Ray Tracing NPR-Style Feature Lines

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Scientific Computing and Imaging Institute
University of Utah

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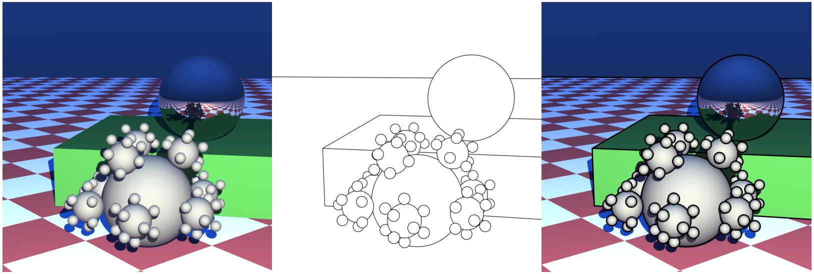
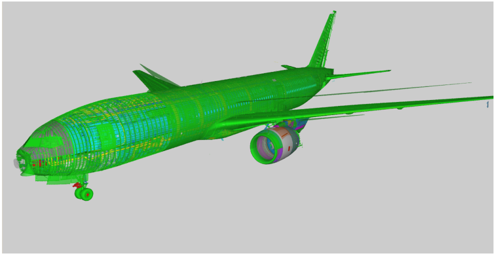


Why Ray Tracing?

- Large numbers of primitives
- Secondary effects
- Advanced shading



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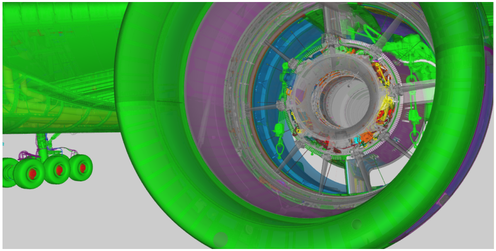

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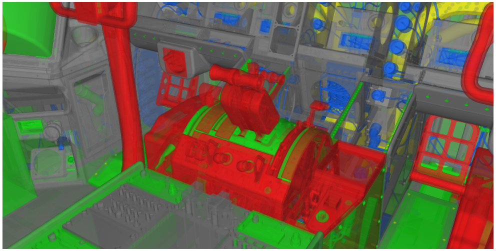

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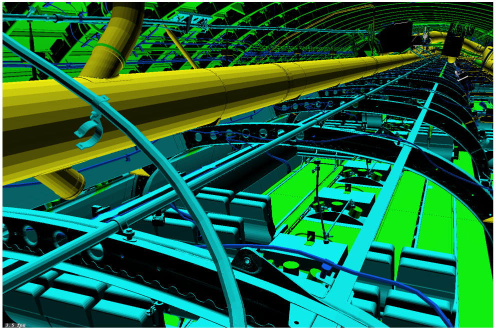

Abe Stephens

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Asbjørn Heid (pbrt.org)

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Rui Wang (pbrt.org)

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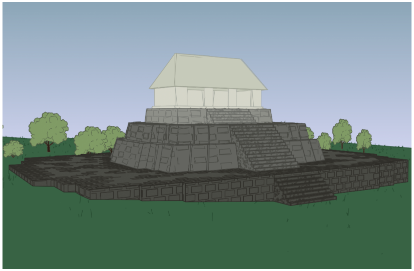
pbrt.org

Why Feature Lines?

Feature lines can

- indicate confidence in architectural rendering (Potter et al. 2009)
- succinctly express shape (Judd et al. 2007, Dooley and Cohen 1990)
- enhance geometric features (Saito and Takahashi 1990)



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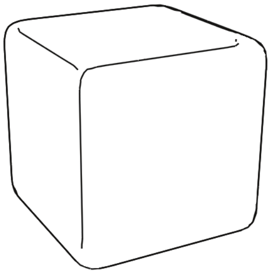
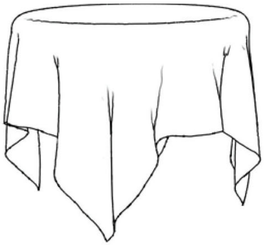
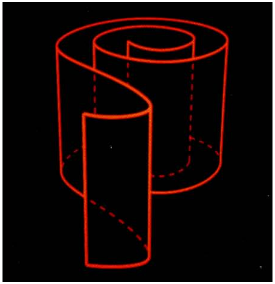

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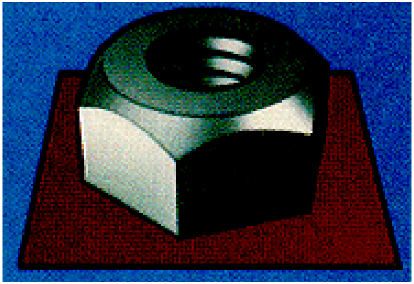
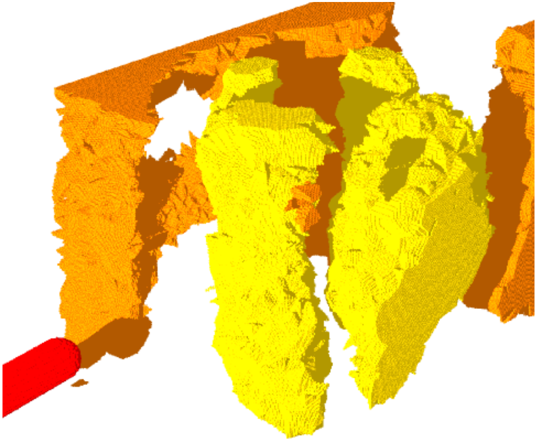


Some People Need Both!

