Feature Emphasis and Contextual Cutaways for Multimodal Medical Visualization

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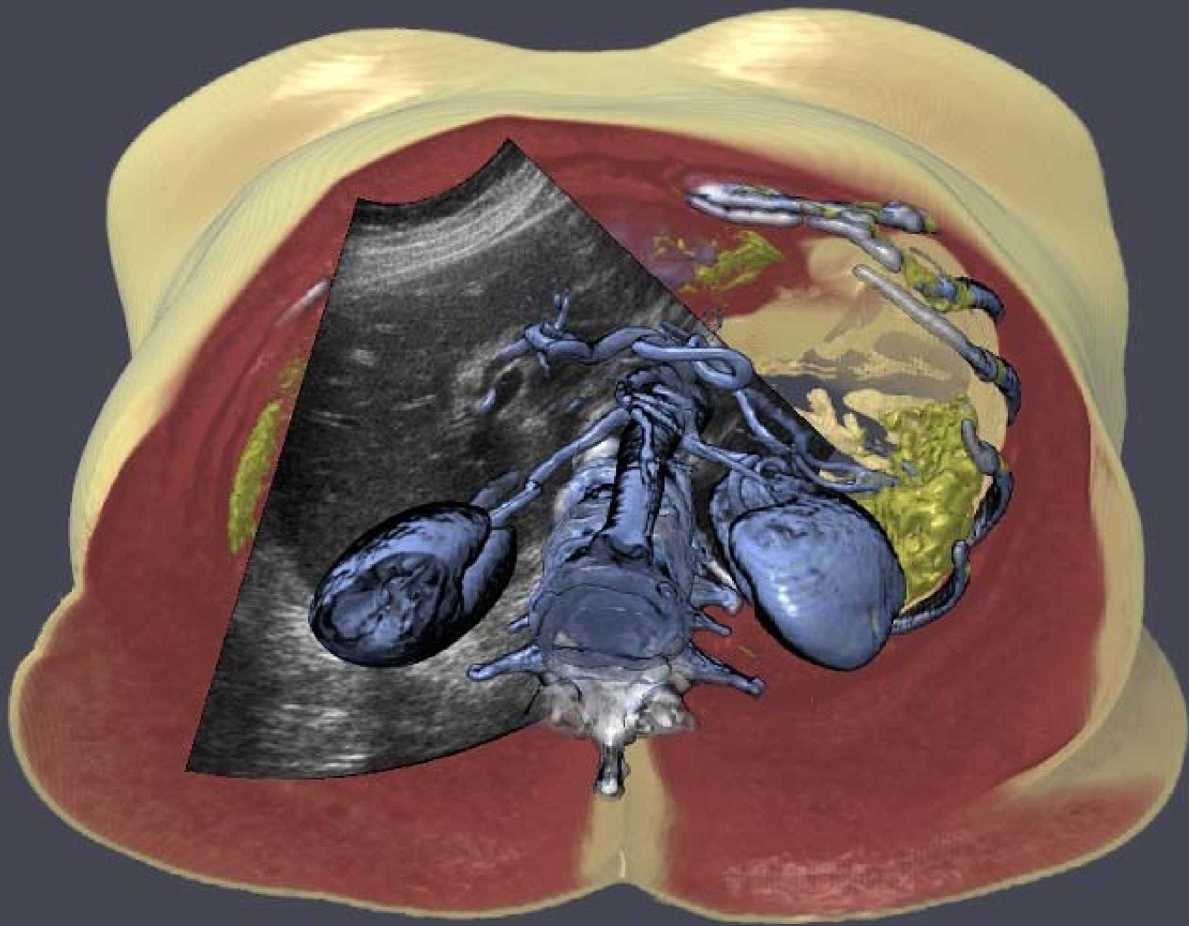
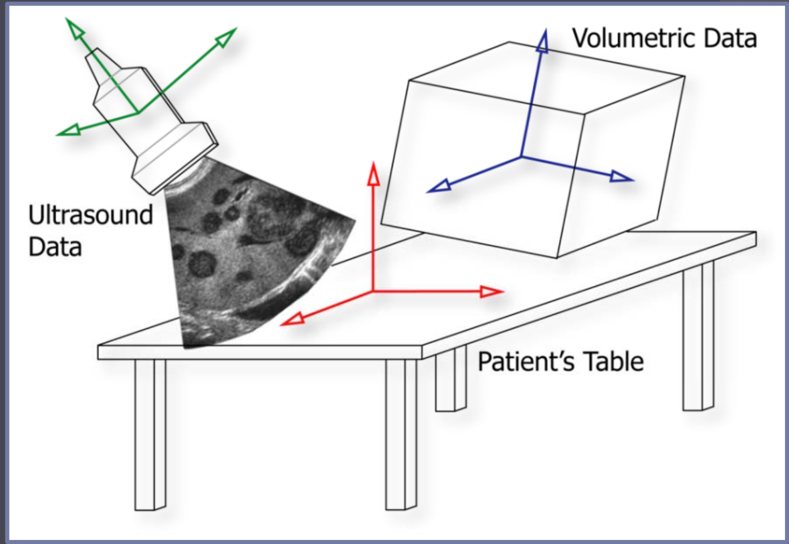
Preface



CT scan with embedded Ultrasound data

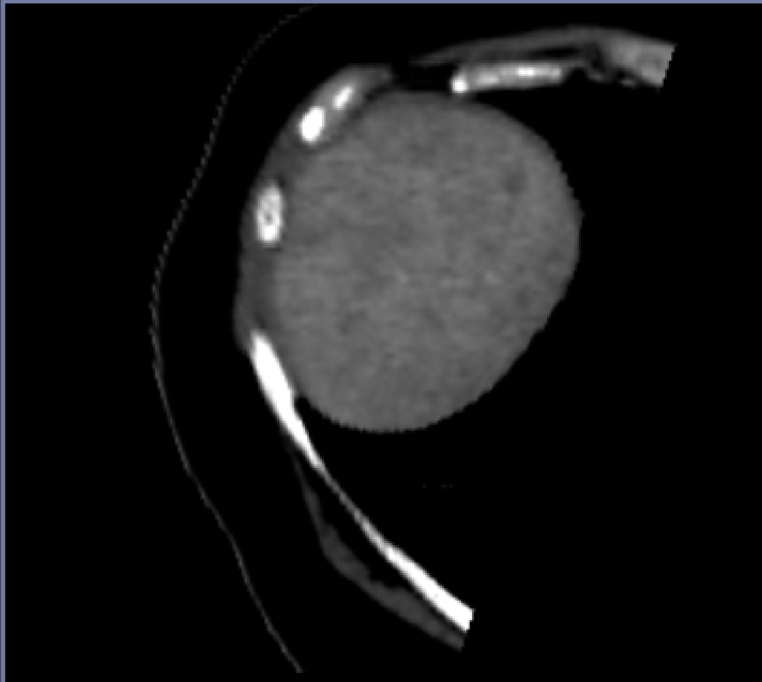
Visualization Scenario

- Poking needles
  - Liver biopsy
  - Radio frequency ablation

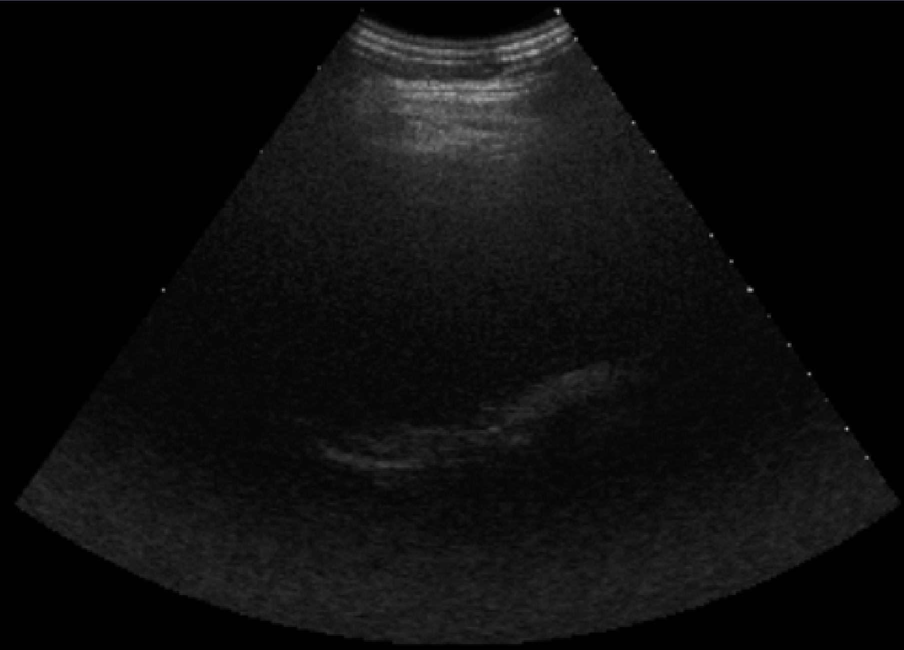


- Procedure:
  - Patient has CT scan
  - Needle path is planned
  - Uses ultrasound probe to help guide needle
  - Doctor views CT scan at time of procedure

