QSplat

Point-Based Rendering of Large 3D Models

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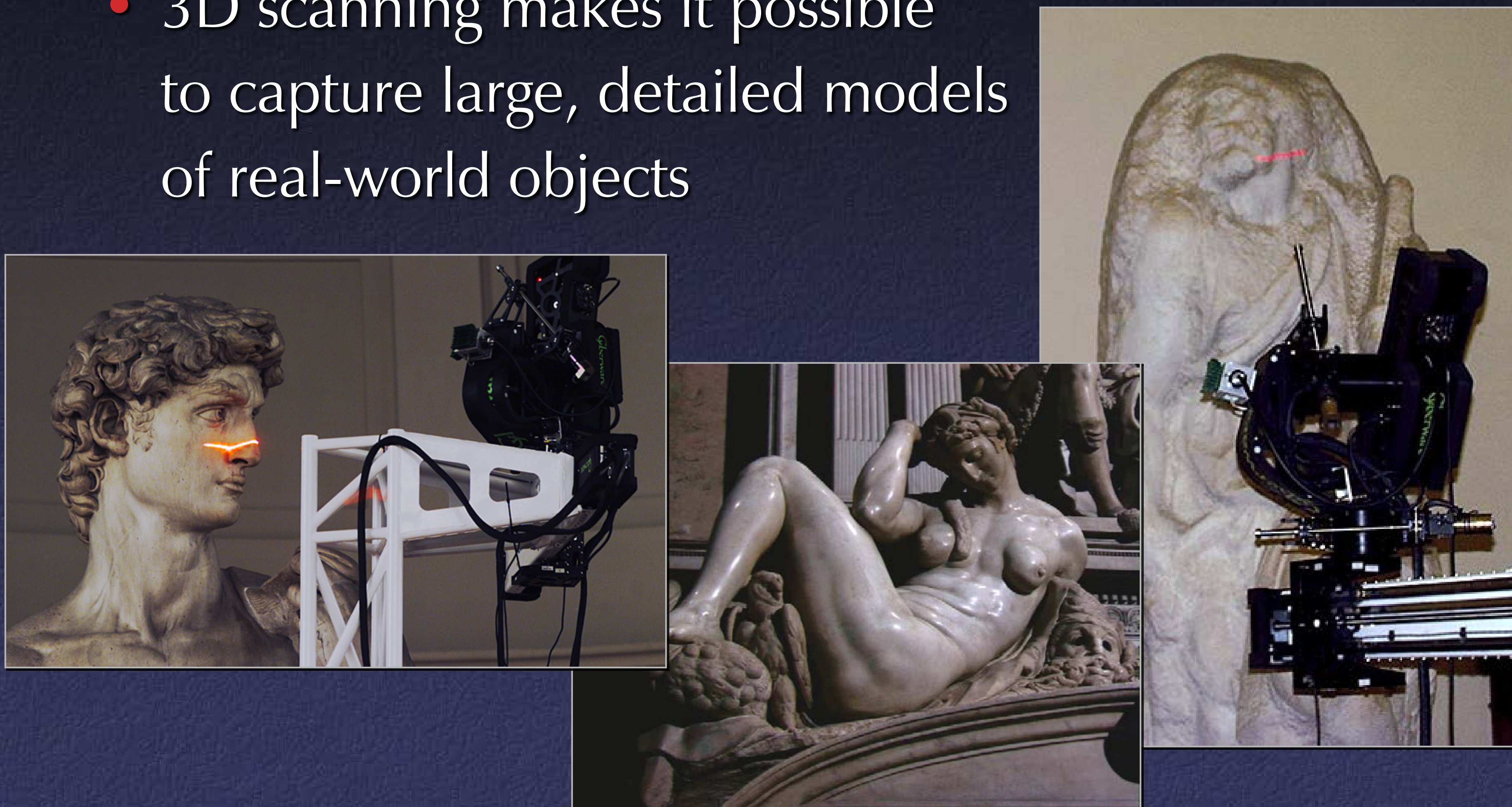
Motivation

- 3D scanning makes it possible to capture large, detailed models of real-world objects



