An Augmented Reality Medical Training Tool

Felix G. Hamza-Lup
Computer Science, Univ. of Central Florida
Advisor: Dr. Charles Hughes,
Dr. Jannick Rolland

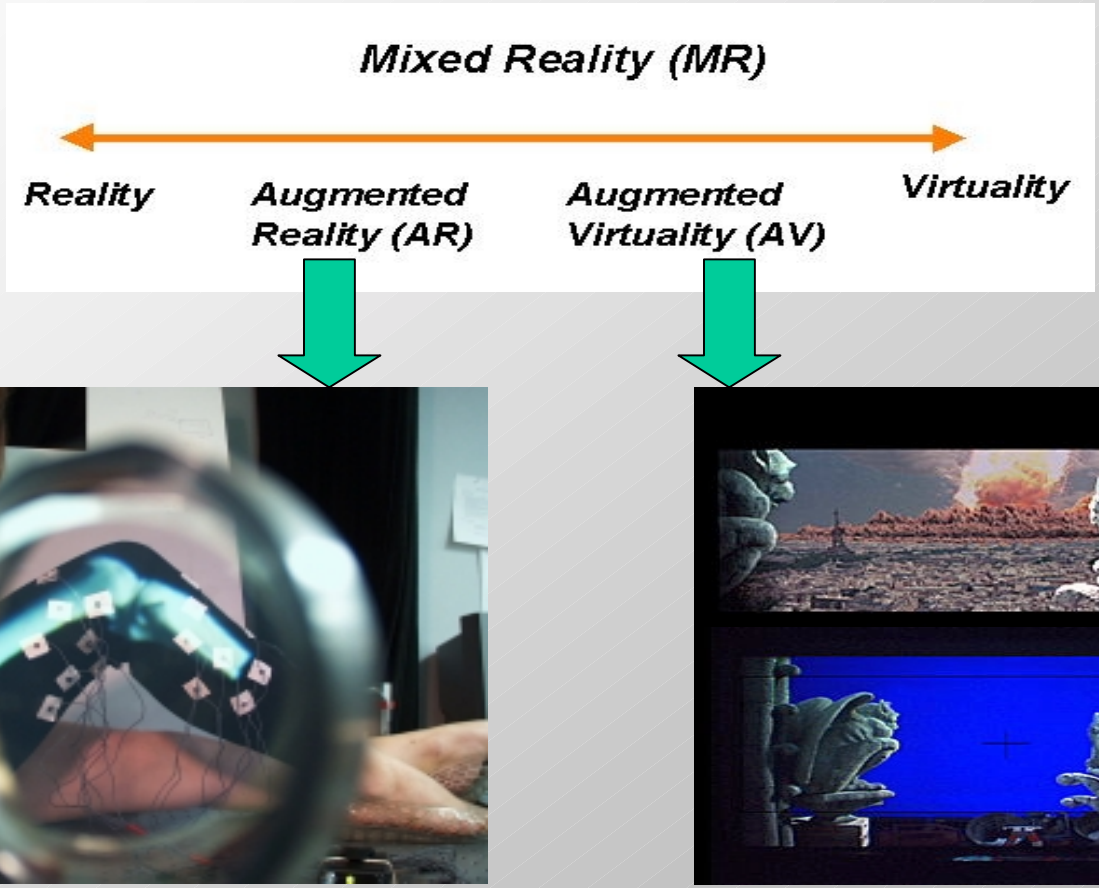
Outline

- Introduction
  - What is Augmented Reality?
  - Application Domains
- AR Systems
- Airway Visualization System
  - hardware components
  - software components
- Infrared Light Emitting Diodes (IREDs) distribution algorithms
- Future Work

What is Augmented Reality?

- Augmented Reality (AR) is a growing area in Virtual Environment research
- AR is a ***computer generated (partially)***, ***interactive***, three-dimensional environment in which a person is ***immersed***
  - *Computer generated*: who else could do it ?
  - *Partially*: only some of the objects in the 3D scene are computer generated
  - *Interactive*: needs real time computation
  - *Immersed*: needs a device to give this impression (ex. HMD)
- Methods for augmented reality (AR) generally include
  - calibration procedure
  - dynamic superimposition procedure to bring virtual objects *in register* with real objects.