(Bigler et al. 2006)



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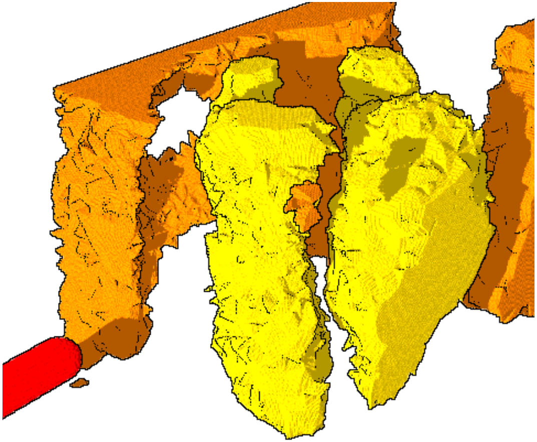

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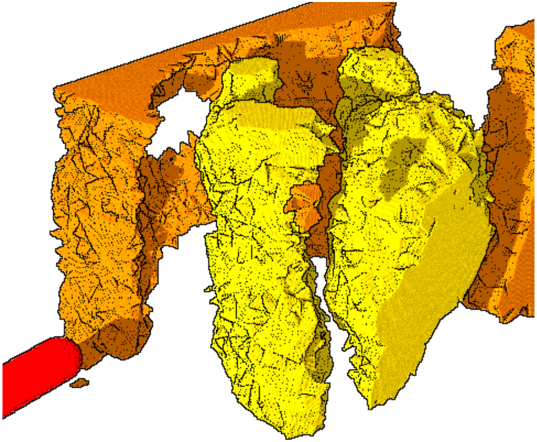

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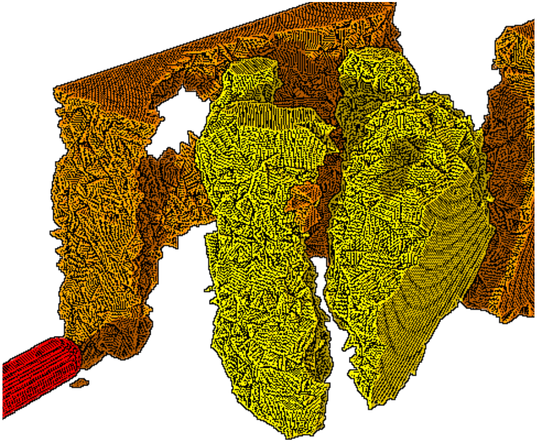
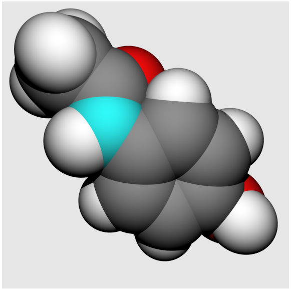
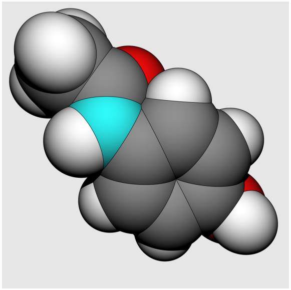


Feature Line Types

- *Intersection lines:* two objects intersect and form a seam
- *Silhouette lines* (or *edges*): the edge of an object lies against the background, a different object, or a further part of itself (i.e. a *self-occluding* silhouette)
- *Crease lines:* an object has a sharp corner (a discontinuity in the gradient of the normal field)

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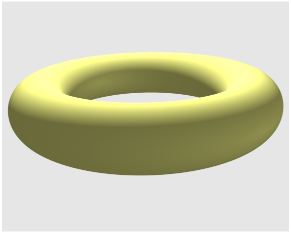
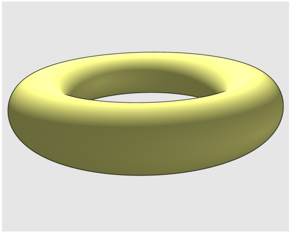

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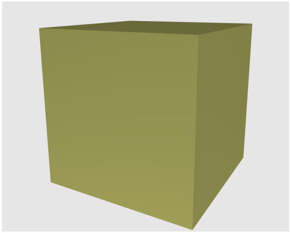
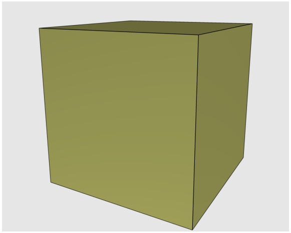

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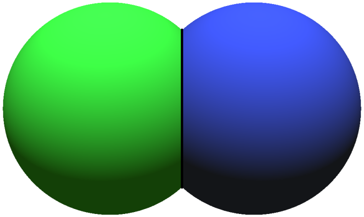
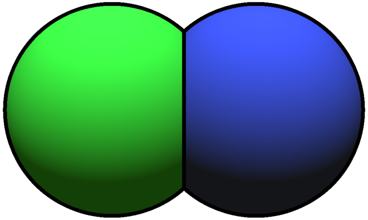
- Lines are *not* physical—they have no breadth
- Can try "line-like" primitives, e.g. thin cylinders and toruses

Lines in Ray Tracing?

