Volume Rendering from Difficult Data Formats

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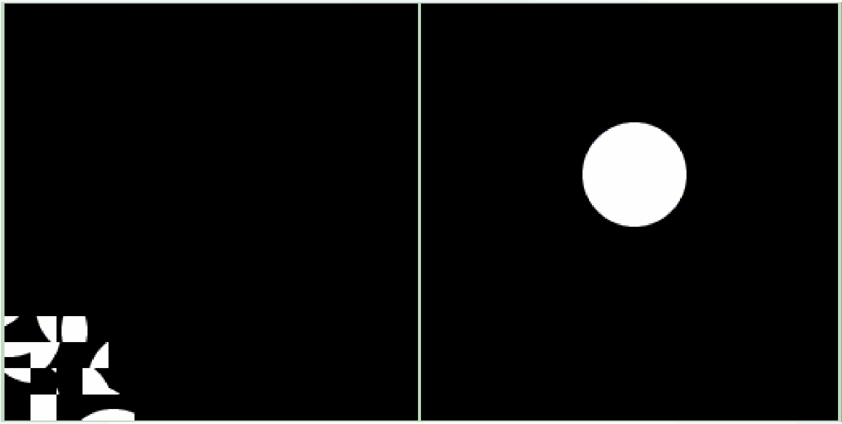
Overview

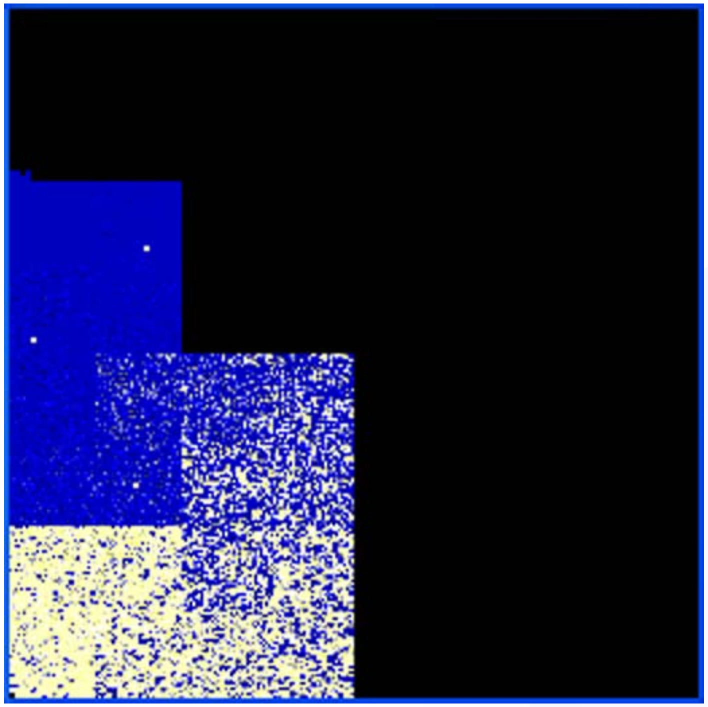
- What is a Difficult Data Format?
- Why Difficult Data Formats?
- The "Difficult Data" Rendering Pipeline
  - Reconstruction of volume data
  - Filtering
  - Transfer function and lighting
- Conclusions

Motivation

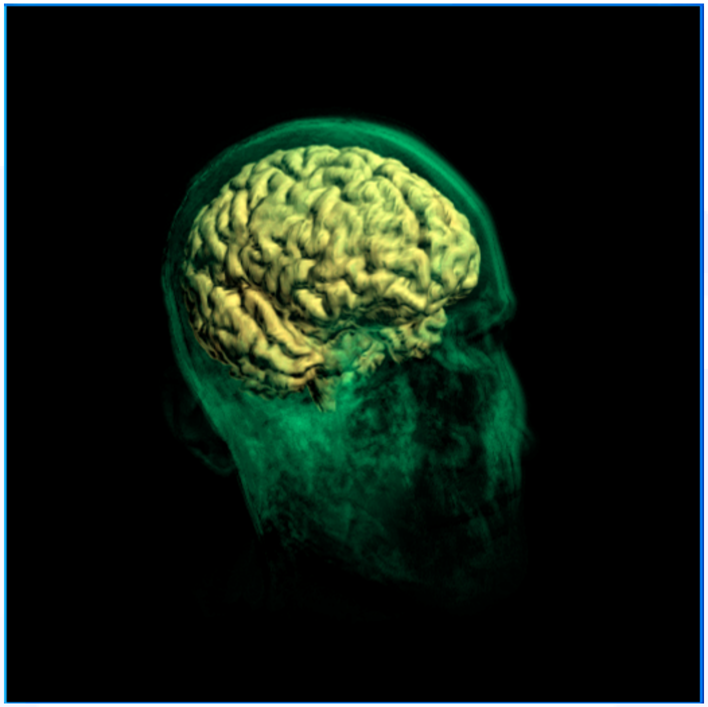
- What is a *Difficult Data Format*?
  - A data format that differs from the 3D domain on which the volume rendering algorithm is defined
  - Examples
    - Compressed data
    - Sparse data
    - Set of 2D slices



