

Hierarchical Techniques for Visibility Computations

Ph.D. Thesis by

Jiří Bittner

supervised by

Pavel Slavík

Department of Computer Science and Engineering
Czech Technical University in Prague

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Talk Outline



- Introduction to visibility
- Taxonomy of visibility problems
- A general concept of a visibility algorithm
- Applications of the concept:
 - Real-time visibility culling in 3D
 - Construction of visibility maps in 3D
 - From-region visibility in 2D
 - From-region visibility in $2\frac{1}{2}$ D
 - From-region visibility in 3D
- Conclusions

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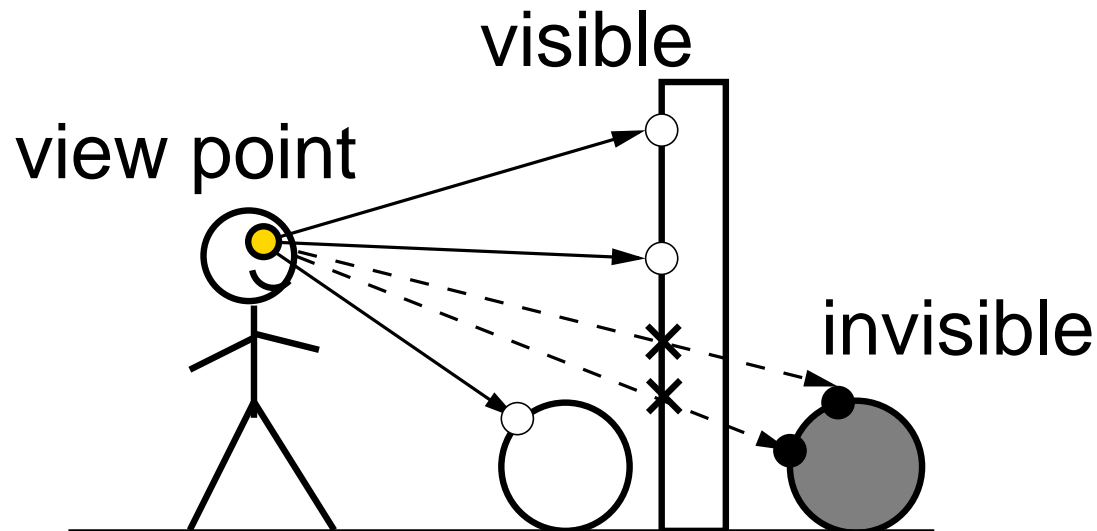
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- Points A and B mutually visible \Leftrightarrow line segment \overline{AB} does not intersect an opaque object
- Questions: What is visible? From where? How much? ...

visibility from a point



- **Computer graphics**, computer vision, robotics, GIS, telecommunications, architecture, computational geometry, ...

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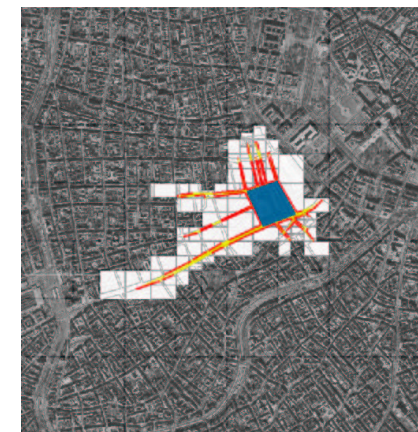
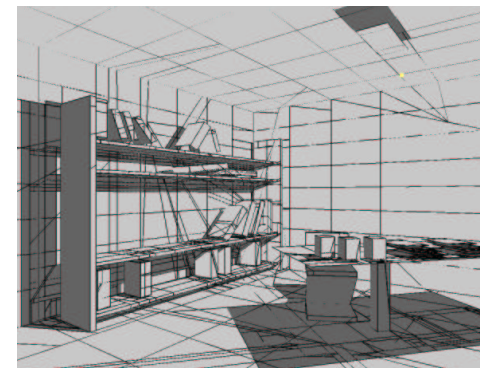
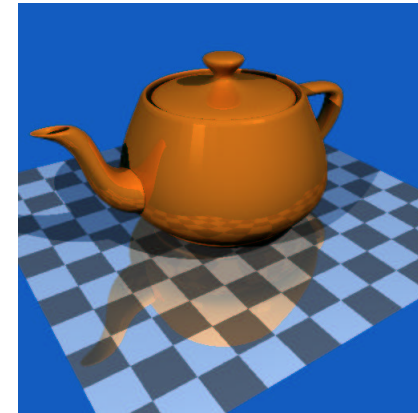
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Application areas

- Global illumination
visibility along light paths
- Shadow computation
visibility with respect to light source
- **Real-time rendering**
rendering only potentially visible
objects



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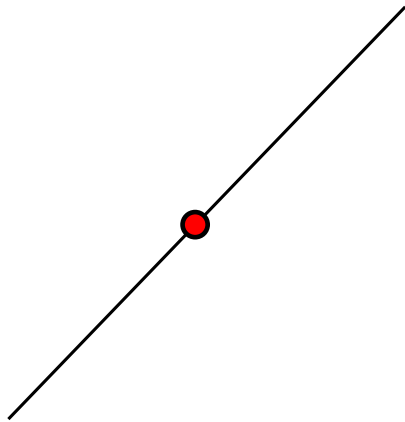
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Taxonomy of Visibility Problems

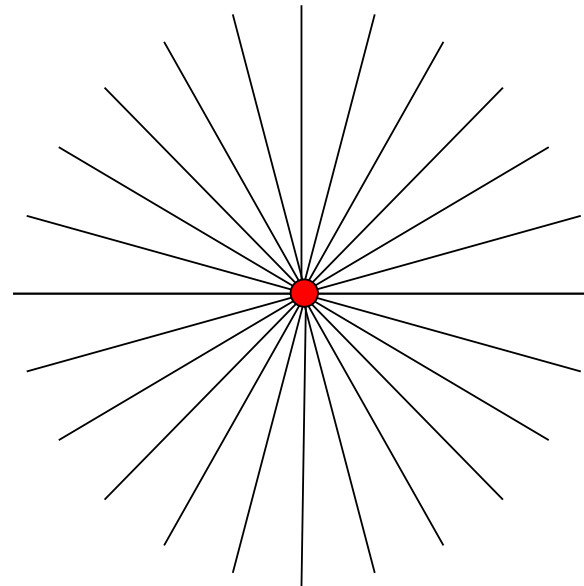


- Visibility **carried by lines** \Rightarrow independent of spatial proximity!
- Problem domain: **problem-relevant line set** \mathcal{L}_R

