Ray Tracing Point Set Surfaces

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Outline

- Introduction
- Related Work
- Surface Definition and Features
- Computing Ray-Surface Intersections
- Implementation
- Results

Introduction

- Why Point Sets
  - Represents more details than triangles
- Why Ray Tracing
  - Popular
  - High Quality Models
  - Flexible

Introduction

- 2 General Approaches
  - The point set is used to compute a surface, which is ray traced
  - The intersection of a ray and the point set is defined without the intermediate definition of a surface
- 2. Appr. is not a surface definition!
  - In each point a disk is constructed using the point normal
  - A cylinder around the ray is intersected with the disks
  - The intersection is computed as a weighted average of disks whose centers are inside the cylinder

Introduction

- The reason of surface definition
  - Primary and secondary rays intersect the same surface
  - The resulting image of the shape is view independent, which is a prerequisite for the generation of animated sequences
  - Renderings of CSG-defined shapes are possible
- Advantages of surface definition
  - The computation is local
  - It is possible to define a minimum feature size
  - The surface is smooth and manifold

Related Work

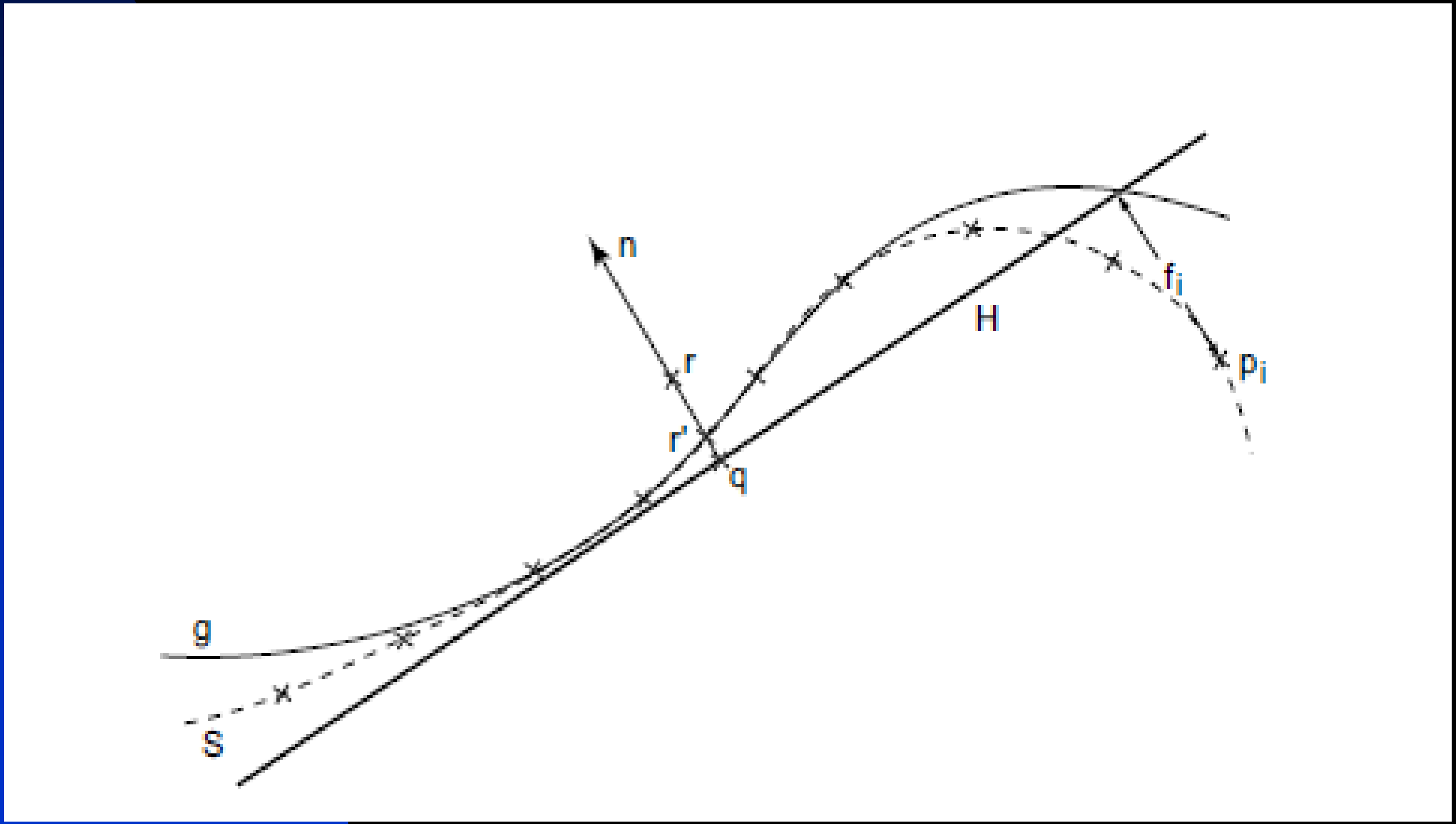
- Hoppe et al. *(SIGGRAPH 92)*
  - A signed distance field from the points
  - Related to Voronoi-based reconstruction techniques
- Implicit Surfaces Researches
  - point set surfaces could be seen as an implicit surface
- Ray Tracing / Ray Marching Techniques
- Efficiency Methods