Difficult-Data Volume Rendering



Compressed Data Format

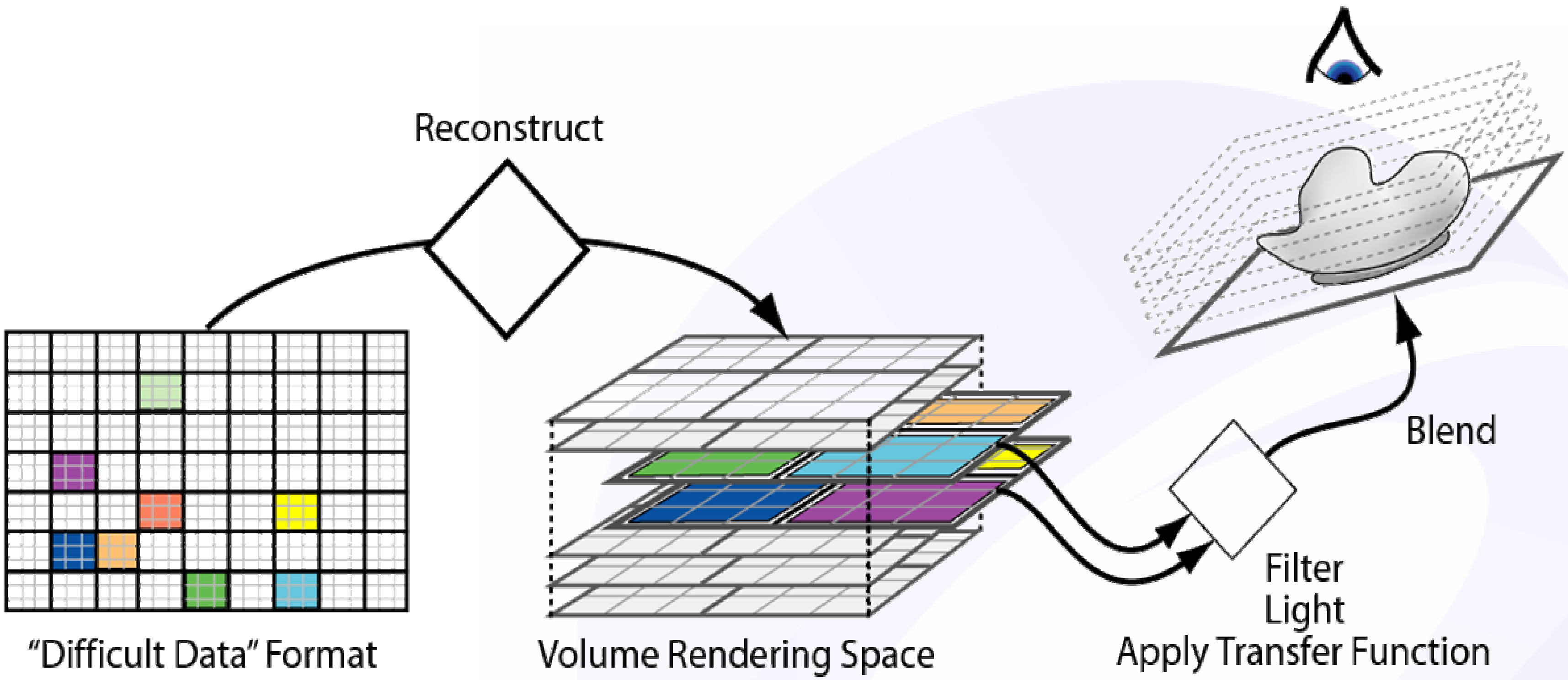


Interactive VolumeRendering

Motivation

- Why *Difficult Data Formats?*
  - Data compression
    - On-the-fly decompression of large data sets
  - Acceleration of volume rendering
    - Store only the “important“ data in a packed format
  - GPU-generated data (GPGPU computation)
    - Set of 2D dynamic textures (pbuffers)

Rendering Pipeline Overview



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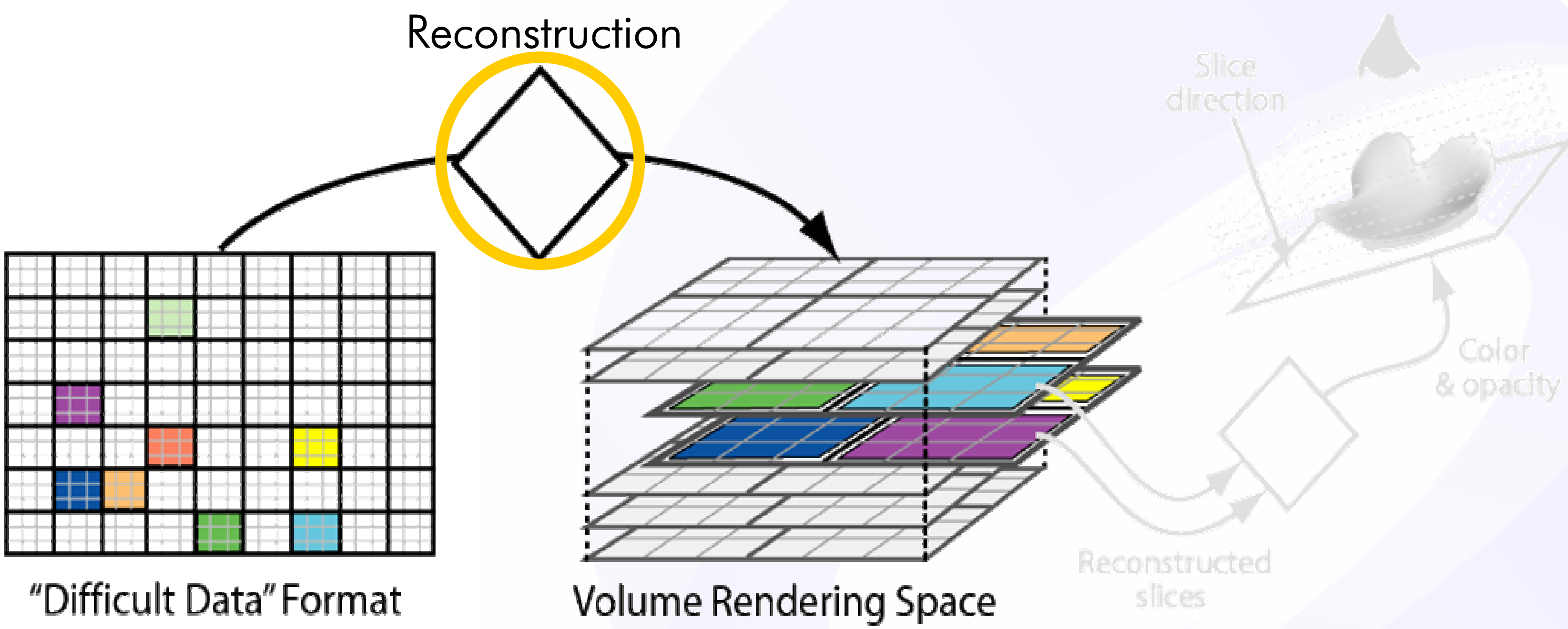
Rendering: Reconstruction