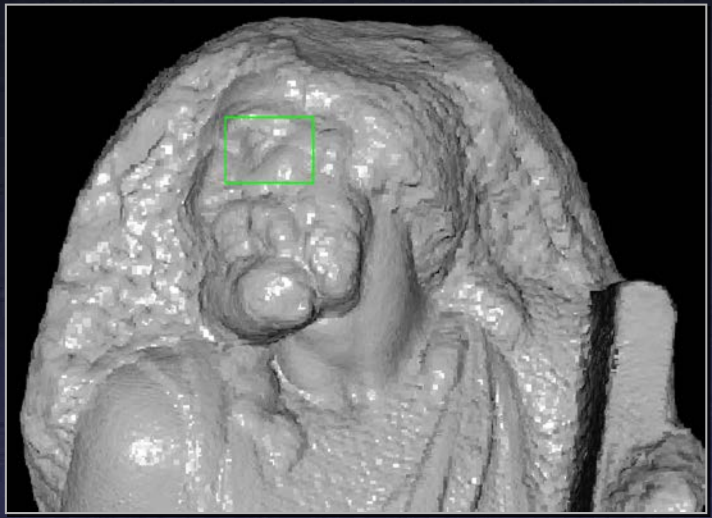
Motivation

- Models may be dense
  - Hundreds of millions of samples
  - Can't decimate without losing detail

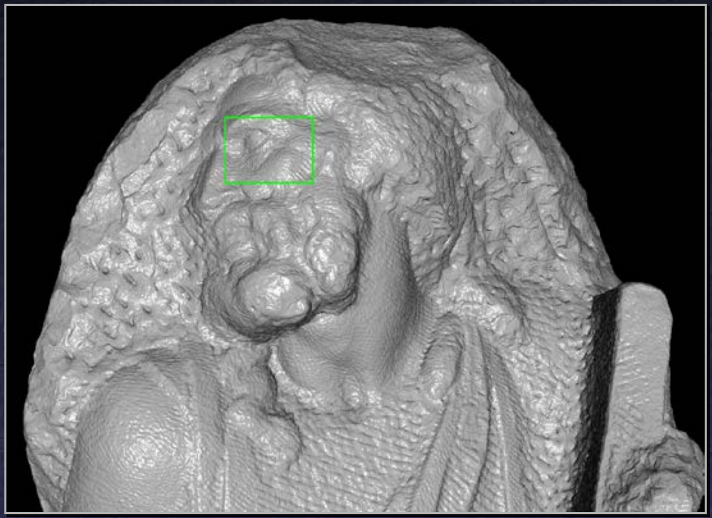
Goals

- An interactive viewer for large models (10^8 – 10^9 samples)
- Fast startup and progressive loading
- Maintains interactive frame rate
- Compact data structure
- Fast preprocessing

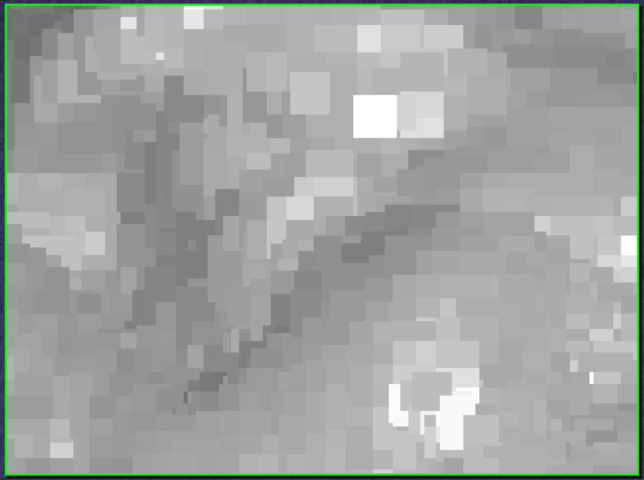
Sample Renderings of a 127-million-sample Model

