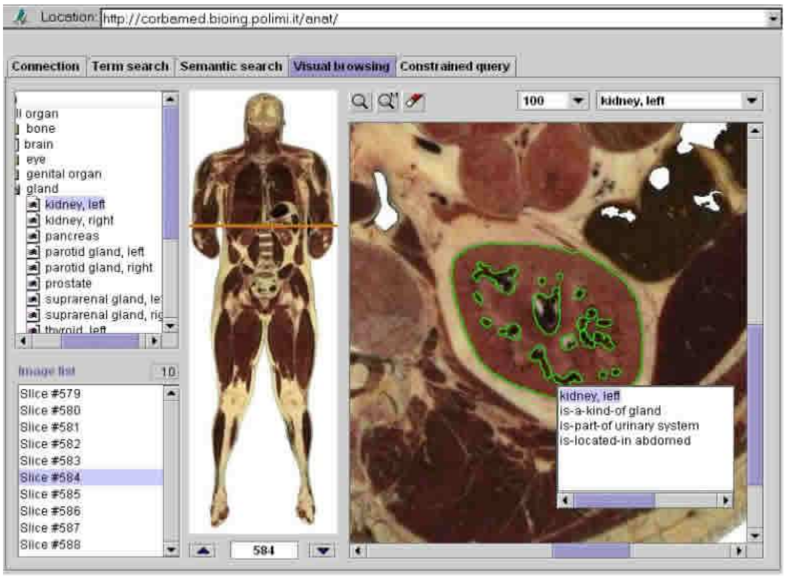




Imaging and 3D printing

Acrylic mandible realized with CAD-CAM technology from CAT images

Virtual anatomy



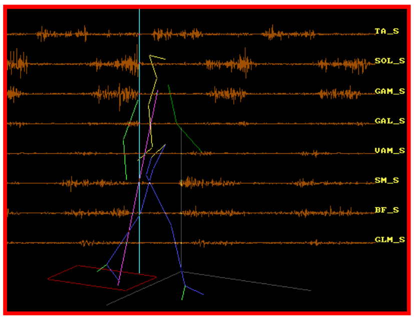
Clinical Motion Analysis

MOTION ANALYSER

FORCE TRANSDUCER

MATHEMATICAL MODELS

EMG



JOINT KINEMATICS

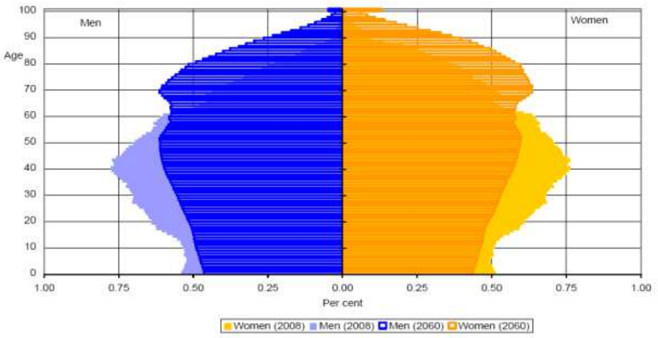
JOINT KINETICS

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

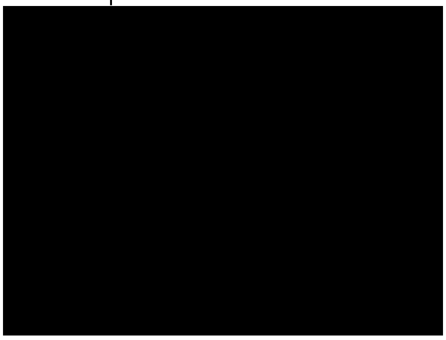
ICT recent developments have made possible facing the challenge

http://www.rewire-project.eu

REWIRE's 3-levels platform

IGER – Intelligent Game Engine for rehabilitation

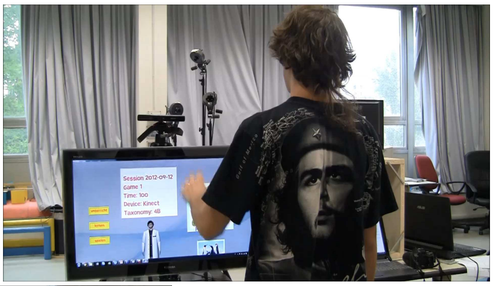
Adaptation

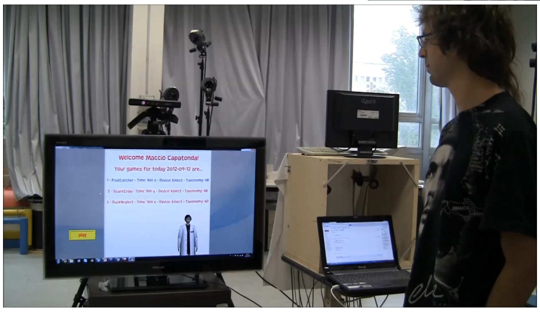


Monitoring

IGER – NUI interfacing

NUI interfacing





NUI interfacing

Speech recognition

Virtual Tosca

Content

- Introduction
- Input Systems
- World Generators
- Graphical Engine
- Output Systems
- Conclusions

Sommario

- Introduzione
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