Medical/Volume Visualizations

John Bartlett

Papers

- Gerald Bianchi, Benjamin Knoerlein, Gabor Szekely, and Matthias Harders. **High Precision Augmented Reality Haptics**. *In EuroHaptics 2006*, pages 169–177, Jul 2006.
- Melanie Tory, Simeon Potts, and Torsten Moller. **A parallel coordinates style interface for exploratory volume visualization**. *IEEE Transactions on Visualization and Computer Graphics*, 11(1):71–80, 2005.
- Christof Rezk-Salama and Andreas Kolb. **Opacity peeling for direct volume rendering**. *Computer Graphics Forum*, 25(3):597–606, 2006.

High Precision AR Haptics

High Precision AR Haptics

- Laparoscopic surgical training more effective with realistic force feedback
  - AR systems with real tissue perform well
- Proof-of-concept haptic systems exist
- Integration in OR not yet feasible:
  - lag
  - tracking error

Problem: Lag

- Computational demands already high:
    - image acquisition/processing
    - virtual overlay
    - rendering output
- System response should be approximately real-time

Solution: Distributed System

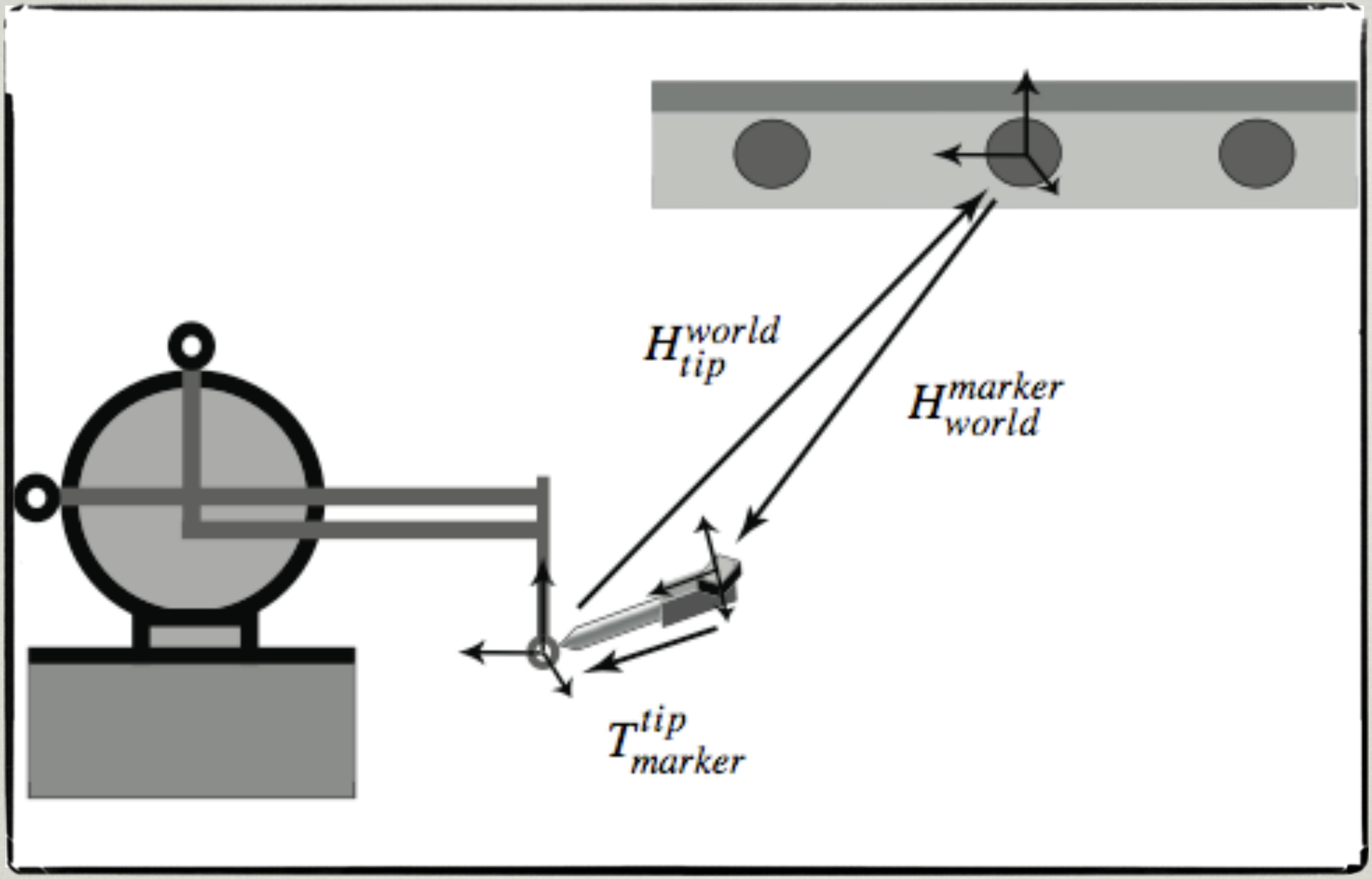
- Distributed system
  - graphics server and physics server
  - communication via ethernet cable
- Haptics and visuals computed independently
- Synchronization of servers
  - within 100μs using NTP server