But *geometry* doesn't work as *lines!*





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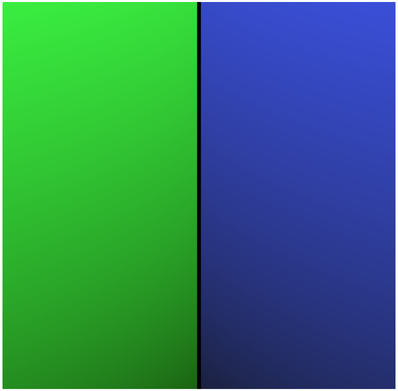

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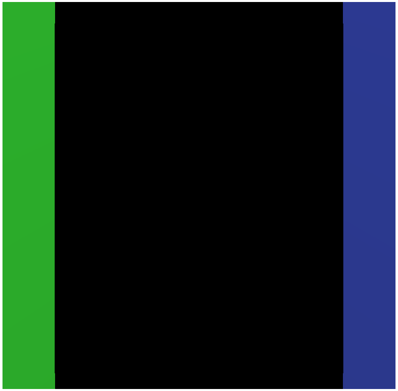
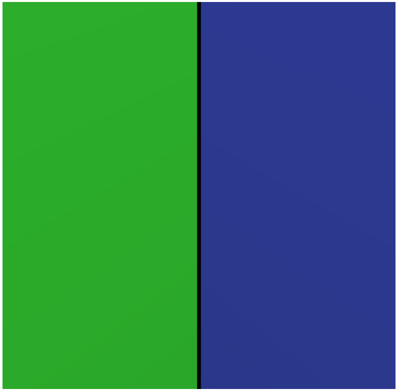

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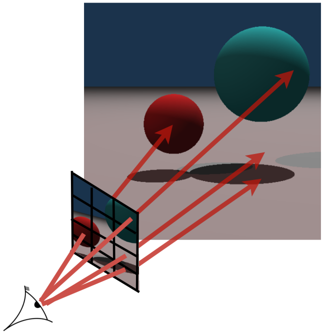
i.e. we want to rasterize lines

Ray Tracing
Algorithm Overview


(Figure courtesy of Thiago Ize)

- *Camera rays* cast through the *image plane*, striking the scene at *intersection points*
- *Secondary rays* cast from the intersection points for secondary effects (shadows, reflections, etc.)
- *Sample colors* computed from ray results and *shading model*
- *Final image* assembled from filtered sample colors

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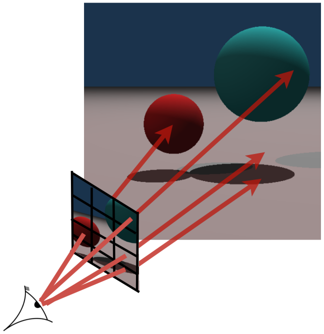
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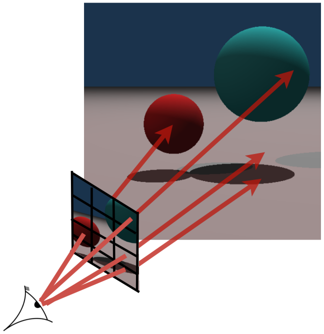
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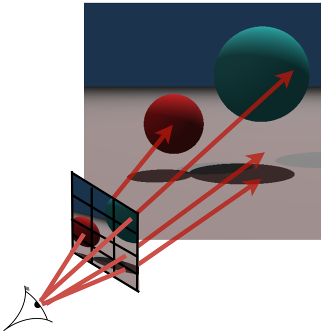

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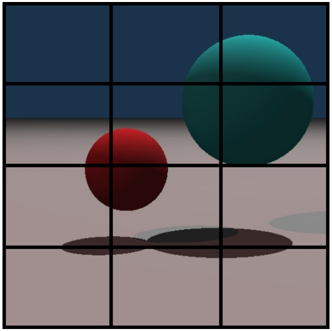
Ray Tracing

Navigating Screen Space



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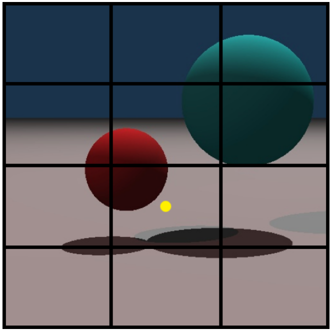
Ray Tracing
Navigating Screen Space



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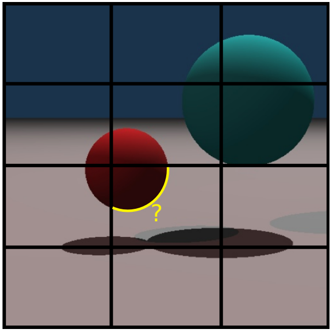

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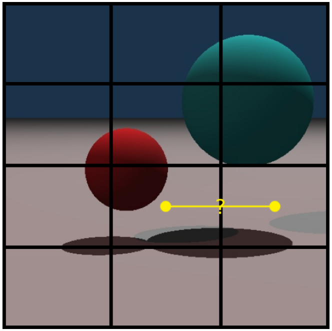
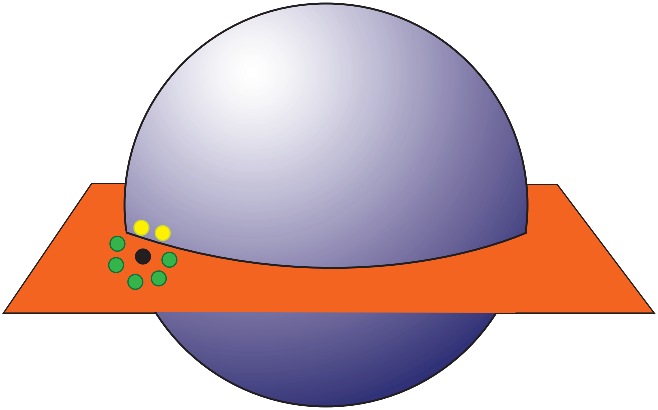


- Camera rays determine visibility
- Parameterized by camera position and pixel position; i.e., they live in screen space
- With a way to
  1. detect feature lines, and
  2. measure distances in screen space

  we can incorporate feature line rendering into a ray tracer.