Visualization Scenario

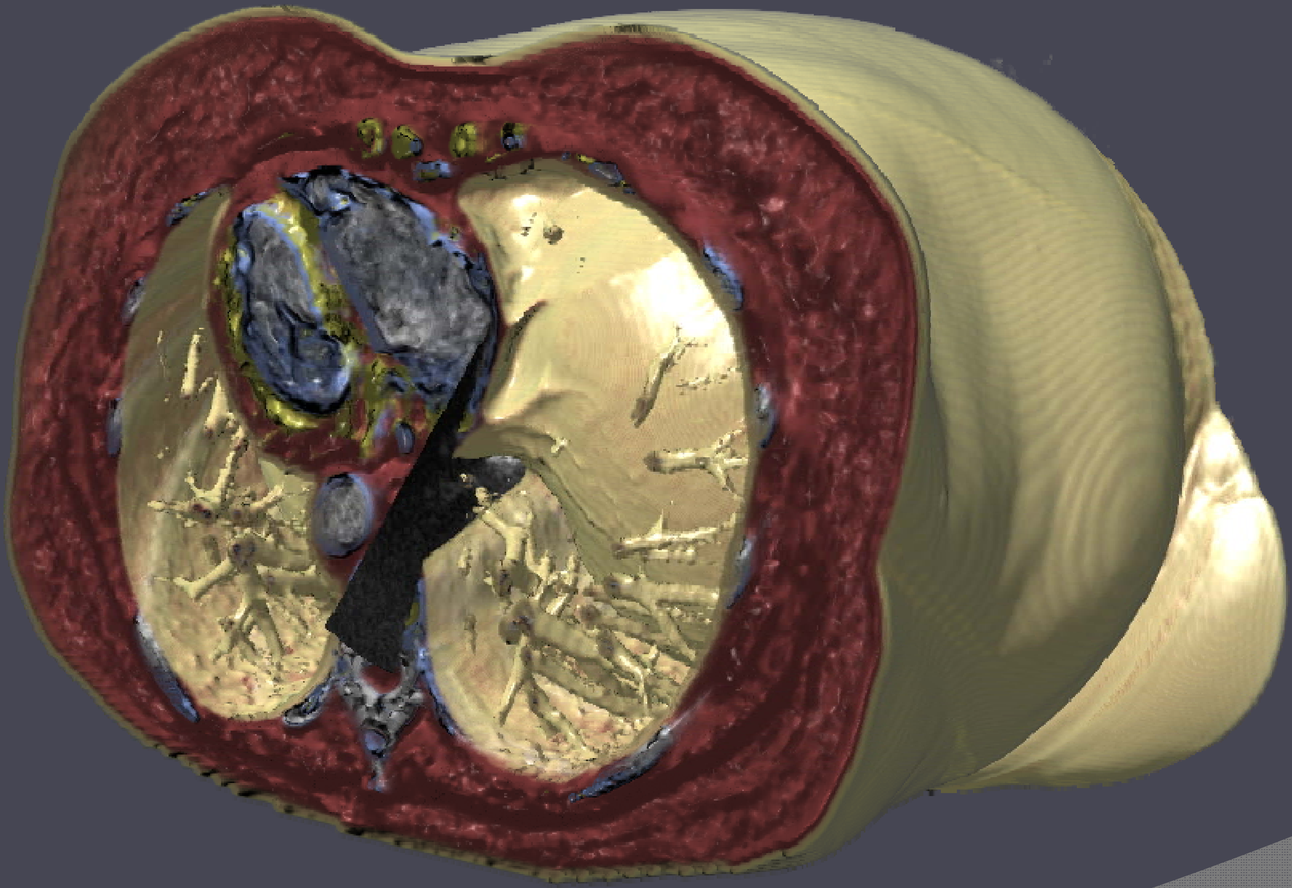


CT Scan Data



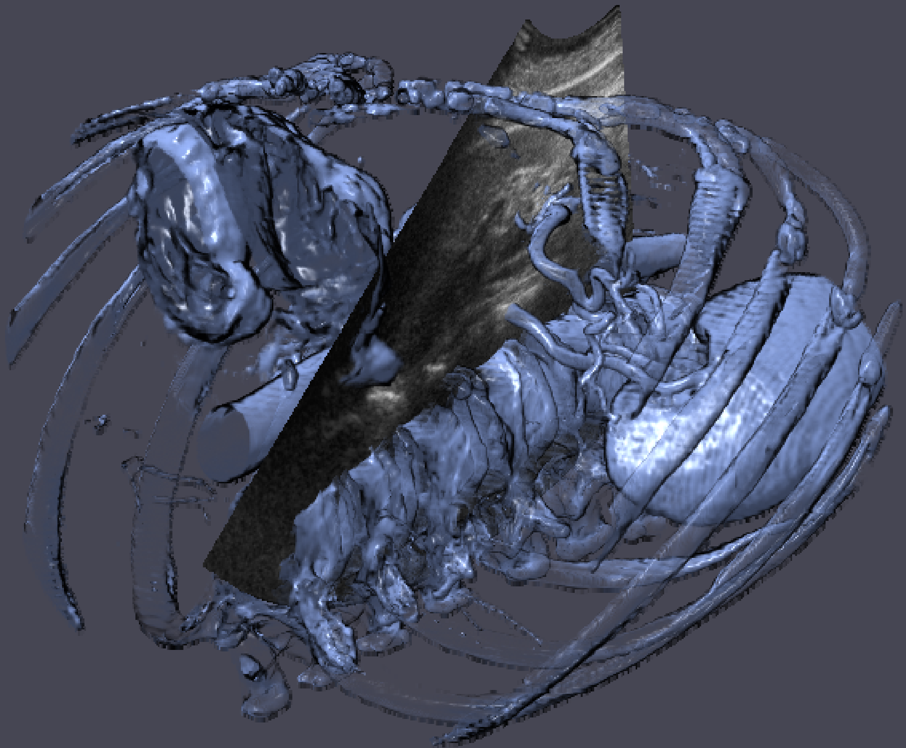
Ultrasound Data

Visualization Scenario



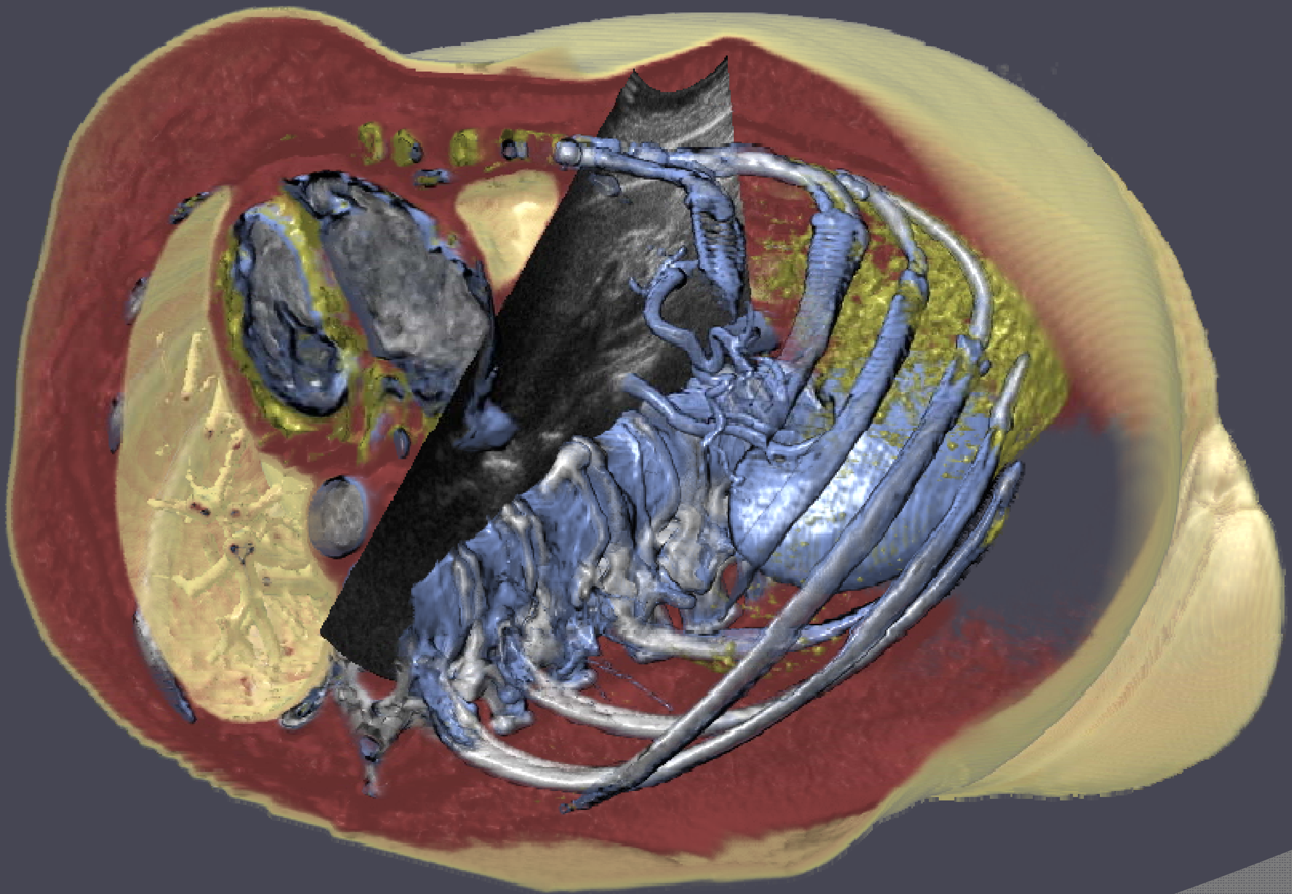
Ultrasound embedded in dense volume

Visualization Scenario



Ultrasound embedded in sparse volume

Visualization Scenario

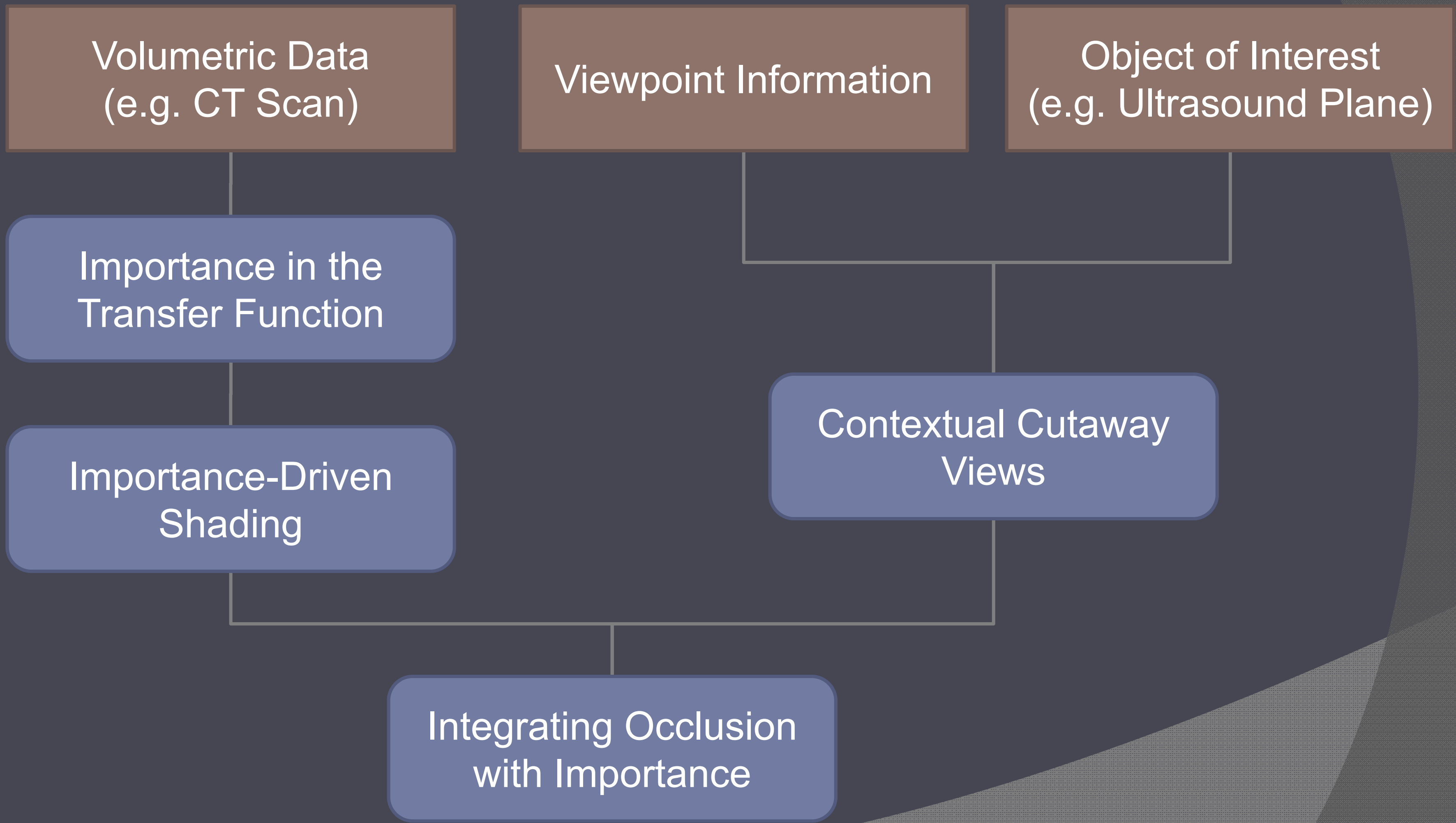


Ultrasound with contextual cutaway

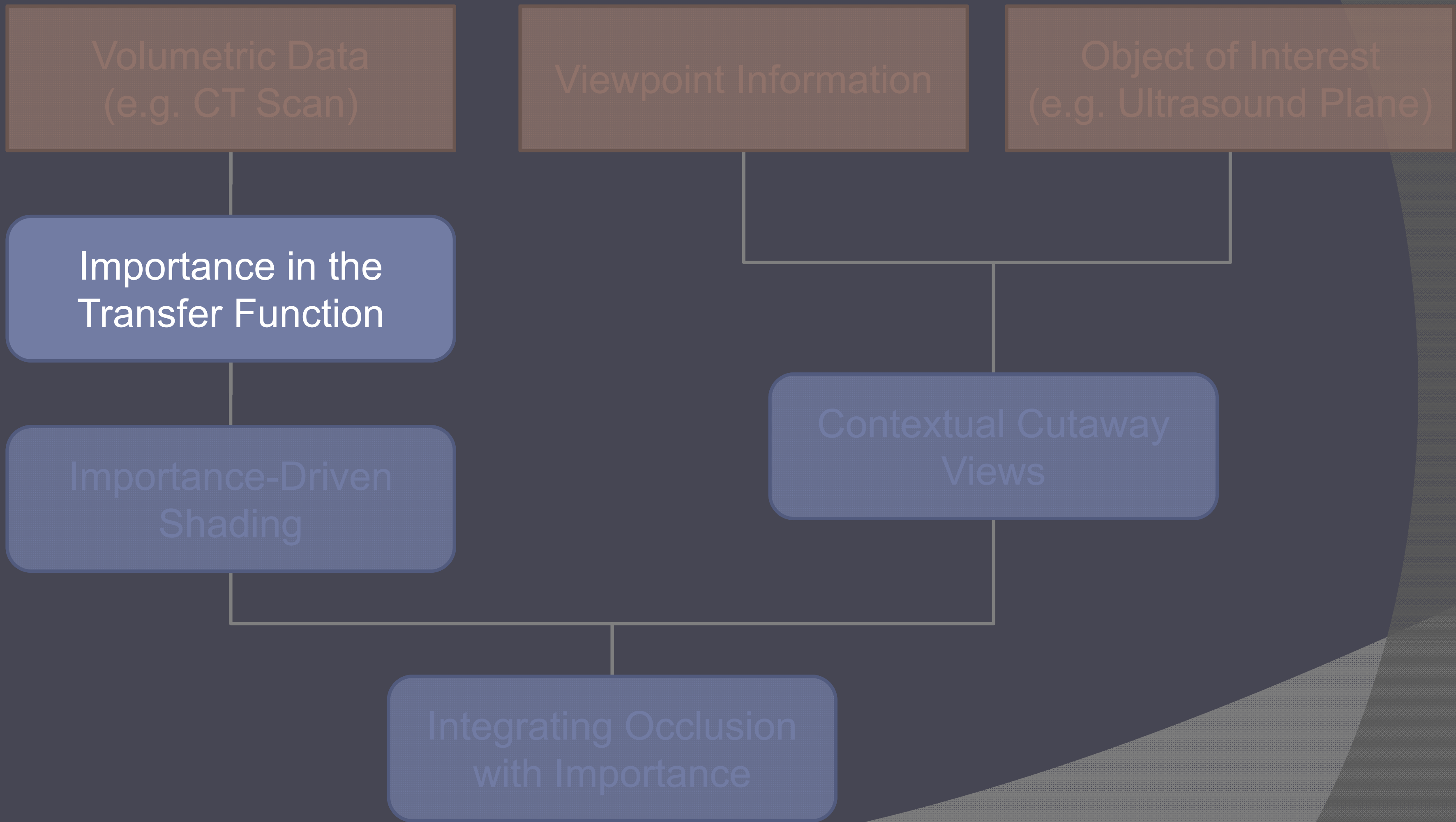
Key Requirements

- Volumetric data
  - Tissue types differentiated and ranked
    - Important materials most visible
    - Unimportant materials provide context
- Ultrasound image
  - Captured with 3D position and orientation of probe
  - Registration between coordinate frames [Wein05]