Problem: Tracking Error

- Goal: precision of a few millimetres
  - 15 mm attained in early studies
  - adequate precision possible with calibration grid
- Problems:
  - only valid for points close to grid
  - assumes planarity

Solution: Tip-marker calibration

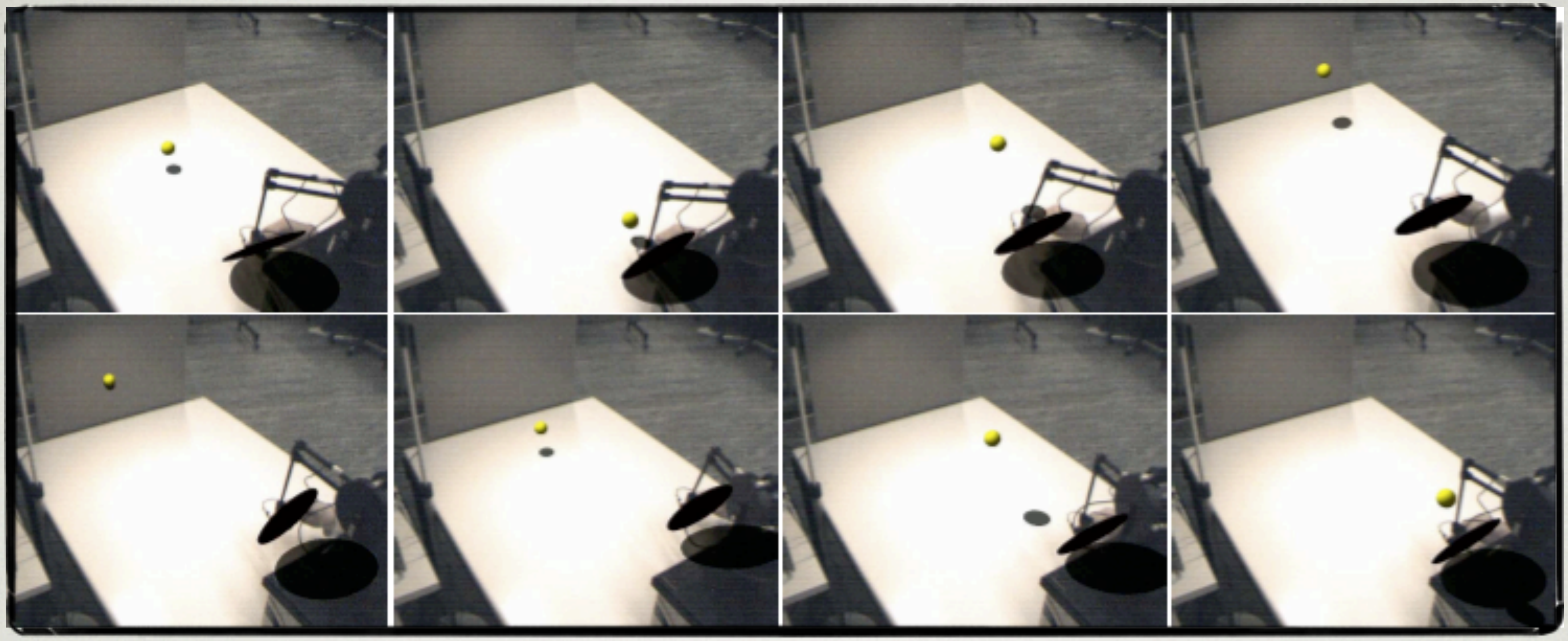
- Fix tip of haptic device and track 3-D rotation of marker
- Follow with haptic-world calibration
- Calibration allowed precision of 1.3 mm