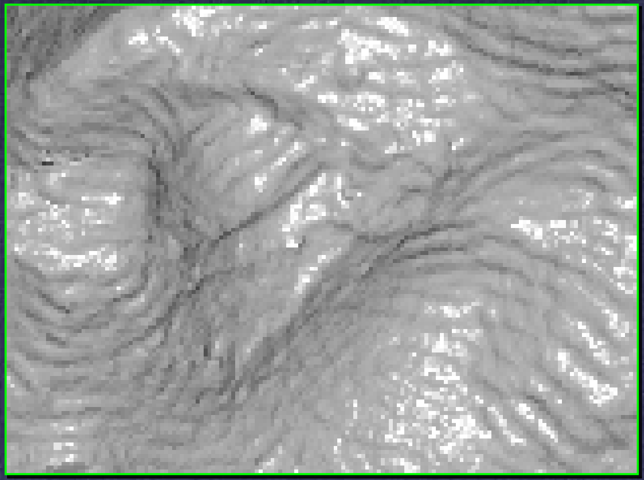


Interactive (8 frames/sec)



High quality (8 sec)





Previous Systems for Rendering Large Models

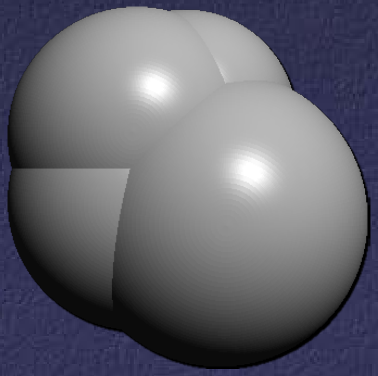
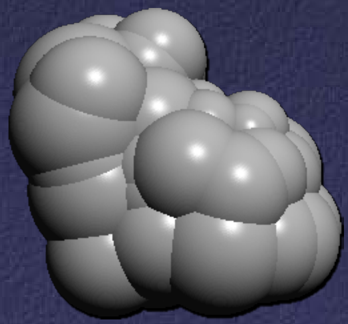
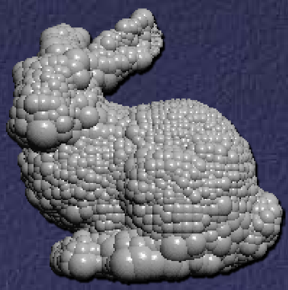
- Level of detail control in architectural walkthrough, terrain rendering systems [Funkhouser 93, Duchaineau 97]
- Progressive meshes [Hoppe 96, Hoppe 97]
- These systems often have expensive data structures or high preprocessing costs

Outline

- Data structure: bounding sphere hierarchy
- Rendering algorithm: traverse tree and splat
- Point rendering: when is it appropriate?

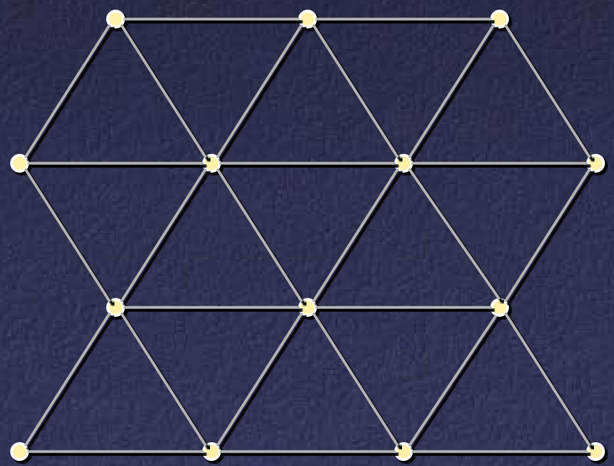
QSplat Data Structure

- Key observation: a single bounding sphere hierarchy can be used for
  - Hierarchical frustum and backface culling
  - Level of detail control
  - Splat rendering [Westover 89]