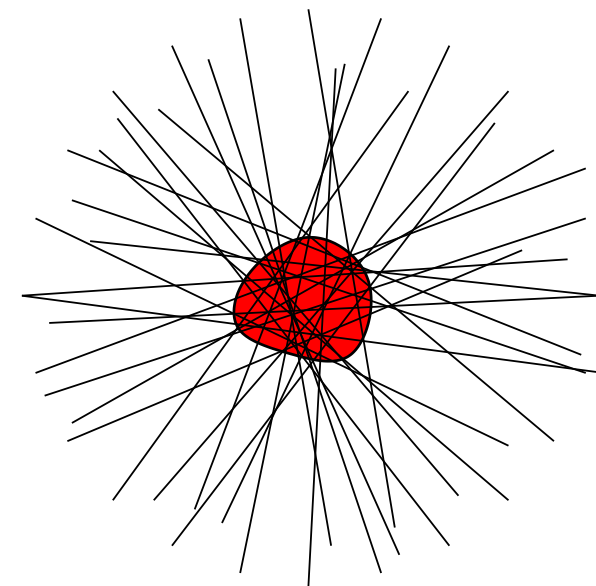
visibility
along a line



visibility
from a point



visibility
from a region



- Natural domain of visibility problems: **line space**
- Classification according to **dimension** of \mathcal{L}_R

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State of the art

- No uniform solution to problems with different domains!

The goal: concept that is

- **General** – problems with different domains
- **Uniform** – reusing implementation and concepts
- **Accurate** – exact, or close to exact
- **Efficient** – output sensitivity, visibility coherence

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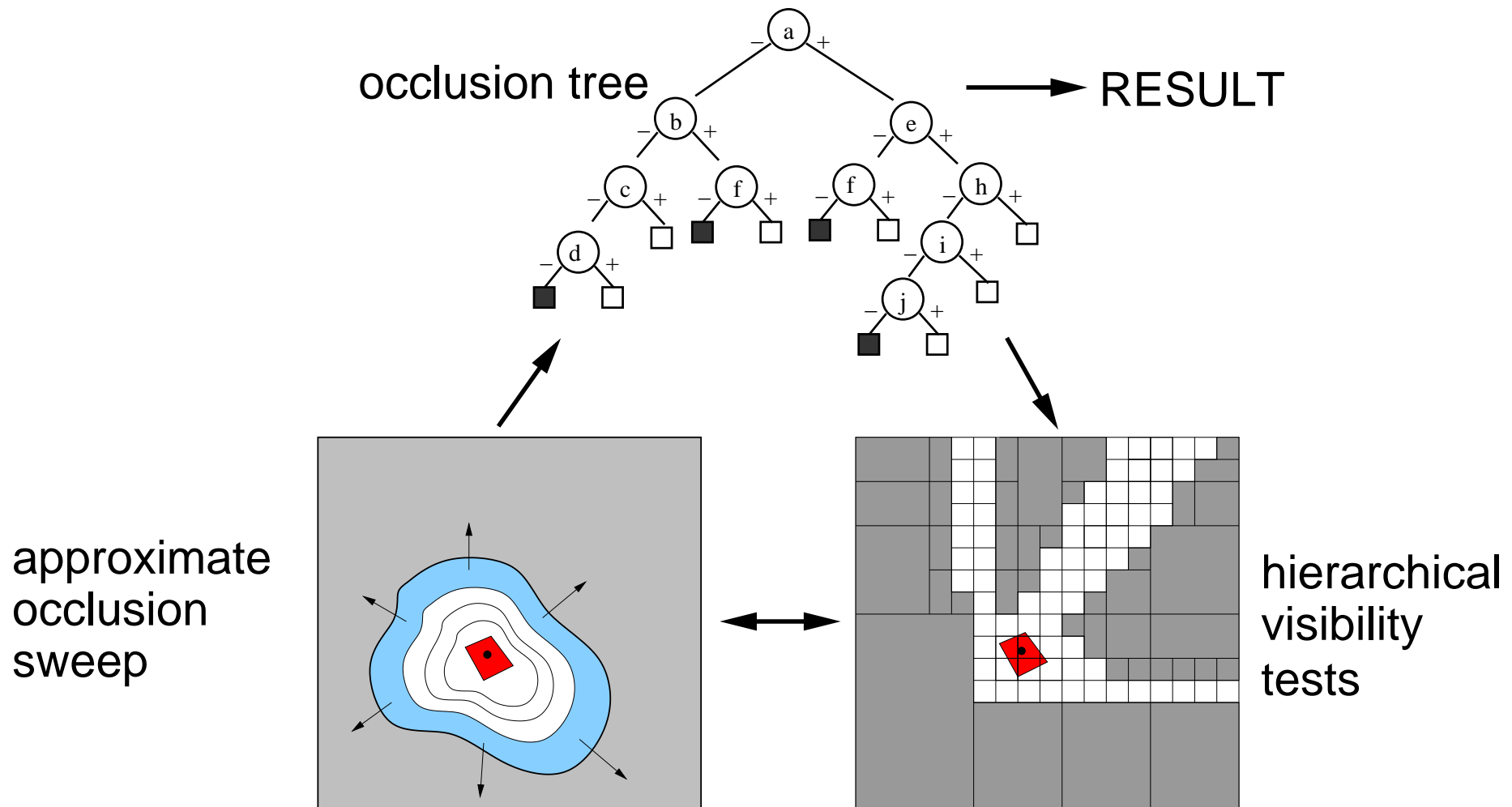
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The General Concept — Cont.



