Occlusion Handling for Medical Augmented Reality using a Volumetric Phantom Model

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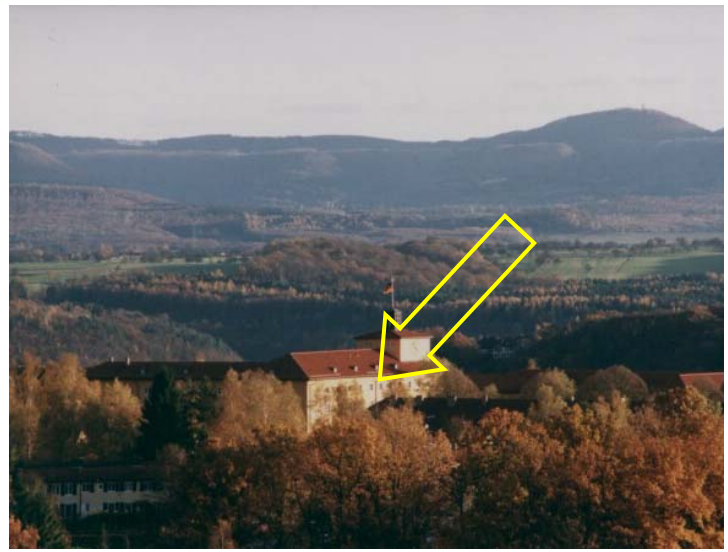
Tübingen



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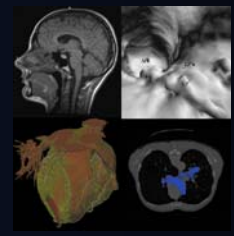
Structure of the Talk



- Medical Augmented Reality
- Related Work
- Motivation for Occlusion Handling
- Volume Preprocessing Pipeline
- Results
- Conclusion

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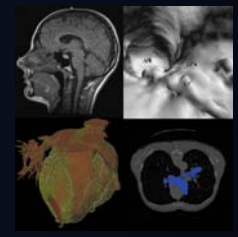
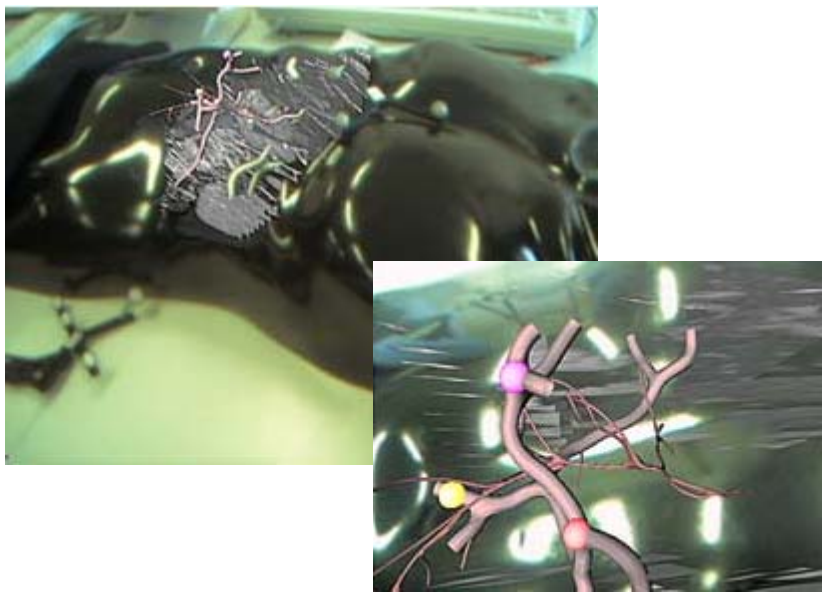
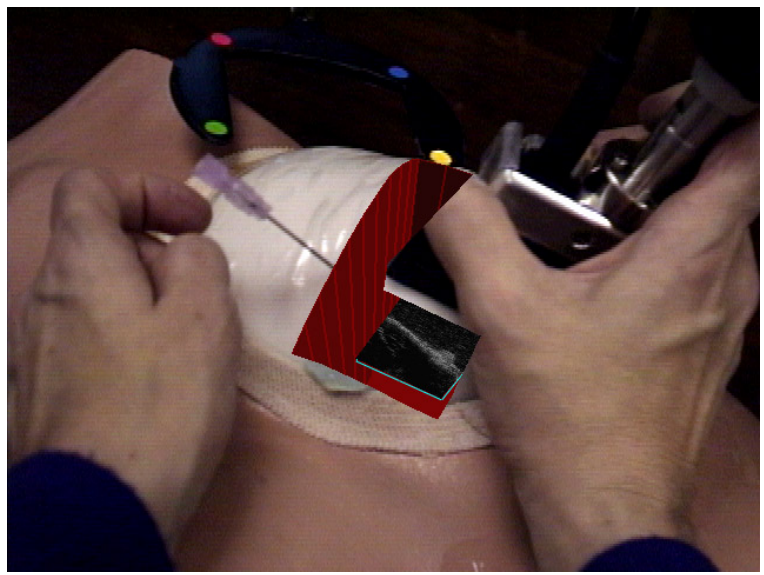
Augmented Reality for Medicine