Virtual environment taxonomy



Application Domains

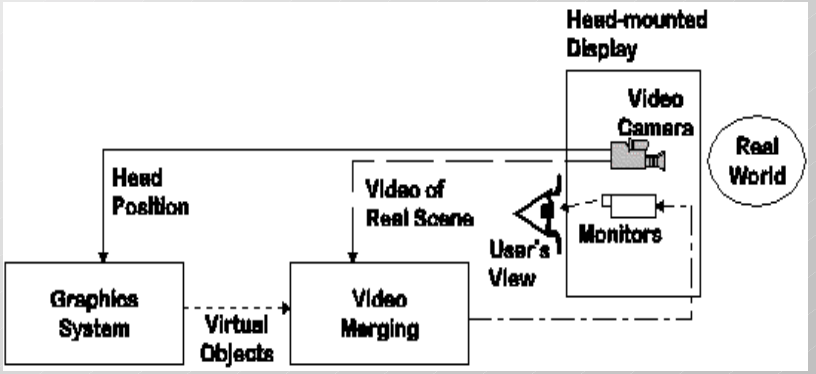
- Training (*Medical*,*Technical*, *Military etc*)
- Entertainment
- Engineering Design
- Consumer Design
- Robotics and Telerobotics
- Manufacturing, Maintenance and Repair
- more to come...

Components of a typical AR system

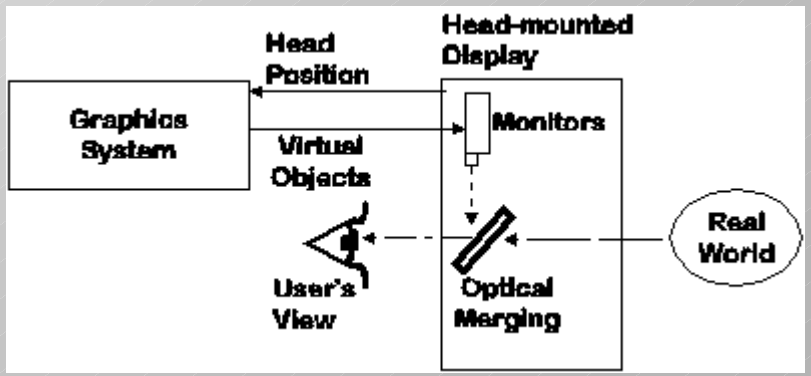
- Visualization device
  - Head Mounted Display
- Tracking System
- Rendering System

Head Mounted Display

- Video see through
  - traditional
  - hybrid



- Optical see through
  - projective (real image)
  - eyepiece (virtual image)



Tracking Systems

- Gives the position and orientation of the 3D objects in the virtual environment
- Types:
  - mechanical
  - magnetic
  - optical
  - acoustic
  - inertial
  - hybrid

Rendering System

- Compute the viewing transformations to render 3D models in register with the real objects.
- Rendering is done at interactive speed (close to real time)

Airway Visualization Project

- Purpose:
  - Visualization of internal anatomy for medical training
    - Endotracheal intubation
  - Deployable system

Courtesy: Stephen Johnson, ODALab

System Components

- Hardware components
  - Head Mounted Projective Display (HMPD)
    - Mannequin & retroreflective material
  - Tracking Systems (Polaris Northern Digital)
  - Linux-based PC
- Software components
  - 3D Models of the Airway (Open Inventor)
  - Tracking layer
  - Calibration module
  - Visualization module

Head Mounted Projective Display

- Custom built optical see-through HMPD
  - Images are formed using projection optics
  - It projects computer-generated images into the environment
  - Uses a retro-reflective screen instead of a diffusing projection screen

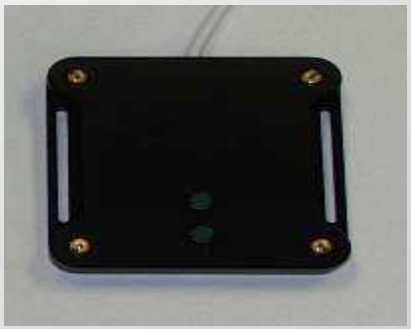
Mannequin and retroreflective material

- Human patient simulator
- Medical intubation device
- Retroreflective material

Tracking system

- Polaris Tracking System: used to determine the position and orientation of real objects within the environment

- Probe = rigid configuration of IREDs
- IRED probes:
  - HMD probe - tracks the HMD position
  - Mannequin probe- gives the manequin's chin position
  - Digitizing probe - gives the 3D position of the probe tip