- Approximate occlusion sweep – front-to-back order of polygons
- **Occlusion tree** – representation of occlusion
- Hierarchical visibility tests – output sensitivity



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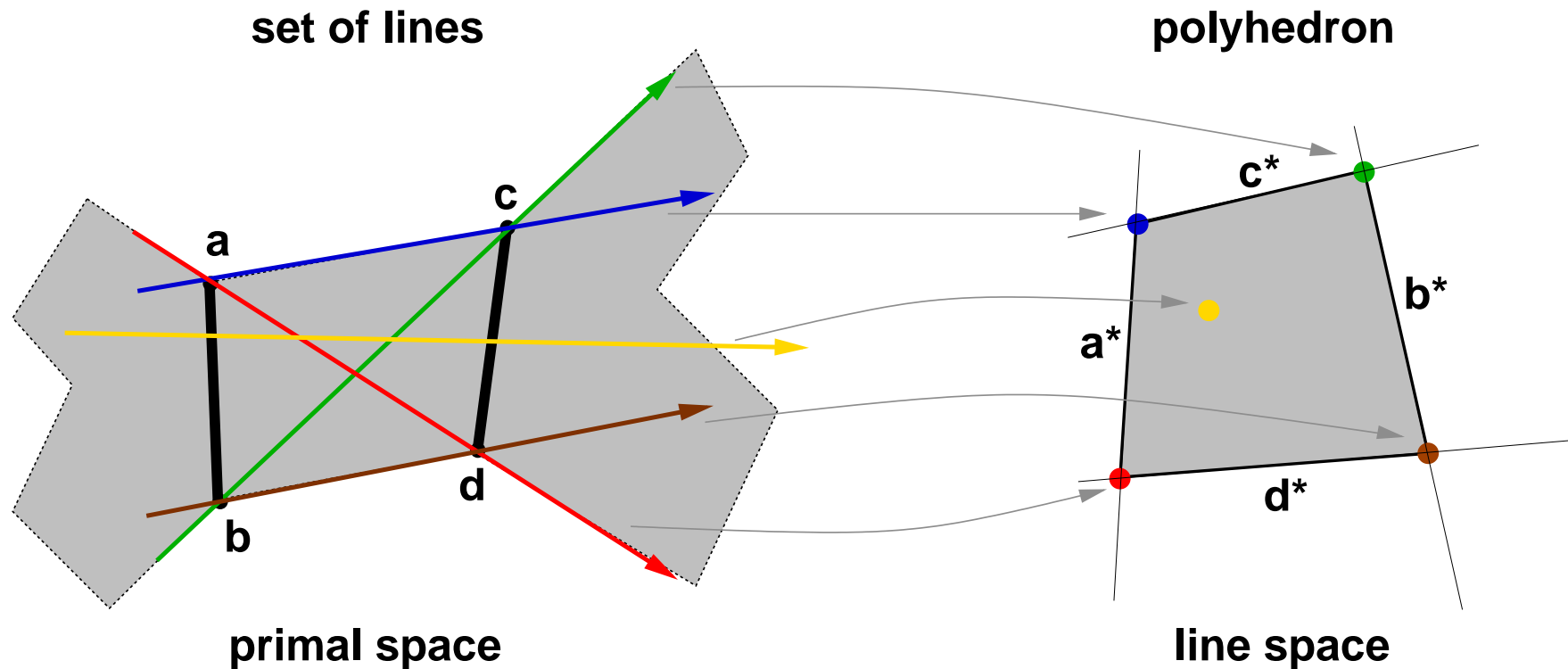
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Occlusion Tree



Structure

- Binary Space Partitioning (BSP) tree
- Represents occluded lines with respect to point, line segment, or region
- Union of **line space polyhedra**



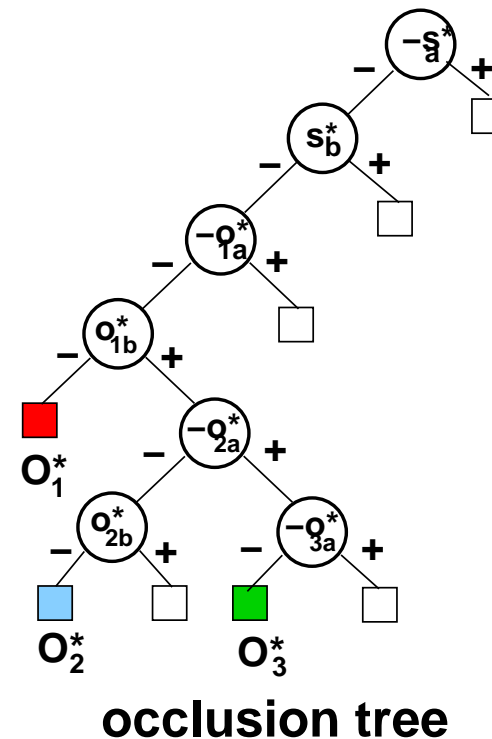
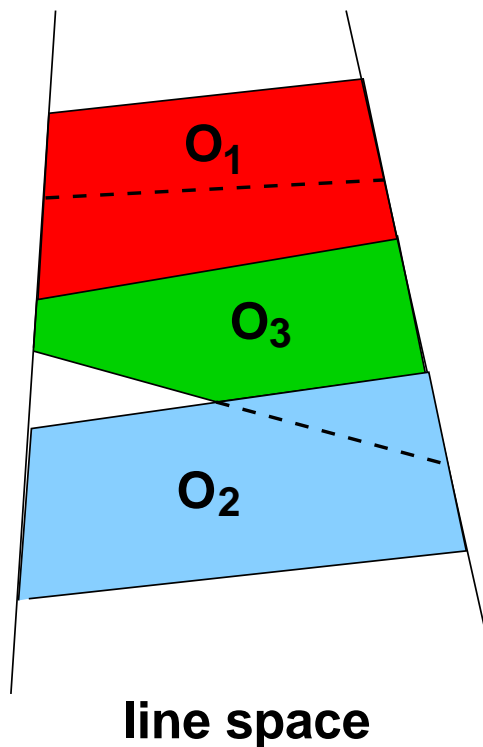
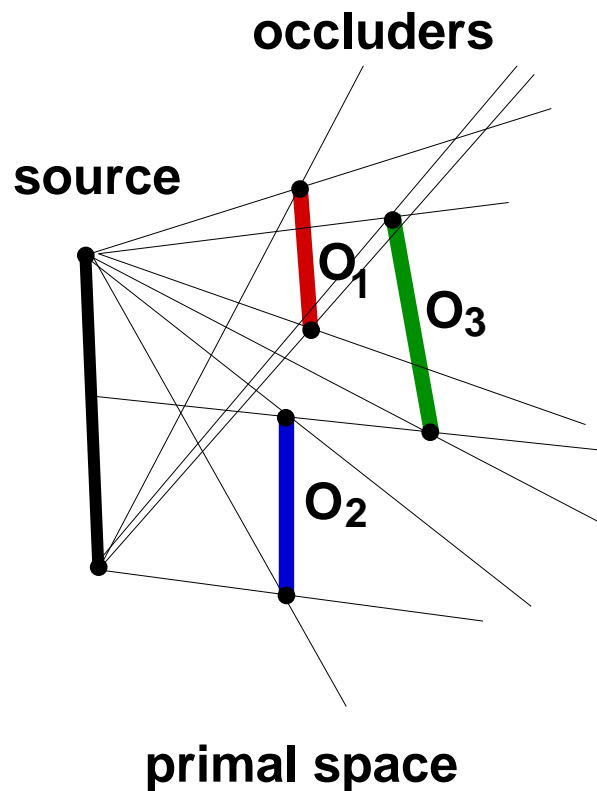
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Occlusion Tree — Cont.