Detecting Feature Lines

Intersection Lines



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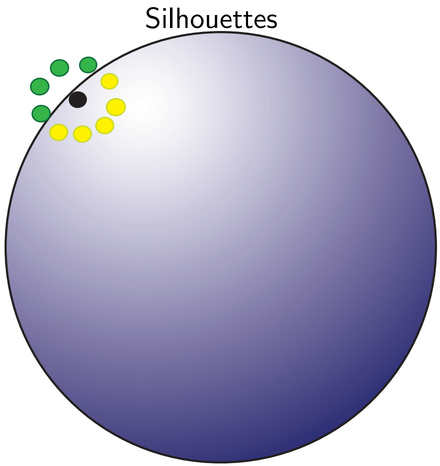
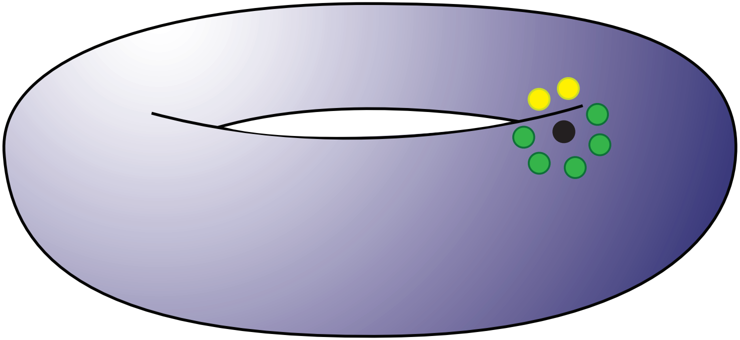


Detecting Feature Lines

Self-occluding Silhouettes



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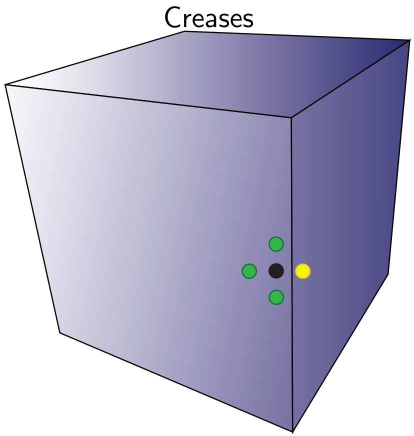
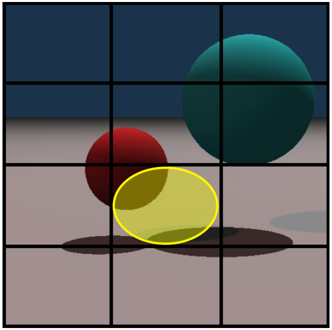


Measuring Distances

Cone Tracing (Amanatides 1984)



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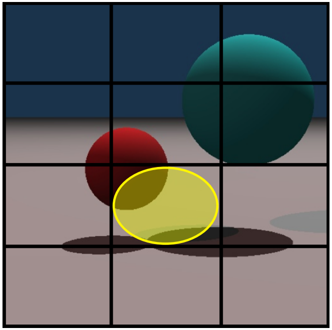

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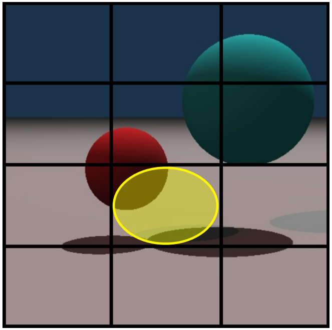
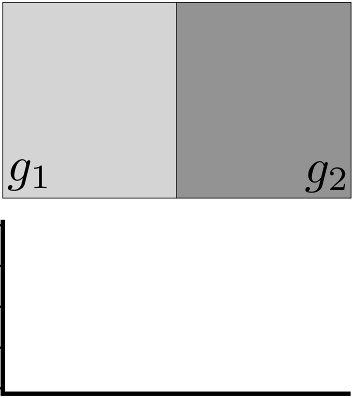


- Trace a *cone* instead of a ray; footprint is circle instead of point
- Used for non-singular scene coverage: anti-aliasing, glossy reflections, etc.
- We borrow the idea of a ray having a radius; our notion of non-physical feature lines exists over some area of the image.

Drawing Feature Lines

Continuous Case



- Estimate *foreign geometry area* (*FGA*)

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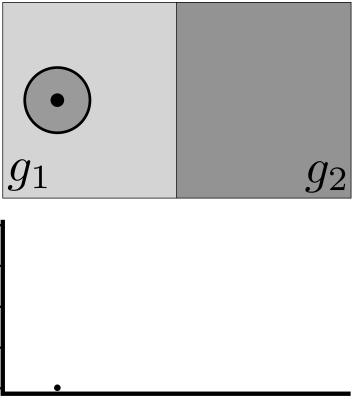

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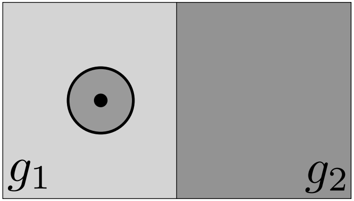

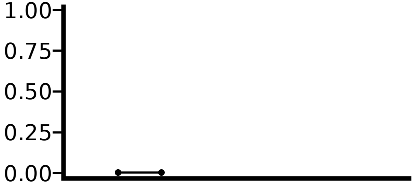

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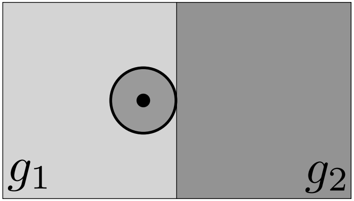

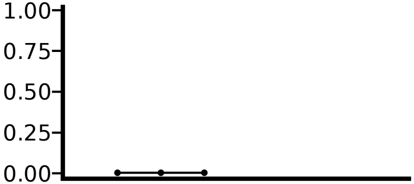

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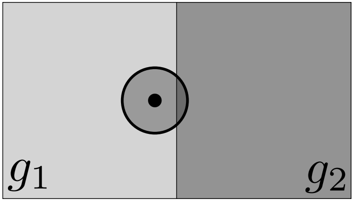