- Idea:
  - Map data from “difficult-data space“ to volume rendering space



Rendering: Reconstruction

- Three Basic Types of Mappings
  - Analytic
    - Mapping is procedurally computed on-the-fly
      - Ex: Heirarchical bricking

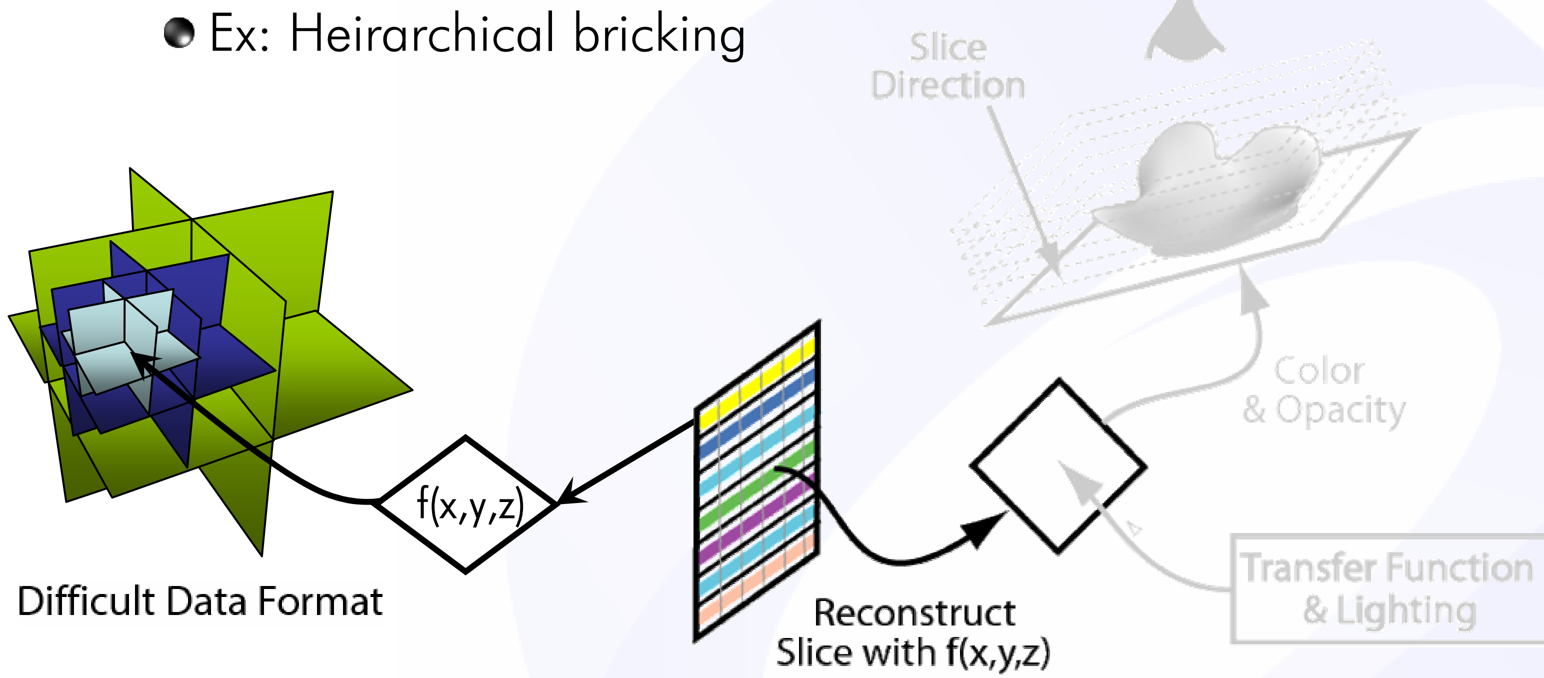
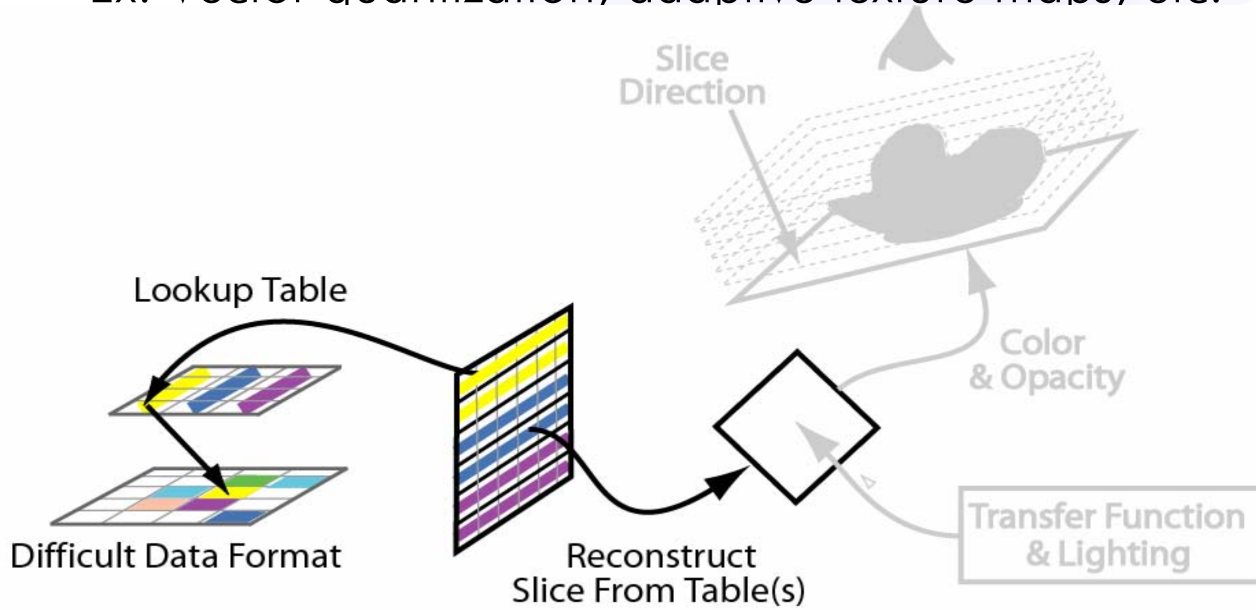