- Supporting visualization of organs, risk structures etc.



[TU Graz, liver surgery]



[UNC Chapel Hill, breast biopsy]

- Requires accurate tracking of surgical tools and camera relative to patient

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AR based on Image Guided Surgery

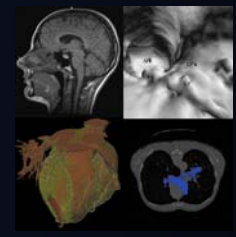

Image Guided Surgery (IGS) system

- Proven technology, certified for medicine
- Accurate infrared tracking
- Provides methods for patient registration

- Infrared marker clamp
- Attached to AR webcam
- Marker clamp pose received using local network
- Specific network interface

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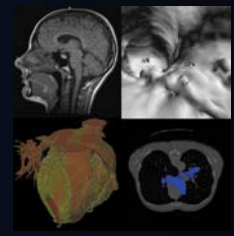
One-time Calibration Step



- Transformation marker clamp → webcam required
- Easy one-time calibration step, based on ARToolKit

1. Manual definition of marker corners
2. Simultaneous optical marker tracking and IR tracking
3. Keystroke-triggered calibration

- Calibration triggered by a single keystroke
- Presented in detail at EGVE'04 (Grenoble)

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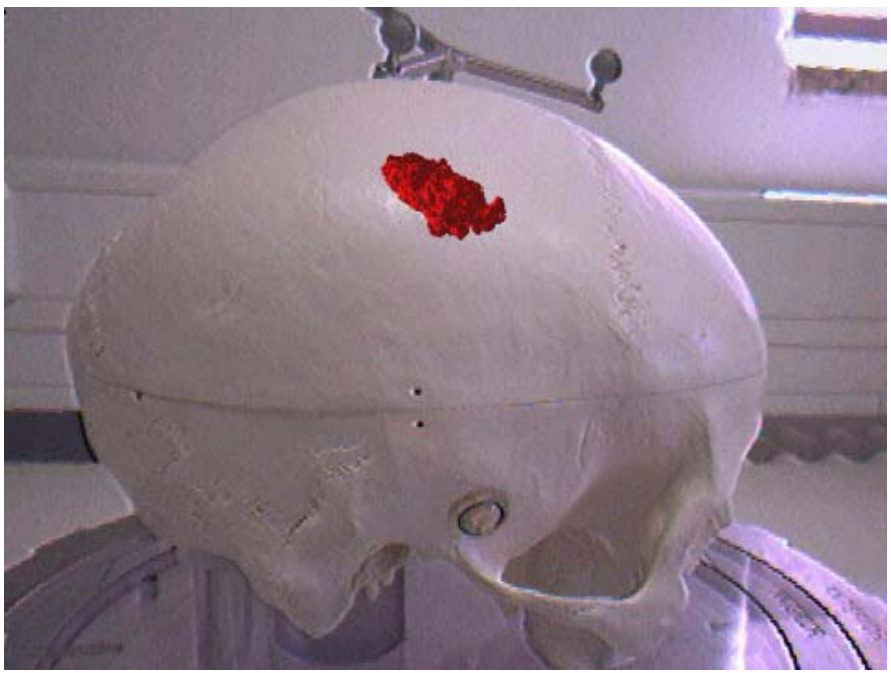
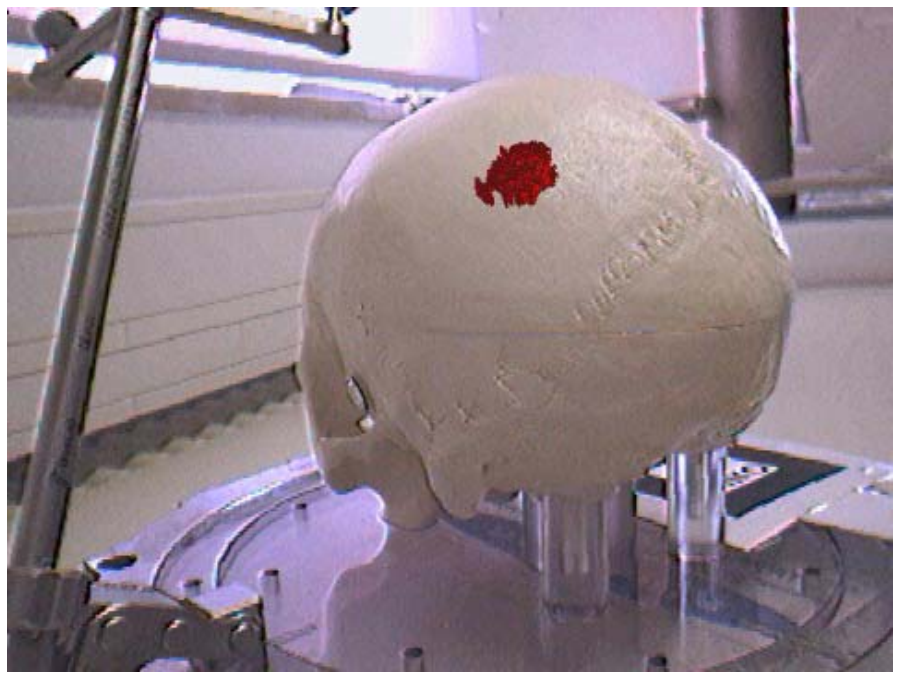
Video: AR based on Image Guided Surgery



Camera tracking



Patient registration

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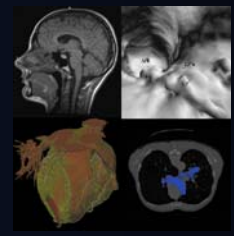

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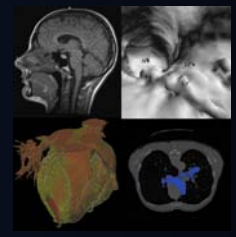
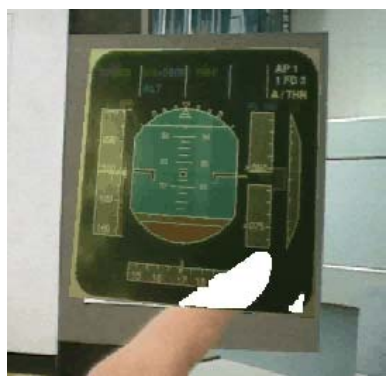
Related Work



Handling Occlusion in AR

- Phantom models (Breen et al., CGF 15(3), 1996)
- Depth from stereo (Wloka et al., I3D 1995)
- Offline augmented reality (Berger and Lepetit, CVPR)
- Static planar backgrounds (Fischer et al., EGVE 2003)



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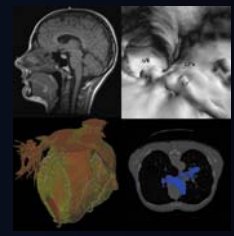