Surface Definition and Features

- Think about the given set of points in 3D
- Reference domain shall be computed to project a point “r”
- That reference domain is determined by minimizing the weighted distance of points to a plane “H”
- Assume the projection of r onto H which is called “q”, then H is found by locally minimizing:

$$\sum_{i=1}^{N} (\langle n, p_i \rangle - D)^2 \, e^{\left(-\|p_i - q\|^2 / h^2\right)}$$

Surface Definition and Features

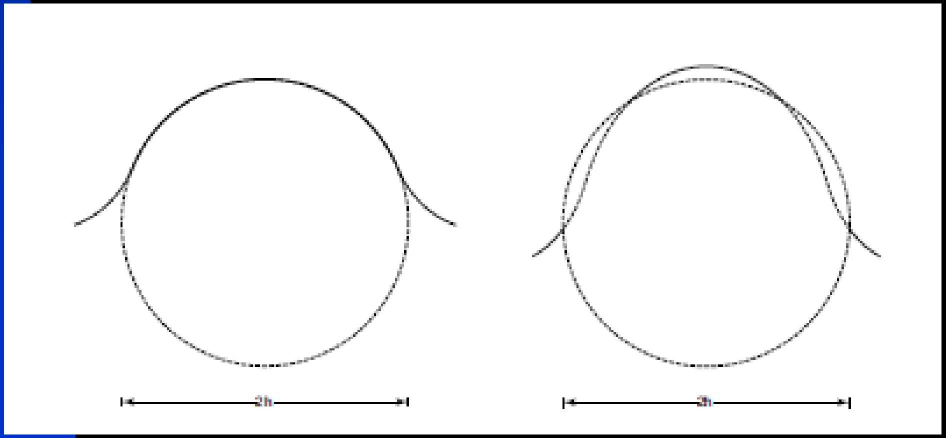


Surface Definition and Features

- Local reference domain is then given by an orthonormal coordinate system on H then q becomes the origin ☺
- In this reference domain a bivariate polynomial g is fitted to the points minimizing the squared distances in normal direction of H
- The projection of ray of r onto point set surface is defined by the polynomial value at the origin i.e. $R(r) = q + g(0,0)n$