Figure Courtesy of Klaus Engel

Aaron E. Lefohn
Institute for Data Analysis and Visualization, UC Davis, USA

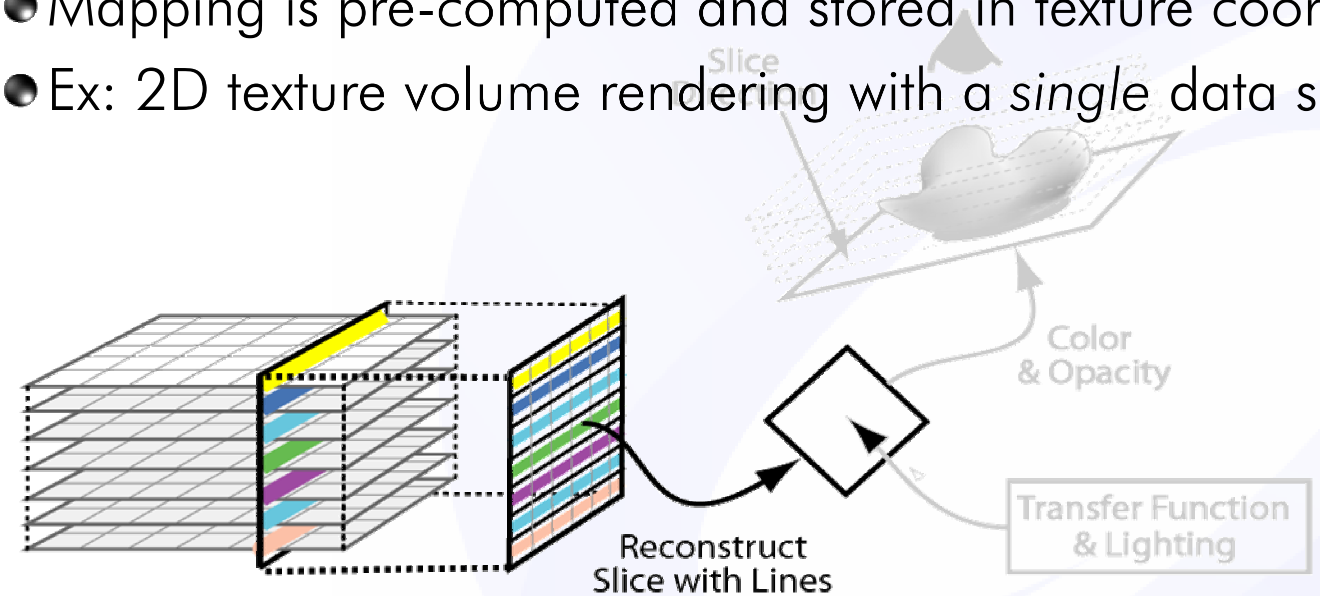
Rendering: Reconstruction

- Three Basic Types of Mappings
  - Analytic
  - Table-Based
    - Mapping is stored in GPU-based table(s)
      - Ex: Vector quantization, adaptive texture maps, etc.



Rendering: Reconstruction

- Three Basic Types of Mappings
  - Analytic
  - Table-Based
  - Geometry-Based
    - Mapping is pre-computed and stored in texture coordinates
    - Ex: 2D texture volume rendering with a *single* data set



Reconstruction Conclusion

- Data reconstruction is the first step in all difficult-data volume rendering algorithms
  - Mapping from rendering-space to data-space
  - Analytic, table-based, or geometry-based

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Rendering: Filtering

- Construct Continuous Signal from Discrete Data

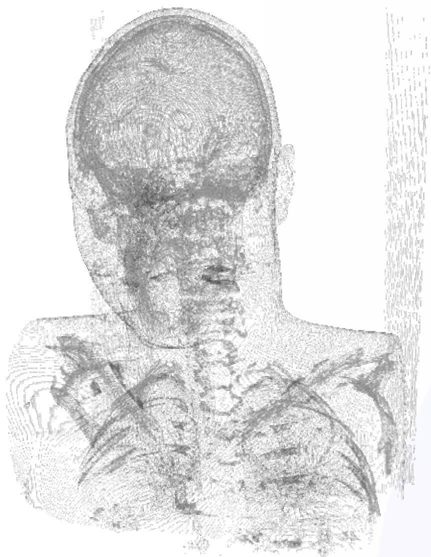
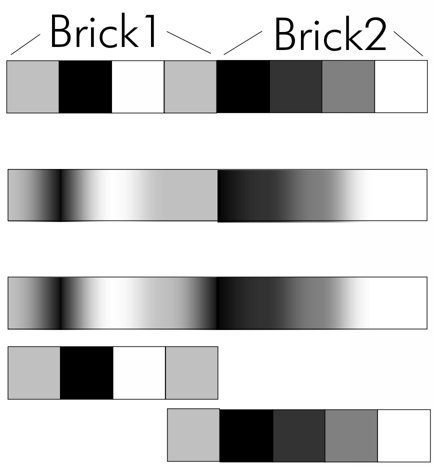