Construction

- Polygon \Rightarrow line space polyhedron
- Insertion of polyhedron \Rightarrow set of visible/invisible fragments



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Features

- Applicable to \mathcal{L}_R of different dimensions !
- Relies only on d-dimensional polyhedron splitting
- Accurate encoding of visibility changes; no discretization
- Hierarchical representation of visibility; $O(\log n)$ searching

The rest of the talk: Applications of the proposed concept

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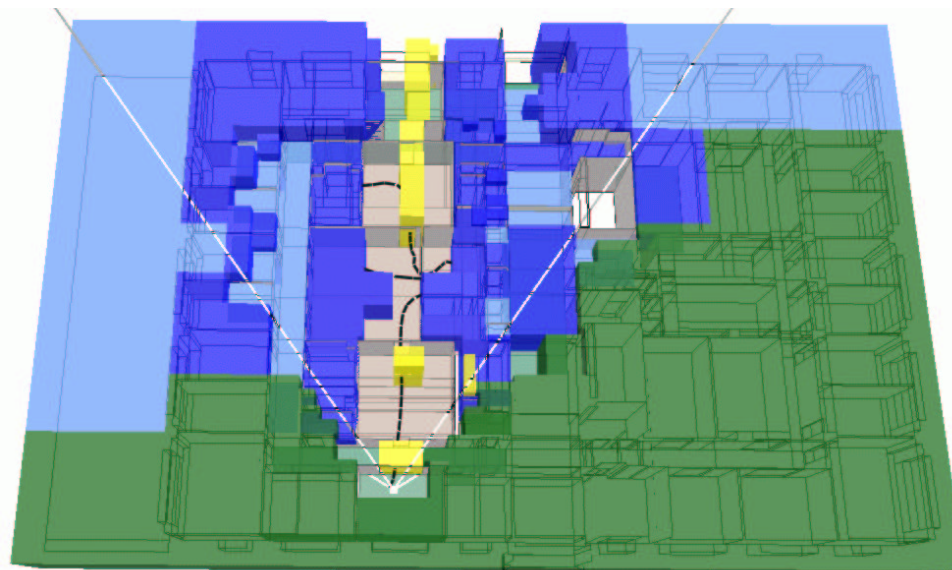
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Motivation

- Acceleration of real-time rendering of large scenes

Main ideas

- Fast conservative from-point visibility
- Select a few large **occluders** \Rightarrow occlusion tree
- Hierarchical visibility tests (kD-tree)
- Render only objects in visible kD-tree nodes



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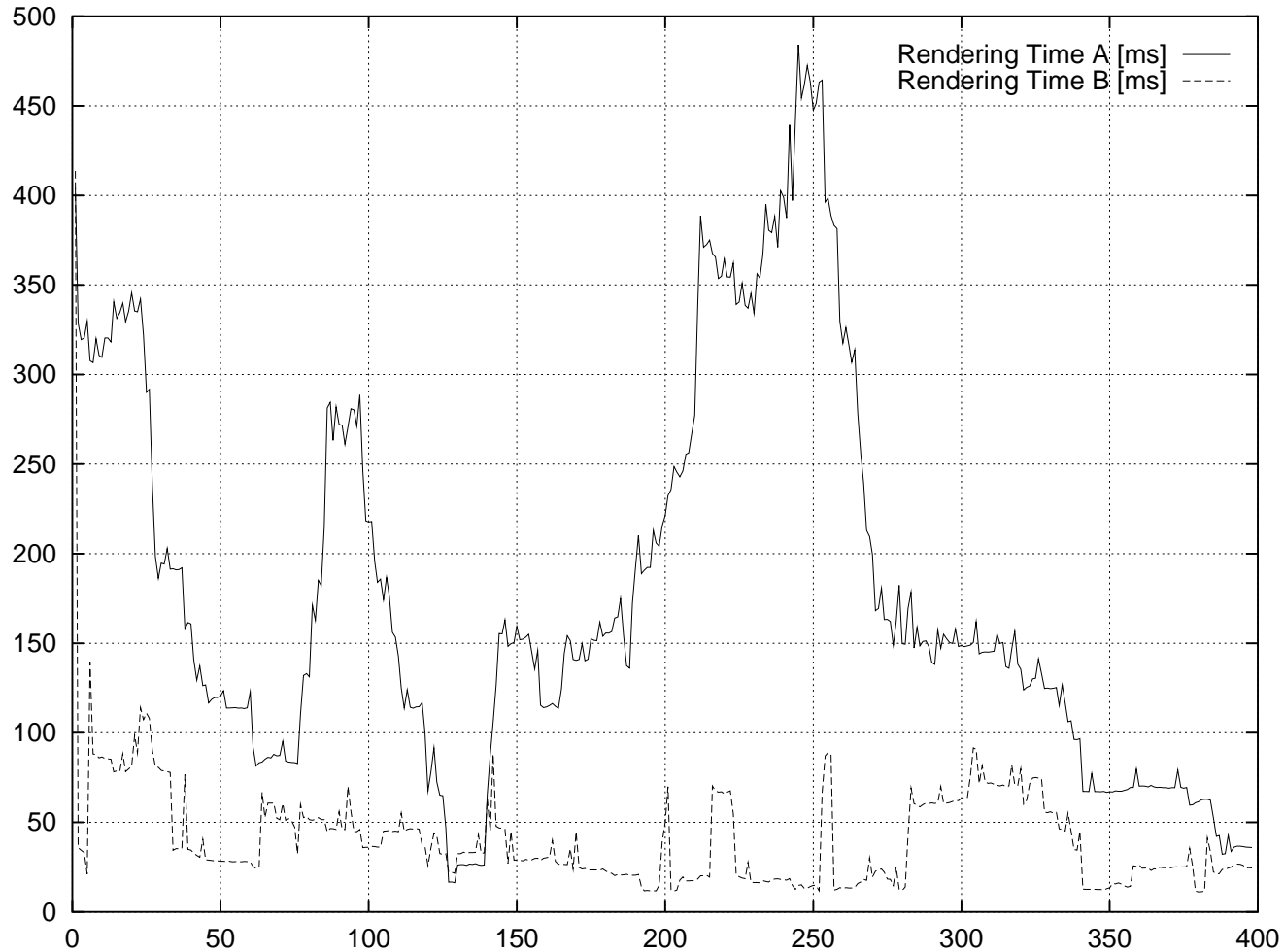
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Real-Time Visibility Culling — Results