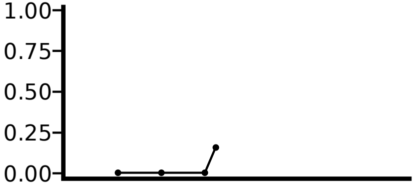

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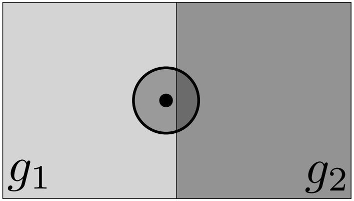

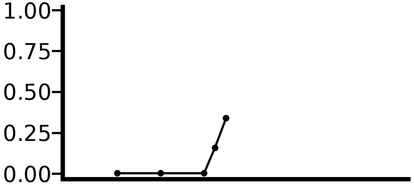

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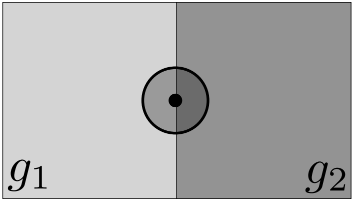

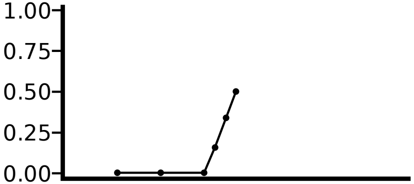

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- Intuition: edge must be strong where *FGA* is 50%

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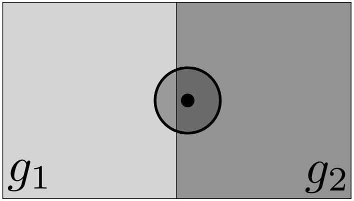

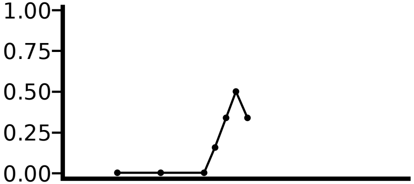

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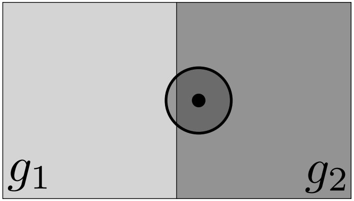

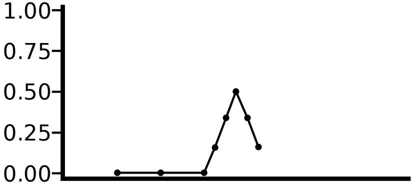

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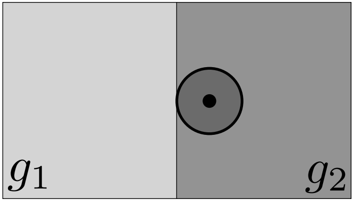
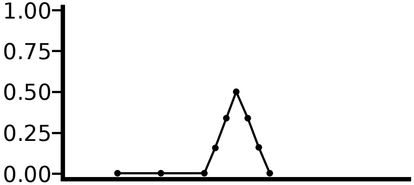
Drawing Feature Lines

Continuous Case

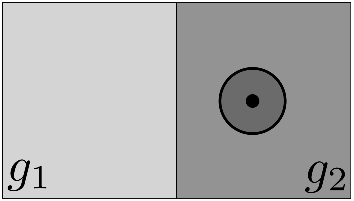


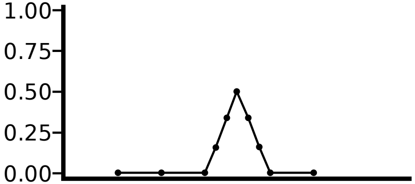


- Estimate *foreign geometry area* (*FGA*)
- Intuition: edge must be strong where *FGA* is 50%

Drawing Feature Lines

Continuous Case





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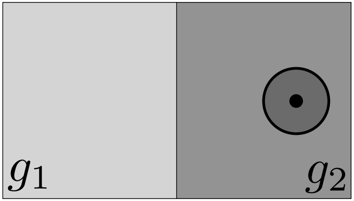
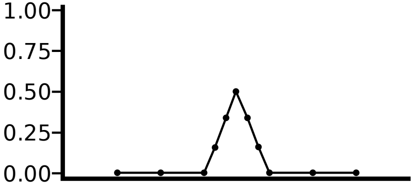
Drawing Feature Lines

Continuous Case





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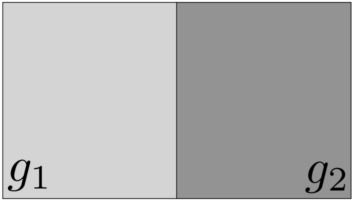
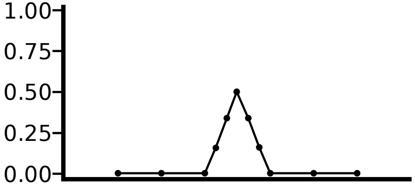
Drawing Feature Lines

Continuous Case





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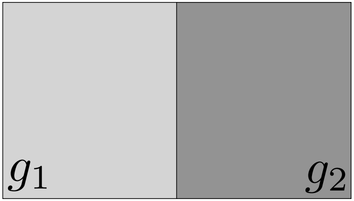
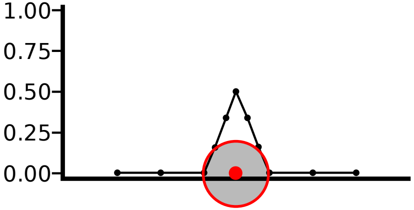
Drawing Feature Lines