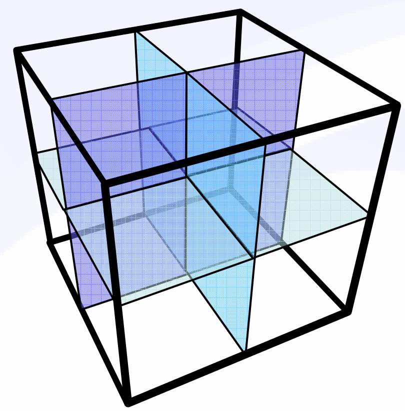
Figure Courtesy of Klaus Engel

- Achilles' heal of difficult-data volume rendering
  - Native GPU filtering cannot be used in many cases
  - Many difficult-data techniques provide no filtering

Rendering: Filtering

- In Which Space Should We Filter?
  - Difficult-data domain
    - Data format must contain contiguous regions of the original volume (e.g. sub-volume bricks, etc.)



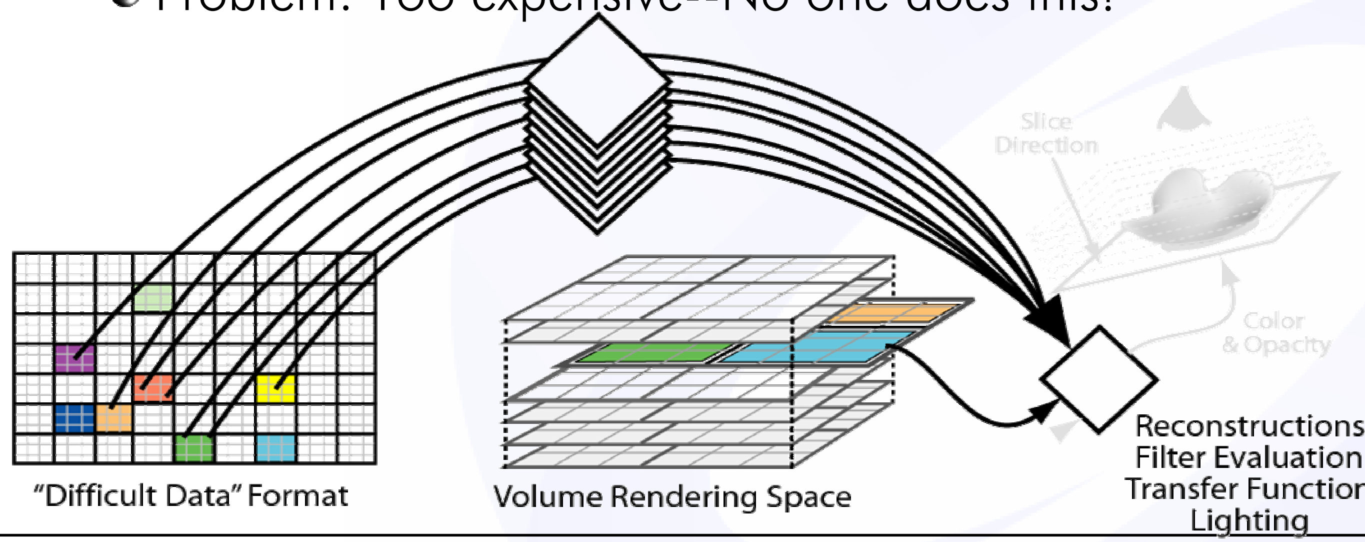


    - Over-represent data by width of filter kernel
    - Use native GPU trilinear filtering

