

*An Augmented Reality
Medical Training Tool*

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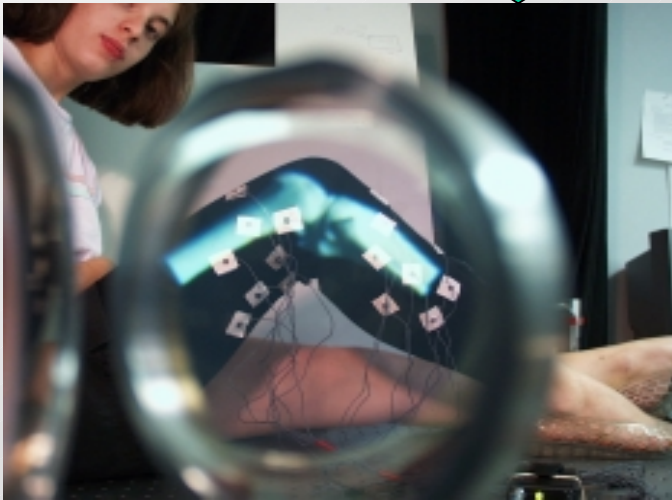
Outline

- 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

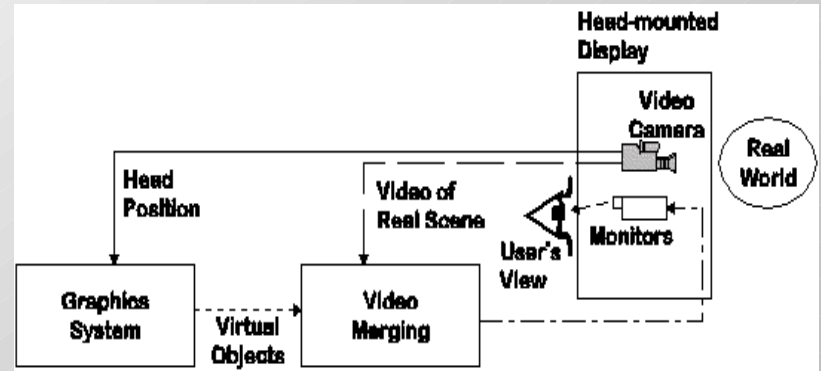
- Training (*Medical, Technical, Military etc*)
- Entertainment
- Engineering Design
- Consumer Design
- Robotics and Telerobotics
- Manufacturing, Maintenance and Repair
- more to come...

Components of a typical AR system

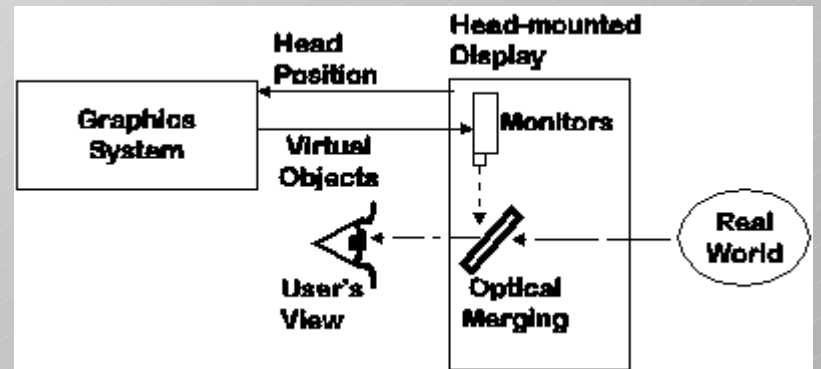
- Visualization device
 - Head Mounted Display
- Tracking System
- Rendering System