Surface Definition and Features

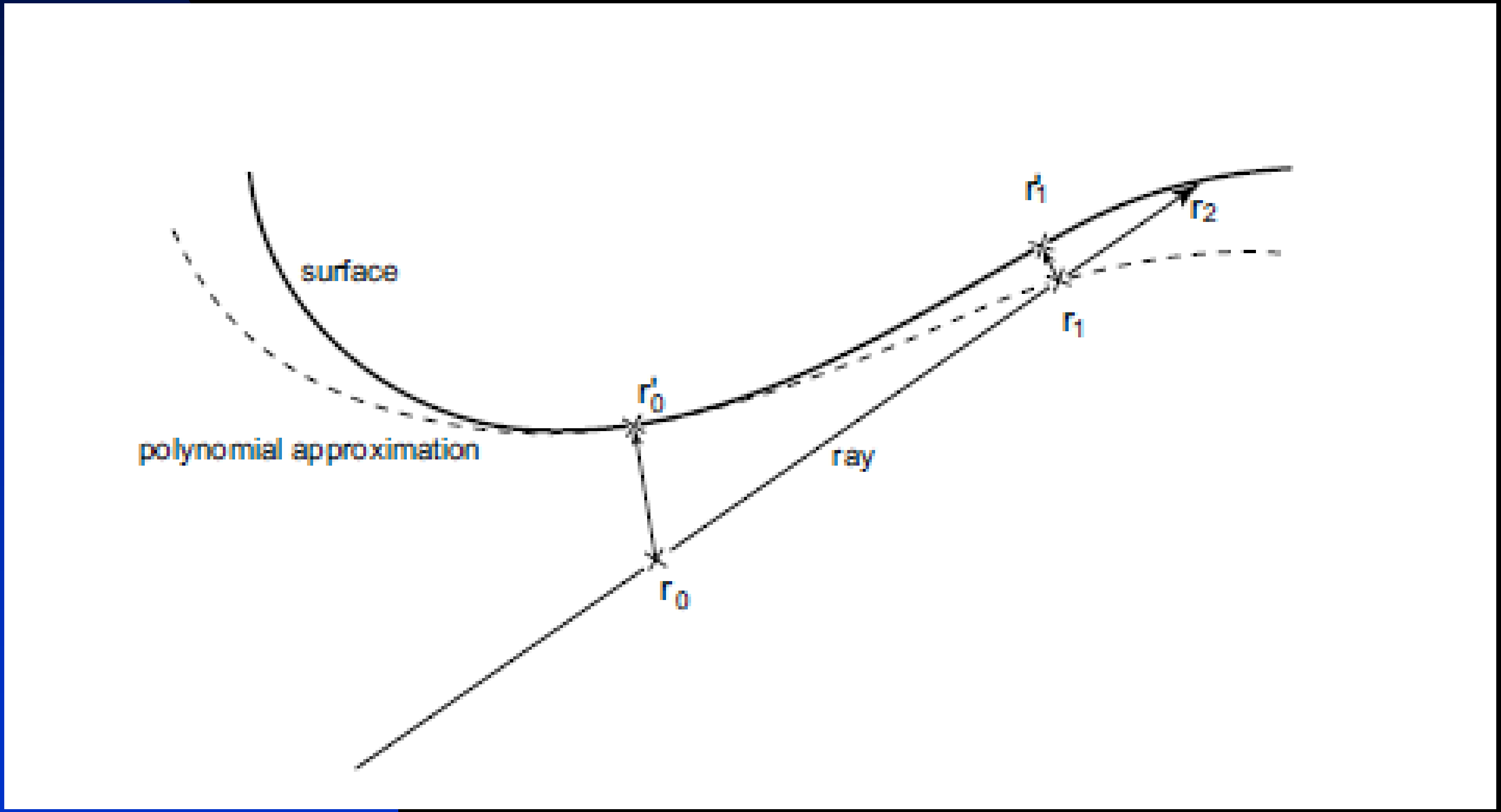
- The implications of Gaussian-weighted distances
  - The projection operator works only in a tubular neighborhood around the point set. Points far from the point set are projected to infinity.
  - Local features are larger than h. This means a ball of radius h intersects only one connected component of the surface