Visualization Pipeline



Visualization Pipeline



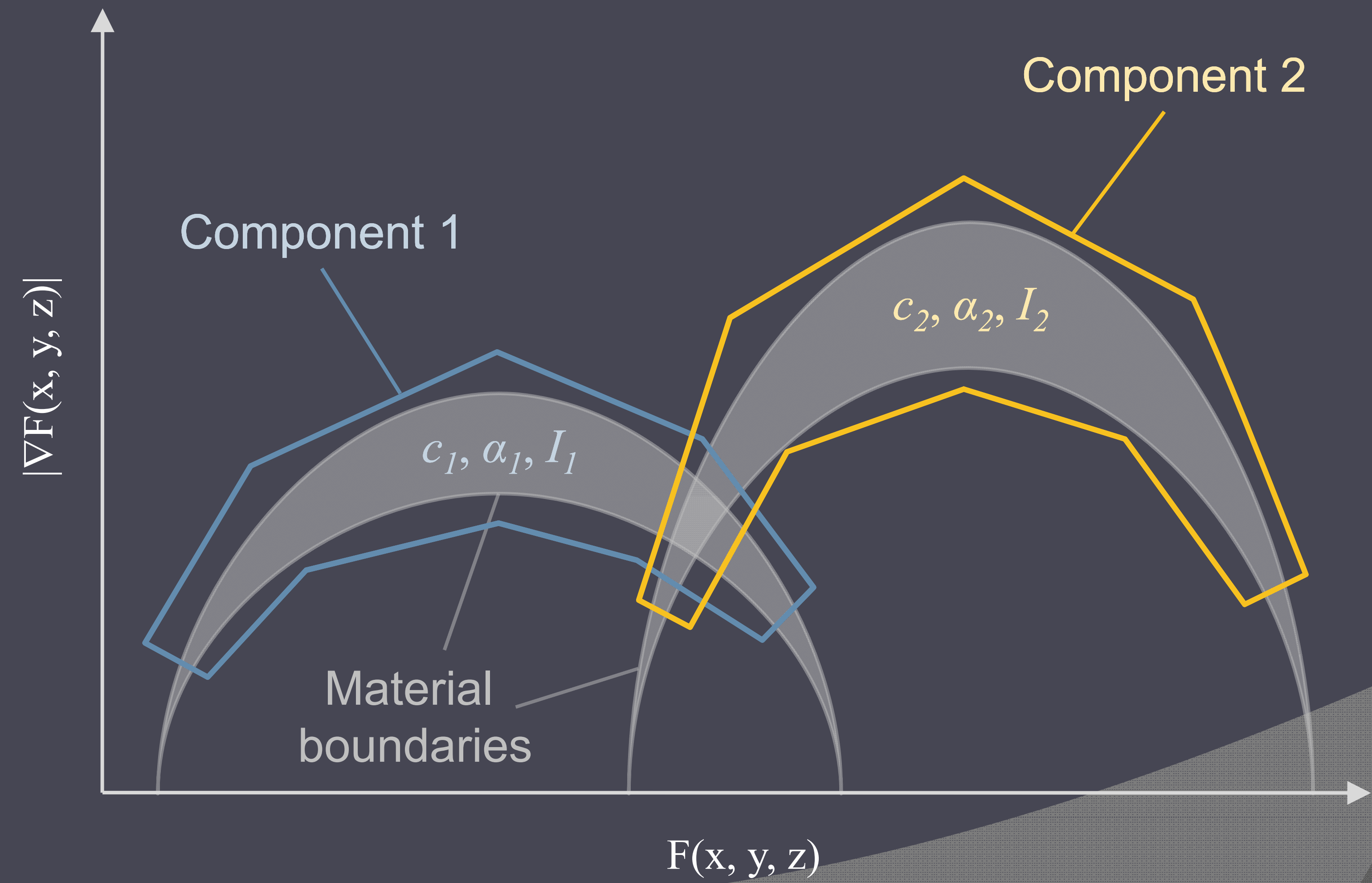
Defining Importance

Rank materials by relevance

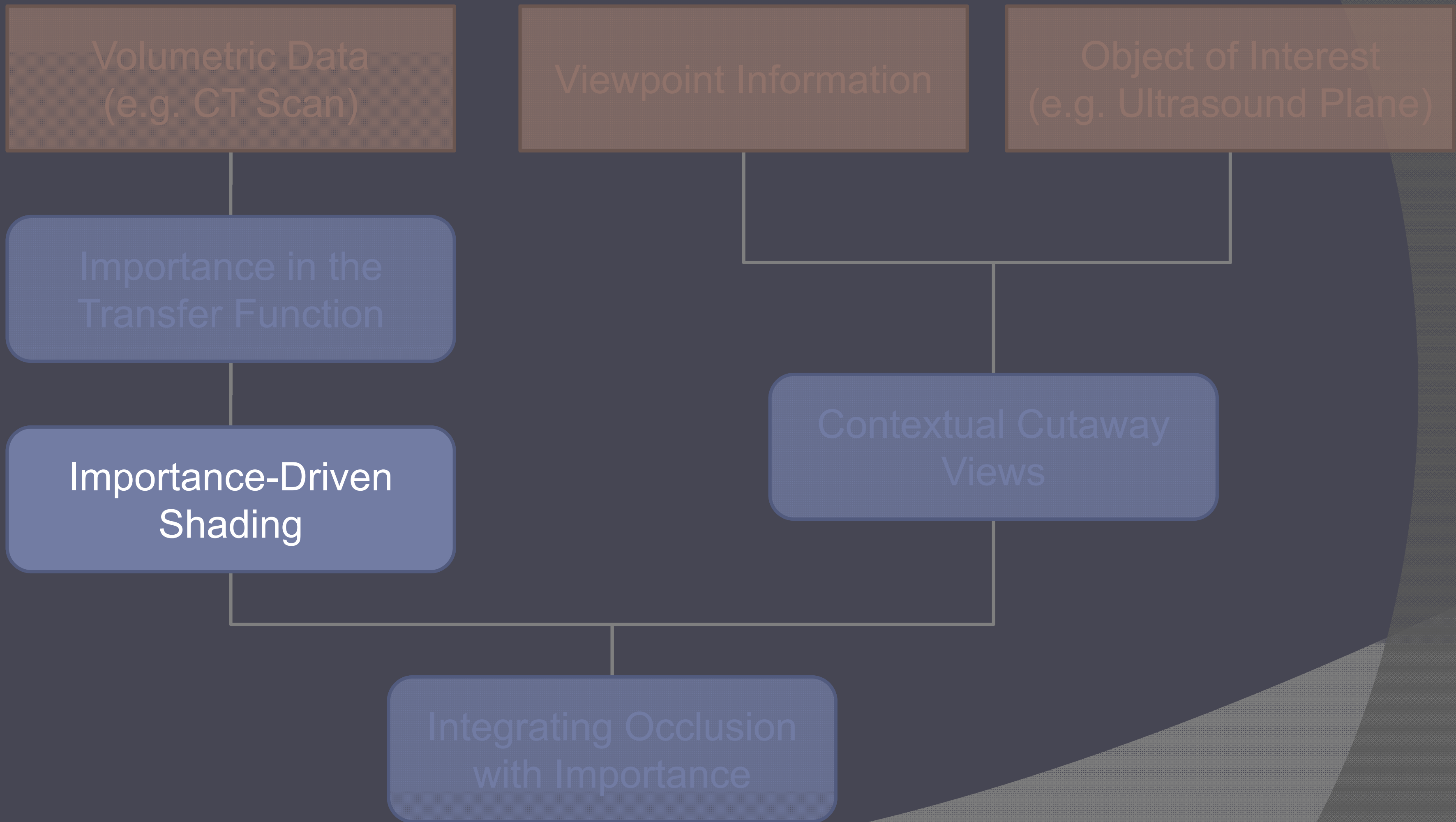
1. Definition in volumetric space
   - Uses auxiliary volume
   - Requires preprocessing per dataset

2. Definition in transfer function space
   - Extra value in transfer function
   - Shared among datasets

Defining Importance



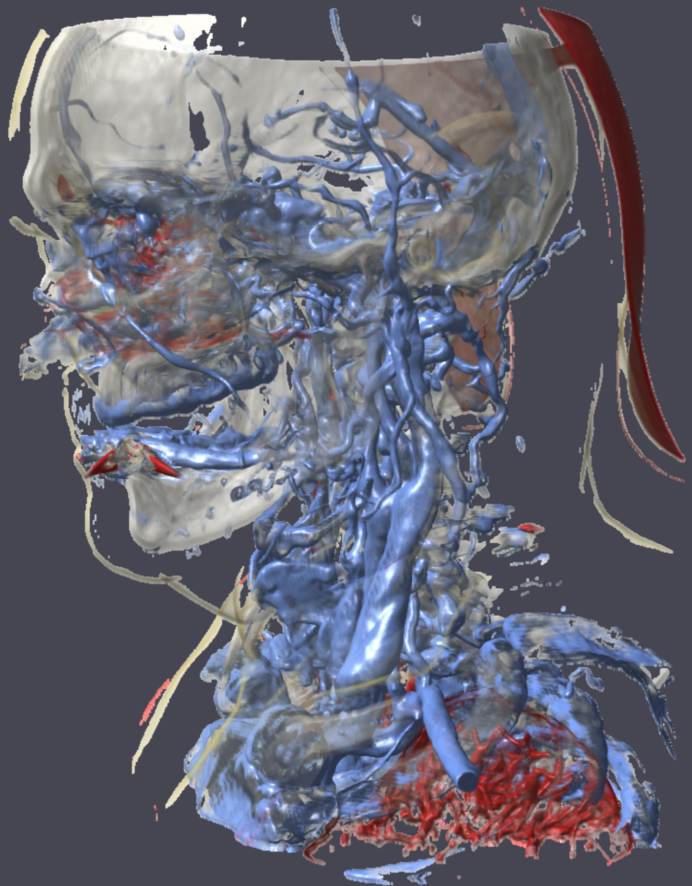
Visualization Pipeline



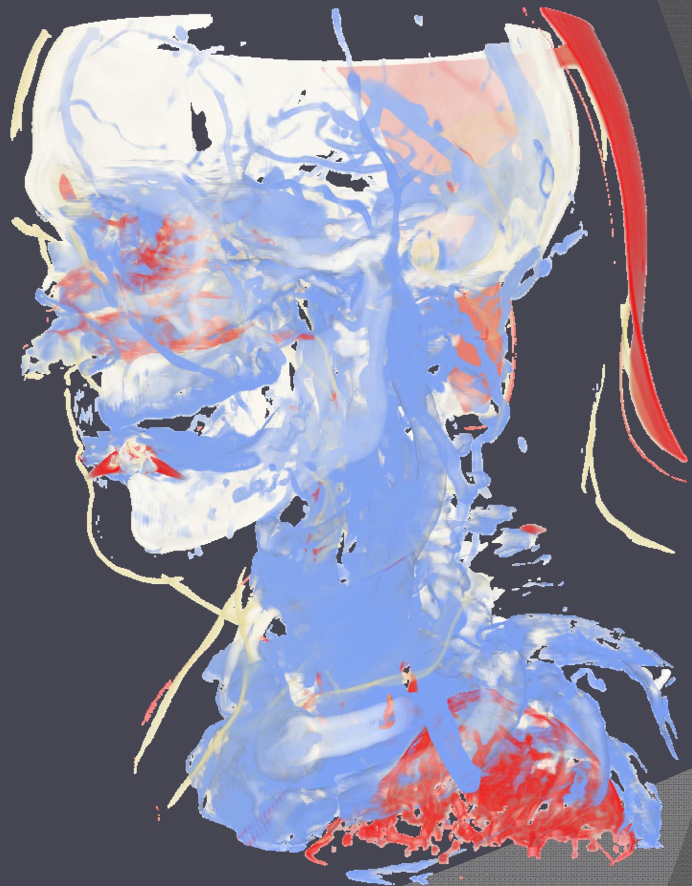
Feature Emphasis

- Visual distinction between materials
  - Emphasis of important materials
- Material properties
  - Color
  - Opacity
- Lighting properties
  - Shading conveys detail