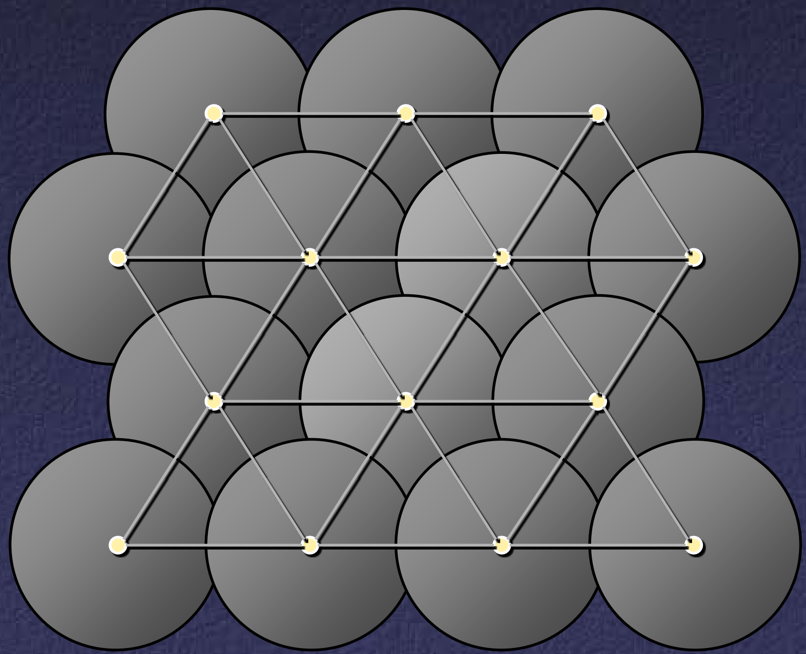
Creating the Data Structure

- Start with a triangle mesh produced by aligning and integrating scans [Curless 96]