- Speedup **1.8x — 3.5x** for tested scenes over VFC



- Modifications exploiting temporal coherence **+2x** speedup

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Construction of Visibility Maps



Motivation

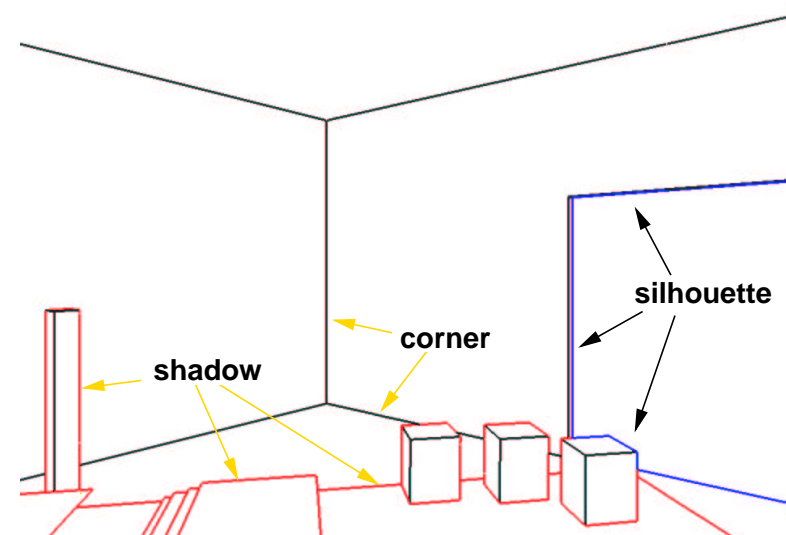
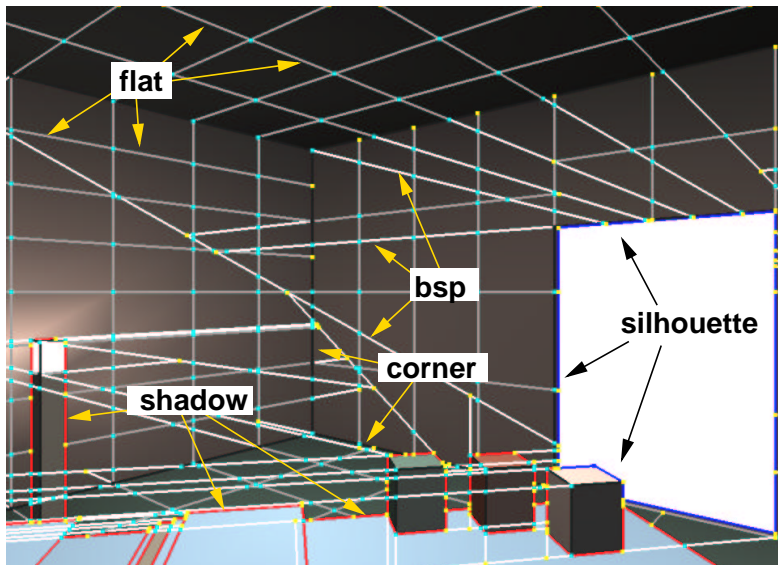
- Visibility map – a graph describing a view of the scene

Main ideas

- All polygons \Rightarrow occlusion tree
- Postprocessing of the occlusion tree \Rightarrow visibility map

Results

scene: 26k polygons, 642 vertices, 1229 edges, time: 0.14s



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From-Region Visibility in 2D



Motivation

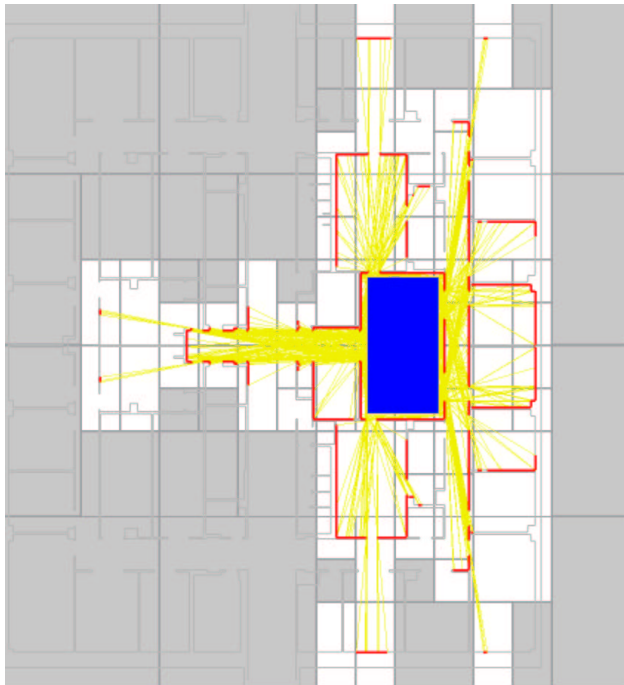
- Computing **potentially visible sets** (PVS) in 2D