Tip-marker calibration

Evaluation: Ping-Pong

- Highly interactive and precise
- Virtual ball, real environment
- Virtual paddle attached to haptic device
- Head-mounted display



Evaluation: Ping-Pong

- Lack of stereo camera impedes depth judgement
- Evaluation inconclusive

Critique

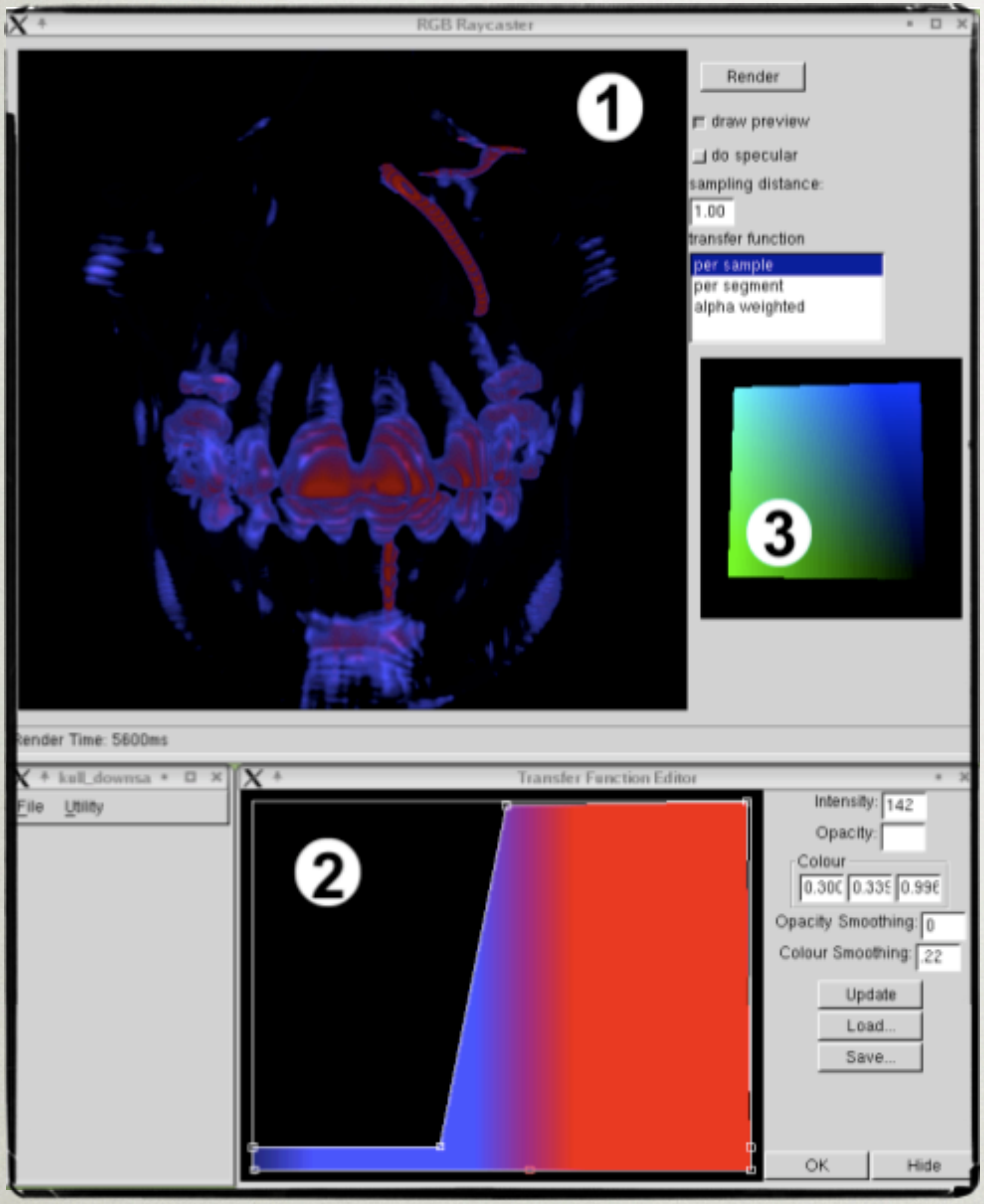
- Pros:
  - distributed framework
  - high precision
- Cons:
  - evaluation unintuitive and inconclusive
  - concluded that system could be applied to medical training scenarios - how?