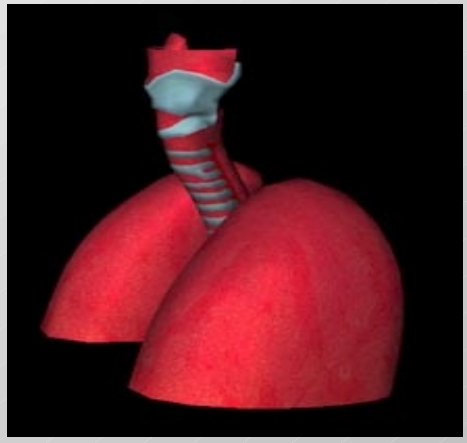


Linux-based PC

- 1 GHz Athlon
- GeForce2 MX dual-head
- RedHat 7.2

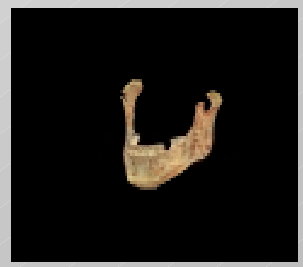
3D Models

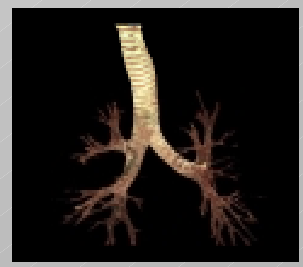
- Preliminary model
  - Trachea and Lungs 3D Open Inventor Model



Courtesy: Seth Frolich, IST

- Realistic model from the Visible Human Data Set
  - trachea & bronchial tree
  - mandible





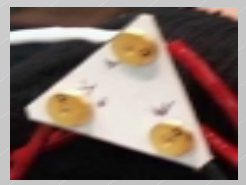
Courtesy: Celina Imielinska, Columbia University

Tracking Layer - main functionality

- Software layer for:
  - initialization and configuration of the tracking system
  - reading the 3D transformation for each probe
  - data parsing and conversions
  - communication on serial port
- Implemented in C++ (Linux platform)

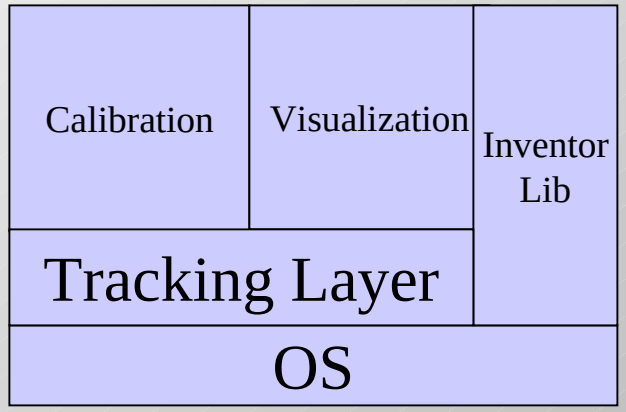
Tracking Layer - how it works

- Each probe is on a separate port:
  - reads the location and orientation for each probe
  - converts ASCII data into floating point
  - transformation is in quaternion format



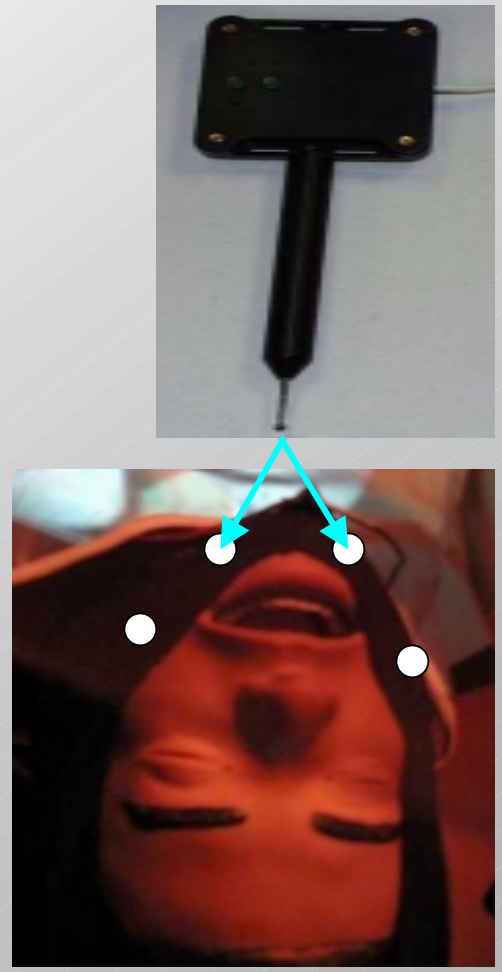
Calibration Module

- Software module used in the calibration procedure applied on the mannequin
  - Input: data from serial port 3
  - Output: position of the landmarks on the real object in mannequin probe coordinate system.
- Implemented in C++