Main idea

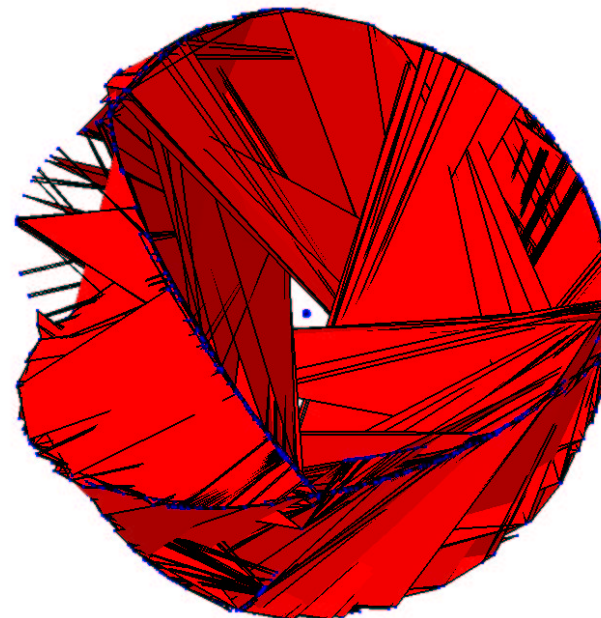
- Line segment \Rightarrow line space polygon \Rightarrow occlusion tree

Results

primal space, 873 segments
159 visible, 0.19s



line space
occlusion tree: 745 nodes



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From-Region Visibility in $2\frac{1}{2}$ D

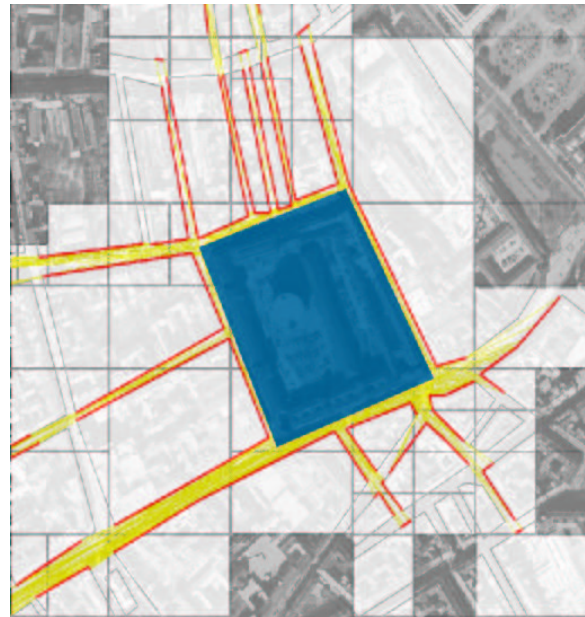
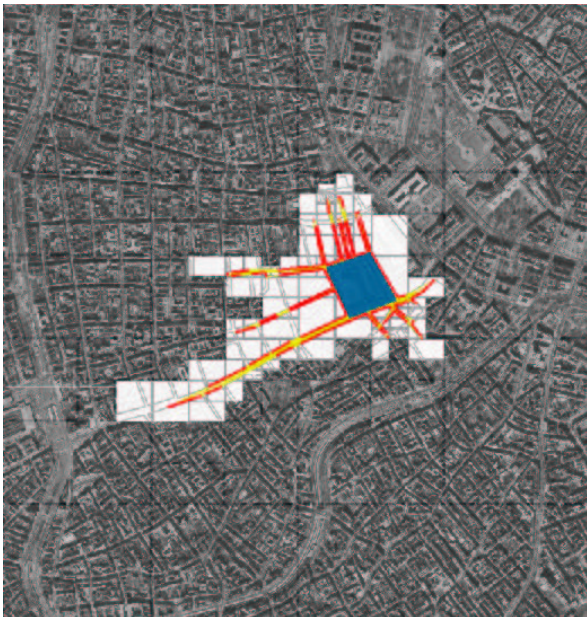


Motivation

- Computing PVS in outdoor urban scenes

Main ideas

- Extension of the 2D method
- Occlusion tree \Rightarrow 2D visibility interactions
- Primal space tests for the remaining dimension



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From-Region Visibility in $2\frac{1}{2}D$ — Results



- Two variants: exact and tightly conservative
- Exact method: first practical exact $2\frac{1}{2}D$ from-region visibility
- Comparison with Wonka et al. (EGWR '00):

method	avg. PVS size [-]	avg. time [ms]
Wonka et al.	274.0	4304.8
Occlusion tree	236.8	211.9

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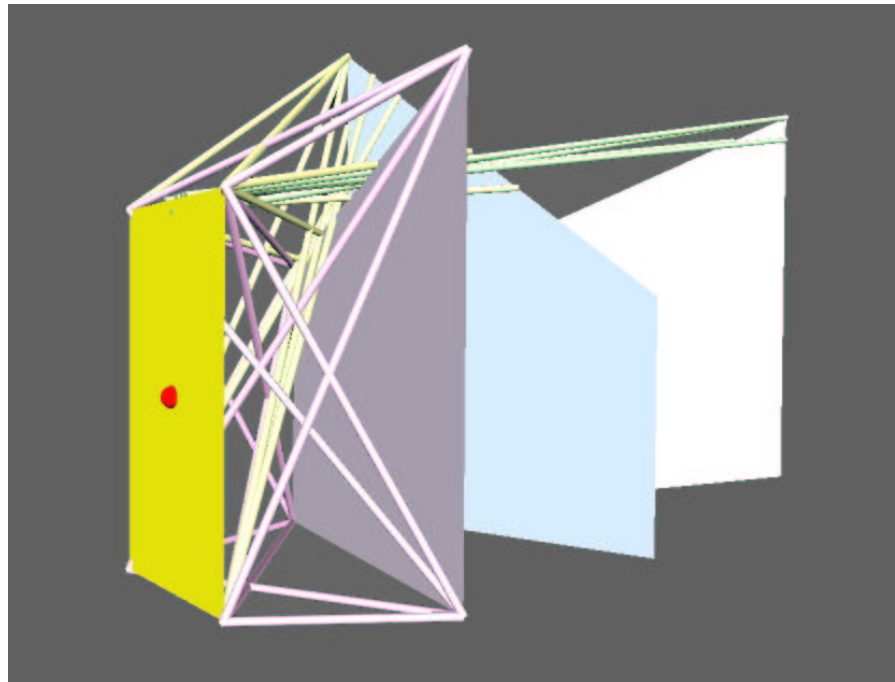
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Motivation

- Exact from-region visibility in polygonal 3D scenes

Main ideas

- Polygon \Rightarrow 5D polyhedron in Plücker coordinates
- Occlusion tree \equiv 5D BSP tree