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



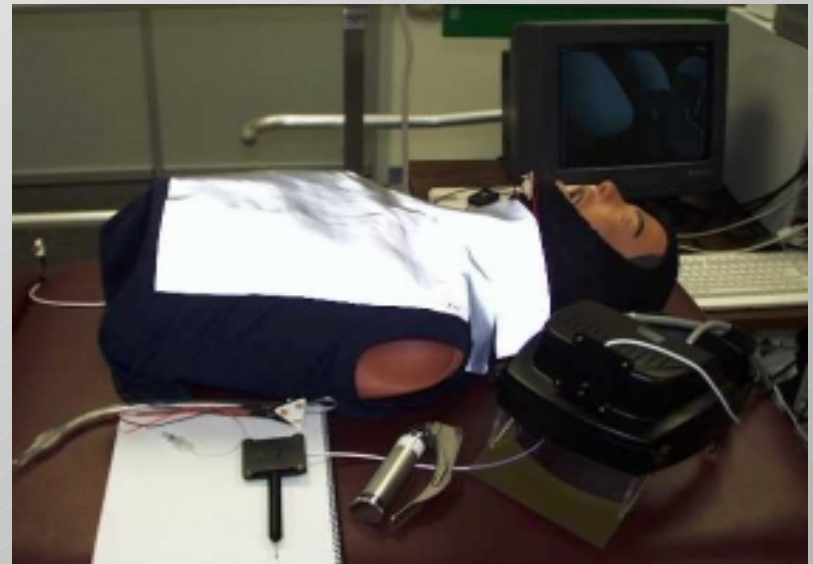
Rendering System

- 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



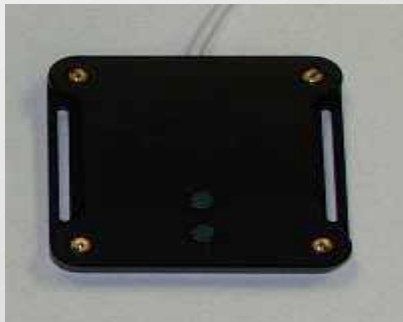
Mannequin and retroreflective material

- 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 mannequin's chin position
 - Digitizing probe - gives the 3D position of the probe tip

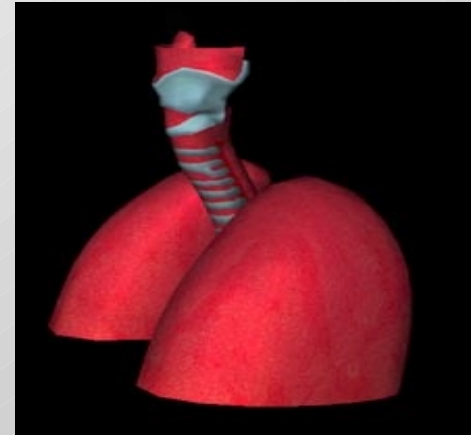


Linux-based PC

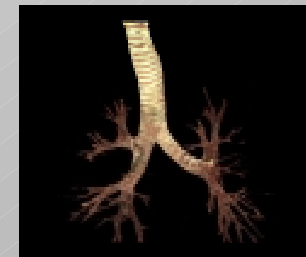
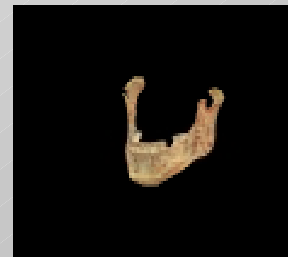
- 1 GHz Athlon
- GeForce2 MX dual-head
- RedHat 7.2

3D Models

- Preliminary model
 - Trachea and Lungs 3D Open Inventor Model
- Realistic model from the Visible Human Data Set
 - trachea & bronchial tree
 - mandible



Courtesy: Seth Frolich, IST



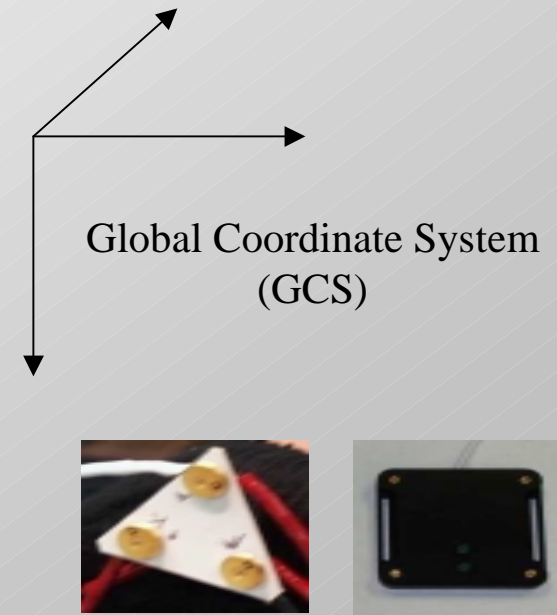
Courtesy: Celina Imielinska, Columbia University

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)