Feature Emphasis

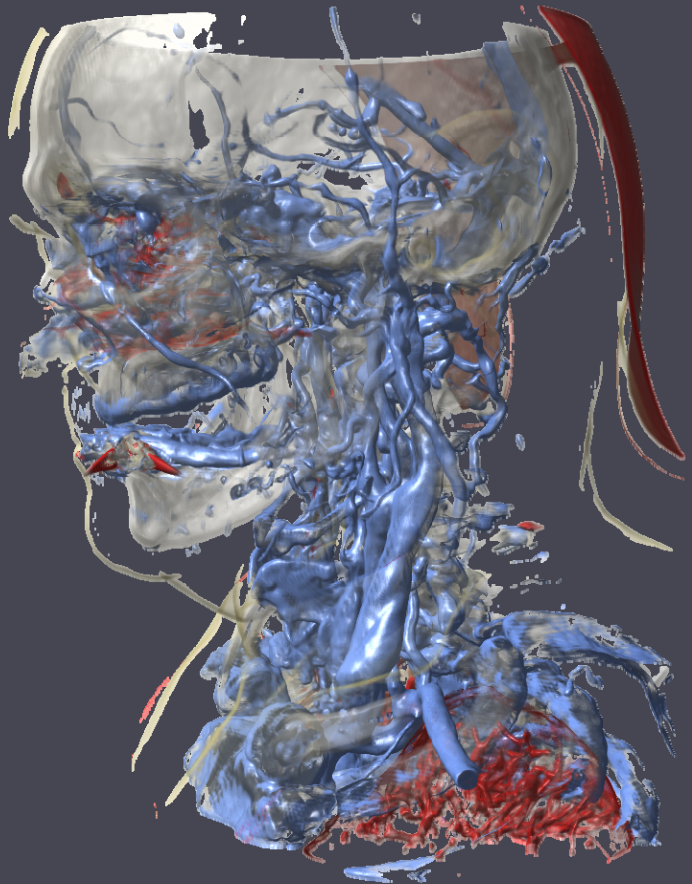


Full Shading

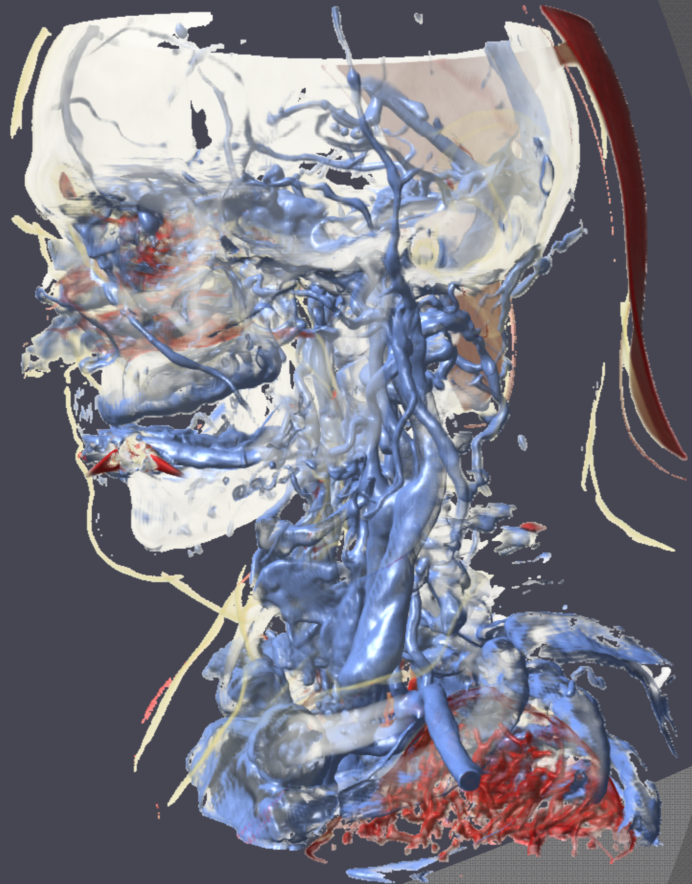


No Shading

Feature Emphasis



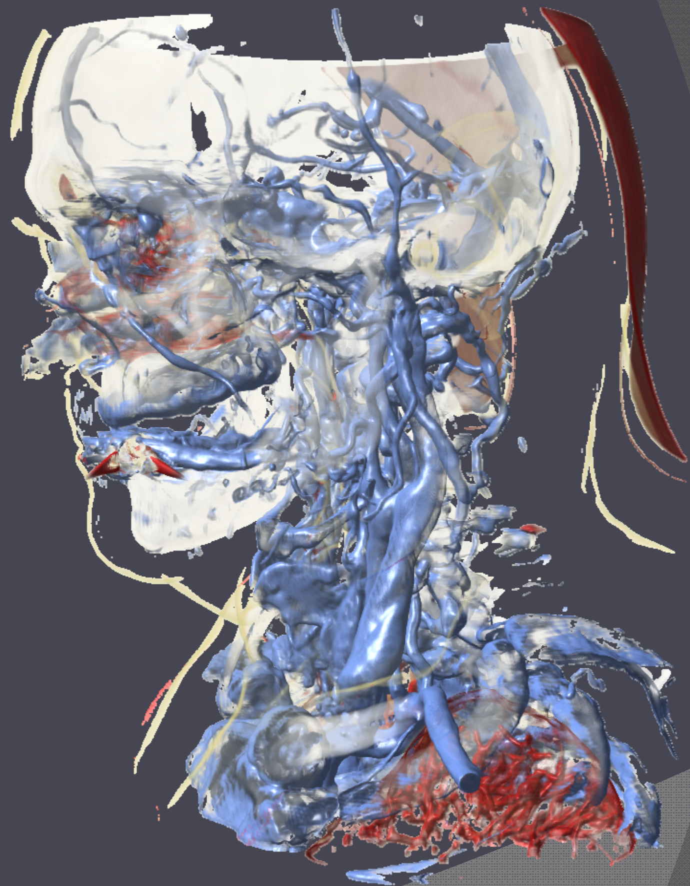
Full Shading



Importance Shading

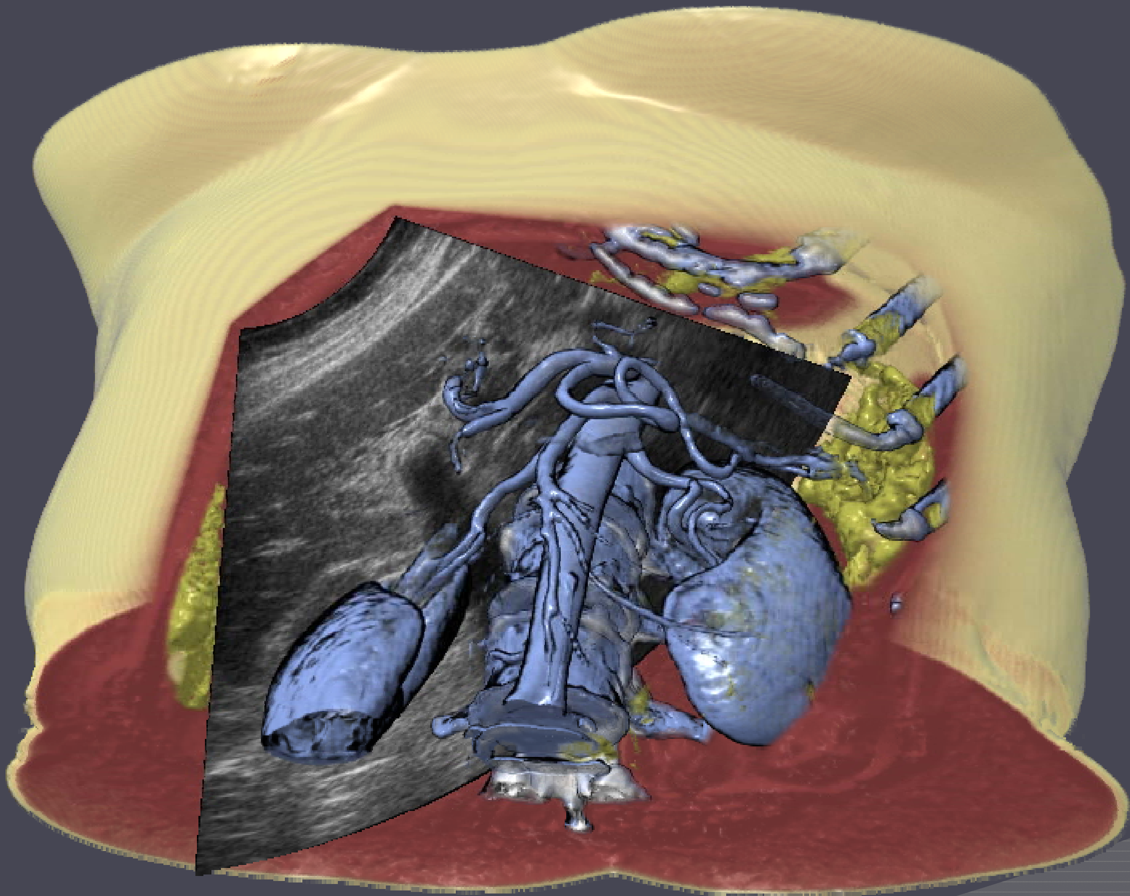
Feature Emphasis

- Emphasis: E
- Shaded color: C_{shaded}
- Subdued color:
  $C_{subdued} = E * C_{unshaded} + (1 - E) * C_{shaded}$
- Final color:
  $C_{final} = I * C_{shaded} + (1 - I) * C_{subdued}$