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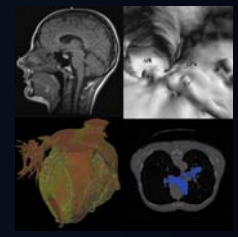
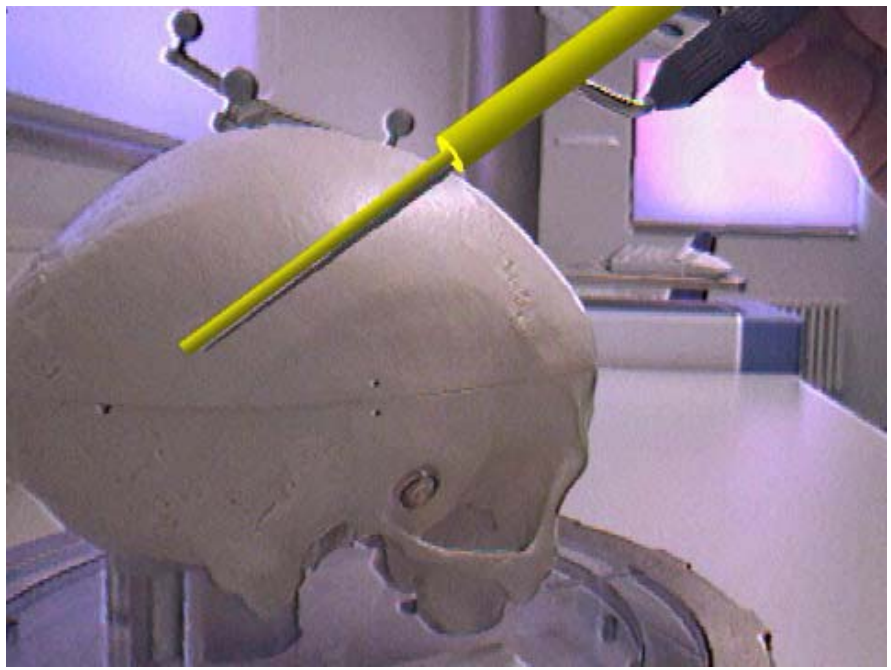
Image Mixing in AR



1. Draw camera image
2. Render virtual objects
   (***over*** camera image)



- Real objects always appear occluded
- Spatial relationships are difficult to understand

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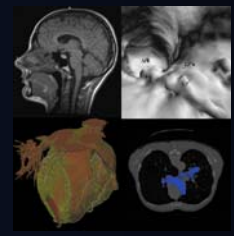
Static Occlusion Handling



- Defined model of real objects
- Here: Patient anatomy / plastic skull
- Draw this "phantom model" into Z-Buffer

- Problem: Medical iso-surfaces can be huge
  $\Rightarrow$ Plastic skull mesh > 2.2 million triangles

- Specific preprocessing of volume dataset
- Significantly reduced mesh size

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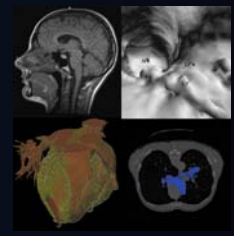

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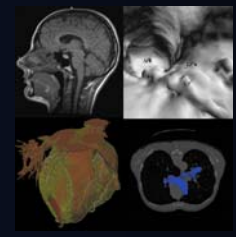
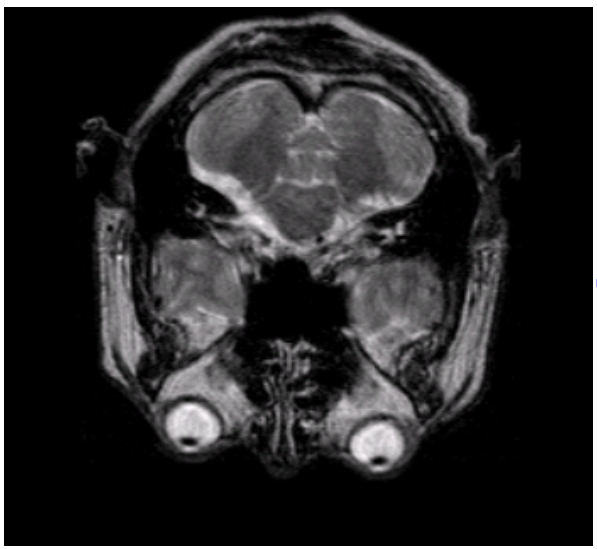
Visual Hull Volume