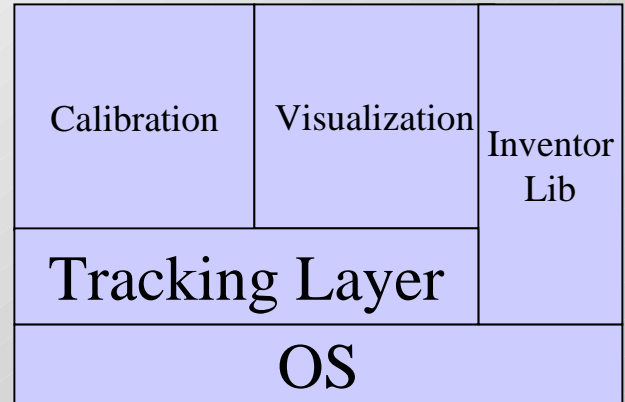
Tracking Layer - how it works

- 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



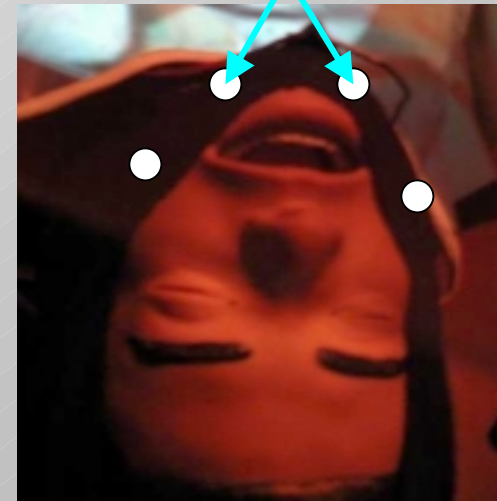
Calibration Module

- 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++



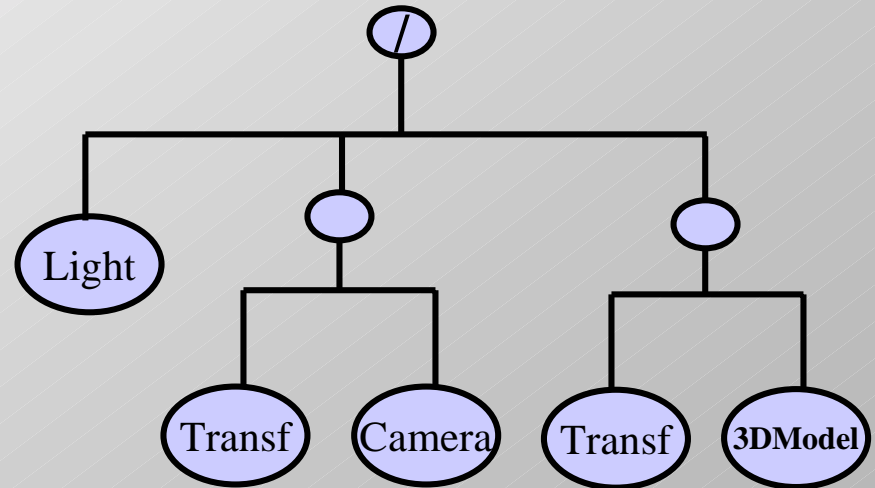
Calibration - steps

- 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



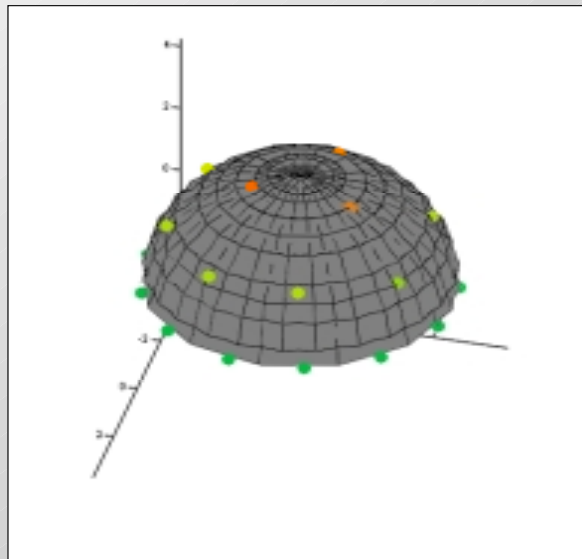
Visualization module - main steps

- 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

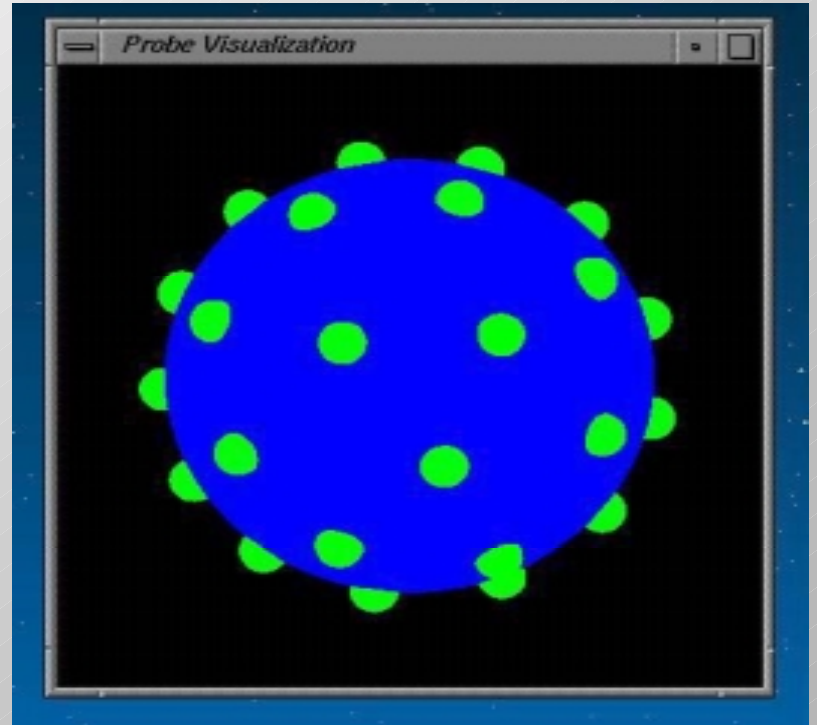