A parallel coordinates-style interface for exploratory volume visualization

Parallel Coordinates for Volume Vis

- Standard interface:
  - graph of colour/opacity for data range
  - slow, tedious parameter selection
- Improvements:
  - parameters constrained as selections are made to reduce search space
  - histogram provided as guide
  - automated parameter generation

Standard Interface



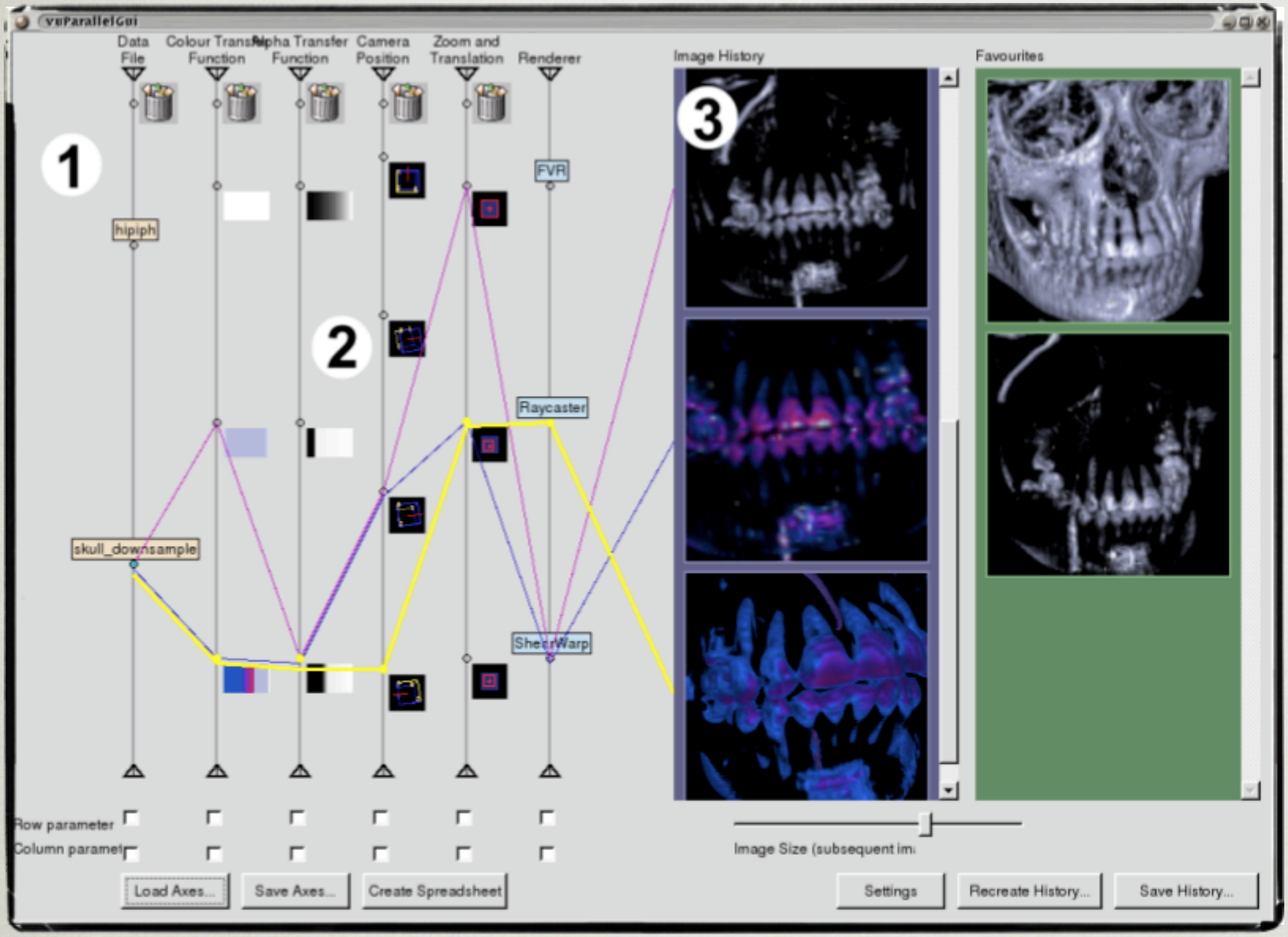
1. Rendering window
2. Transfer function editor
3. Zoom/rotation widget