- Remove invisible inner surfaces before handling occlusion
- Compute binary visual hull volume



Input volume

Visual hull volume

Extract Iso-surface

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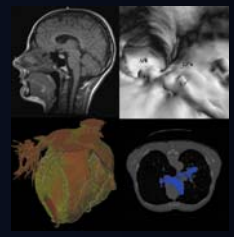
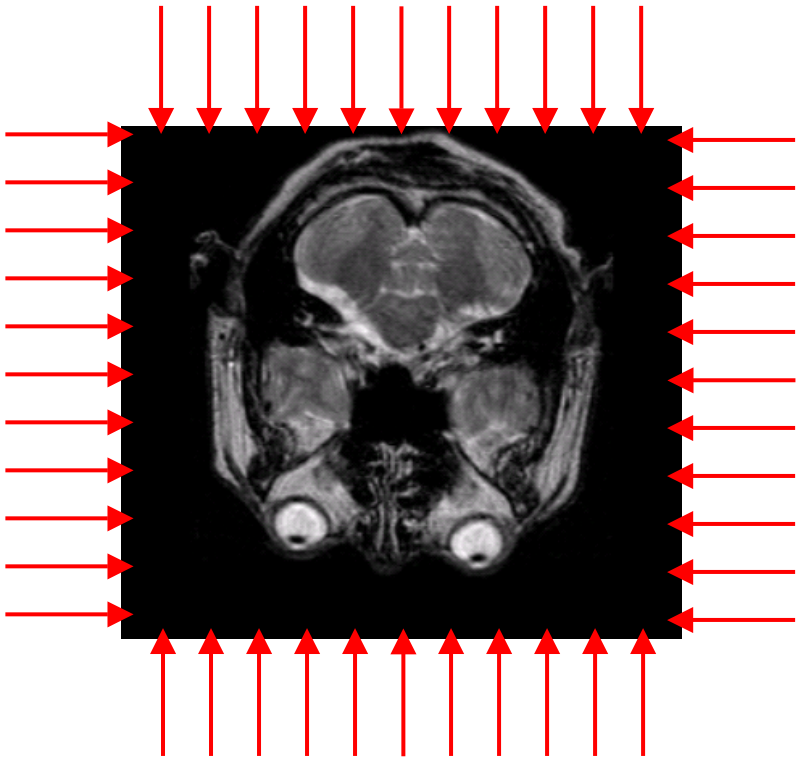
First-Hit Raycasting



- Parallel first-hit raycasting beginning at volume boundaries



- Ray termination criterion: Voxel intensity threshold
- Result volume initialized with full intensity
- Each ray writes zeroes into result volume

