Splat Based Raytracing

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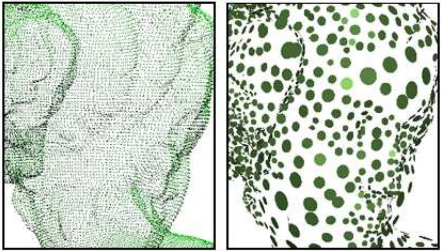
Outline

Point Based Rendering

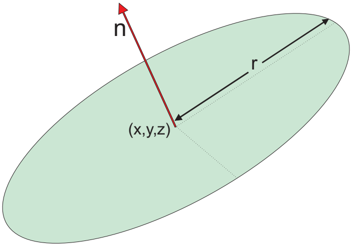
- Points : Model primitives
- Splats : Render primitives



Points and Splats (Iphigenie sculpture)

Source: Kobbelt et al., Optimized Sub-Sampling for Surface Splatting

What information is associated with a splat?



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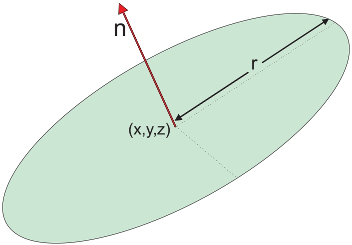
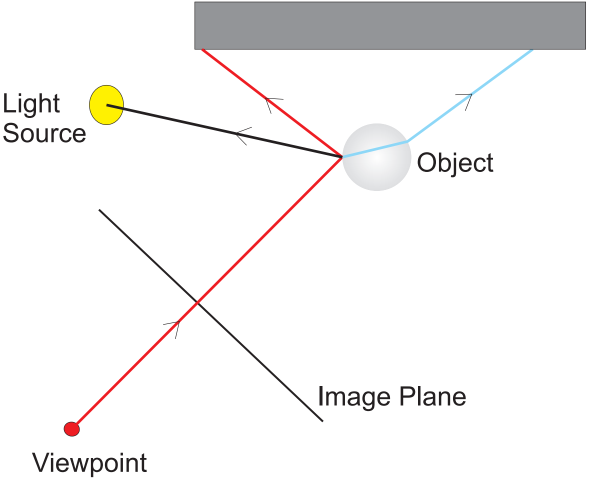


- Position
- Normal Vector
- Radius
- Color

Raytracing



Raytracing

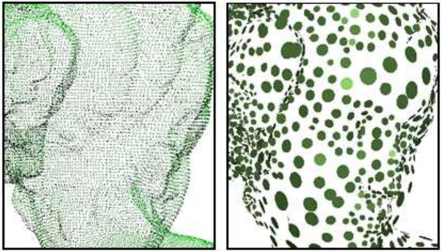
- Send out primary rays from the camera position through the center of each pixel of the resulting image onto the scene
- Compute the intersection of the primary rays with the objects of the scene using ray-splat intersections
- From the intersection points, send out secondary rays (shadow, reflection and refraction rays)
- Recurse reflection and refraction rays till ray-trace depth

Raytracing

Examples of point based rendering

Source: Jensen et al., Raytracing point sampled geometry

Points to Splats



- Input: A large number of points, representing the surface of the object
- Output: A set of disks (splats) which cover the entire surface

Overview of Splat Generation

Initialisation

- Let there be a splat S at point p
- Normal vector of S = normal vector at p
- Initial radius of $S = 0$

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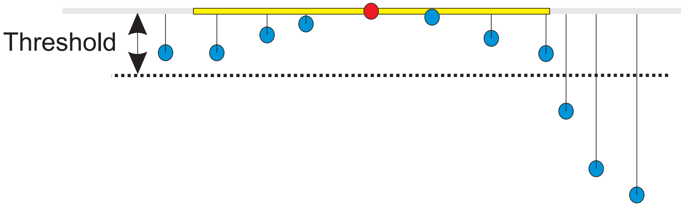
Splat Growth

- Grow the radius of the splat, till an error threshold is reached
- Error $= \max(\forall p_i \in S$, shortest distance between p_i and $S)$