Continuous Case

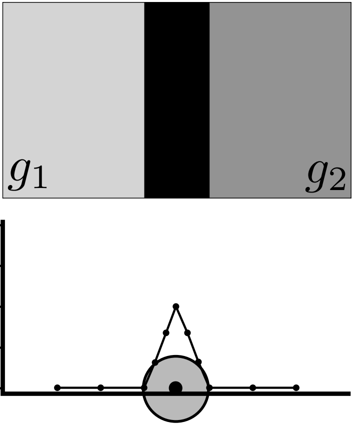




- Estimate *foreign geometry area* (*FGA*)
- Intuition: edge must be strong where *FGA* is 50%
- Note: filter diameter equals width of peak

Drawing Feature Lines

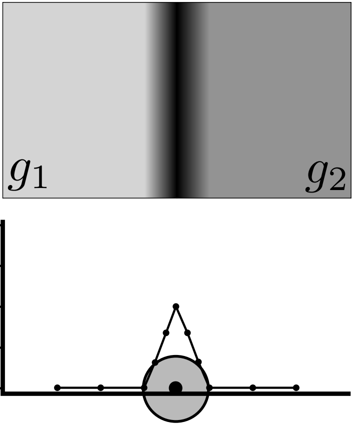
Continuous Case



- Estimate *foreign geometry area* (*FGA*)
- Intuition: edge must be strong where *FGA* is 50%
- Note: filter diameter equals width of peak
- Easiest way to create a line: black where $FGA > 0$; sample color where $FGA = 0$

Drawing Feature Lines

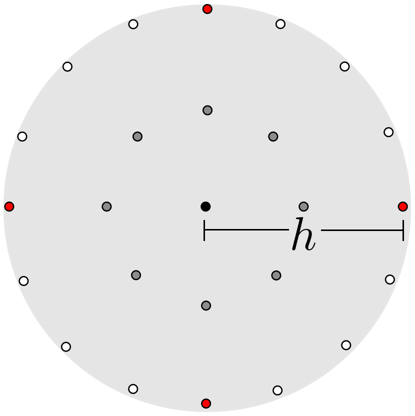
Continuous Case



- Estimate *foreign geometry area* (*FGA*)
- Intuition: edge must be strong where *FGA* is 50%
- Note: filter diameter equals width of peak
- Easiest way to create a line: black where $FGA > 0$; sample color where $FGA = 0$
- More generally: determine darkness of line *as a function of FGA*; i.e. use an *edge strength metric*

Drawing Feature Lines

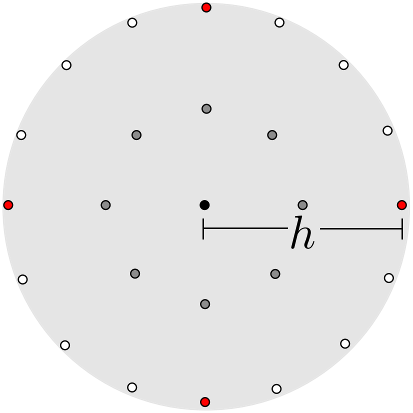
Ray Stencils



- Approximate filter by sampling the disc
- *h* is a distance in screen space (measured in pixels, e.g.)
- Increase sampling density by packing more rings of samples
- Now, estimate F.G.A. by *counting* which rays hit what.
- Red samples form *finite difference stencil*

Drawing Feature Lines

Computing Edge Strength

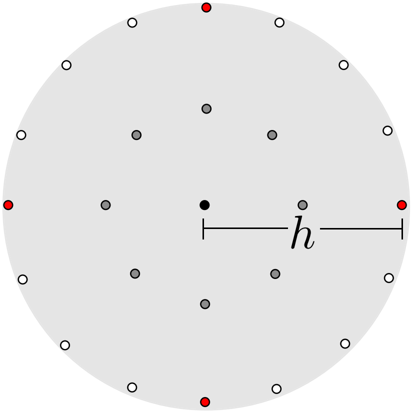


one sample ray s (black) and M stencil rays (gray, white, red)

- Select *edge strength metric* E (e.g. $E(m) = \frac{m}{\frac{1}{2}M}$)
- s, and m stencil rays, hit g_s
- if $m = M$
  1. compute $\nabla \vec{n}$ using FD stencil; if greater than threshold, edge strength $e_s = 1$, otherwise,
  2. d is the number of stencil rays "near" to the sample ray: $e_s = E(d)$
- otherwise, $m < M$, and $e_s = E(m)$

Drawing Feature Lines

Computing Edge Strength



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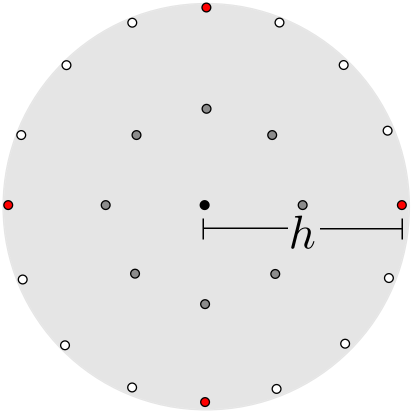
Drawing Feature Lines

Computing Edge Strength



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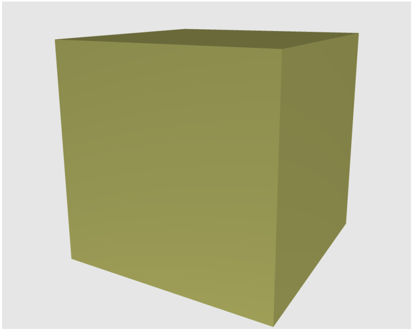
Drawing Feature Lines