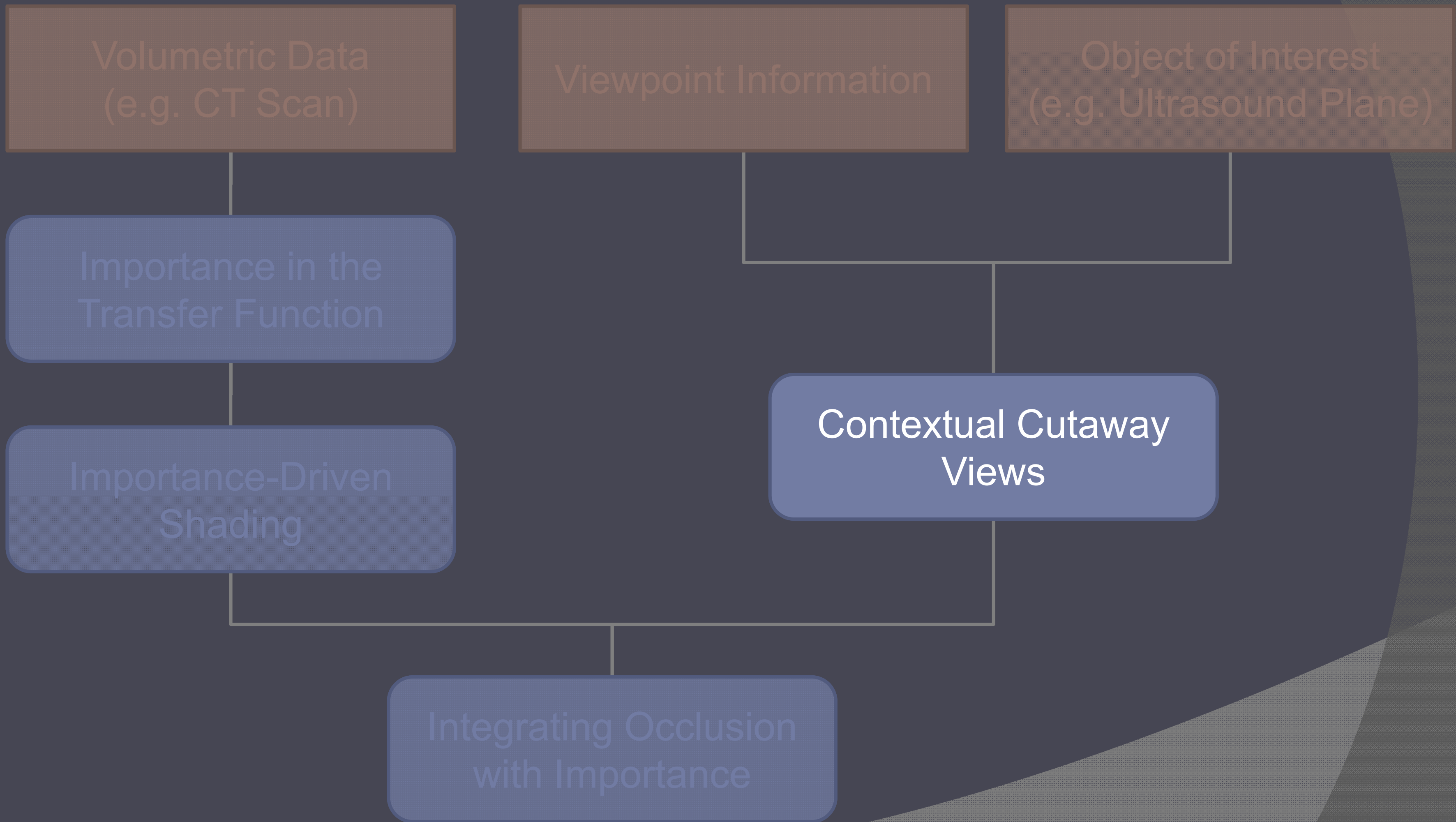


Importance Shading

Feature Emphasis



Visualization Pipeline

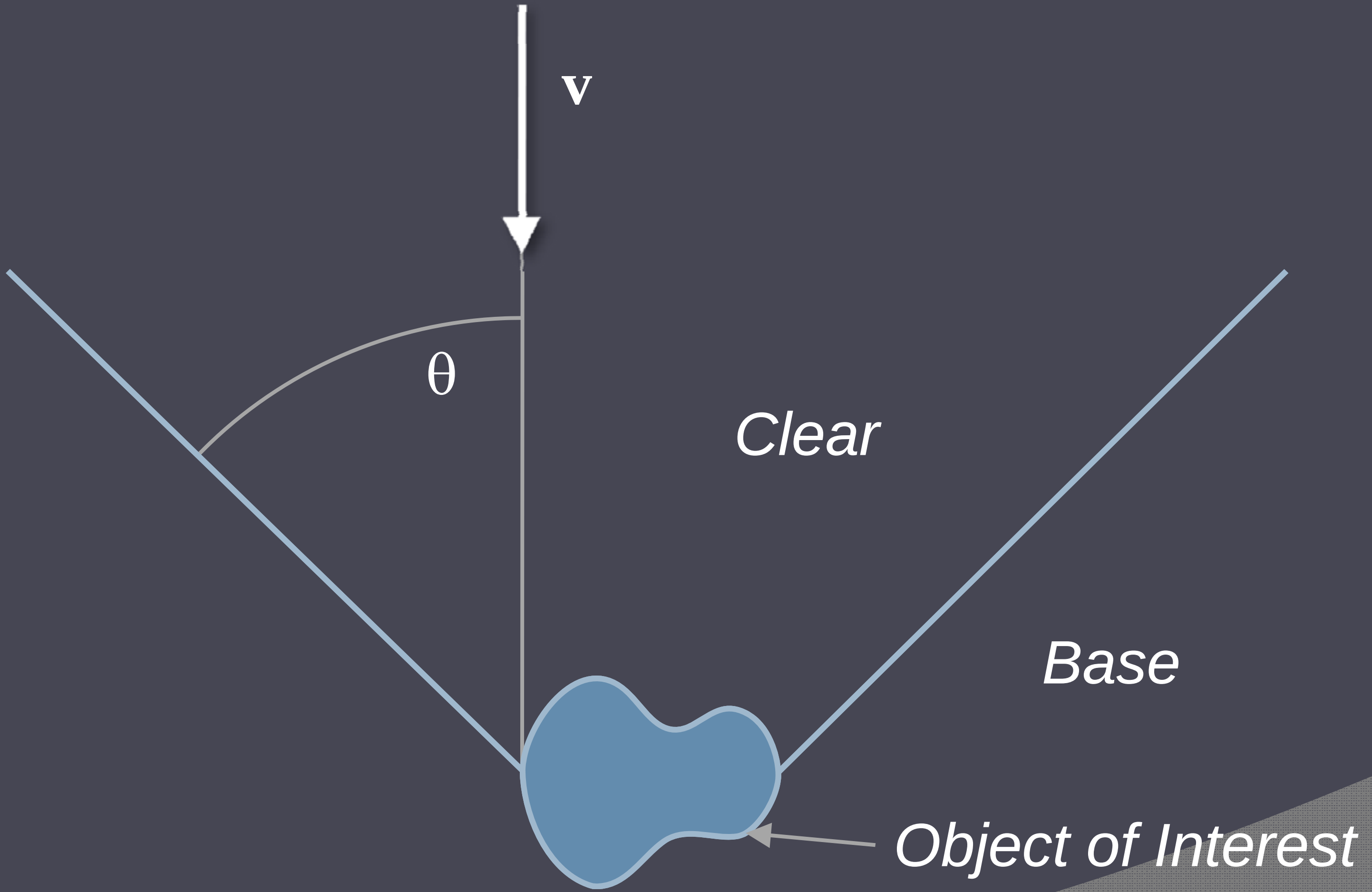


Contextual Cutaways

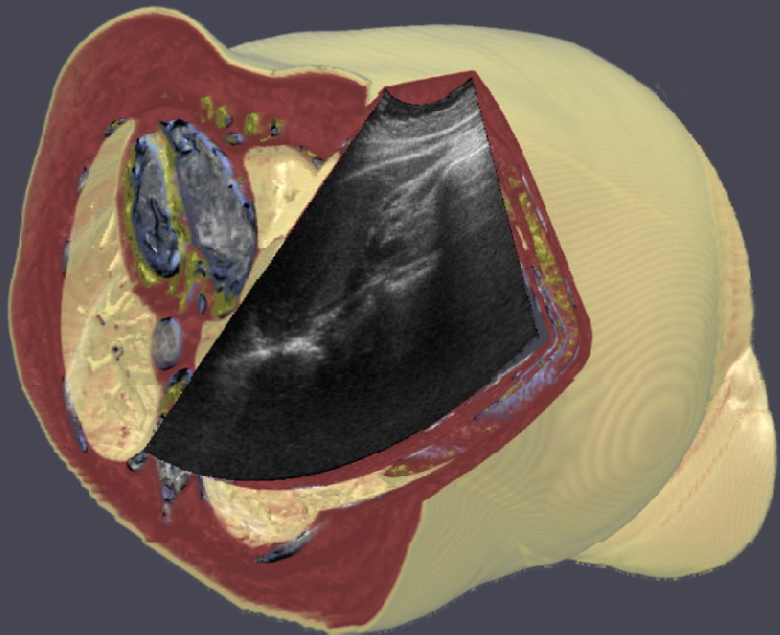
- Object of interest obscured by volume
  - High importance
    - Should be visible
    - May obscure object
  - Low importance
    - Not necessarily visible
    - May not obscure object