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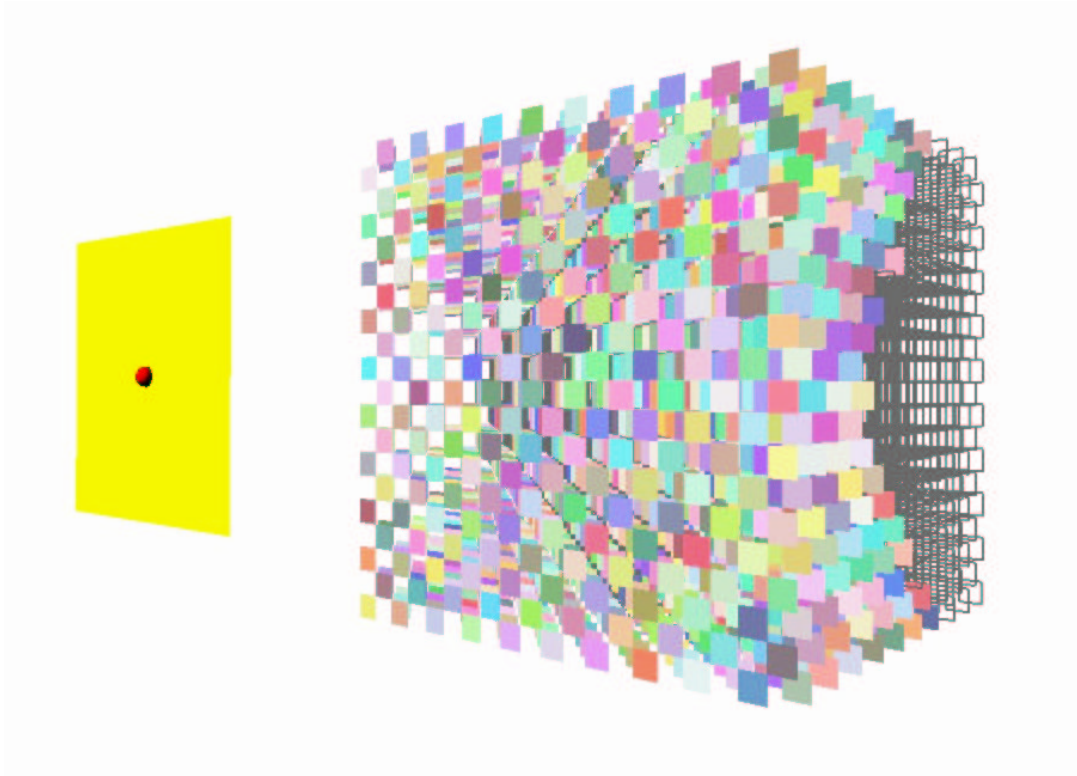
Applications

- PVS in general 3D scenes
- Occluder simplification

PVS

4k polygons

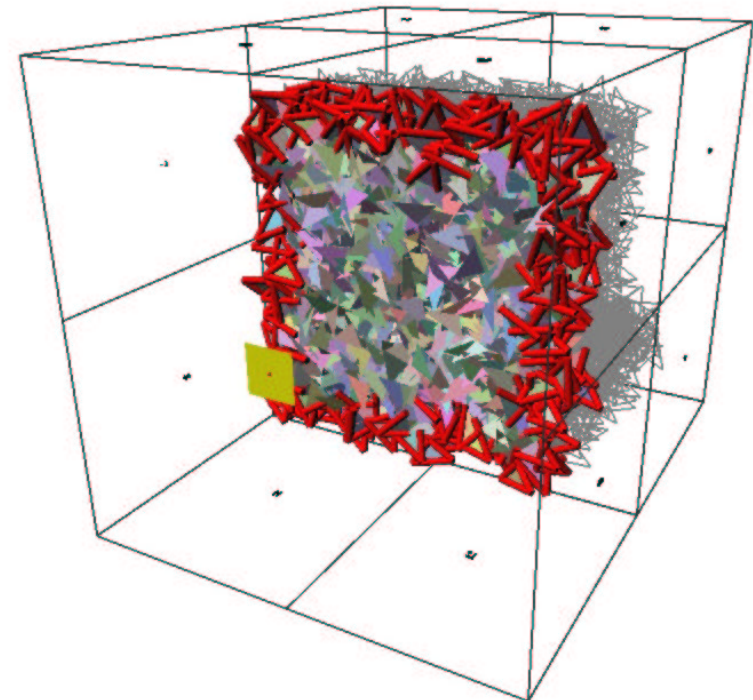
1430 visible, 28.9s



Occluder simplification

10k triangles

521 edges, 40s



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Taxonomy

- Dimension of problem-relevant line set
- Groups visibility problems of similar complexity

The general concept

- Central idea: occlusion tree
- Generality + Uniformity + Accuracy + Efficiency

Applications of the concept improving previous results

- From-point visibility (real-time visibility culling, visibility maps)
- From-region visibility in 2D, $2\frac{1}{2}$ D, and 3D

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Thank you for your attention!

Publications overview

- 10 refereed international conference papers
- 4 refereed journal papers
- 13 citations in papers
- 3 citations in books

