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Surfels: Surface Elements as Rendering Primitives

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SIGGRAPH 2000: International Conference on Computer Graphics and Interactive Techniques, pages 338-242

Problems with Current Graphics Rendering Systems

- Interactive computer graphics has not reached the level of realism that allows true immersion into a virtual world
- Rendering realistic, organic looking models requires highly complex shapes with a huge number of triangles
- Processing many small triangles leads to bandwidth bottlenecks and excessive floating point and rasterization requirements

New Solution: Surfels

A Surfel is a zero-dimensional n-tuple + attributes.

- Local approximation of an object surface
- Attributes: depth, texture color, normal and others

Conceptual Overview

Pre-processing - Surfels generation:

Rendering of Surfels:

Preprocessing

Geometry → Sampling and Texture Pre-filtering → Surfel LDC Tree → 3-to-1 Reduction (optional) → Reduced LDC Tree

Sampling

Goal: Optimal Surfel representation of the geometry

→ Layered Depth Cube (Lischinsky et al.)

- Create three orthogonal Layered Depth Images → LDC

Bsp: Hubschrauber
Propeller
zu wenig Bilder/sec

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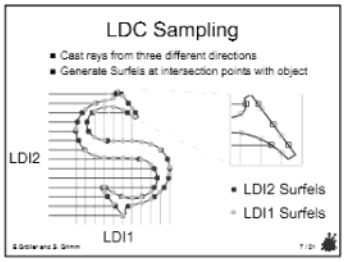
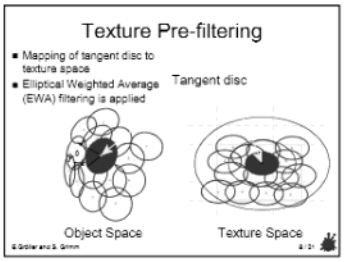
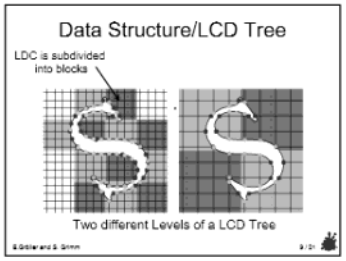
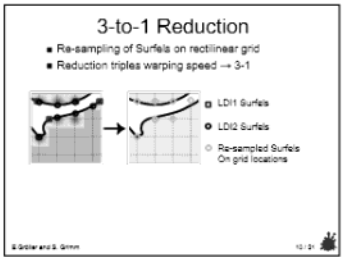
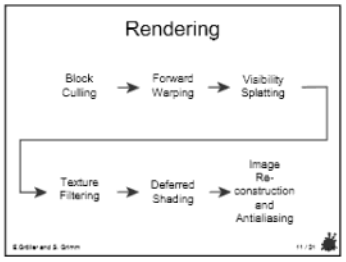
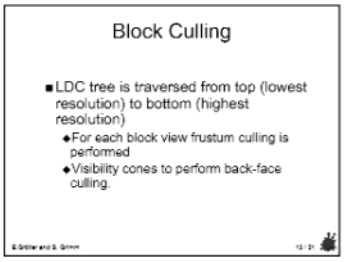

LDC Sampling
Cast rays from three different directions
Generate Surfels at intersection points with object
LDI2
LDI1
LDI2 Surfels
LDI1 Surfels


Texture Pre-filtering
Mapping of tangent disc to texture space
Elliptical Weighted Average (EWA) filtering is applied
Tangent disc
Object Space
Texture Space


Data Structure/LCD Tree
LDC is subdivided into blocks
Two different Levels of a LCD Tree


3-to-1 Reduction
Re-sampling of Surfels on rectilinear grid
Reduction triples warping speed → 3-1
LDI1 Surfels
LDI2 Surfels
Re-sampled Surfels On grid locations


Rendering
Block Culling
Forward Warping
Visibility Splatting
Texture Filtering
Deferred Shading
Image Re-construction and Antialiasing

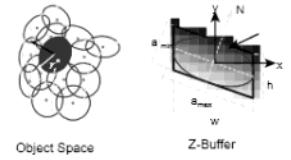

Block Culling
LDC tree is traversed from top (lowest resolution) to bottom (highest resolution)
For each block view frustum culling is performed
Visibility cones to perform back-face culling.

Block Warping

- During rendering LDC tree is traversed from top to bottom.
- Octree level is determined by Surfels per pixel
  - Fast rendering: One Surfel per Pixel
  - High Quality rendering: Multiple Surfels per pixel (super-sampling)
- Appropriate octree level is determined by the distance between two Surfels in image space

Visibility Splatting

Z-Buffer projection of Surfel

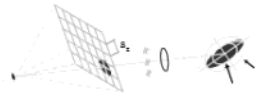


Object Space Z-Buffer

Texture Filtering

Projected Pixel Coverage

Image Space Object Tangent Space

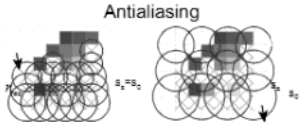


- Surfel color determination by linear interpolation of Surfel mipmaps
- Mayor axis of the projection determines Surfel mipmap level

Shading

- Shading after visibility testing: avoiding unnecessary work
- Per-surfel Phong illumination using cube reflectance and environmental maps
- High quality specular highlights: Shading with per-Surfel normals

Image Reconstruction and Antialiasing



- Surfels are mapped to pixel centers
- Output pixel size == z-Buffer pixel size
- Holes are marked by green crosses → Filled by using symmetric Gaussian filter

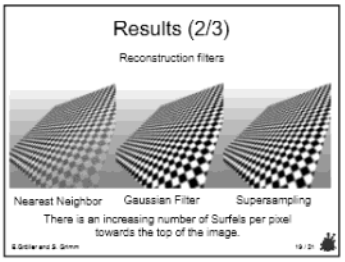
- Super-sampling
- Output pixel size is multiple of z-Buffer size
- Reconstruction by putting a Gaussian filter at the centers of output pixels

Results (1/3)

Surfel object with holes

Hole detection: Green pixels are holes

Image reconstruction with Gaussian filter


Results (2/3)
Reconstruction filters
Nearest Neighbor
Gaussian Filter
Supersampling
There is an increasing number of Surfels per pixel towards the top of the image.
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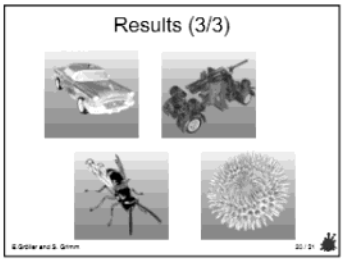
Results (3/3)
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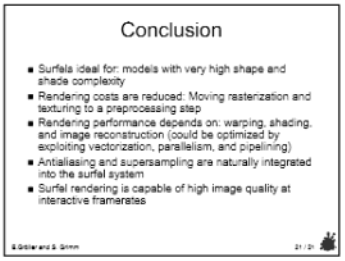
Conclusion
Surfels ideal for: models with very high shape and shade complexity
Rendering costs are reduced: Moving rasterization and texturing to a preprocessing step
Rendering performance depends on: warping, shading, and image reconstruction (could be optimized by exploiting vectorization, parallelism, and pipelining)
Antialiasing and supersampling are naturally integrated into the surfel system
Surfel rendering is capable of high image quality at interactive framerates
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