Computing Edge Strength



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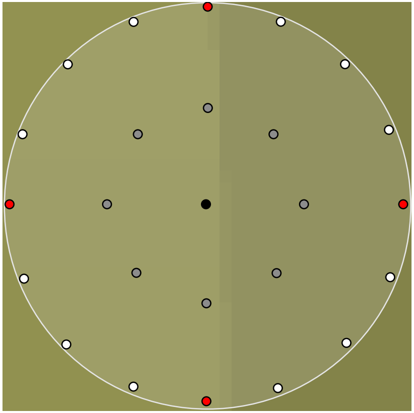
Drawing Feature Lines

Computing Edge Strength



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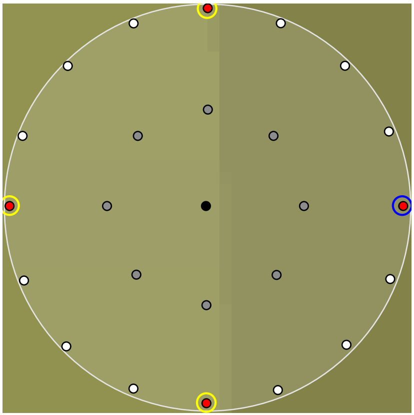
Drawing Feature Lines

Computing Edge Strength



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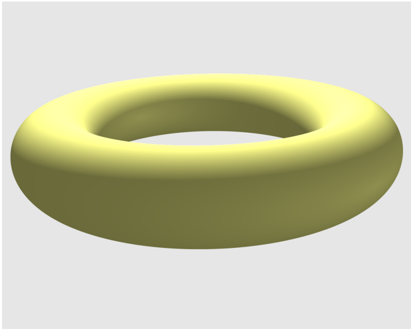

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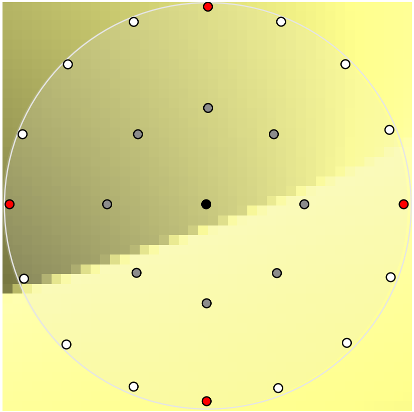

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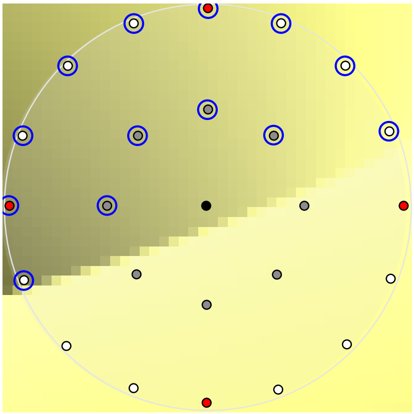

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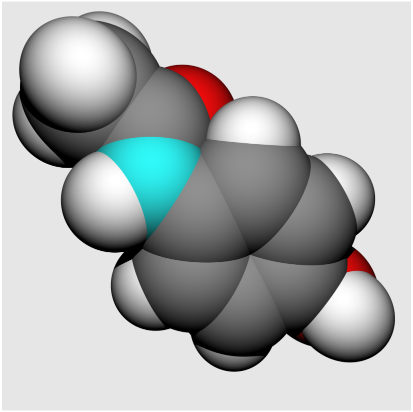

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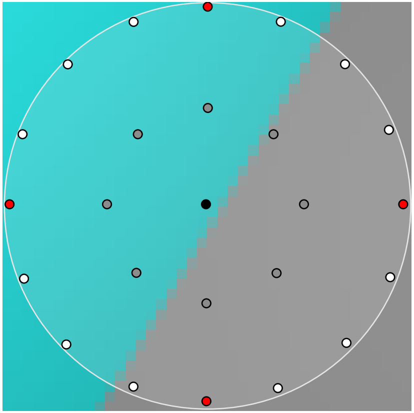

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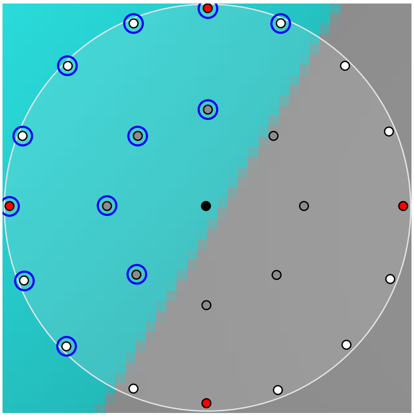
Drawing Feature Lines

Computing Edge Strength



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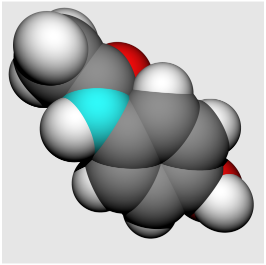
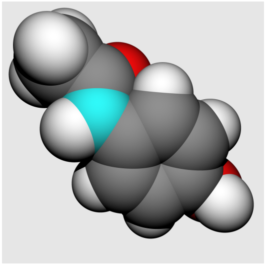
Ray Tracing Feature Lines

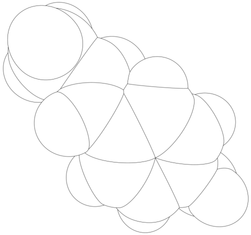
- Compute and shade *sample rays* as normal