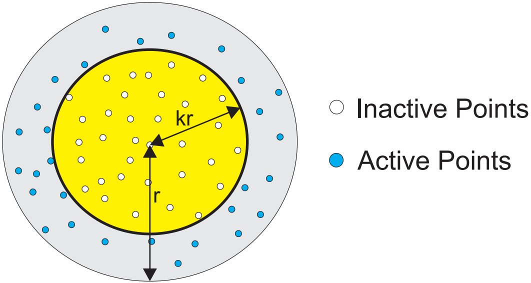
Splat Generation



Splat Density

Reducing Splat Density

- Consider a splat S at a point p, with radius r
- Let $D = k * r, k \in [0, 1]$
- Points within a distance D of p are no longer candidates for Splat Generation



Raytracing

Fundamental operations in Raytracing

- Ray-surface intersection
- Reflection/Refraction based on surface normal

Raytracing

Fundamental operations in Raytracing

- Ray-surface intersection
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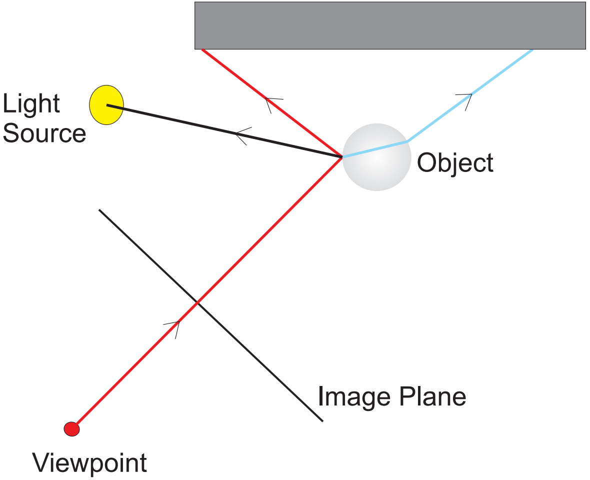
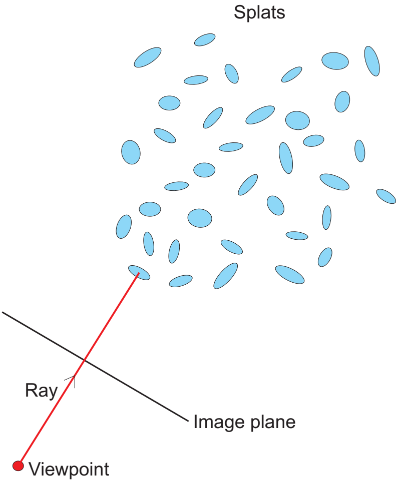
- Finding the point of intersection of ray with objects in the scene
- Calculating surface normal at that point

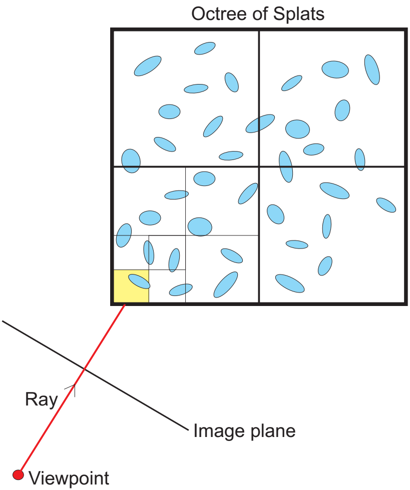
Raytracing: Overview



Ray-Splat Intersection



Ray-Splat Intersection

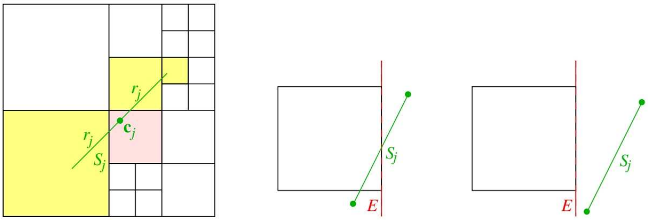


Octree generation

The generation of the octree is done as follows:

- Start with an empty octree which is the bounding box of the entire scene
- Iteratively insert each splat into that leaf cell that contains the center of the splat
- When one leaf cell contains more than a given number of splats, the cell gets subdivided
- After the entire tree is built, insert the splats into all leaf cells they intersect