Problems

- Hard to keep track of previous choices
- No "undo" button or history
- Comparing between settings is difficult

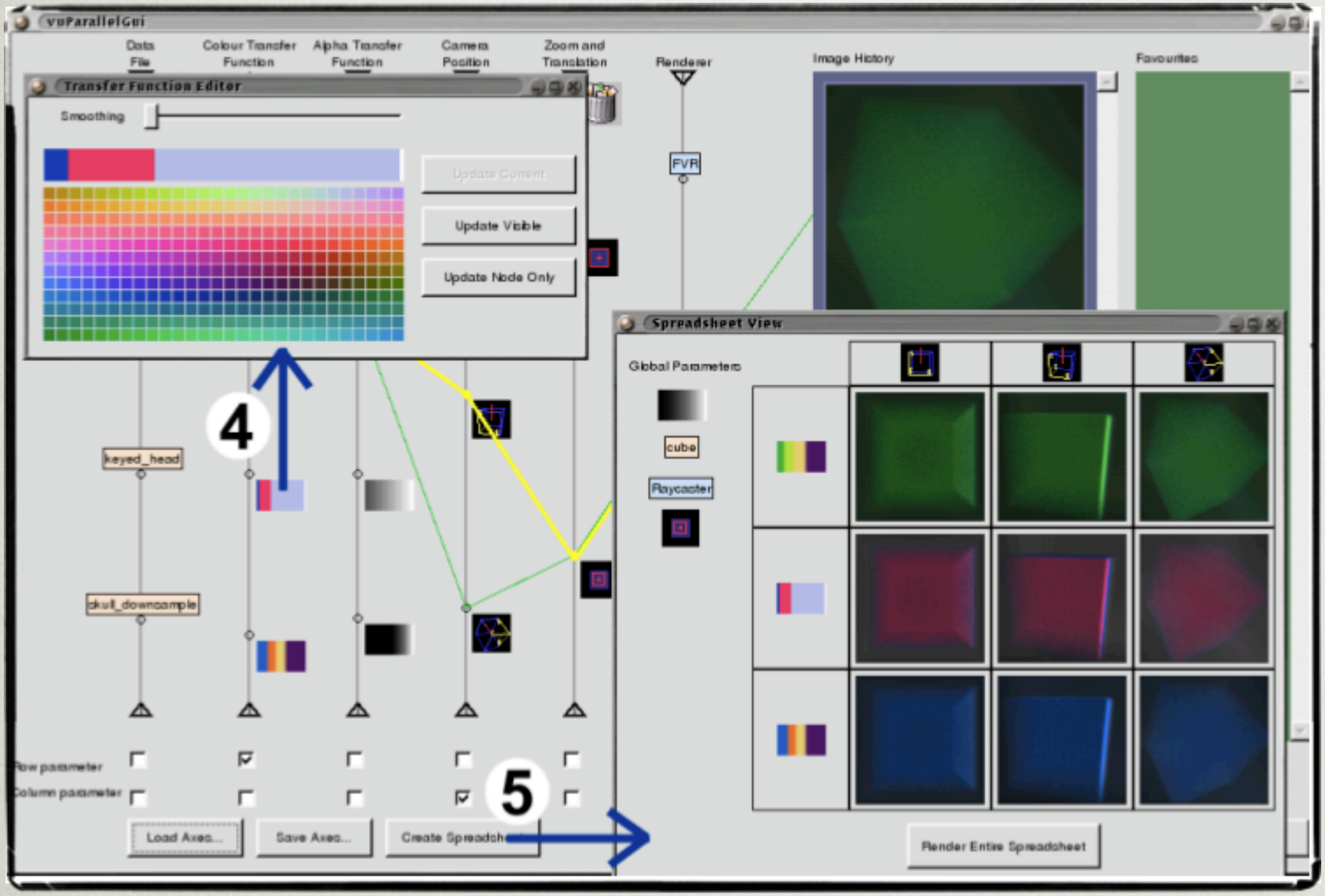
Solution: Parallel Coordinates

- Design Goals:
  - Overview
  - Zoom & Filter
  - Relate
  - History
  - Extract