- Enhancing and implementing the algorithms for IRED's positioning on irregular shaped and amorphous 3D objects



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

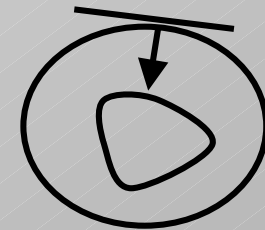
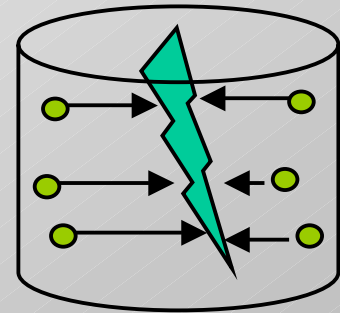
Distribution on irregular objects

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



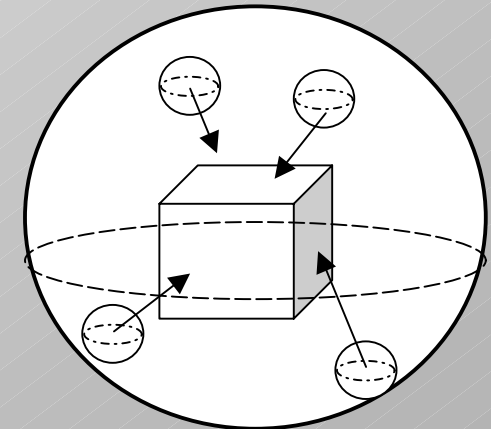
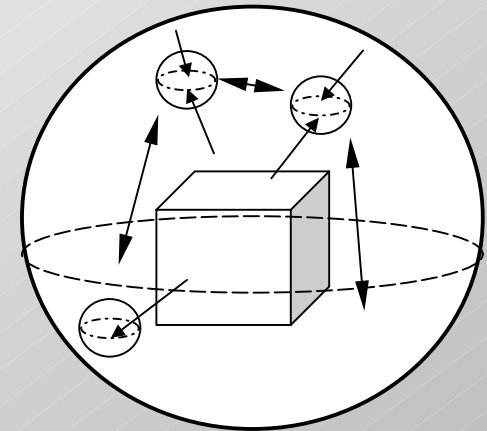
Algorithm 1 (texture mapping approach)

- 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



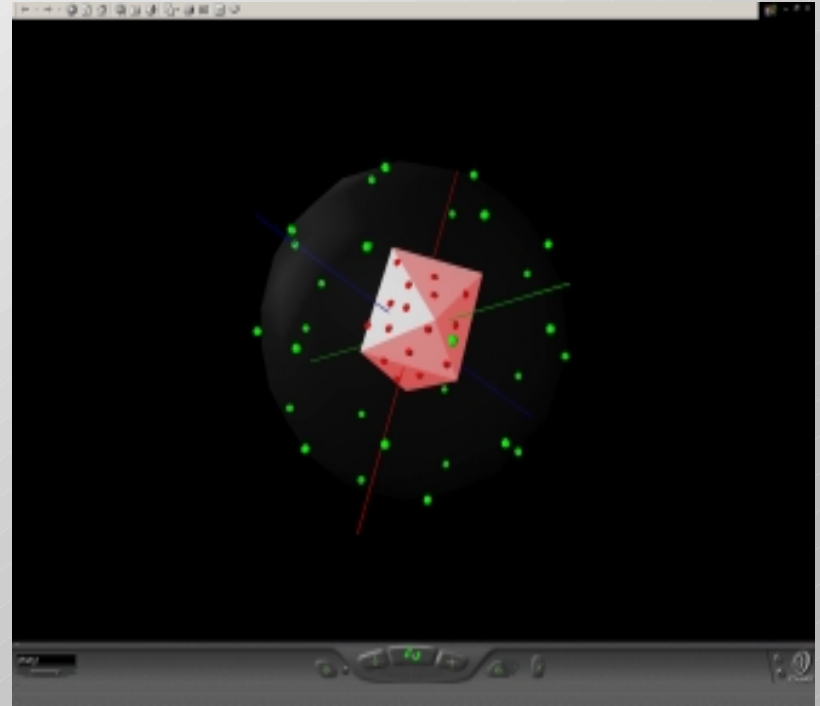
Algorithm 2 (electrostatic field approach)