- Empty regions are "carved out" of binary result volume

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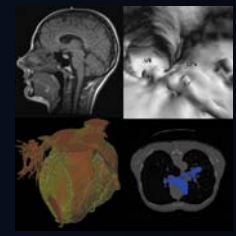
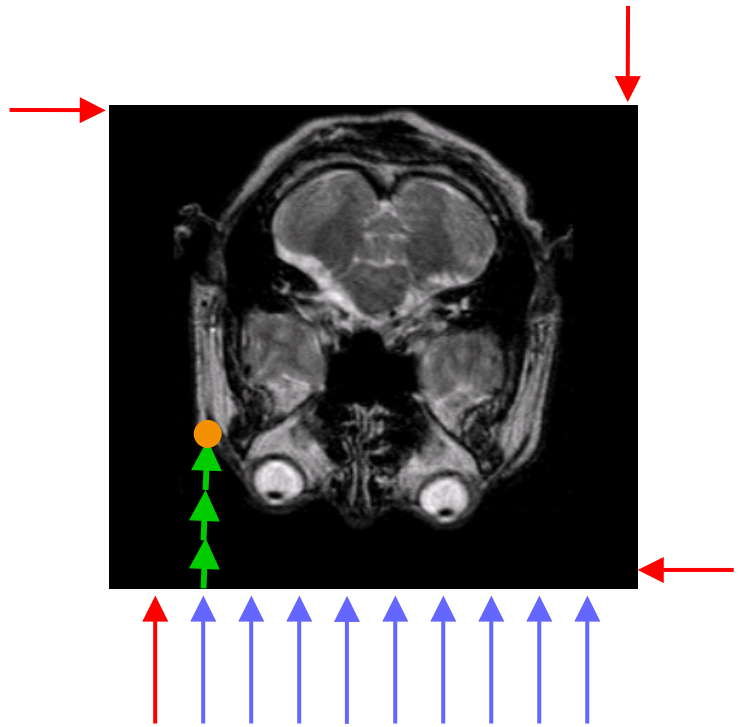
Pseudo-Code



```
rayCastingDirs: Vector3d[6] :=
     { { 0, 0, 1 } , { 0, 0,-1 } , {  0, 1, 0 } ,
       { 0,-1, 0 } , { 1, 0, 0 } , { -1, 0, 0 }
     };

procedure preprocessVolume(threshold: double)
begin

   initializeWithFullIntensity(visualHull);

   for directionLoop := 1 to 6 do

     for startPos ∈ all positions on corresponding
           face of volume boundary do

       pos := startPos;

       while (pos within volume boundaries) do

         if (originalVolume[pos] > threshold)
           break;

         visualHull[pos] := 0;
         pos := pos + rayCastingDirs[directionLoop];

       done
     done
   done

end
```



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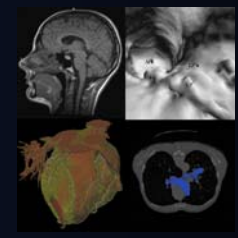
Volume Processing Pipeline



- For removing noise in input volume and interpolating binary volume, etc.

Gaussian filter → Morphological open + close → First-hit raycasting → …

… → Median filter → Gaussian filter → Zero-layer padding

Required step Optional step

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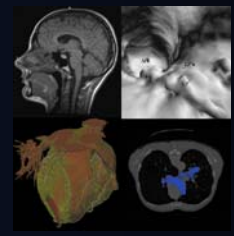
Integration into Renderer



```
glClear(GL_DEPTH_BUFFER_BIT);
drawCameraImage();
computeAndLoadTransformationMatrix();

// Disable color buffer access
glDrawBuffer(GL_NONE);
renderOcclusionVisualHullSurface();

// Enable color buffer access
glDrawBuffer(GL_BACK);
renderVirtualObjects();
```

Only modify Z-Buffer

Generated by iso-surface extraction

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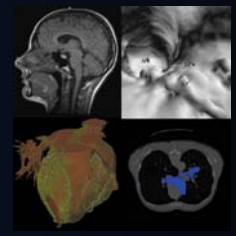

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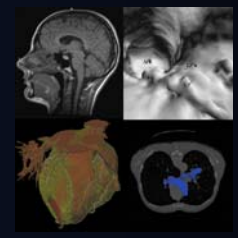
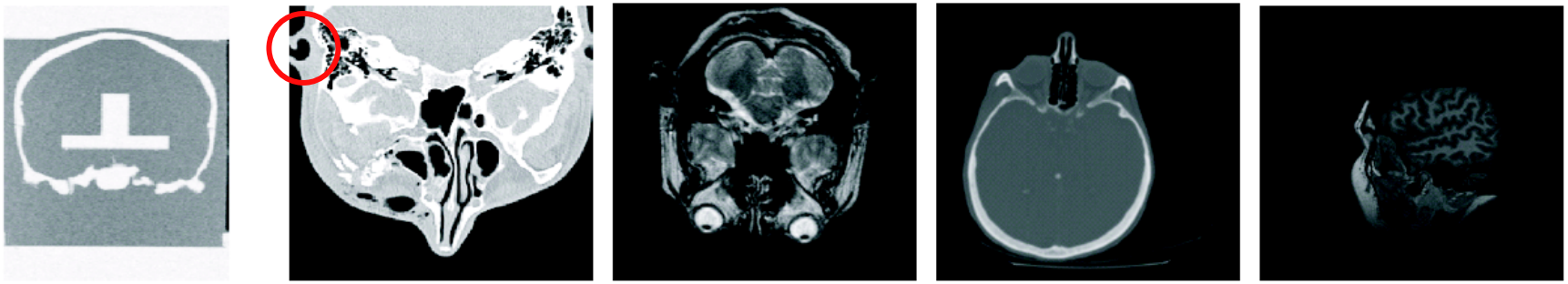
Visual Hull Volumes