- View-dependent cutaway structure

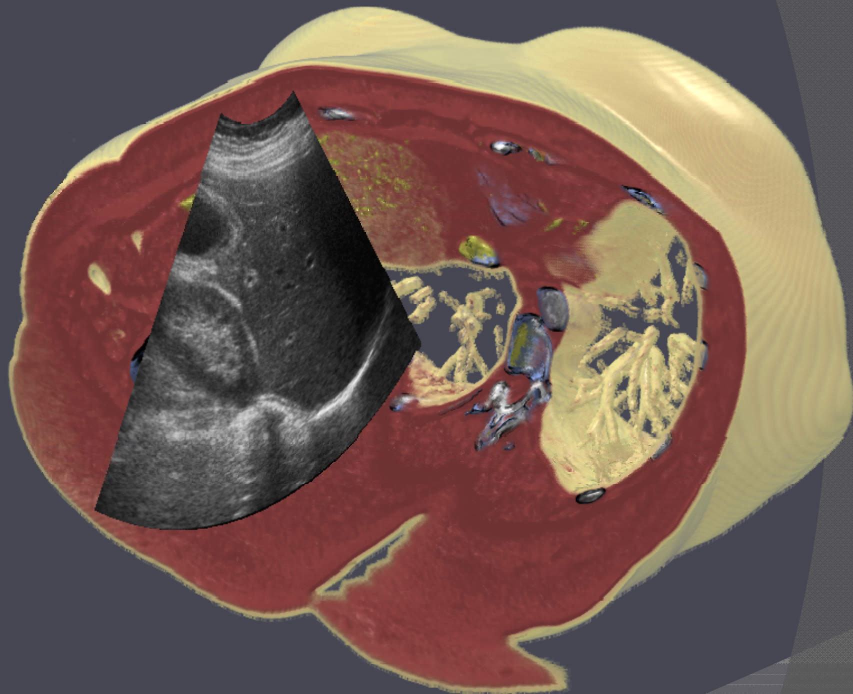
Traditional Cutaways



Traditional Cutaways

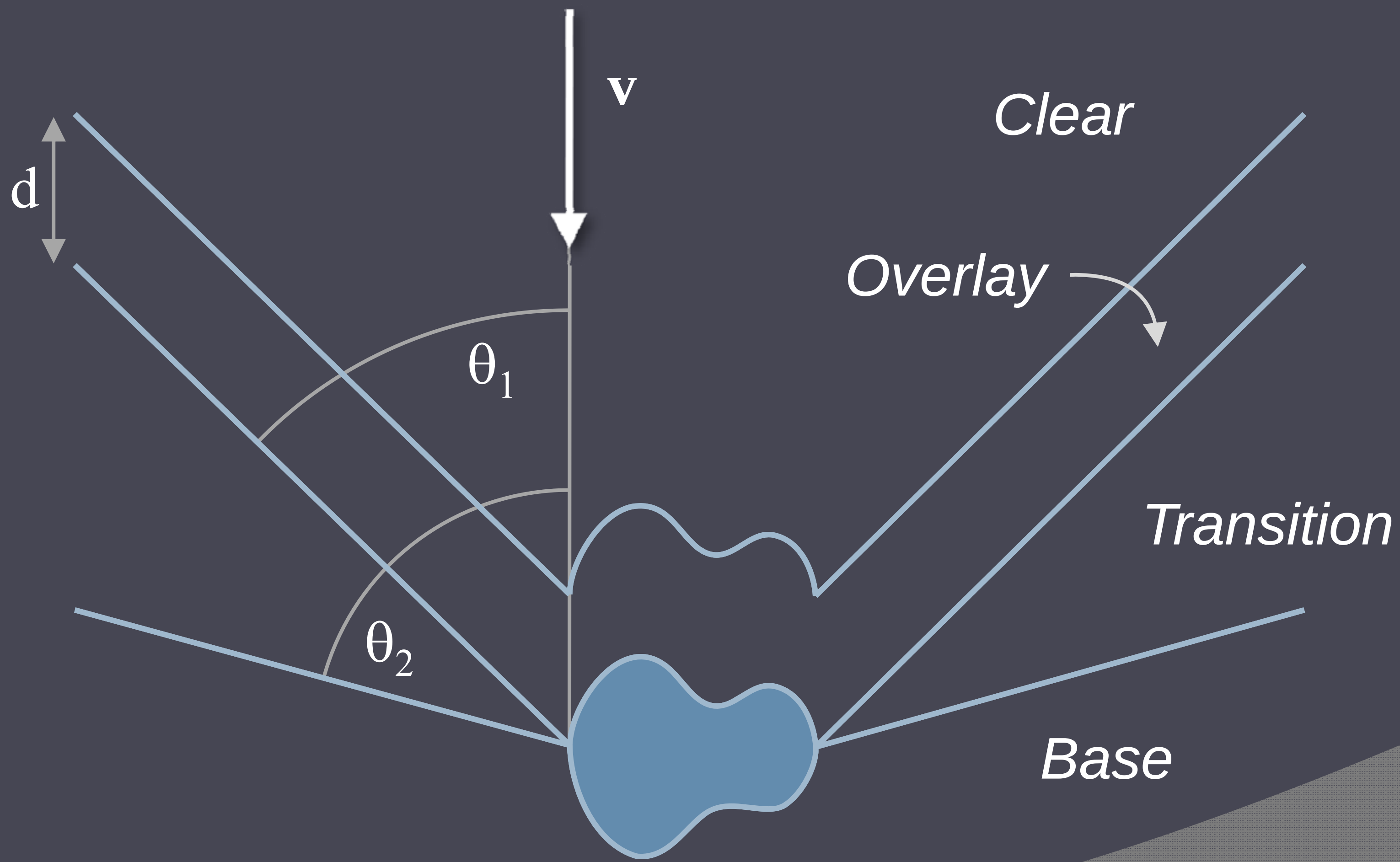


Small θ

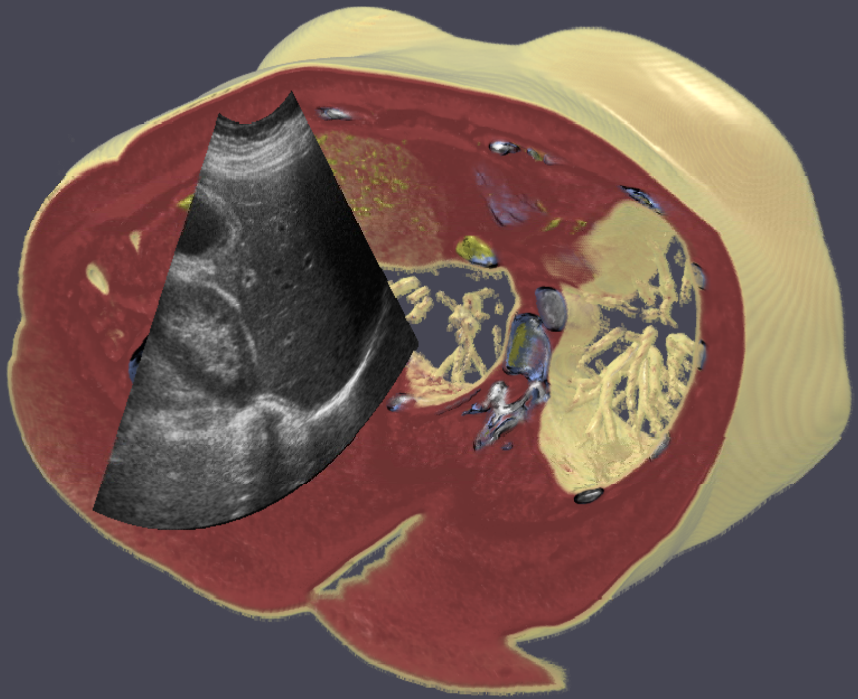


Large θ

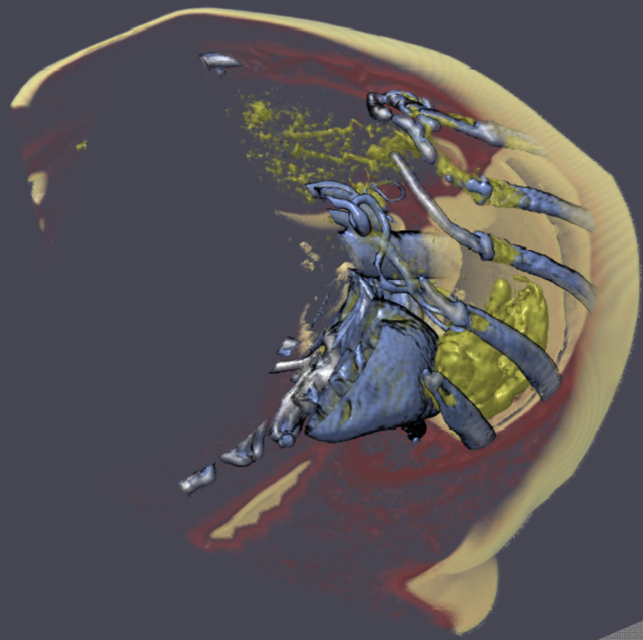
Contextual Cutaways



Layered Visualization

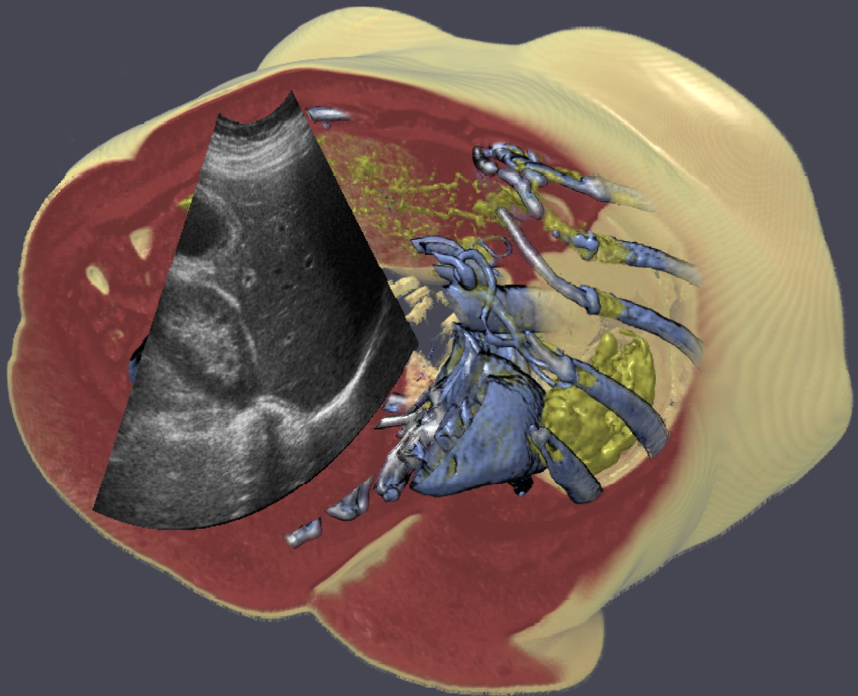


Base

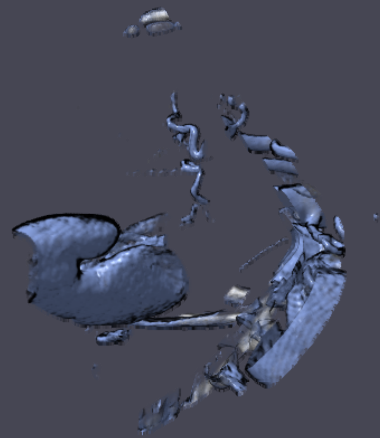


Transition

Layered Visualization

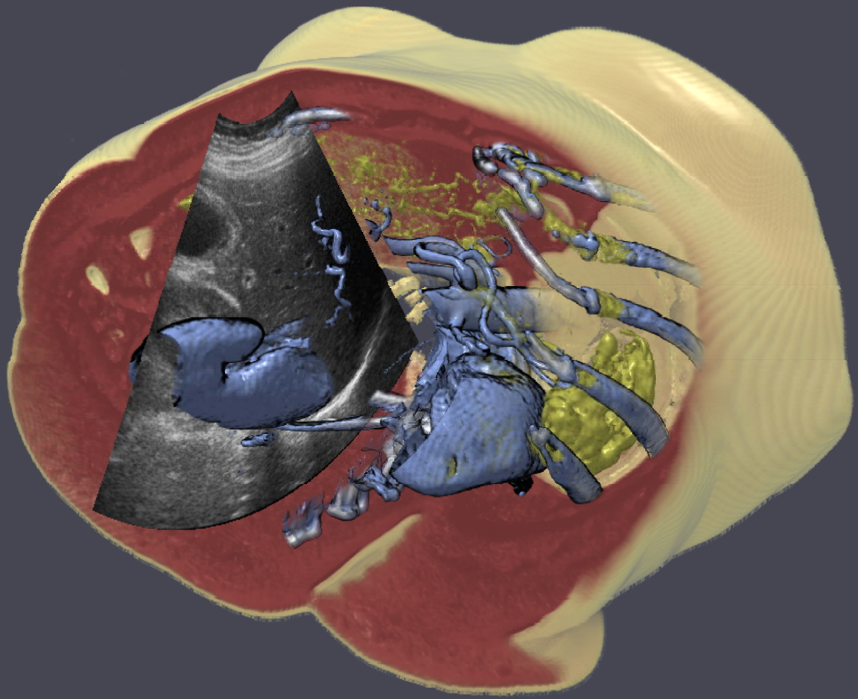


Base, Transition

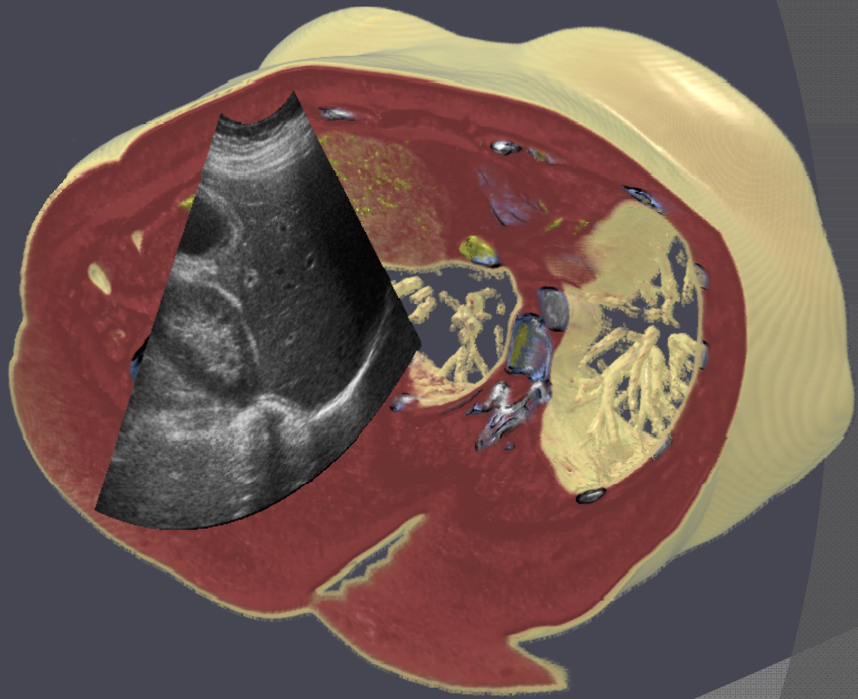


Overlay

Layered Visualization

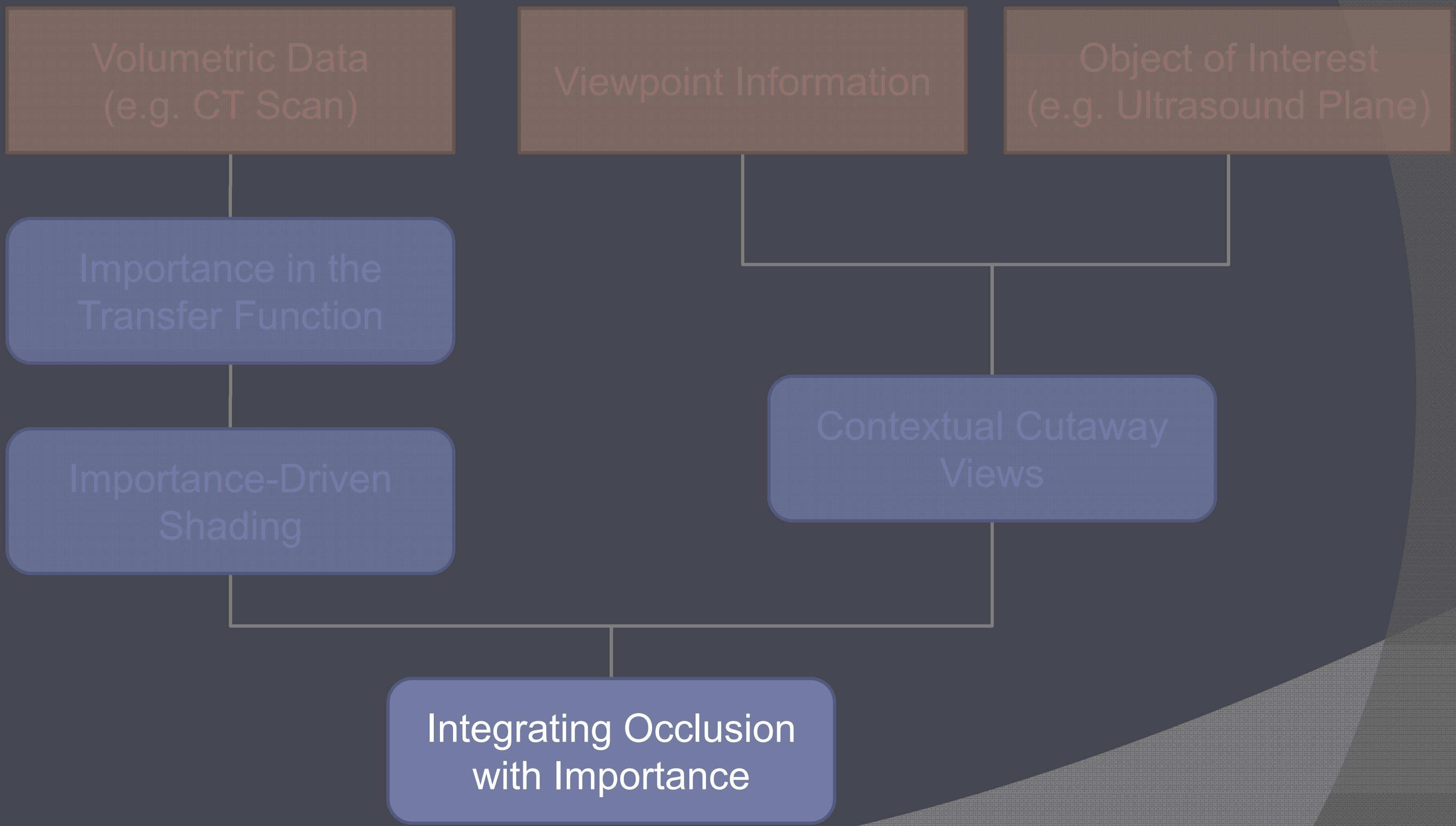


Base, Transition, Overlay