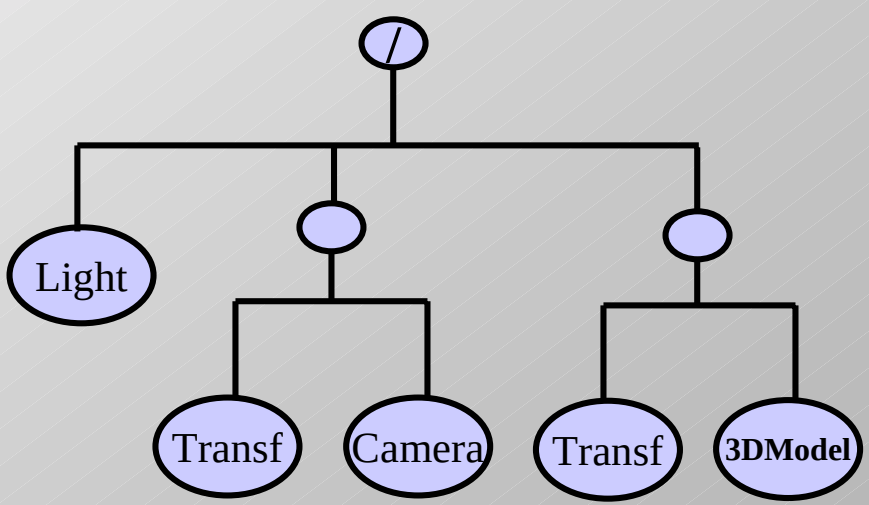
Calibration - steps

- Read data from calibration probe for 4 points (landmarks) on the mannequin mandible
- Compute the landmarks coordinates taking into account the probe tip offset (*in GCS*)
- Compute the transformation from GCS to the mannequin probe system.
- Compute the transformations from 4 points from the 3D Model to the landmarks



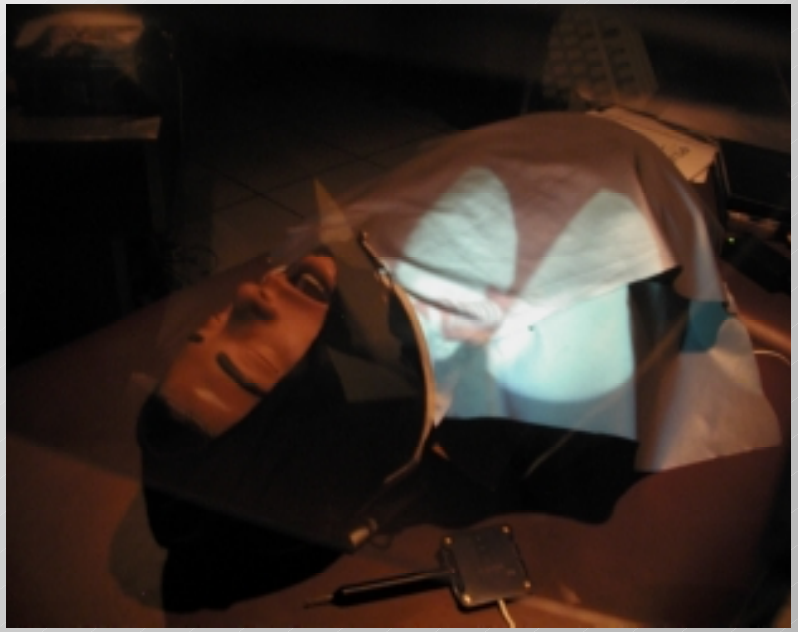
Visualization module

- Uses Open Inventor libraries to render the projection scene.
- Scene graph is the same for both eyes except for the camera transformations