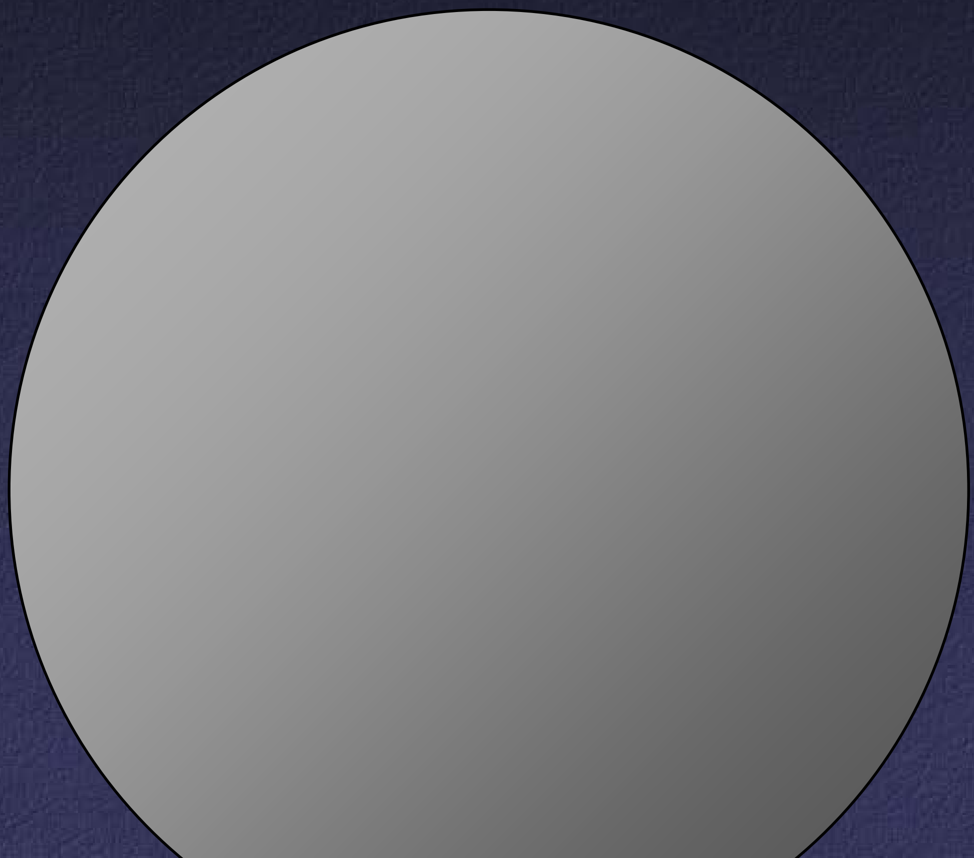
Creating the Data Structure

- Place a sphere at each node, large enough to touch neighbor spheres

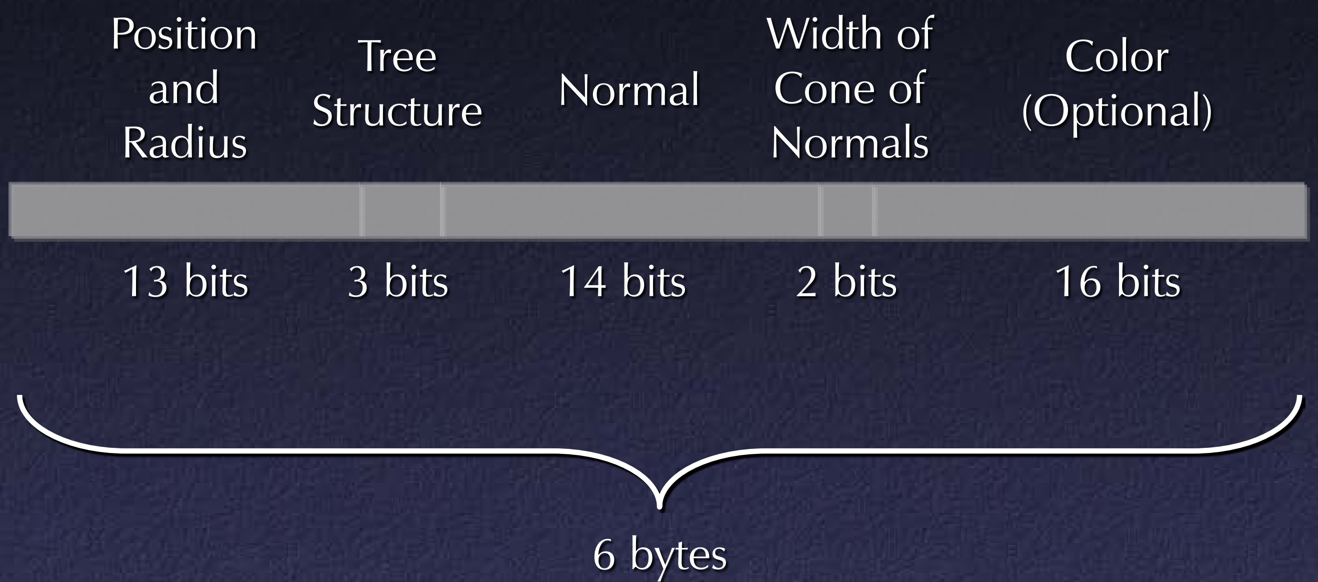


Creating the Data Structure

- Build up hierarchy



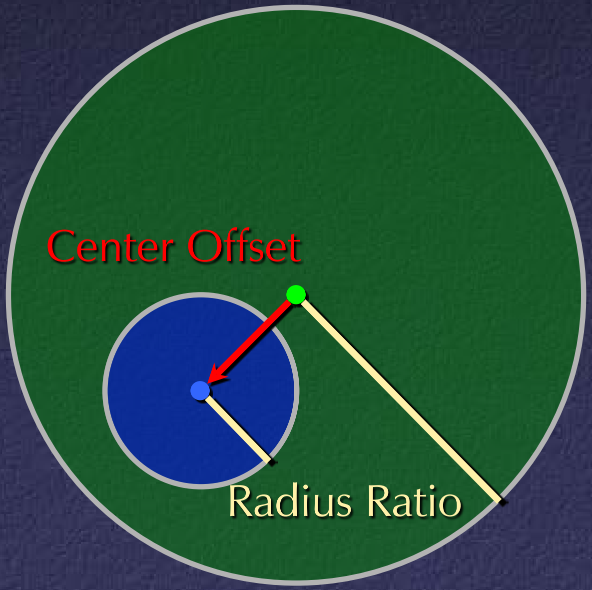
QSplat Node Structure



QSplat Node Structure

Position and Radius	Tree Structure	Normal	Width of Cone of Normals	Color (Optional)
13 bits	3 bits	14 bits	2 bits	16 bits

- Position and radius encoded relative to parent node
  - Hierarchical coding vs. delta coding along a path for vertex positions