Ray Tracing Feature Lines

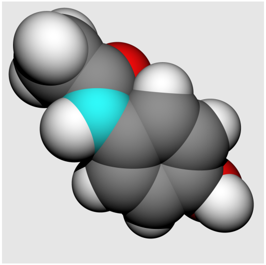
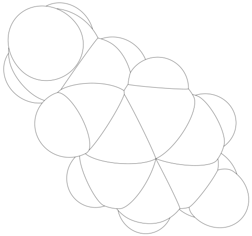
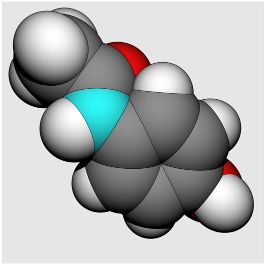
- Compute and shade *sample rays* as normal
- Compute *edge strengths* at each sample point



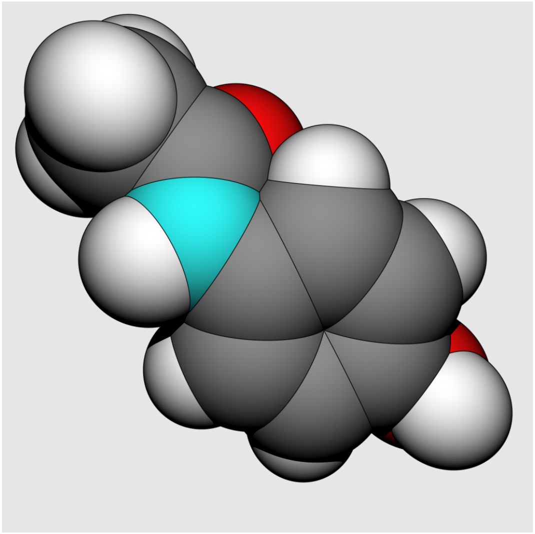


Ray Tracing Feature Lines

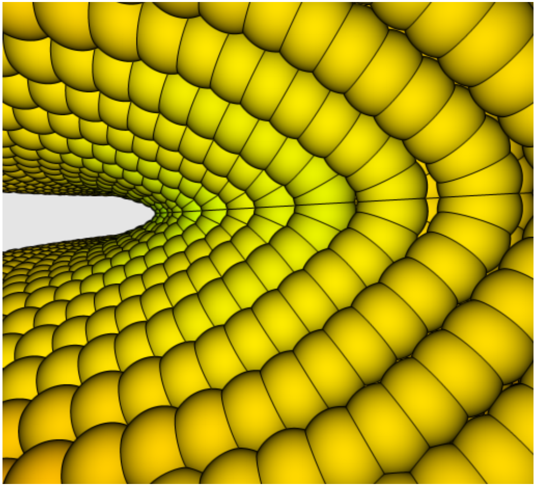
- Compute and shade *sample rays* as normal
- Compute *edge strengths* at each sample point
- *Multiply* shaded image with inverse edge strength image

Primitive Joints



Particle Impaction



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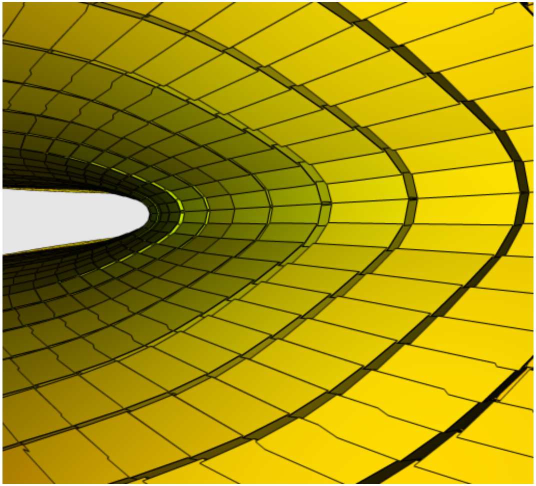
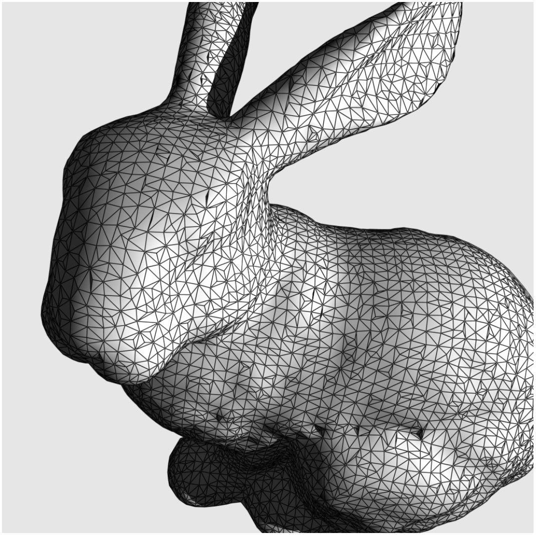
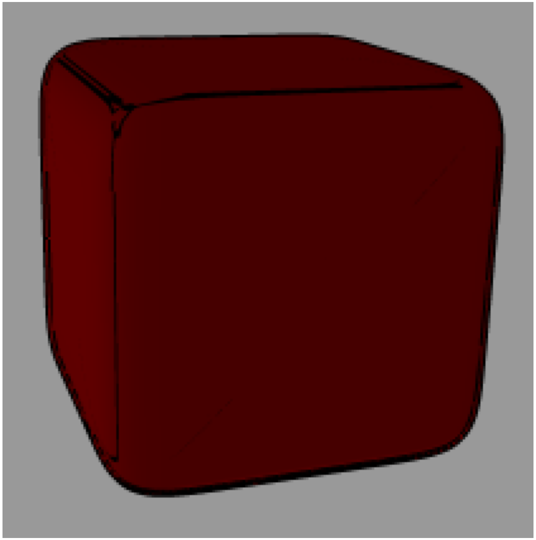


Mesh Visualization



Other NPR Techniques



Thank You!

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