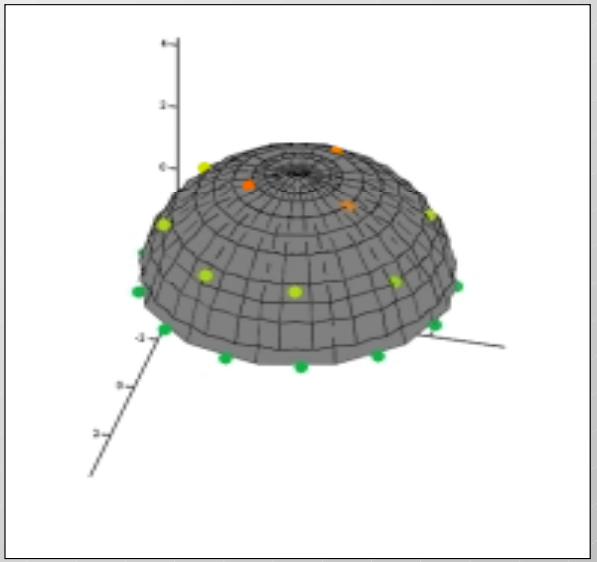
Visualization module - main steps

- Read HMPD p&o (camera p&o in the scene), mannequin p&o and transformation matrix from calibration module.
- Combine transformations and render 3D model at proper position relative to the HMPD (camera) location



IREDs distribution

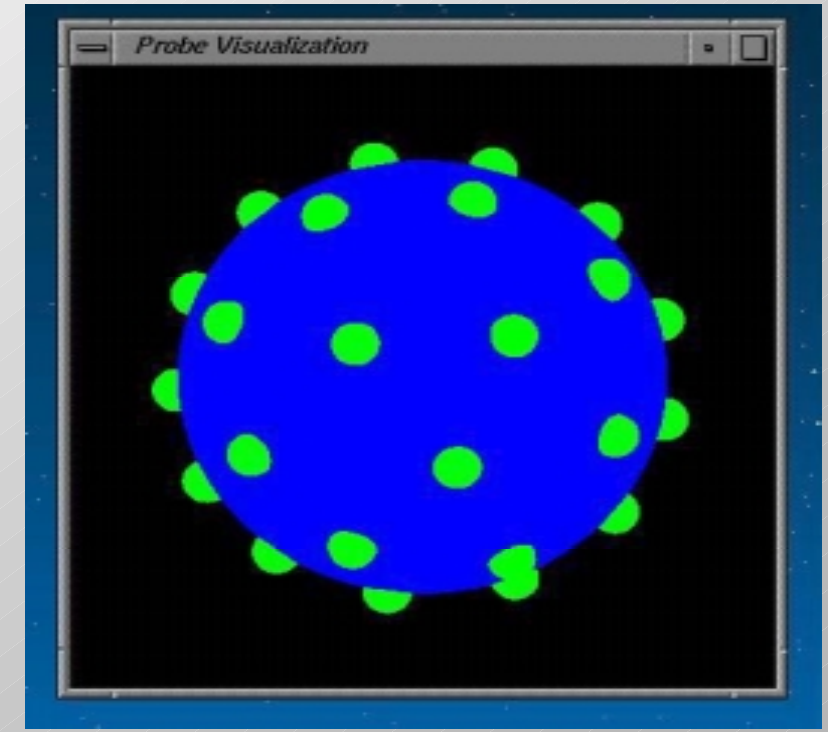
- Enhancing and implementing the algorithms for IRED's positioning on irregular shaped and amorphous 3D objects



(f, g, h), (x1, y1, z1)

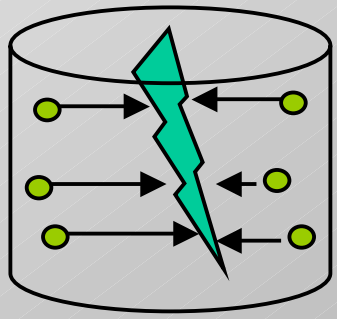
Distribution on irregular objects

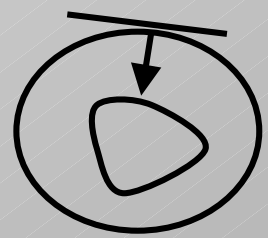
- Intermediary regular surface
- Simulated annealing
- Mapping or Electrostatic field approach



Algorithm 1 (texture mapping approach)