Input volumes used for experiments (one slice shown)



Area not reached by rays (not critical)

Corresponding visual hull volumes

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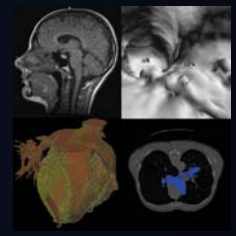
Experimental Results



Triangle count reduction

Dataset	Input	Visual hull	Reduction
Plastic skull	2,219K	1,279K	42.4%
Patient A	3,312K	1,627K	50.9%
Patient B	767K	230K	70.0%
CTHead	339K	283K	16.5%
MRBrain	433K	282K	34.9%
Average			42.9%

Rendering speedups

Dataset	Input (msecs)	Visual hull (msecs)	Speedup
Plastic skull	35.7	17.4	105.2%
Patient A	51.7	23.3	121.9%
Patient B	14.4	6.4	125.0%
CTHead	4.6	3.7	24.3%
MRBrain	5.9	4.9	20.4%
Average			79.4%

Dataset parameters

Dataset	Size X	Size Y	Size Z	Depth
Plastic skull	512	512	160	8 bits
Patient A	512	512	147	8 bits
Patient B	256	256	40	8 bits
CTHead	256	256	113	8 bits
MRBrain	256	256	109	8 bits

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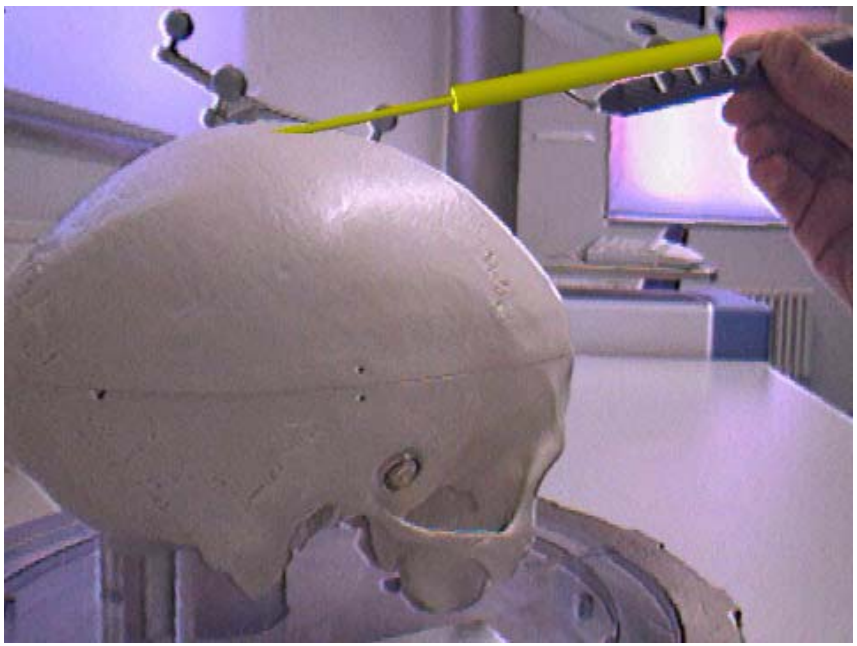
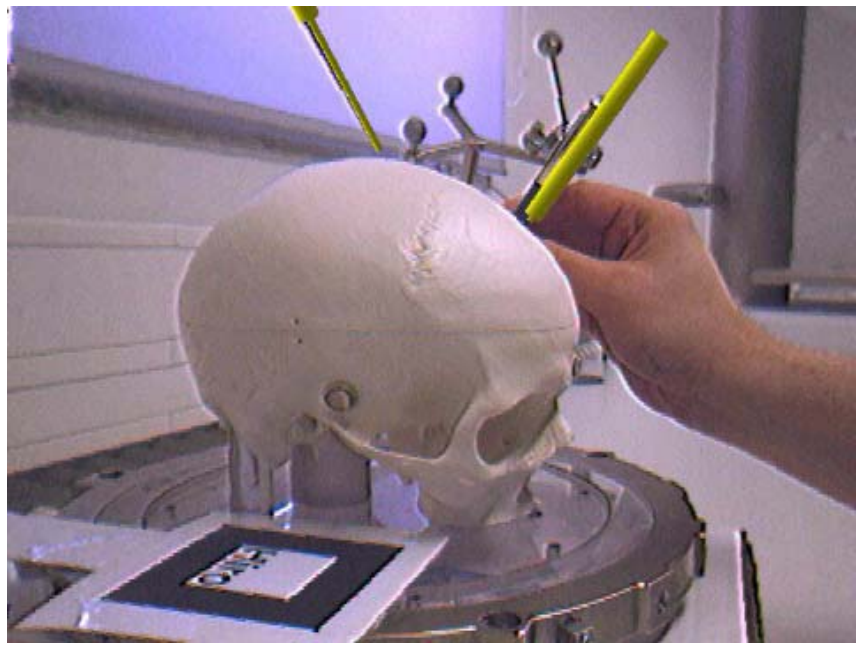
Video: Occlusion Handling