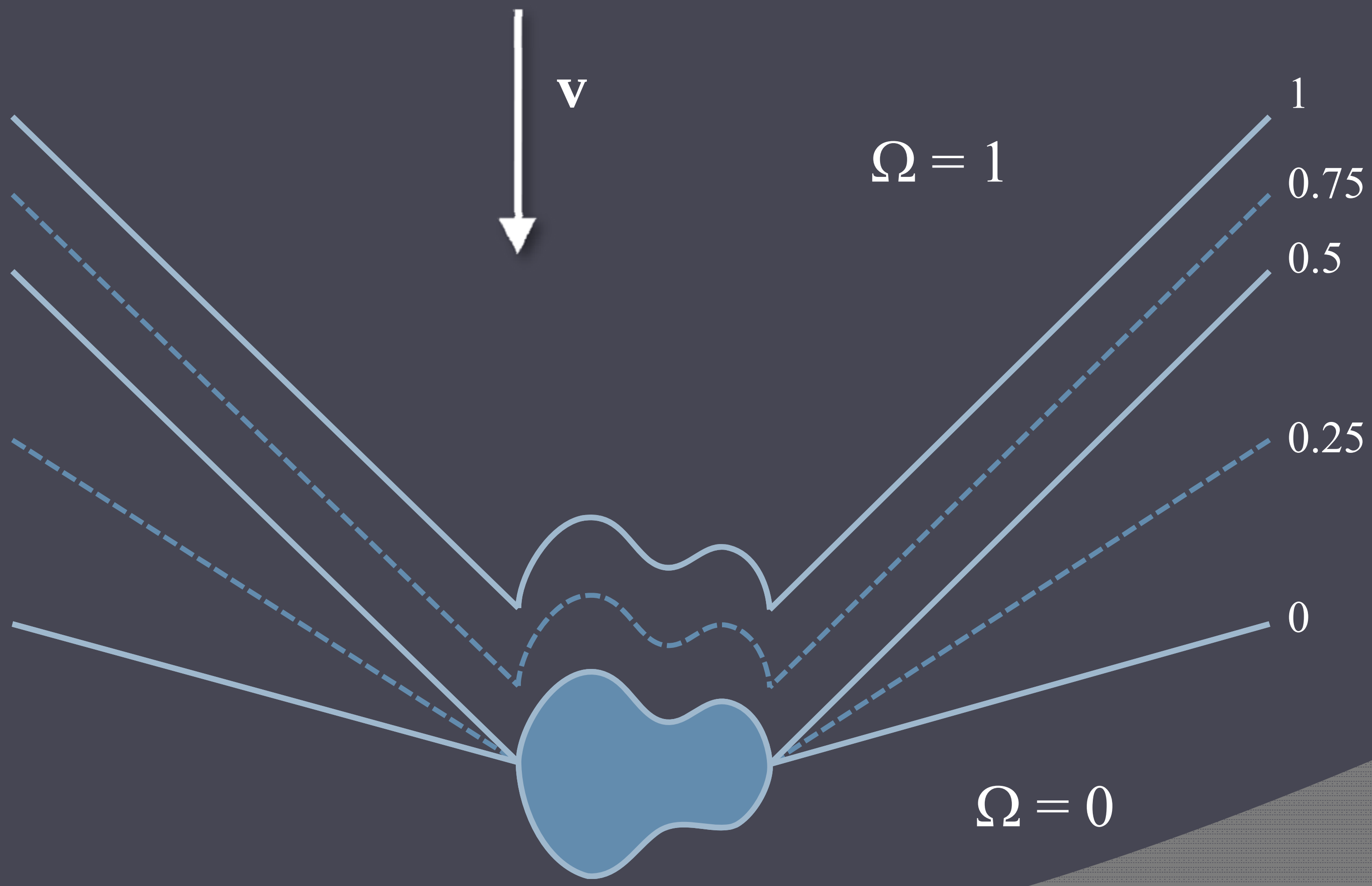


Base

Visualization Pipeline



Occlusion

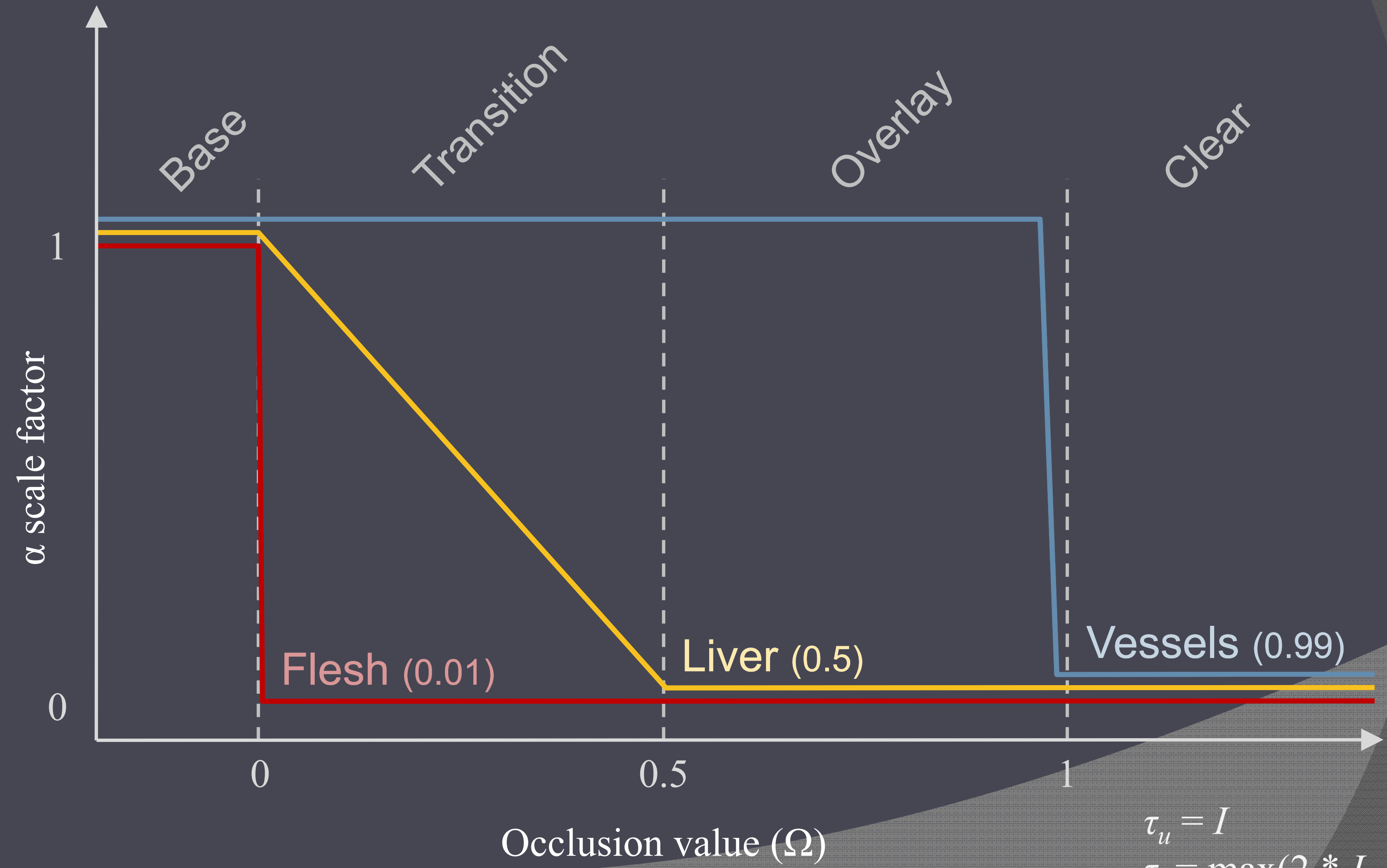


Occlusion Compensation

- Fade material based on occlusion value between two occlusion thresholds
  - Thresholds based on importance

- Modify opacity:
  - $\tau_u = I$
  - $\tau_l = \max(2 * I - 1, 0)$
  - $\alpha' = \alpha * (1 - \mathrm{ramp}(\tau_u, \tau_l, \Omega))$

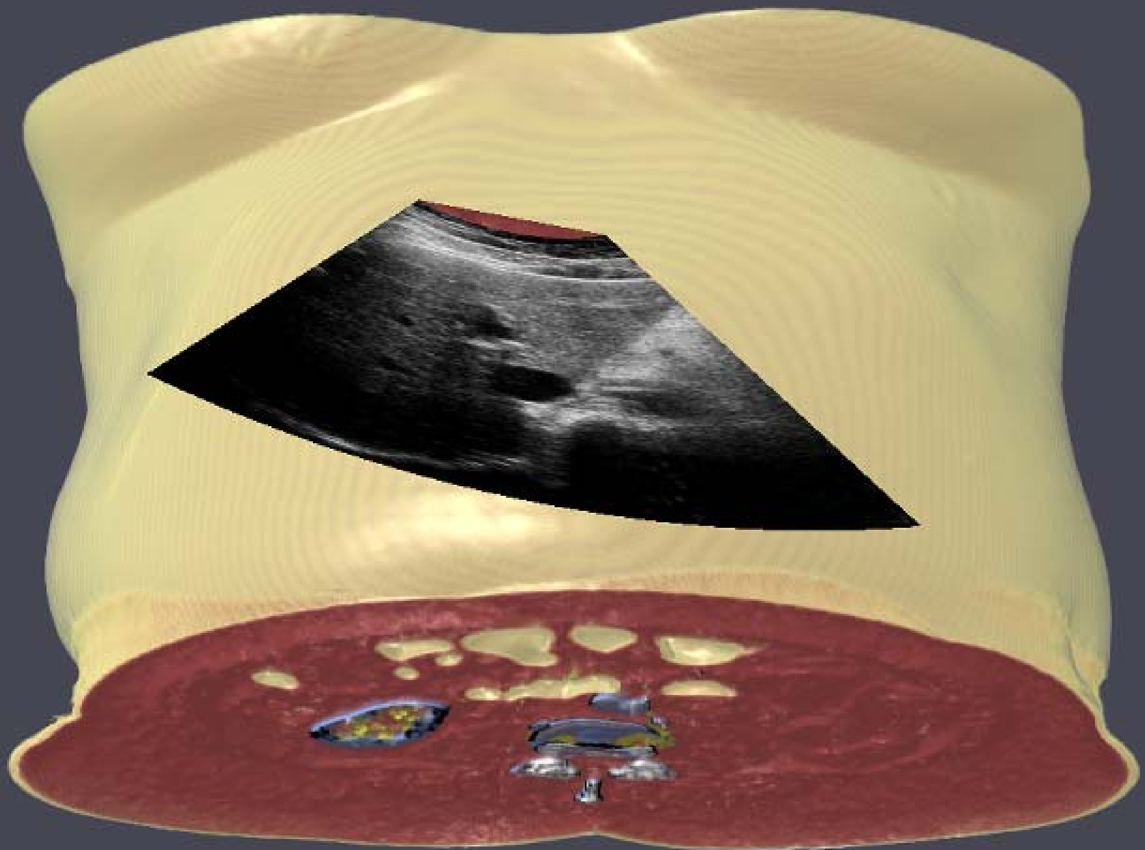
Occlusion Compensation

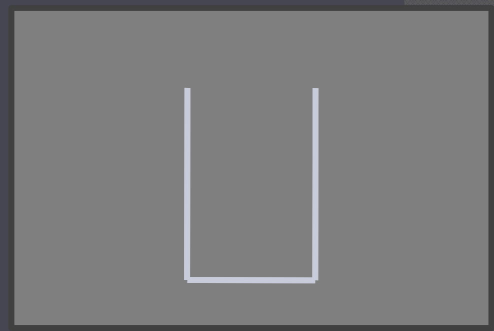


$\tau_u = I$

$\tau_l = \max(2 * I - 1, 0)$

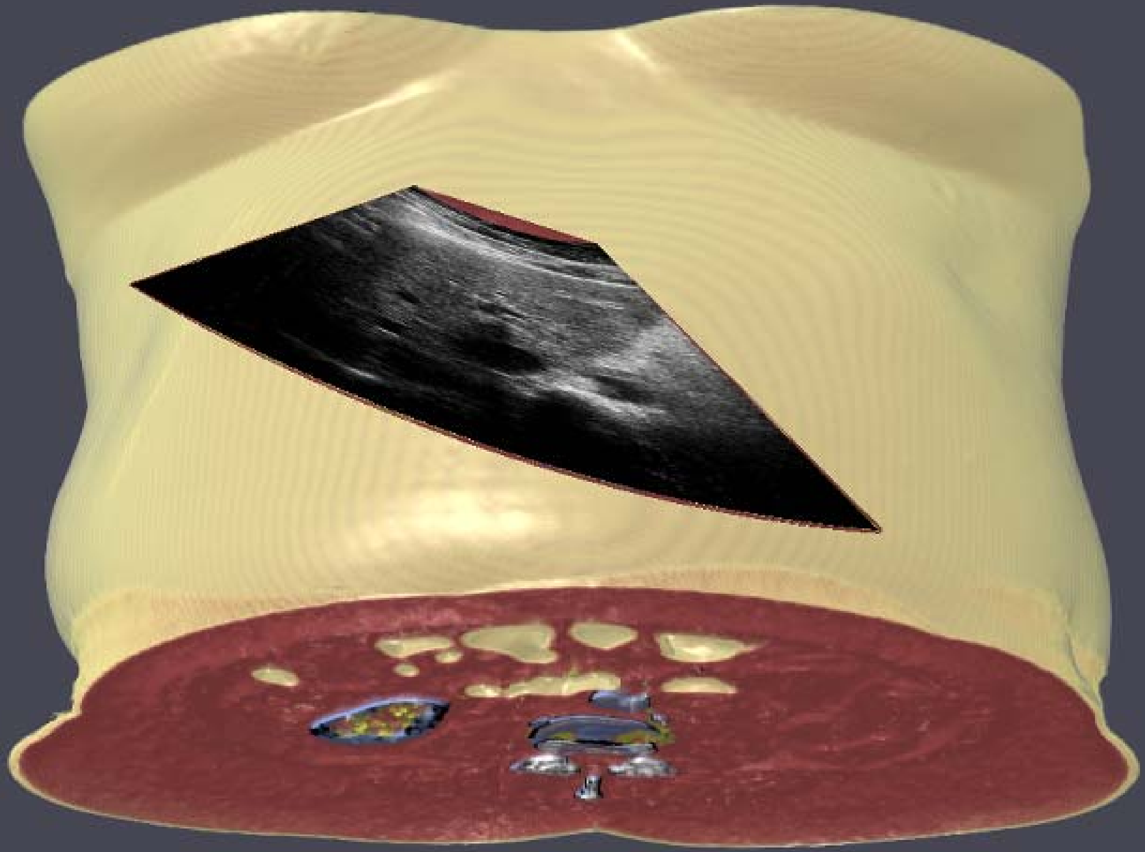
Results

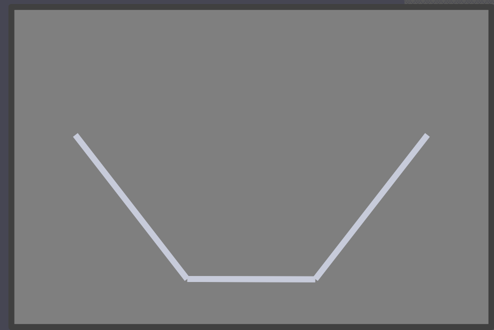




No cutaway
(over draw)