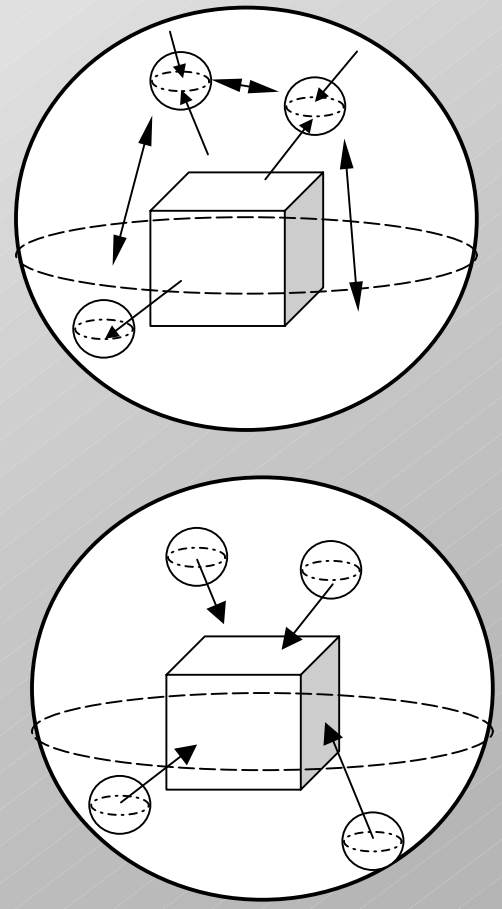
- 3D scan of the irregular object to obtain a ***triangular mesh*** approximation of the 3D object.
- Distribute the points onto a regular **intermediate** 3D object
  - sphere for irregular objects ***without*** concave depressions
  - cylinder for irregular objects ***with*** concave depressions
- Apply two-dimensional texture mapping :
  - using the normal from the intermediate surface





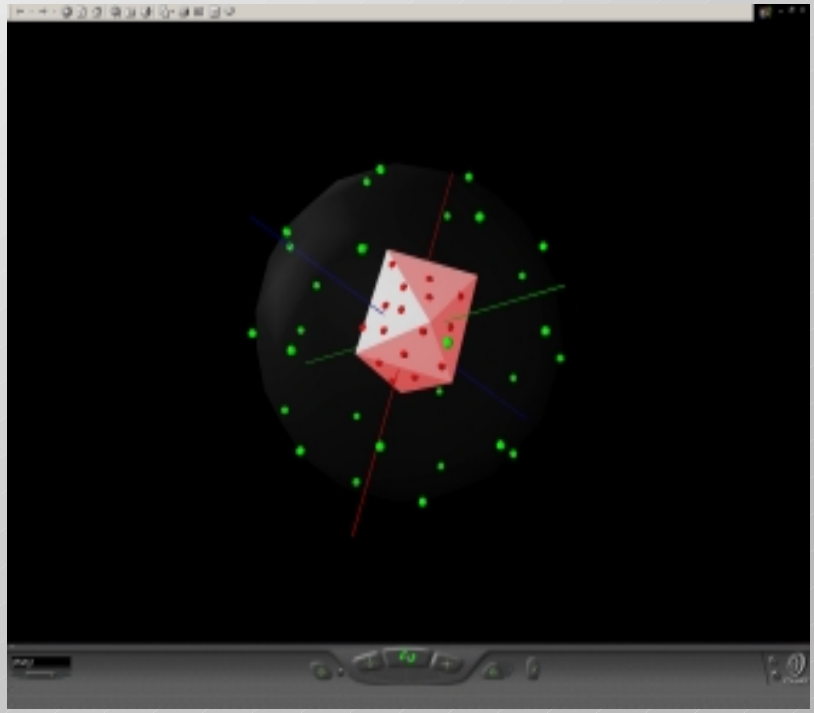
Algorithm 2 (electrostatic field approach)

- Surround the irregular object with a sphere which is positively(+) charged. Each IRED is represented by a dot positive(+) charge.
- Place the IRED inside the sphere volume but outside the object.
- Allow for the dot charges to reach equilibrium.
- Change the charge of the 3D object to negative (-)