Computing Ray-Surface Intersections

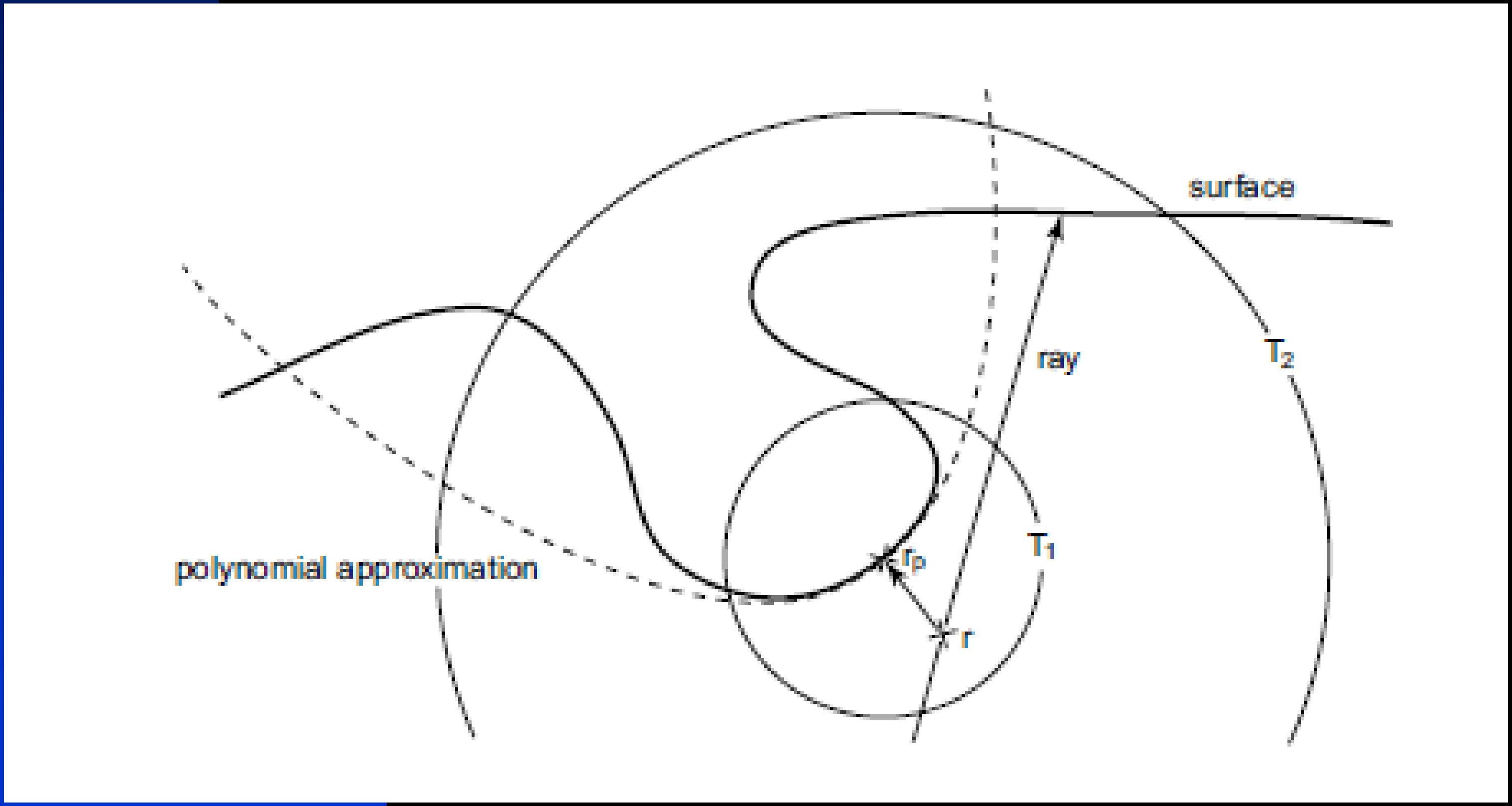
- The general idea of computing ray-surface intersections is to converge iteratively by projecting points from the ray onto the surface
- Every projection of a point r provides following useful information
  - Distance of r to the surface
  - Direction of projection
  - The local plane H of ray
  - The local bivariate polynomial approximation of ray