Figure Courtesy of Klaus Engel

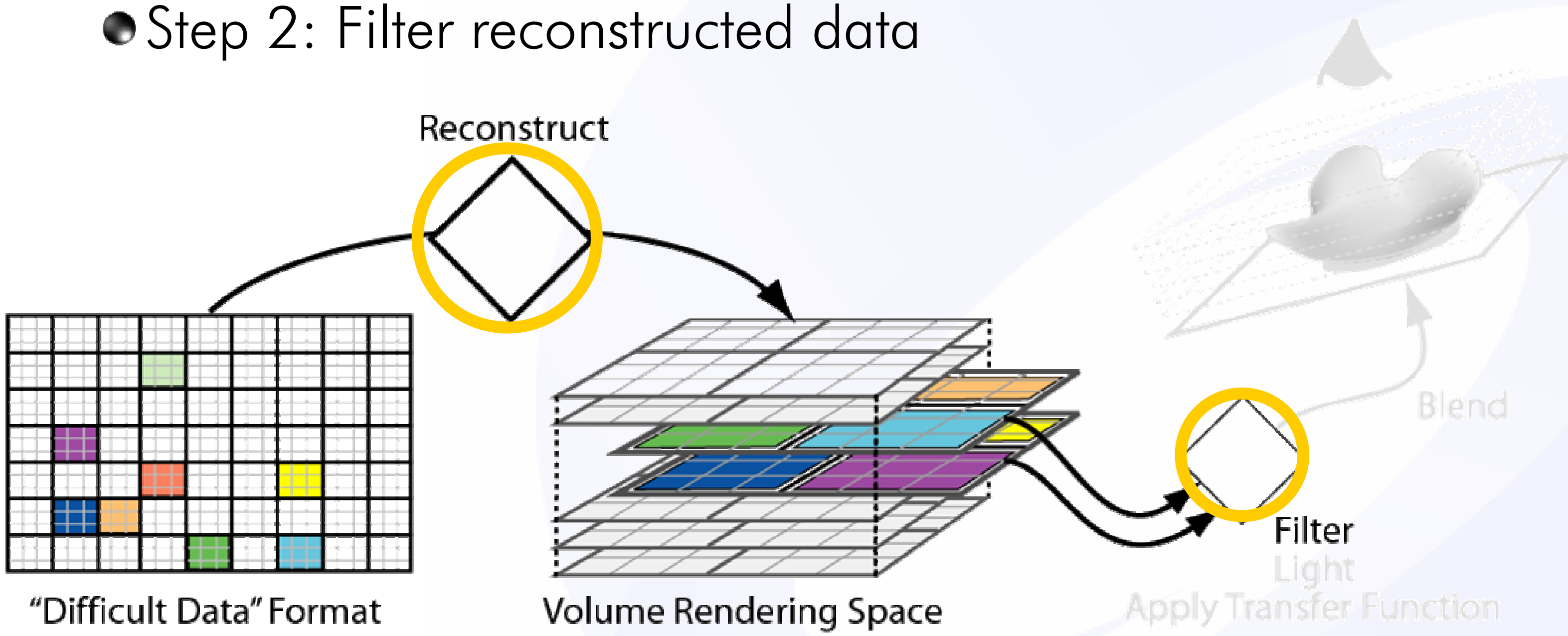
Rendering: Filtering

- In Which Space Should We Filter?
  - Difficult data domain
  - Reconstructed rendering domain
    - Required if data is not “over-represented sub-volumes“
    - Must reconstruct a data point for each filter sample
      - Problem: Too expensive--No one does this!



Solution: Deferred Filtering

- Idea
  - Similar to deferred shading and separable convolution
  - Separate reconstruction and filtering steps
    - Step 1: Reconstruct original discrete data
    - Step 2: Filter reconstructed data

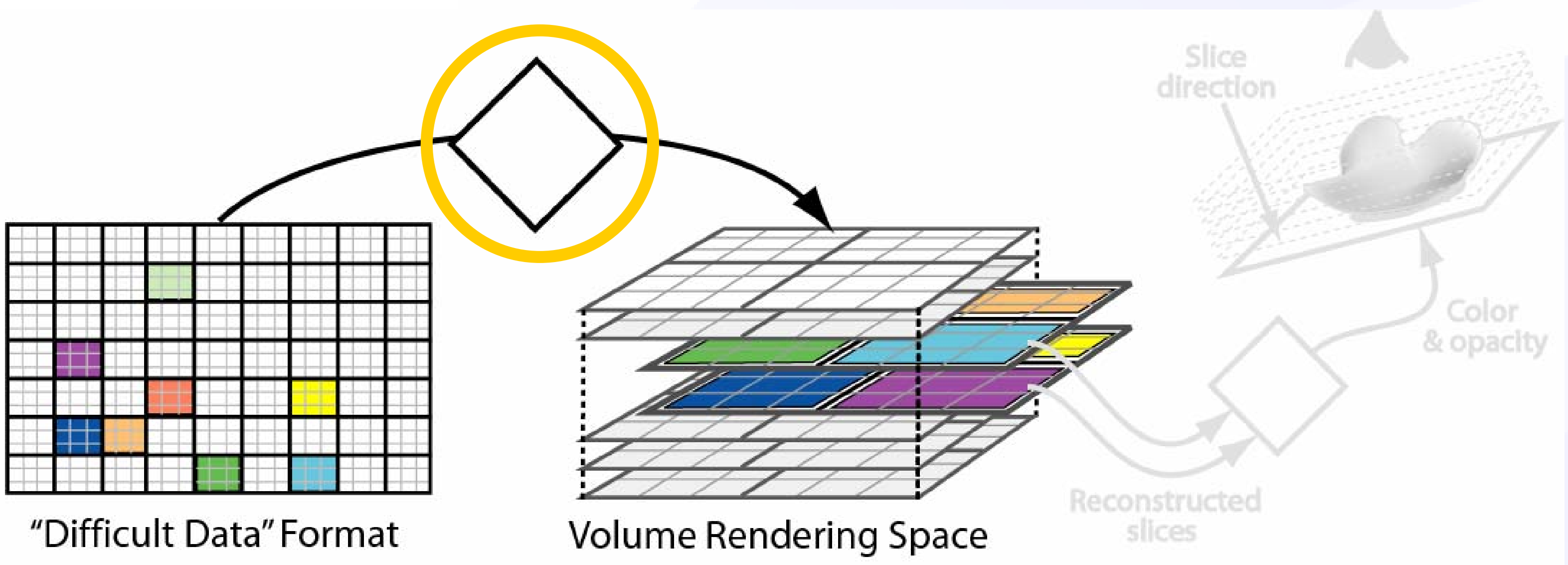


Deferred Filtering: Why?