Solution: Parallel Coordinates

1. One axis for each parameter
2. Parameter sets are represented as lines connecting parameters to resultant image
3. History bar shows previous settings

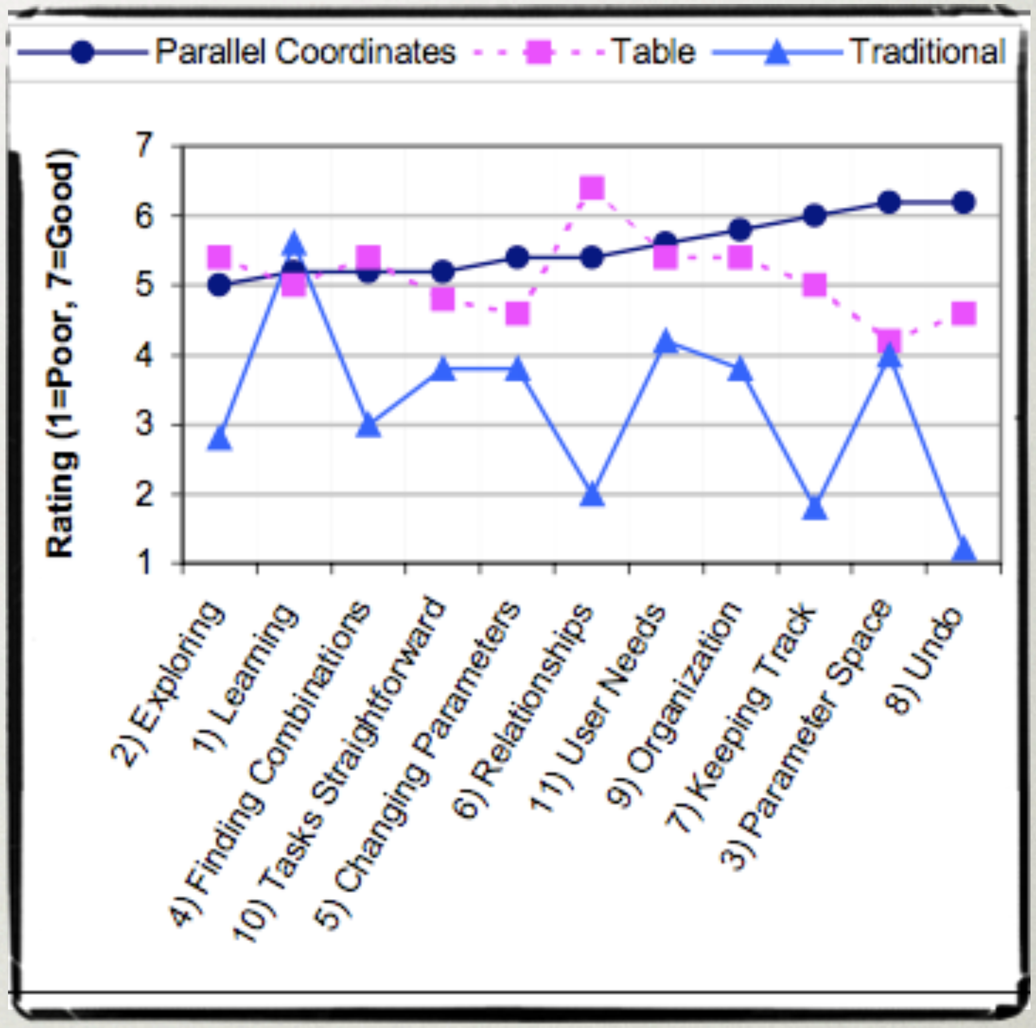


Solution: Parallel Coordinates

4. Edit existing parameter nodes to make new ones
5. Choose parameters to plot on row and column of table

Evaluation

- 5 experts chosen for qualitative user study
- Data exploration and search tasks
- Outperformed traditional and table interfaces



Discussion

- Parameter-based vs. image-based visualization
- Parameters occupy a lot of space
- Lacks transfer function interactivity
- Multi-dimensional parameter values treated as discrete and unrelated
- Scalability issues