Computing Ray-Surface Intersections



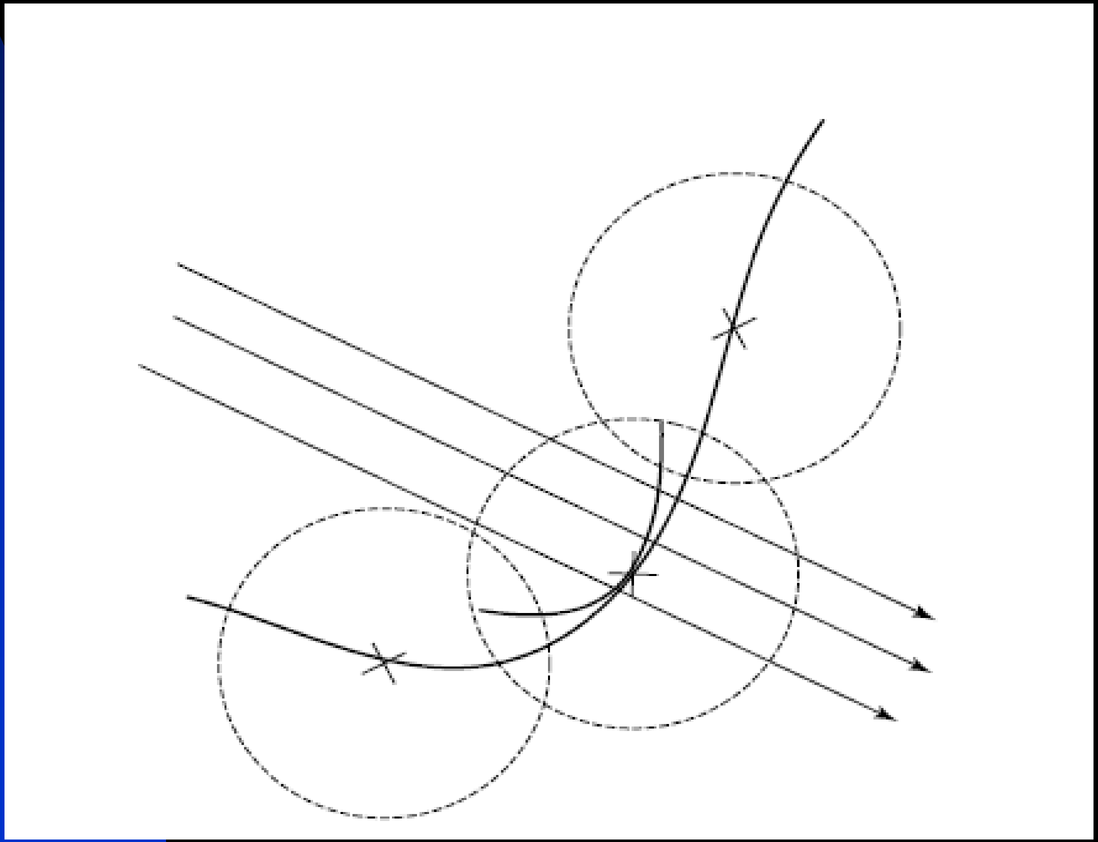
Computing Ray-Surface Intersections

- The region of trust for local polynomials



Computing Ray-Surface Intersections

- Enclosing sphere structure

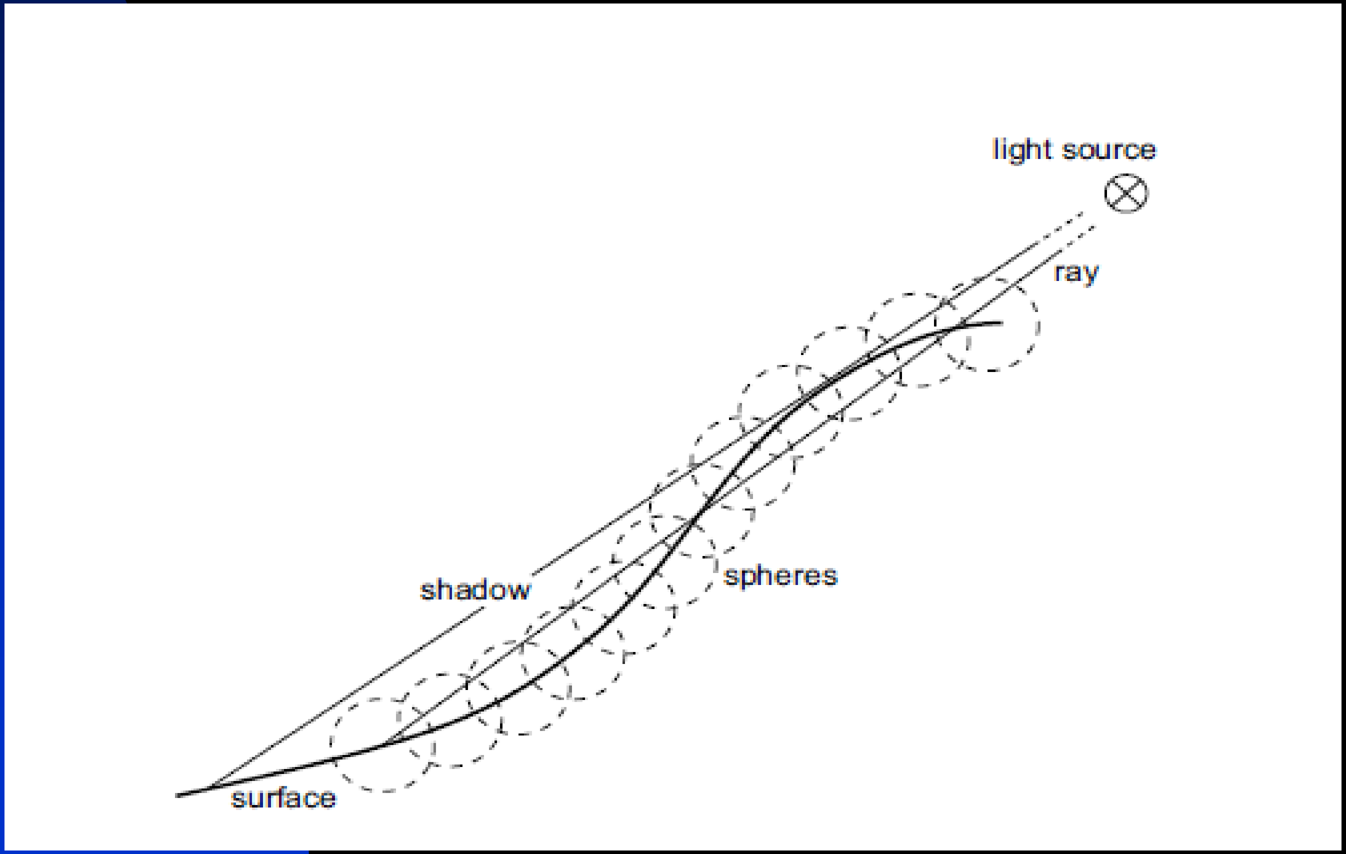


Implementation

- Spatial hierarchy
  - Checking all the spheres for potential intersections
  - To avoid unnecessary ray-sphere intersection tests, use a bounding sphere hierarchy that is built bottom-up from the region of trust spheres
- Exploiting coherence
  - When ray intersects a sphere a point needs to be projected onto the surface to yield the local polynomial approximation
  - use the sphere center for the first projection