- Fast
  - Avoid redudant data reconstruction computations
  - Use native GPU filtering
- Modular
  - Works with any reconstruction algorithm

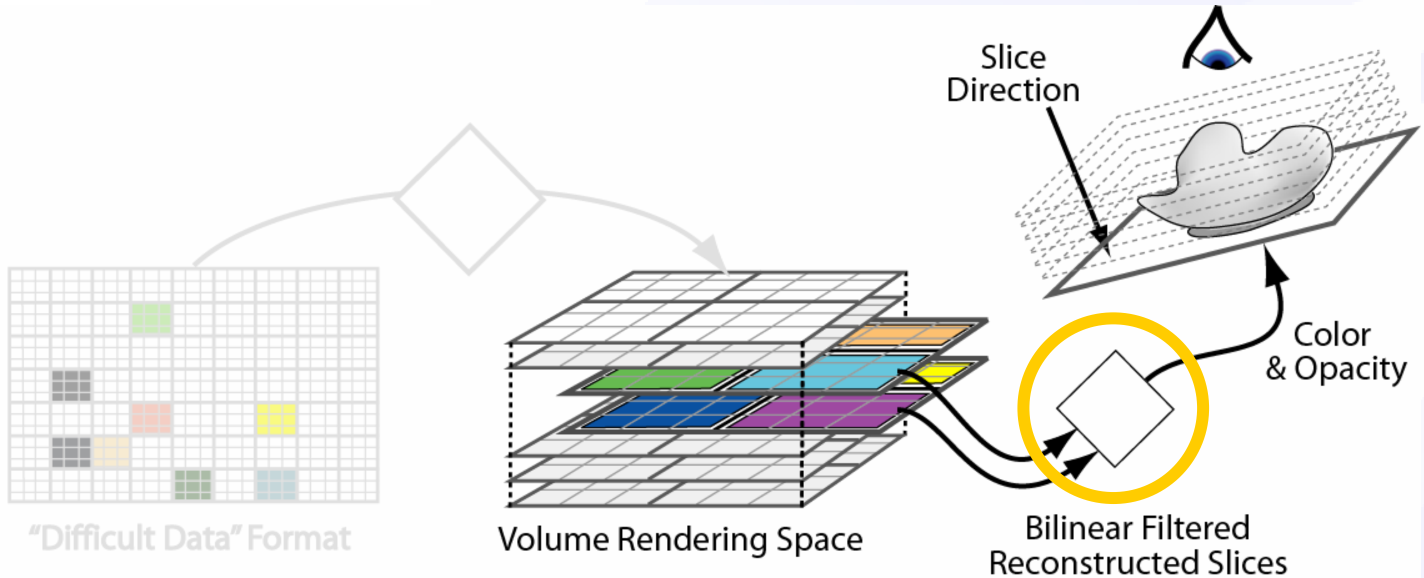
Deferred Filtering

- Algorithm
  - Pass 1:
    - Reconstruct data for two adjacent slices
    - Save results to textures/pbuffers



Deferred Filtering

- Implementation
  - Pass 2:
    - Read data from saved slices
      - Both samples are bilinearly filtered by GPU
    - Compute z-interpolation in fragment program



Deferred Filtering: Cost Analysis

- Let's Run Some Numbers…
  - Nr = Number instructions to reconstruct one value 4
  - Nf = Number of samples in filter 8
  - Ni = Number of instructions for trilinear interp 14
  - Nd= Number of elements in data space 256^3
  - Nv = Number of elements in rendering space 512^3

- Non-Deferred Filtering
  (Nr * Nf + Ni) * Nv = 6.2 Billion

  Deferred Filtering
  (Nr * Nd) + Nv = 0.6 Billion

- Deferred filtering gives nearly ~10x fewer instructions!
- Real-world example shows ~7x speedup (Nathan Fout)

Deferred Filtering Conclusions

- Pros
  - Enables filtering with any data reconstruction algorithm
  - Avoids redundant data reconstruction (fast)
  - Leverages GPU's native bilinear filtering (fast)

- Cons
  - Partitioning shader at reconstruction/filter call
  - Overhead of extra render pass (??)

- Reference
  - "A Streaming Narrow-Band Algorithm: Interactive Computation and Visualization of Level Sets," Lefohn, Kniss, Hansen, Whitaker, TVCG July/August 2004

Filtering Conclusions

- If Data Stored as "Over-Represented Sub-Volumes"
  - Reconstruct and filter data simultaneously
    - GPU's native trilinear filtering
    - Other filtering methods discussed in this course
- Else
  - Use deferred filtering
    - Pass 1: Reconstruct data for two adjacent slices
    - Pass 2: Filtering
      - Trilinear
        - GPU's native bilinear filtering with in-shader z-interpolation
      - Other filtering methods discussed in this course