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Video: Anatomical Detail

Cheek-bone detail

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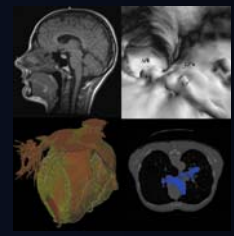

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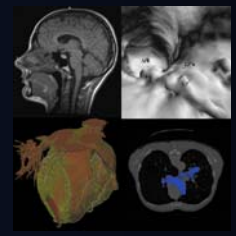

- Static occlusion handling using volumetric data
- Specific volume preprocessing pipeline
- Unnecessary inner surfaces are removed
- Improved rendering speed

- Possible application in fields other than medicine?
- Combination / comparison with conventional mesh decimation algorithms?

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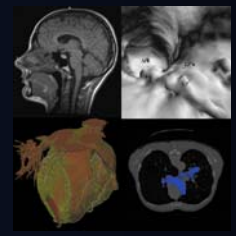
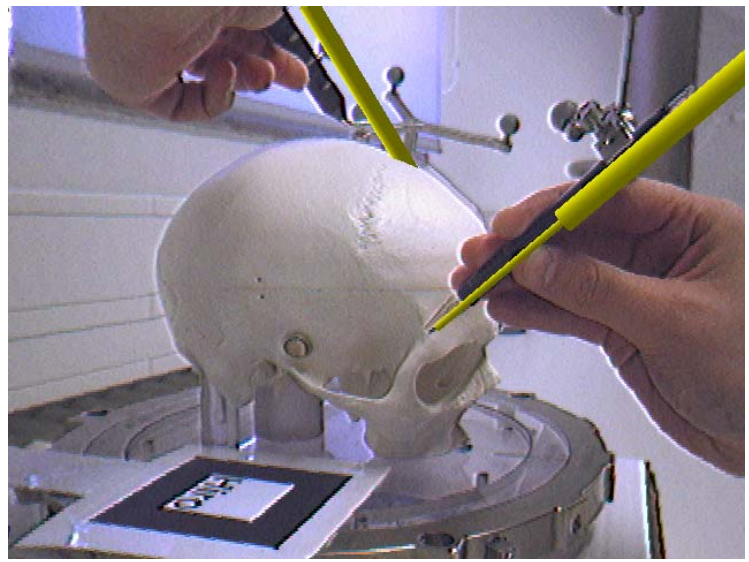
The End



Questions?



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- BrainLAB AG
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