Octree generation



Splat spanning multiple leaves of the octree

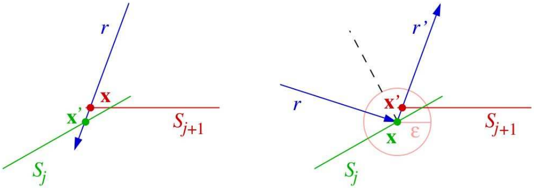
Source: Rosenthal et al., Splat-based Ray Tracing of Point Clouds

Ray-Splat Intersection

Finding the splats that intersect with the ray:

- Each ray is tested for intersection against the root node
- Find the leaf cell at the point of intersection
- Check for splat intersections in this leaf
- If there are no intersections, move to next leaf in ray direction
- Else compute the precise intersection point with the splat(s)

Ray-Splat Intersection



Finding the most 'appropriate' splat in case of multiple intersections

Source: Rosenthal et al., Splat-based Ray Tracing of Point Clouds

Surface normals

- Point models are rendered using splats
- Each splat has a single normal vector
- A splat spans several pixels

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Finding the normal vector at different points on the splat

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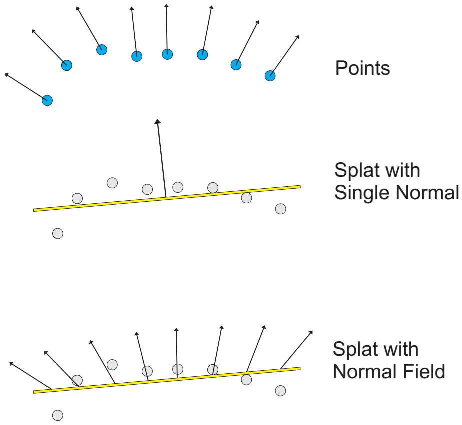
Finding the normal vector at different points on the splat

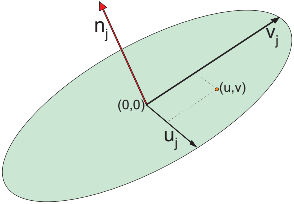
Use Phong splats

Phong Splatting



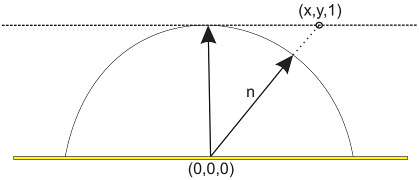
Associate a linearly varying normal field with each splat

Phong Splat



- Orthogonal principal vectors: $\mathbf{u_j}$ and $\mathbf{v_j}$
- The normal vector at a point (u, v) on the splat S_j is: $N_j(u, v) = \mathbf{n_j} + u\alpha_j\mathbf{u_j} + v\beta_j\mathbf{v_j}$

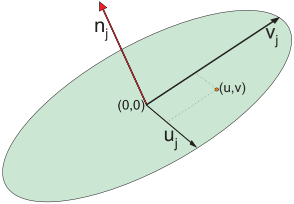
Representation of normals



Each normal vector is represented by 2 parameters (x,y), formed by intersecting the normal with an offset tangent plane

Source: Botsch et al., Phong Splatting

Normal field calculation



- $\mathbf{n_j} = (x_c, y_c)$
- Let (u_i, v_i) denote the coordinates of a point on the splat
- The normal at this point : $N_j(u_i, v_i) = \mathbf{n_j} + u_i\alpha_j\mathbf{u_j} + v_i\beta_j\mathbf{v_j} = (x_i, y_i)$

$$x_c + u_i\alpha = x_i$$
$$y_c + v_i\beta = y_i$$

Normal field calculation

For each point $p_i \in S_j$, we have its corresponding projection on the splat, (u_i, v_i) and normal vector (x_i, y_i)

$$\begin{aligned}
x_c + u_1\alpha &= x_1 \\
x_c + u_2\alpha &= x_2 \\
x_c + u_3\alpha &= x_3 \\
x_c + u_4\alpha &= x_4 \\
&\vdots \\
x_c + u_n\alpha &= x_n
\end{aligned}$$

Solve for x_c and α by fitting a straight line to these points with least square error