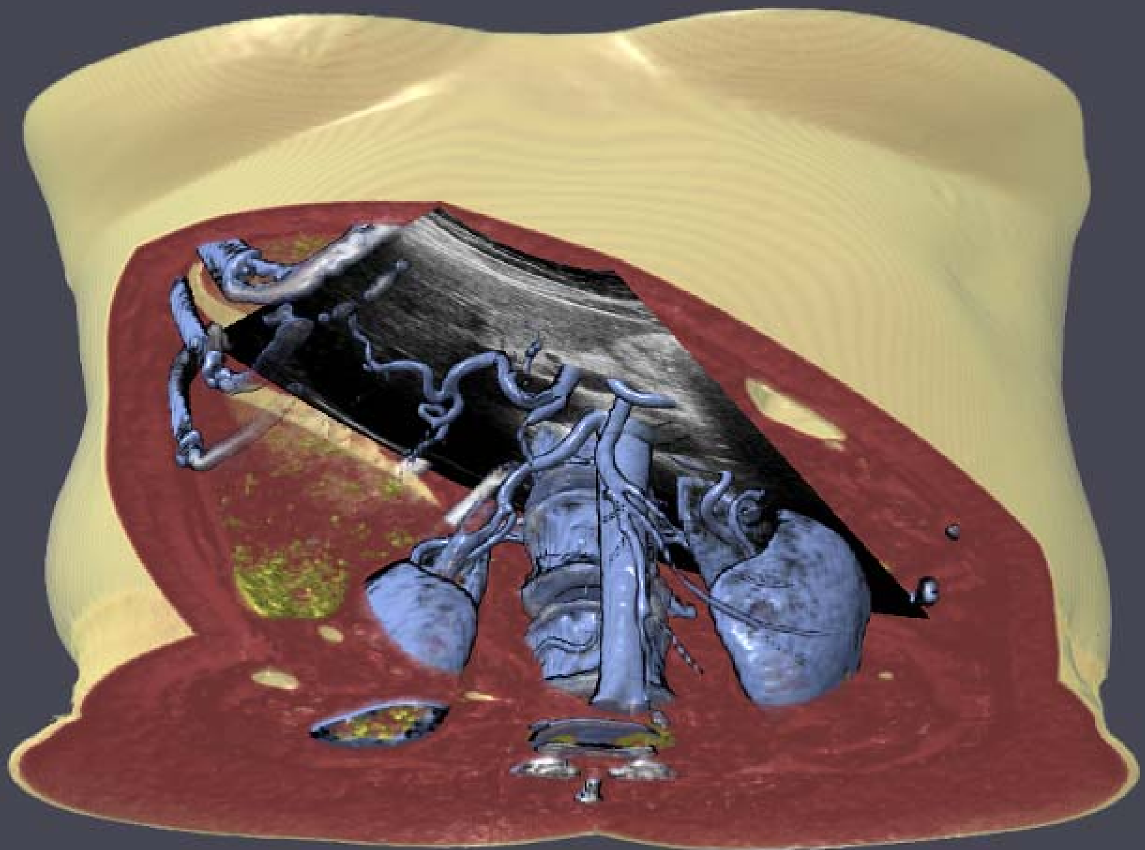
Results

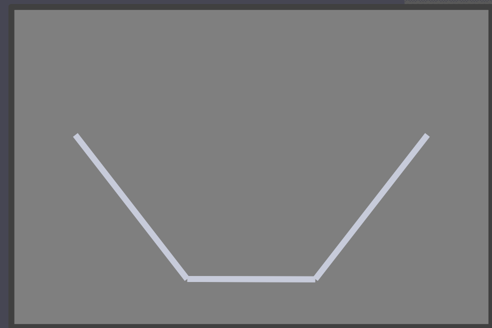




Simple cutaway

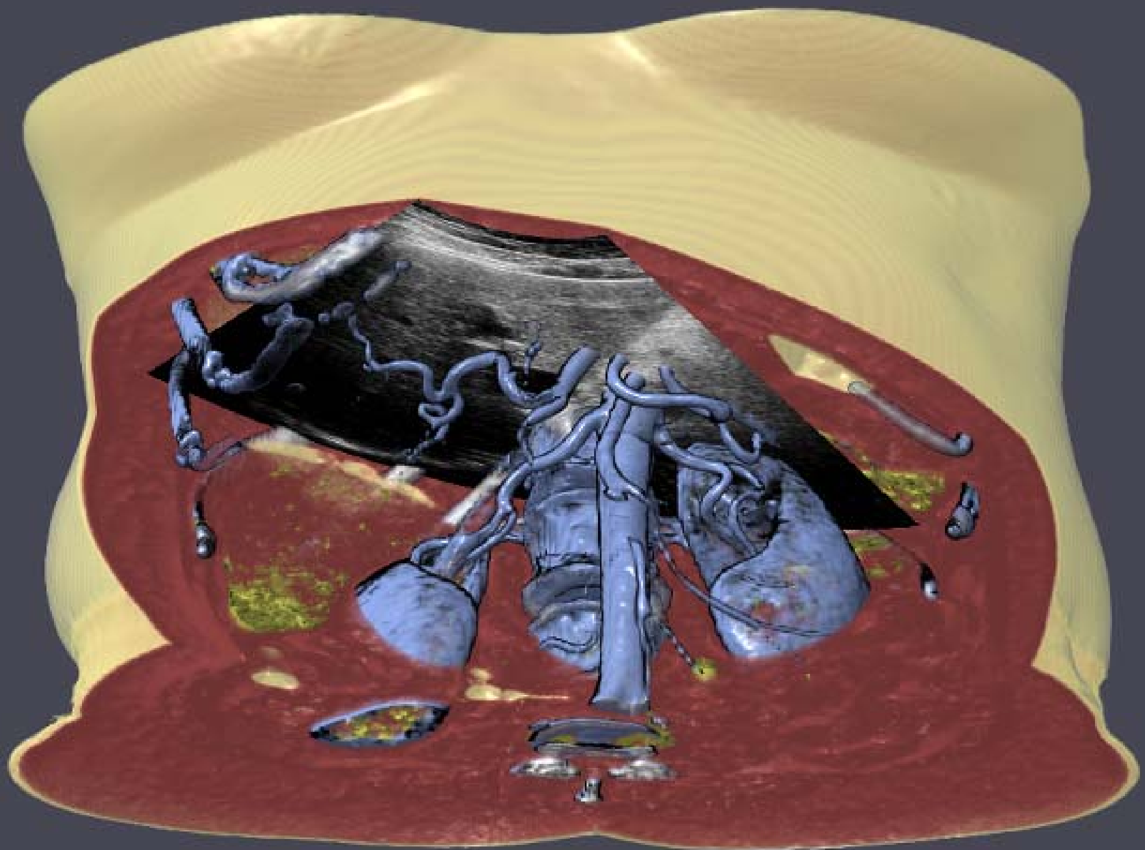
Results

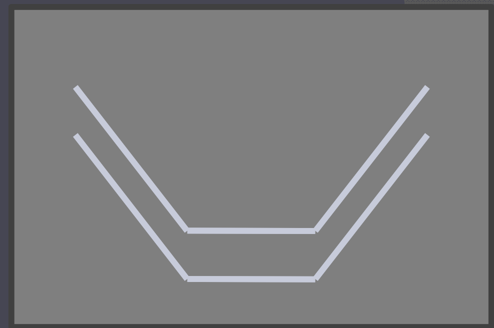




Simple cutaway
with interior

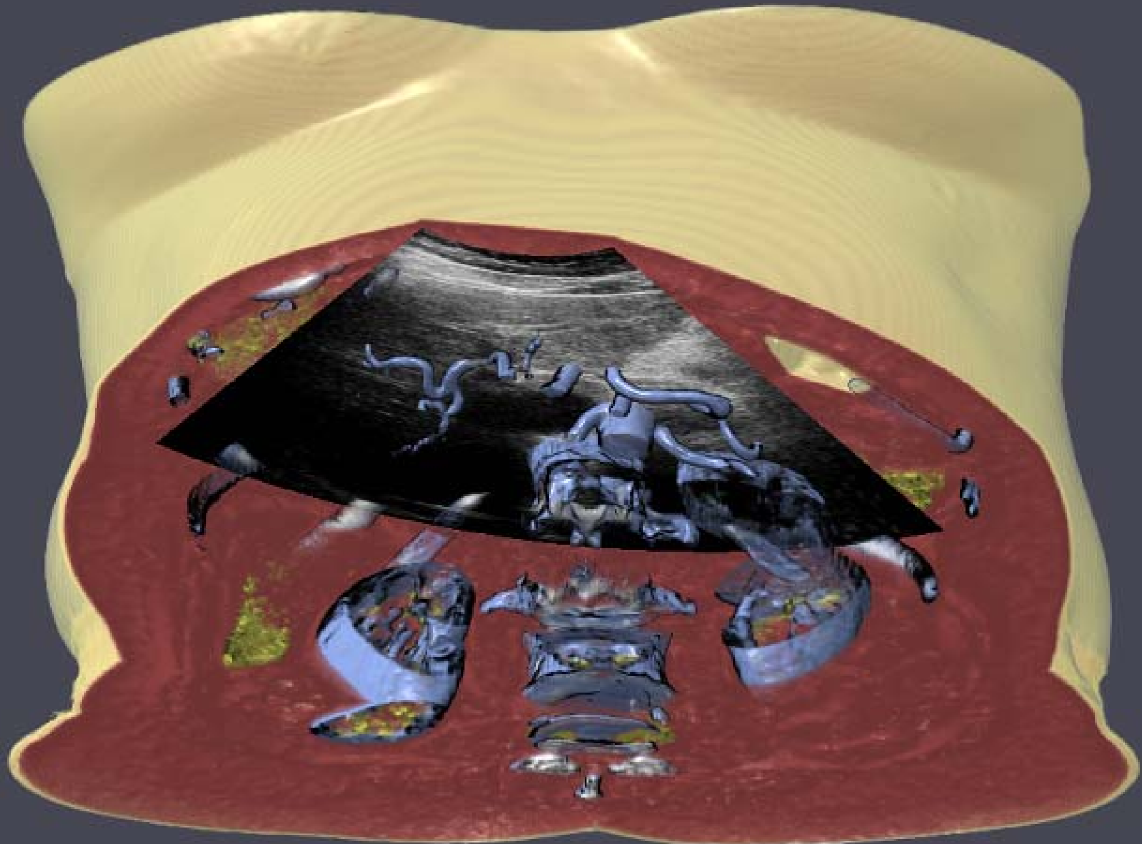
Results

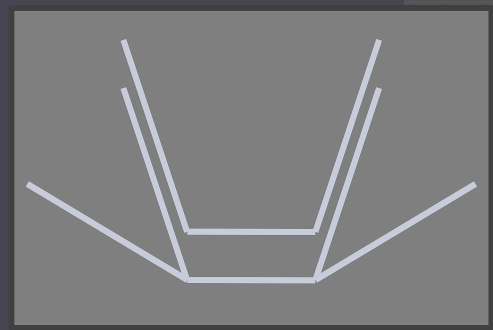




Interior becomes overlay region

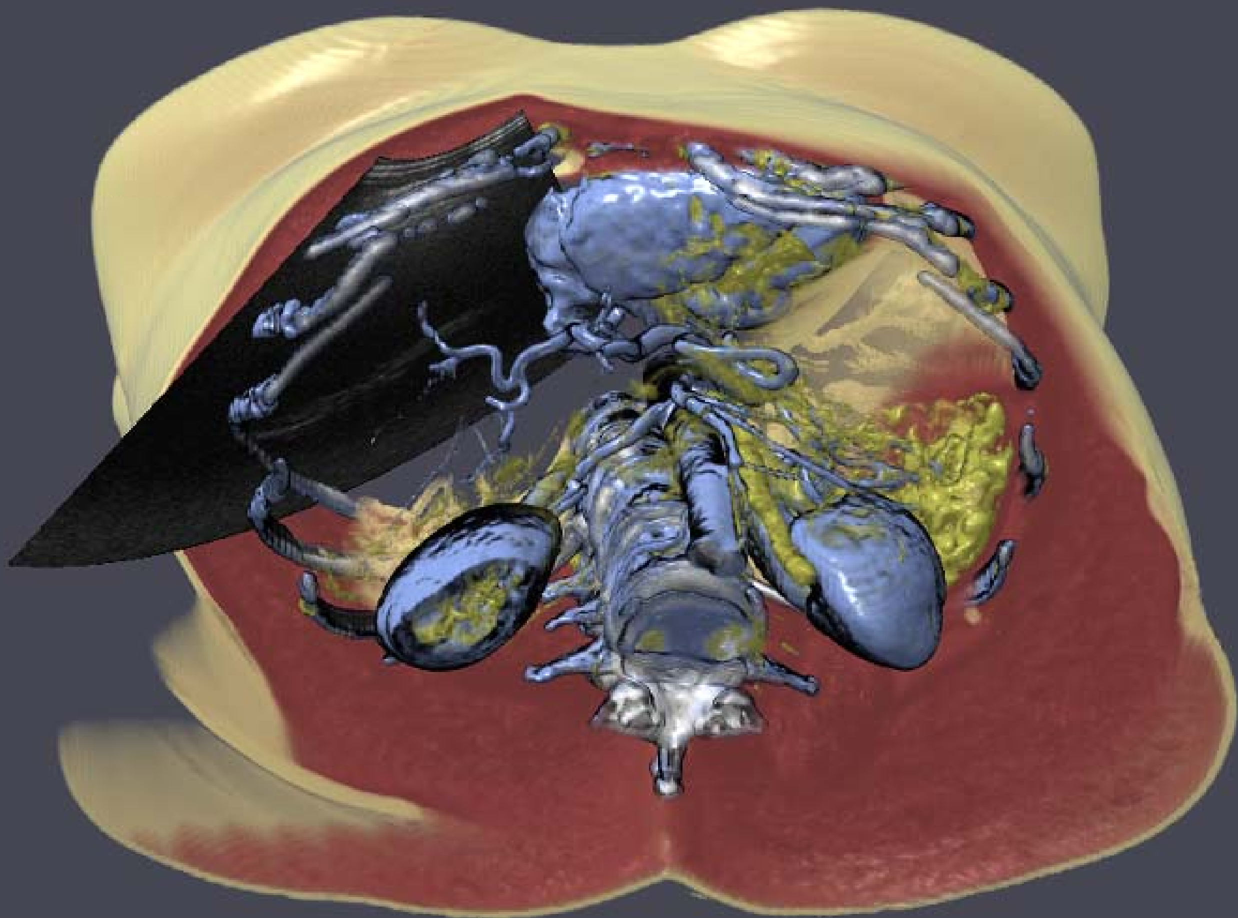
Results





Transition area added

Results



Implementation

- GPU Raycaster in GLSL
- Cutaway represented as height field
  - Created by rendering extruded geometry
  - Requires only 1 lookup per ray
- Performance
  - Interactive frame rates
  - 10-15 fps on high-end hardware
  - Dependent on sample rate, volume size, empty space skipping, etc.

Conclusions

- Visualization
  - Material importance defined within transfer function
  - Important materials emphasized through shading
  - View-dependent cutaway structure determines occlusion of object-of-interest
  - Materials removed in occluding areas, according to their importance

- Application
  - Visualize ultrasound data within CT scan for needle driven operations
  - Initial feedback has been positive
  - Currently being evaluated for clinical use

Acknowledgments

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