Implementation

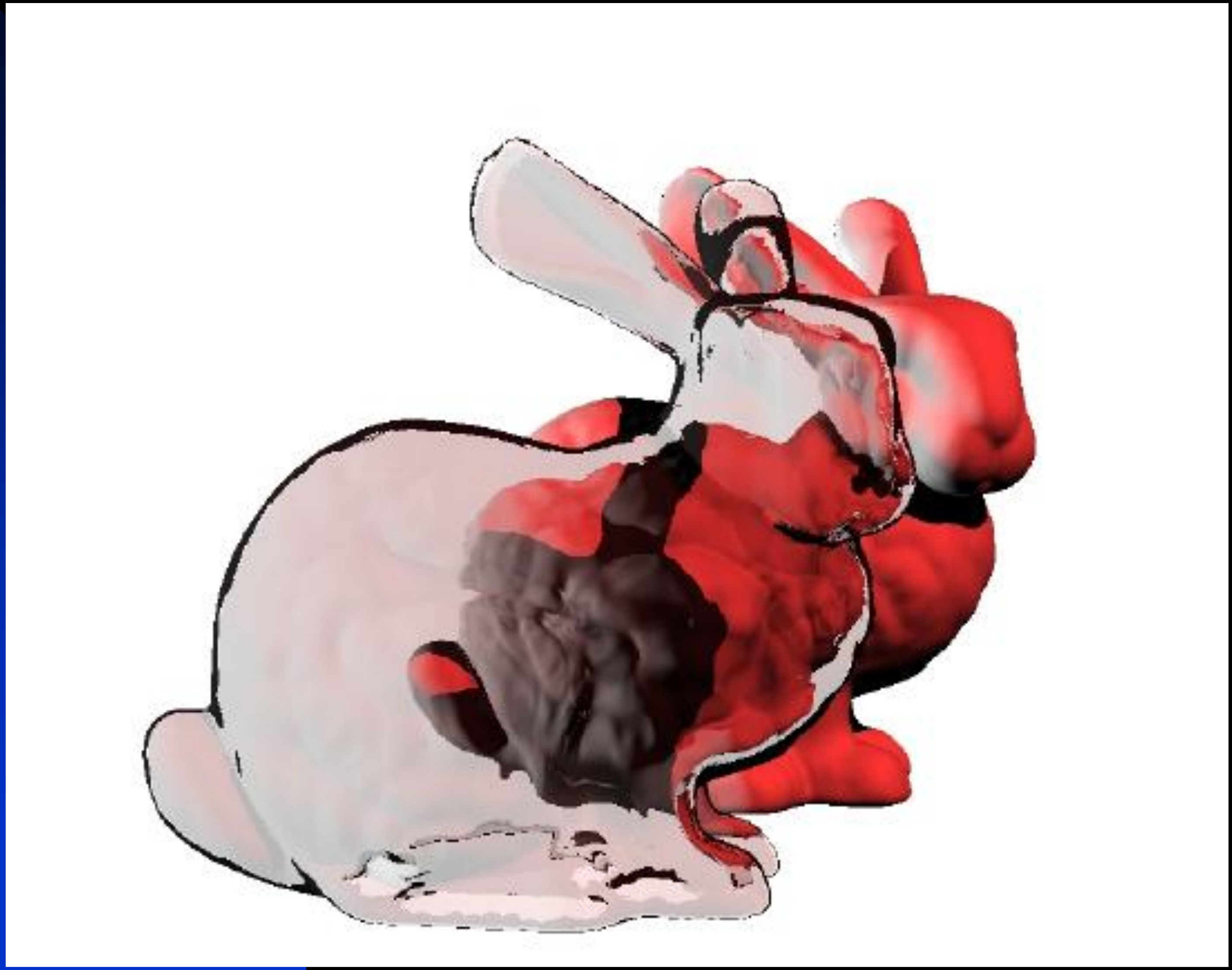
- Sorting for shadow rays



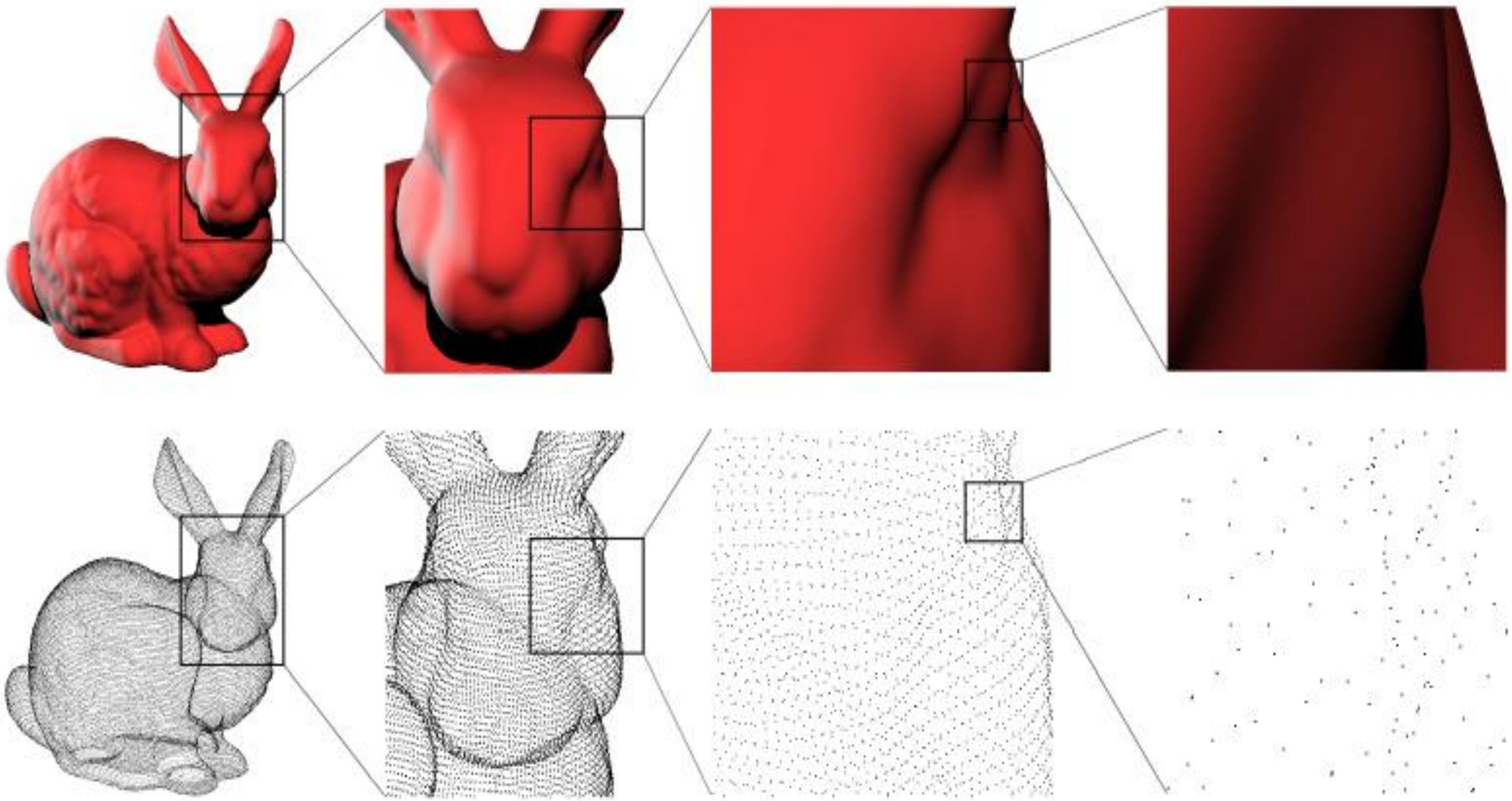
Implementation

- Brief Algorithm
  - Traverse the spacial hierarchy, collect all spheres intersected by the ray