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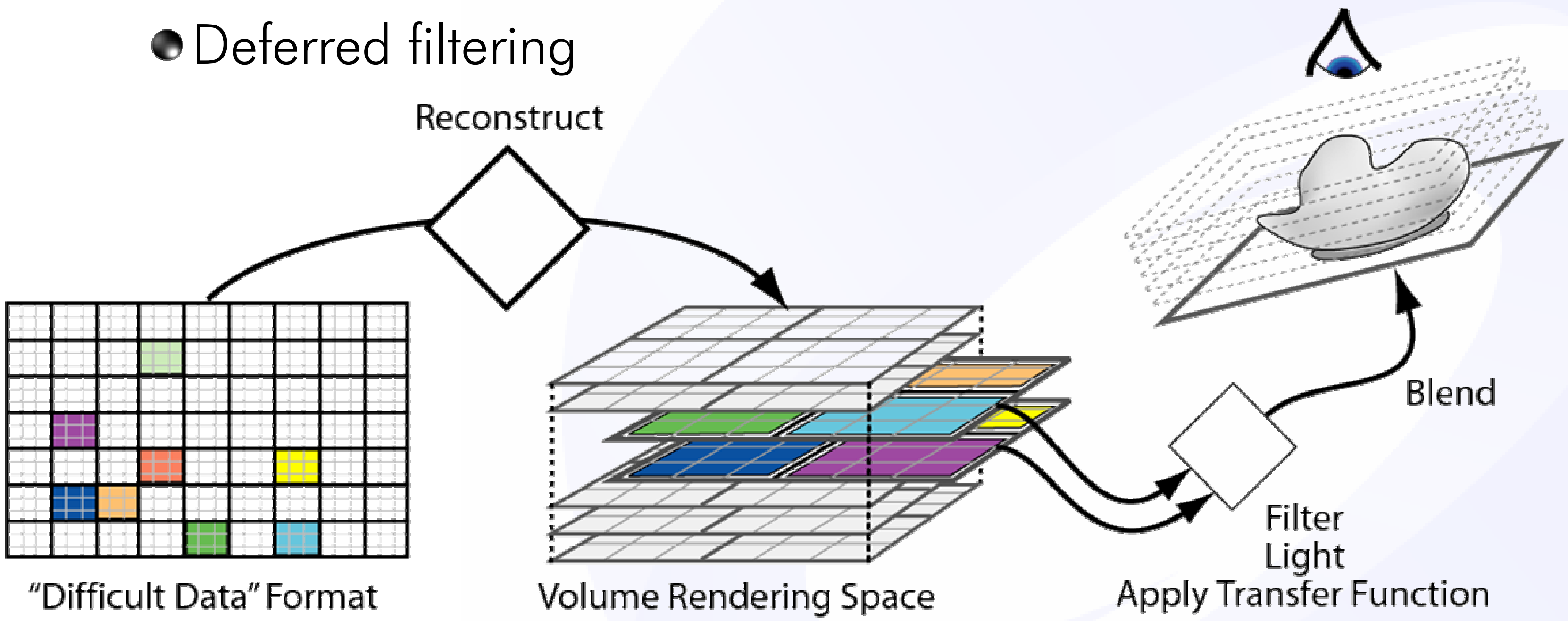
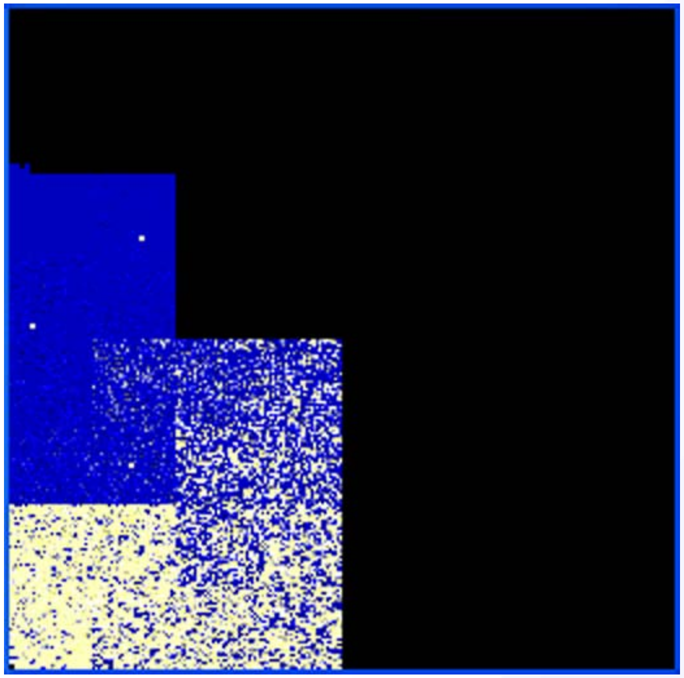
Transfer Function and Lighting

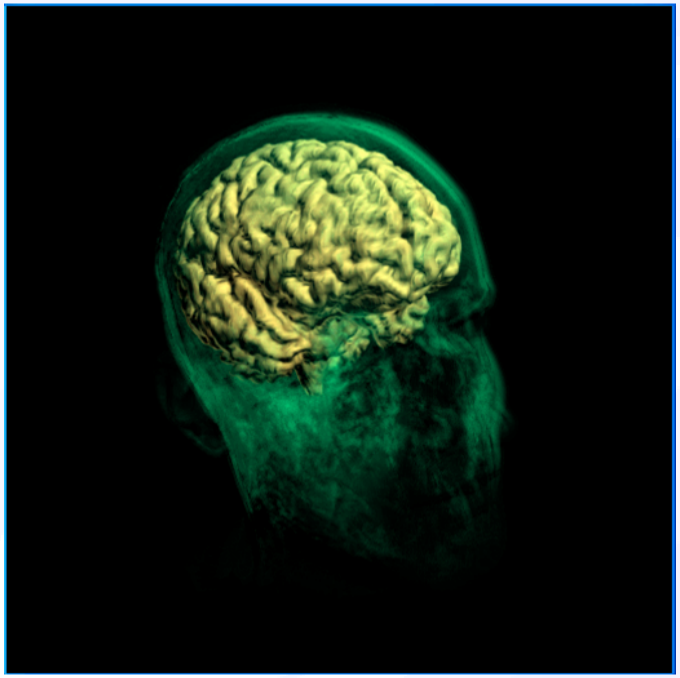
- Nothing Changes!
  - Exactly the same techniques discussed throughout course
  - Difficult data formats simply add two steps to the pipeline
    - Reconstruction
    - Deferred filtering



Rendering

- Putting it all together
  - Reconstruction
  - Filtering
  - Transfer function and lighting





Conclusions

- Volume Rendering from Difficult Data Formats
  - Adds two steps to volume rendering pipeline
    - Reconstruction
    - Deferred filtering
  - Enables
    - Acceleration strategies
    - Data compression: Rendering large data sets
    - Interactive rendering of 3D GPGPU computations
  - Increasingly important as more powerful GPUs permit more complex on-the-fly reconstruction schemes

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- ALIENWARE Interchangeable mobile GPUs

Questions?

- Thank you!

- For more information
  - Google “Lefohn GPU“
  - http://graphics.cs.ucdavis.edu/~lefohn/