Phong Splatting: Resolution Scaling

Gaussian Blending vs Phong Splatting : 350k Splats

Source: Botsch et al., Phong Splatting

Phong Splatting: Resolution Scaling

Gaussian Blending vs Phong Splatting : 110k Splats

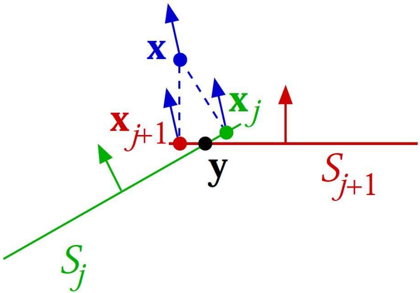
Source: Botsch et al., Phong Splatting

Phong Splatting: Resolution Scaling

Gaussian Blending vs Phong Splatting : 35k Splats

Source: Botsch et al., Phong Splatting

Normal field discontinuity



When two splats S_i and S_j overlap, ray splat intersections need to move smoothly across the point y

Source: Rosenthal et al., Splat-based Ray Tracing of Point Clouds

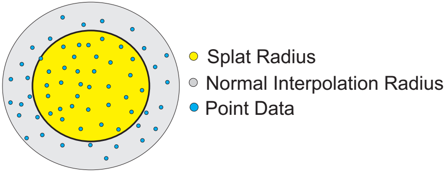
Normal field discontinuity

Weighted averaging of normals

Let $S_1, ...S_p$ be all the splats that are hit by a ray within a small environment ξ around the intersection point.
Let $(u_1, v_1), ...(u_p, v_p)$ be the coordinates of the ray intersection points.
Let $n_1, ...n_p$ be the normals at the intersection points.
Then, the normal $\mathbf{n}$ at the intersection point is given by:

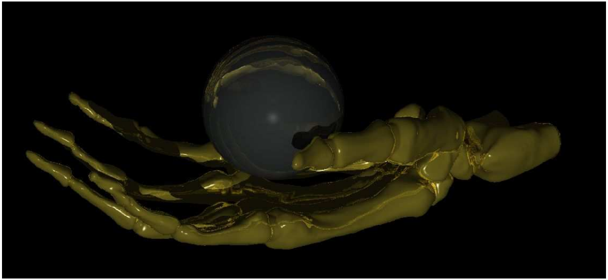
$$\mathbf{n} = \frac{\Sigma_{i=1}^{p}(1 - \|(u_i, v_i)\|_2)\mathbf{n_i}}{\Sigma_{i=1}^{p}(1 - \|(u_i, v_i)\|_2)}$$

Improving the Normal Field



- Small splats → minimal overlap
- Large splats → smooth normals
- Proposal: Use different splat radius for splat generation, and normal field generation

Skeleton Hand data set



Source: Rosenthal et al., Splat-based Ray Tracing of Point Clouds

Buddha data set

Source: Rosenthal et al., Splat-based Ray Tracing of Point Clouds

Conclusion

- Point based rendering techniques have advanced to an extent where they can perform most tasks that can be accomplished through traditional rendering methods
- Splat rendering can be an efficient alternative to traditional rendering methods for complex scenes

Pitfalls

- Lack of connectivity requires that implementations rely heavily on thresholds to distinguish between different surfaces
- Efficient only for dense and complex models (not suited for rendering large plain surfaces)
- Triangle based rendering is very well established and current algorithms for triangle rendering are far more efficient
- Existing graphics hardware have been optimised for triangle mesh rendering
- Currently, there is no advantage of point based raytracing as compared to traditional methods

References

- Mario Botsch, Michael Spernat and Leif Kobbelt, "Phong Splatting", Eurographics Symposium on Point Based Graphics, pp. 25-32, 2004
- Lars Linsen, Paul Rosenthal and Karsten Muller, "Splat-based Ray Tracing of Point Clouds",Journal of WSCG, Vol. 15, No. 1-3
- Gernot Schaufler and Henrik Wann Jensen, "Ray Tracing Point Sampled Geometry", Rendering Techniques 2000. Springer-Verlag, p. 319-328
- Jianhua Wu and Leif Kobbelt, "Optimized Sub-Sampling of Point Sets for Surface Splatting", Computer Graphics Forum, 2004, pp. 643-652