Critique

- Pros:
  - presented a novel exploratory visualization technique
  - addressed existing problems
  - thorough discussion - identified weaknesses and planned future work
- Cons:
  - only 5 people chosen in user study

Opacity Peeling for Direct Volume Rendering

Medical Volume Visualization

- More info than can be displayed
- Often a focus + context task
  - structure of interest smaller than relevant contextual info

Filtering Volume Data

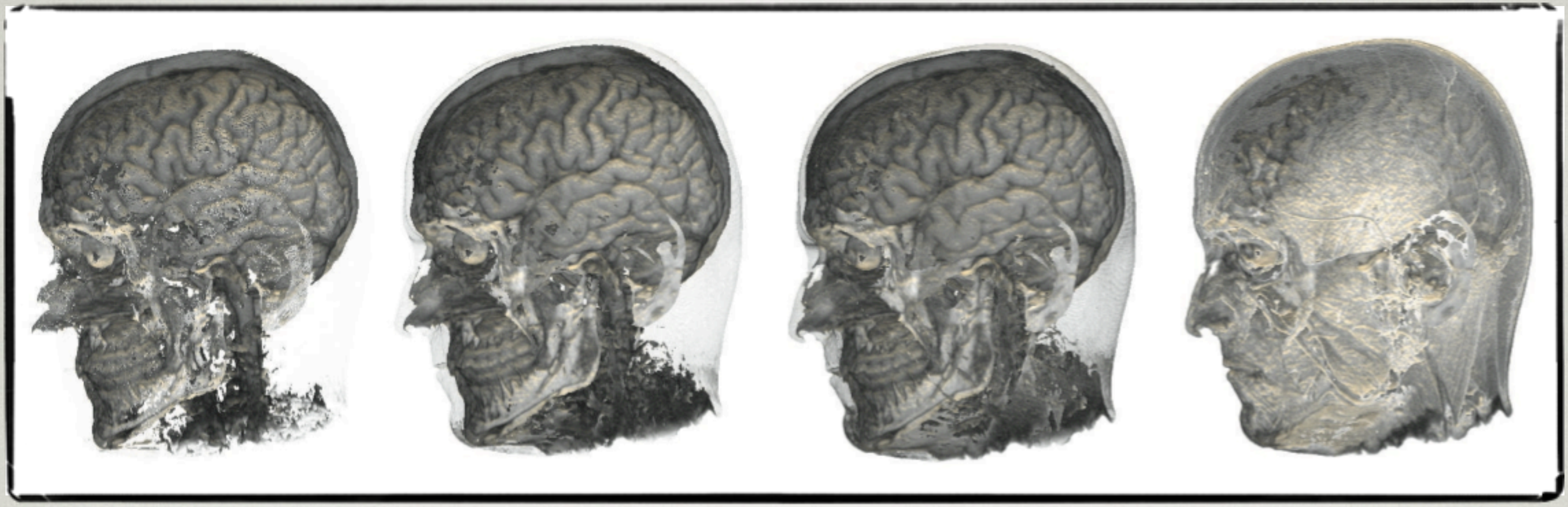
- Reducing opacity:
    - occlusion still an issue
    - may consider values, gradients, etc.
- Volume clipping:
    - preserve context manually
- Importance/Classification-based:
    - requires segmentation/annotation

Ray Tracing

- Common volume rendering technique
- Project rays through volume along viewing axis and either:
    - attenuate according to transfer function,
    - select maximum intensity, or
    - select first intensity that satisfies threshold

Opacity Peeling

- Ray tracing with attenuation, but reset rays to full strength when ray either:
  - becomes insignificant or
  - reaches a strong gradient
- Remember layers where new rays are cast



Opacity Peeling

Leftmost: threshold too low

Rightmost: can see muscle layer below skin

Advantages

- GPU implementation allows on-the-fly rendering
- Opacity peeling: can remove/modify "remembered" layers
- Great for looking beneath skull and fat in brain MRI images
- Can reveal unexpected structures

Critique

- Pros:
  - good segmentation for time-critical visualization scenarios
  - potential for integration in OR
  - discussed using complex transfer functions for offline visualizations
- Cons:
  - crude segmentation compared to offline techniques

Questions?