QSplat Node Structure

Position and Radius	Tree Structure	Normal	Width of Cone of Normals	Color (Optional)
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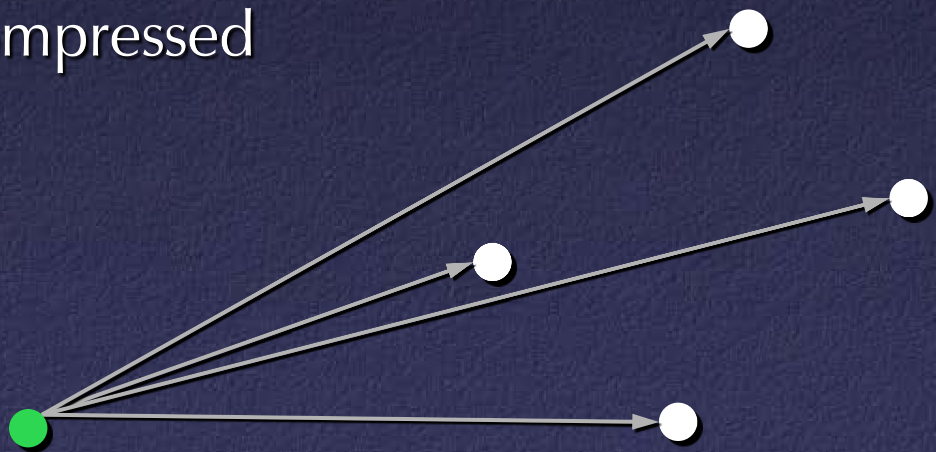
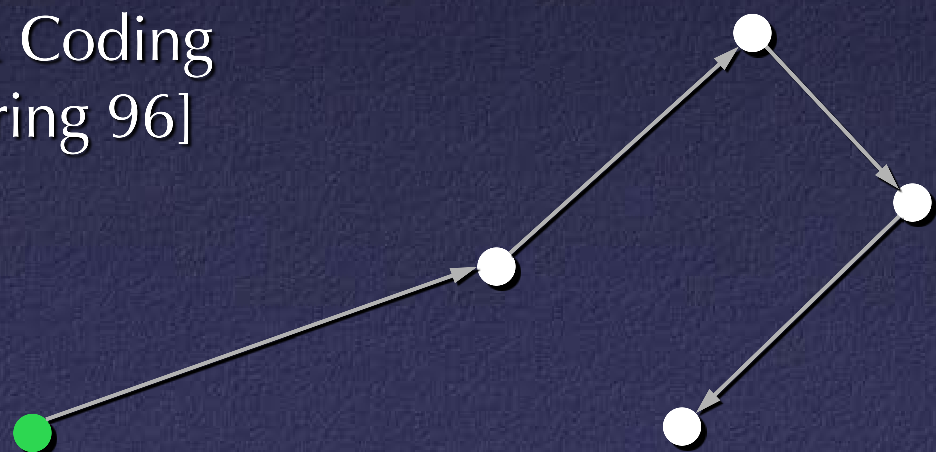
Uncompressed



QSplat Node Structure

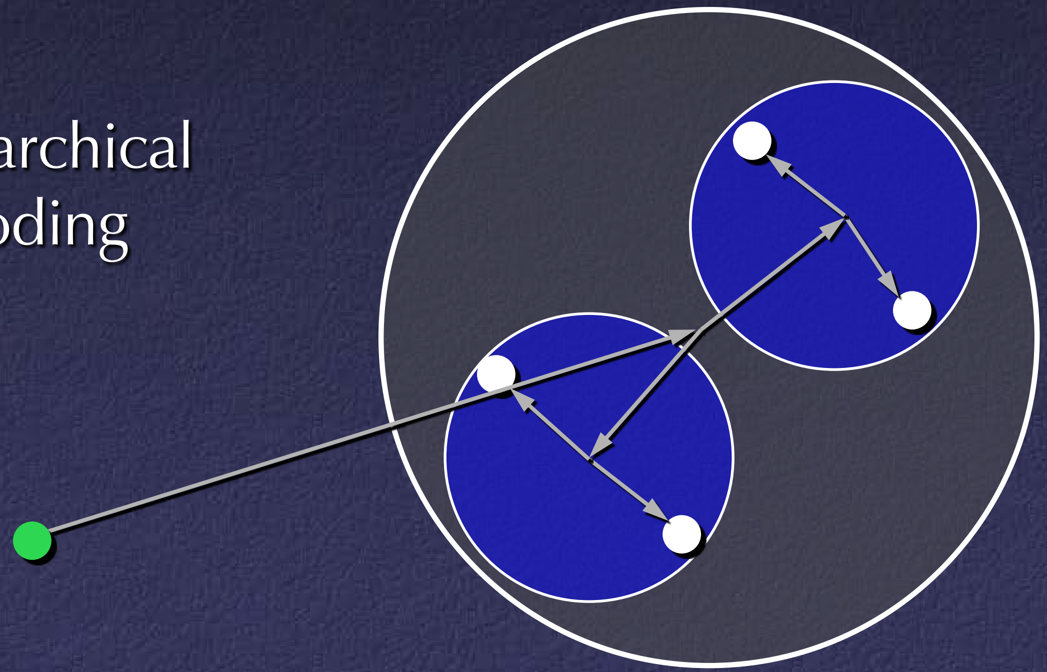
Delta Coding
[Deering 96]