Experimental results

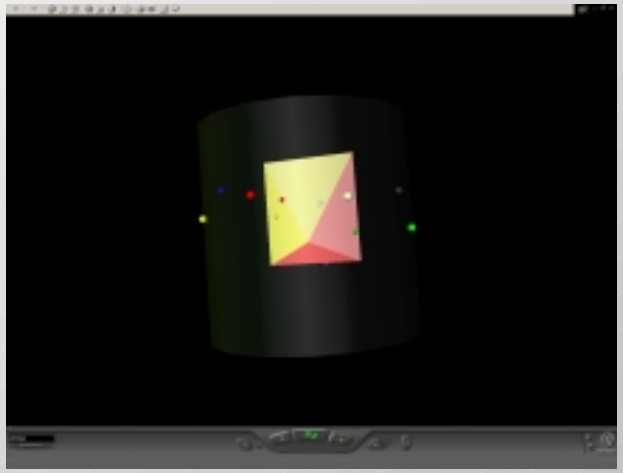
- Annealing followed by texture mapping
- 30 IREDs
- Triangular mesh composed of 10 triangles
- WRML output

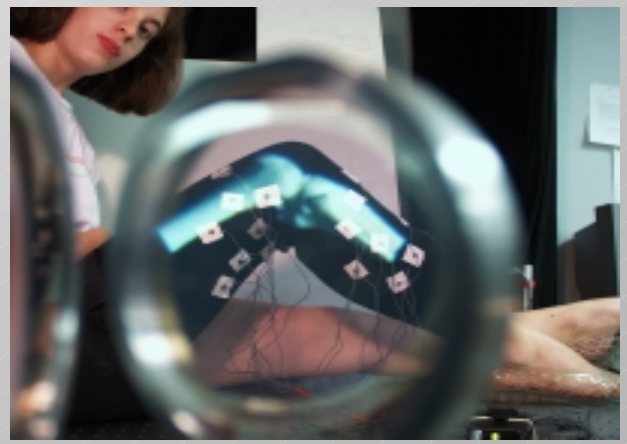


Cylindrical intermediary surface

- For objects of cylindrical shape
- Principal axis of symmetry alignment

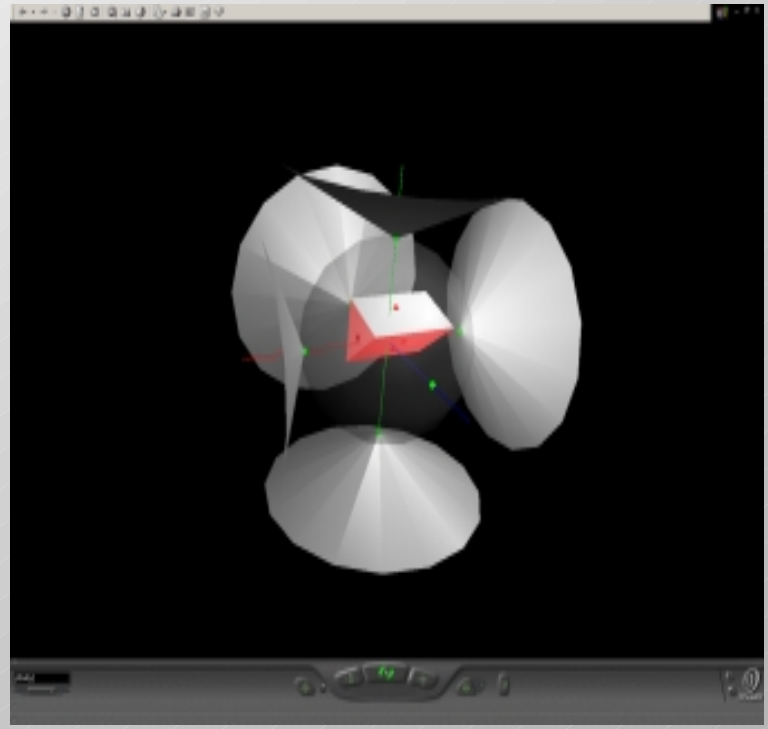
- Medical applications
  - leg ,arm, torso





FOV – Field of View

- IREDS
  - limited FOV
  - limited number
- Algorithms assessment



Future Work

- Building a dynamic model of the airway to simulate in real time the inhaling/exhaling process.
- Remote collaboration and visualization
- Enhancing the IREDs distribution algorithms
- Extending for amorphous objects

Acknowledgements:

Dr. Jannick Rolland
Dr. Charles Hughes
Larry Davis
and
ODALab team