- 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 (-)



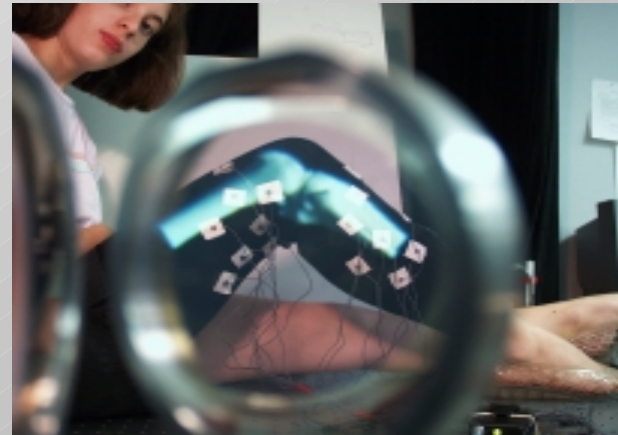
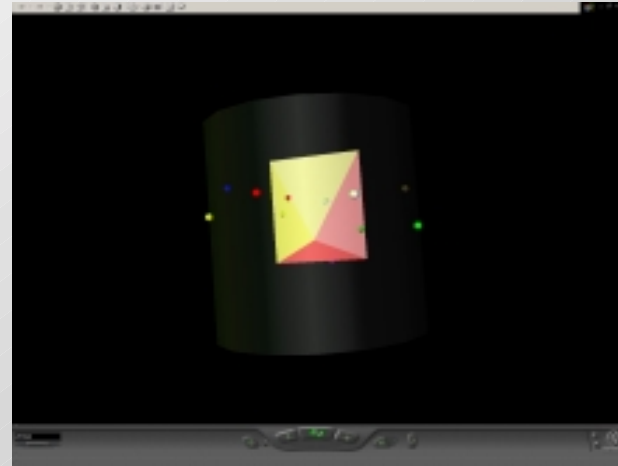
Experimental results

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



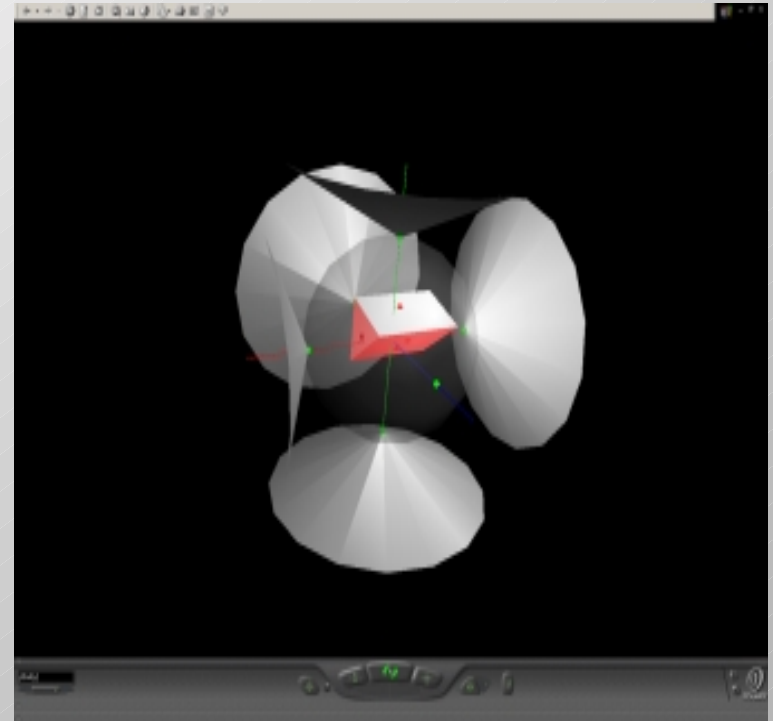
Cylindrical intermediary surface

- 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



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