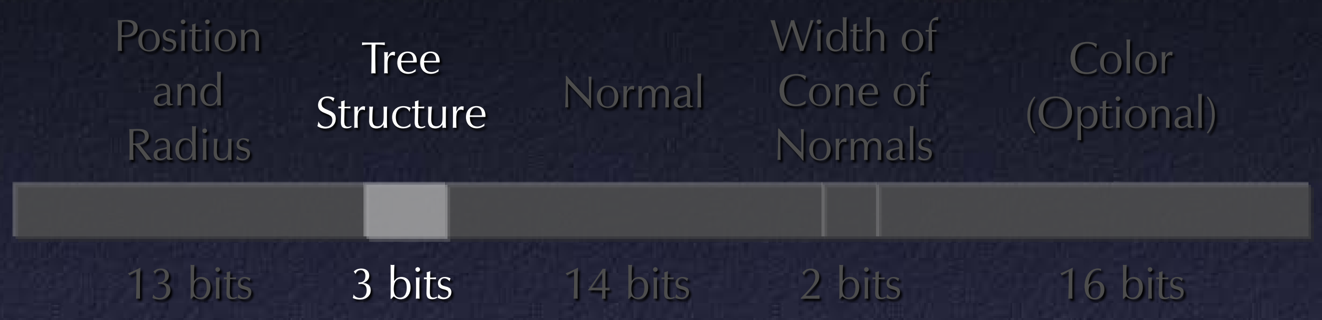
QSplat Node Structure

Position and Radius	Tree Structure	Normal	Width of Cone of Normals	Color (Optional)
13 bits	3 bits	14 bits	2 bits	16 bits

Hierarchical Coding



QSplat Node Structure

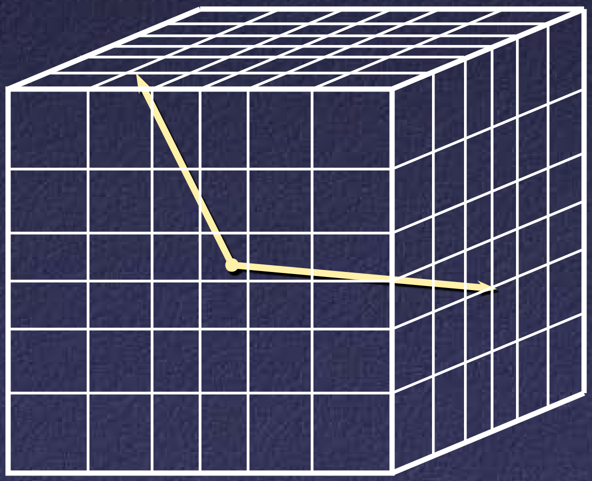


- Number of children (0, 2, 3, or 4) – 2 bits
- Presence of grandchildren – 1 bit

QSplat Node Structure

Position and Radius	Tree Structure	Normal	Width of Cone of Normals	Color (Optional)
13 bits	3 bits	14 bits	2 bits	16 bits

- Normal quantized to grid on faces of a cube



52×52×6

QSplat Node Structure

Position and Radius	Tree Structure	Normal	Width of Cone of Normals	Color (Optional)
13 bits	3 bits	14 bits	2 bits	16 bits

- Each node contains bounding cone of children's normals
- Hierarchical backface culling [Kumar 96]