  - Sort the spheres with respect to their distance from the ray-origin
  - Pop a sphere from the priority-queue and execute the refinement procedure

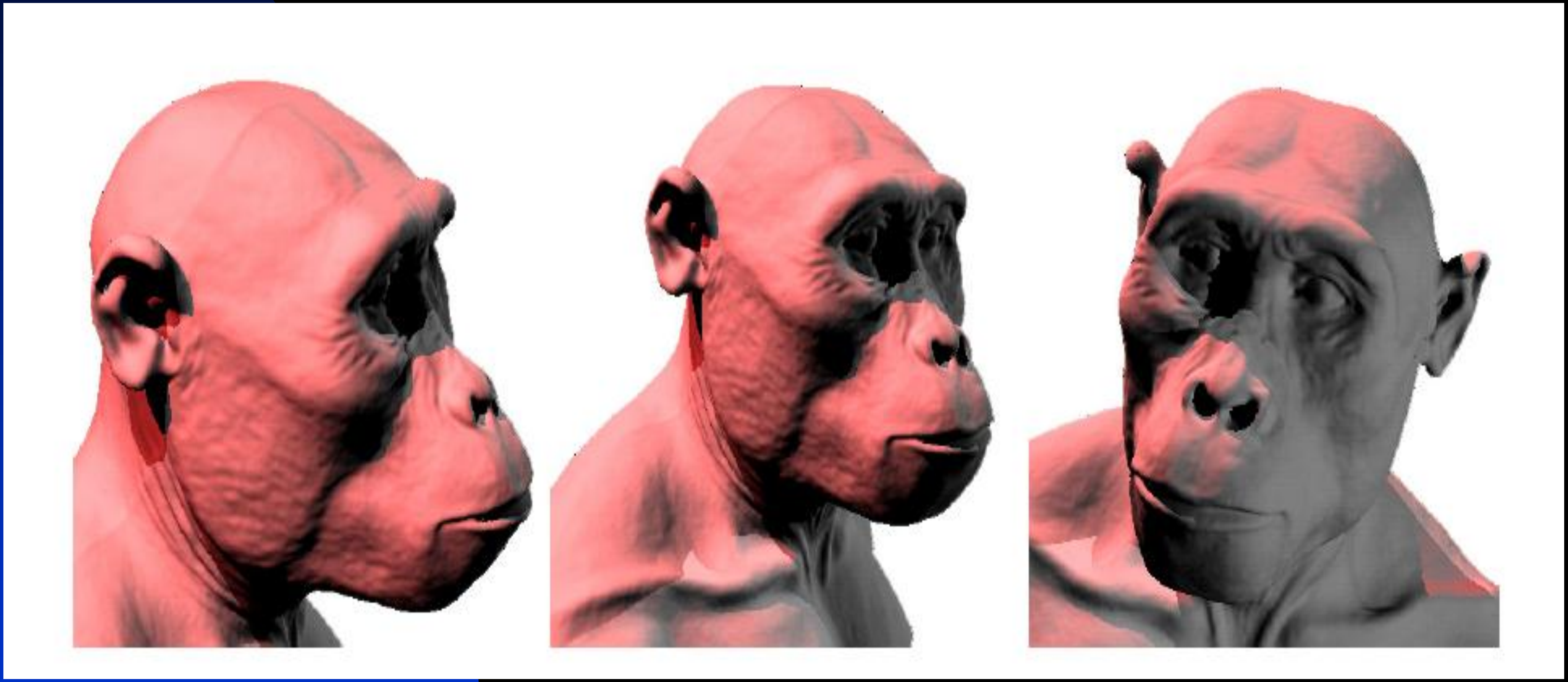
Results



Results



Results



- Any Problem?