QSplat Node Structure

QSplat Node Structure

Position and Radius	Tree Structure	Normal	Width of Cone of Normals	Color (Optional)
13 bits	3 bits	14 bits	2 bits	16 bits

- Per-vertex color is quantized 5-6-5 (R-G-B)

QSplat Rendering Algorithm

- Traverse hierarchy recursively

Hierarchical frustum / backface culling

```
if (node not visible)
        Skip this branch
else if (leaf node)
        Draw a splat
else if (size on screen < threshold)
        Draw a splat
else
        Traverse children
```

Point rendering

Level of detail control

Adjusted to maintain desired frame rate

Frame Rate Control

- Feedback-driven frame rate control
  - During motion: adjust recursion threshold based on time to render previous frame
  - On mouse up: redraw with smaller thresholds
  - Consequence: frame rate may vary
- Alternative:
  - Predictive control of detail [Funkhouser 93]

Loading Model from Disk

- Tree layout:
  - Breadth-first order in memory and on disk
- Working set management:
  - Memory mapping disk file
  - Consequence: lower detail for new geometry
  - Alternative: Active working set management with prefetching [Funkhouser 96, Aliaga 99]

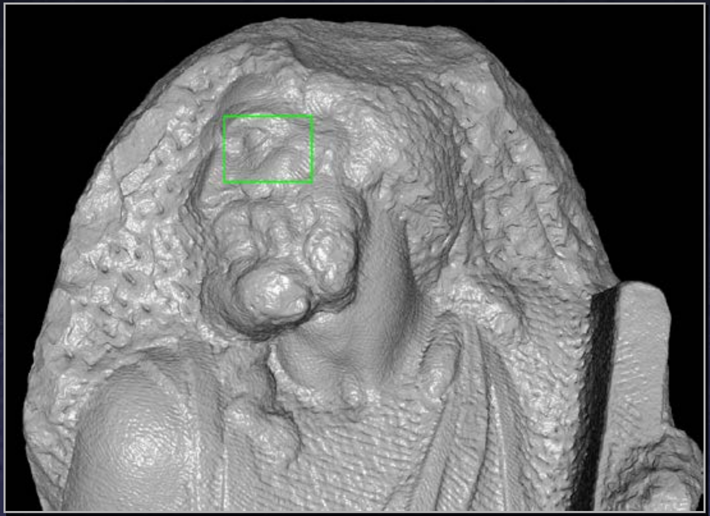
Tradeoffs of Splatting

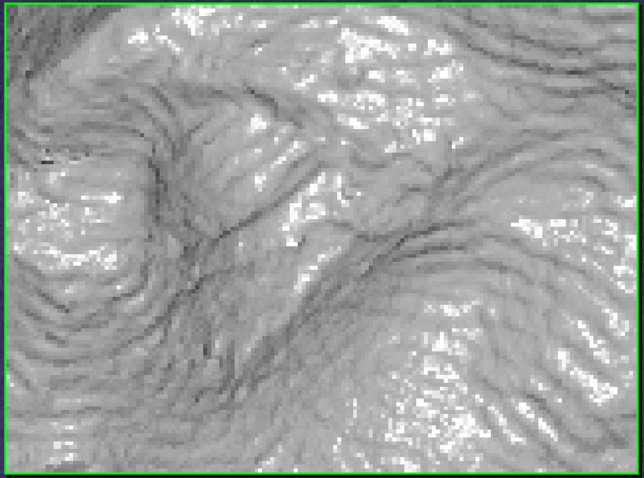
- For rendering large 3D models, what are the tradeoffs of:

Polygons	QSplat
Good for large, flat or subtly curved regions	Good for models with detail everywhere
Highly-efficient rasterization with 3D graphics hardware	Higher per-pixel cost, but less slowdown in absence of 3D hardware
Decimation or creating LOD data structures is often expensive	Fast preprocessing

Demo – St. Matthew

- 3D scan of 2.7 meter statue at 0.25 mm
- 102,868,637 points
- File size: 644 MB
- Preprocessing time: 1 hour





Conclusion

- Non-polygonal rendering
  - Works well when # samples >> # pixels
  - Lack of connectivity may = simpler algorithms
  - Bad for flat regions
- Time, space efficiency important for big data sets