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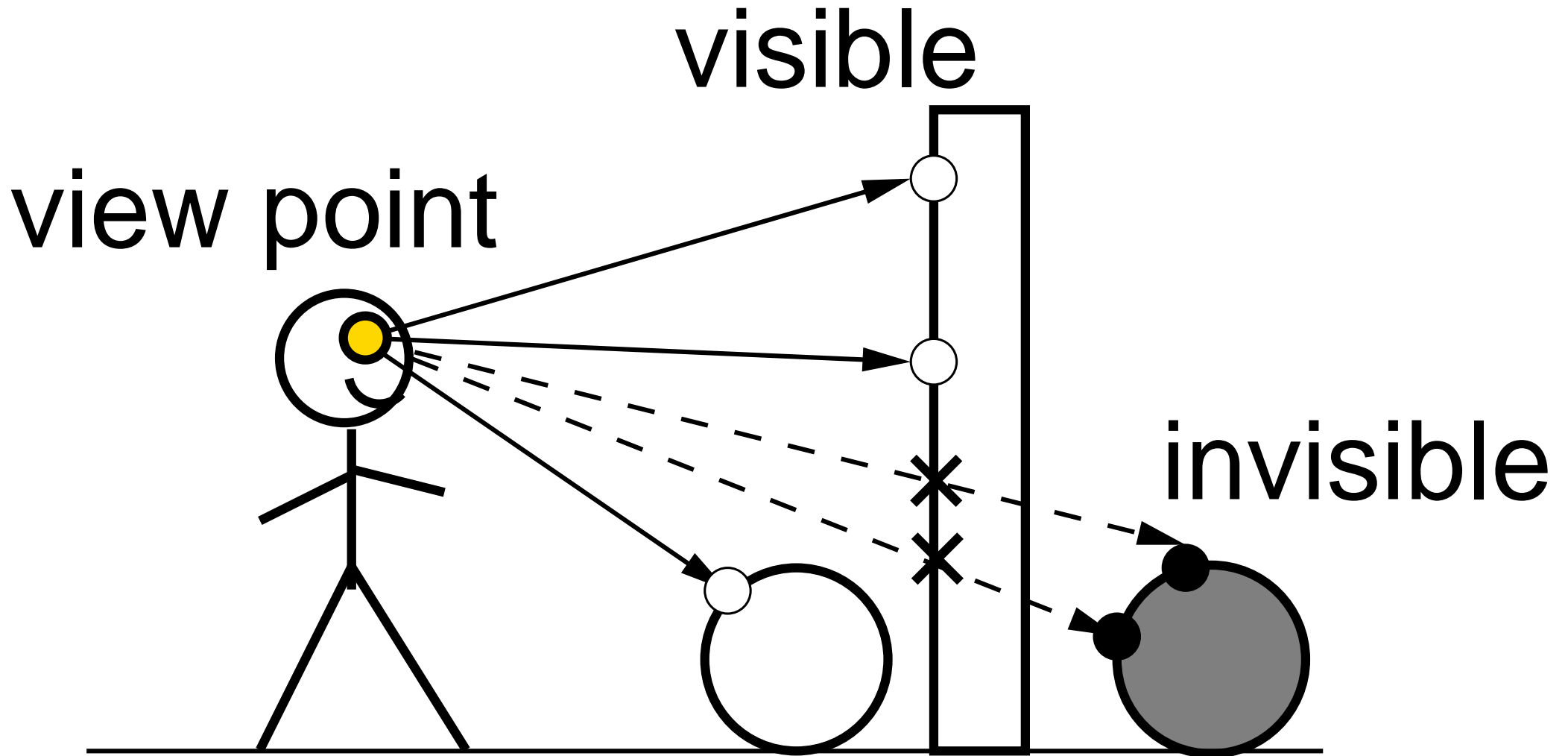
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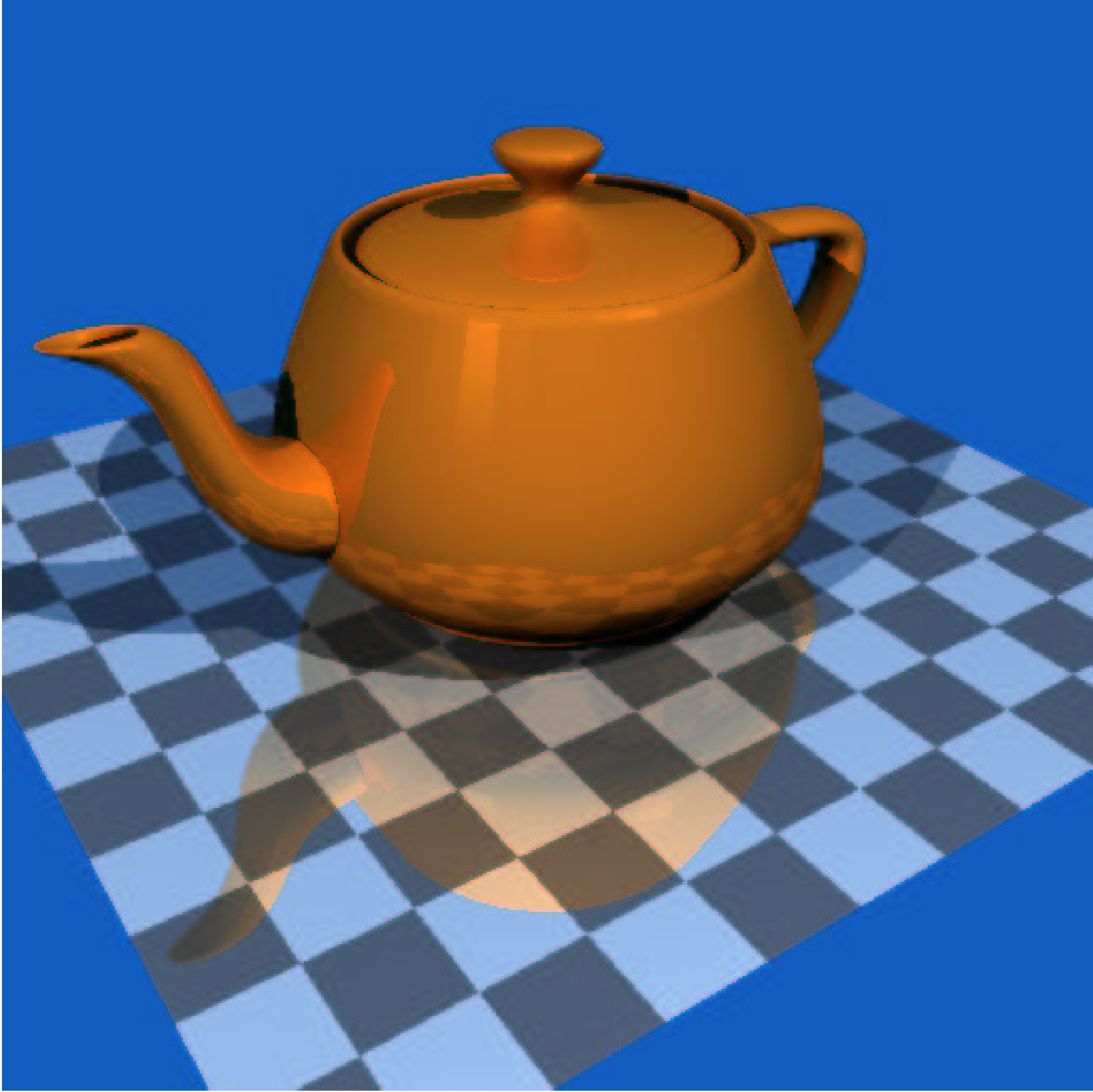
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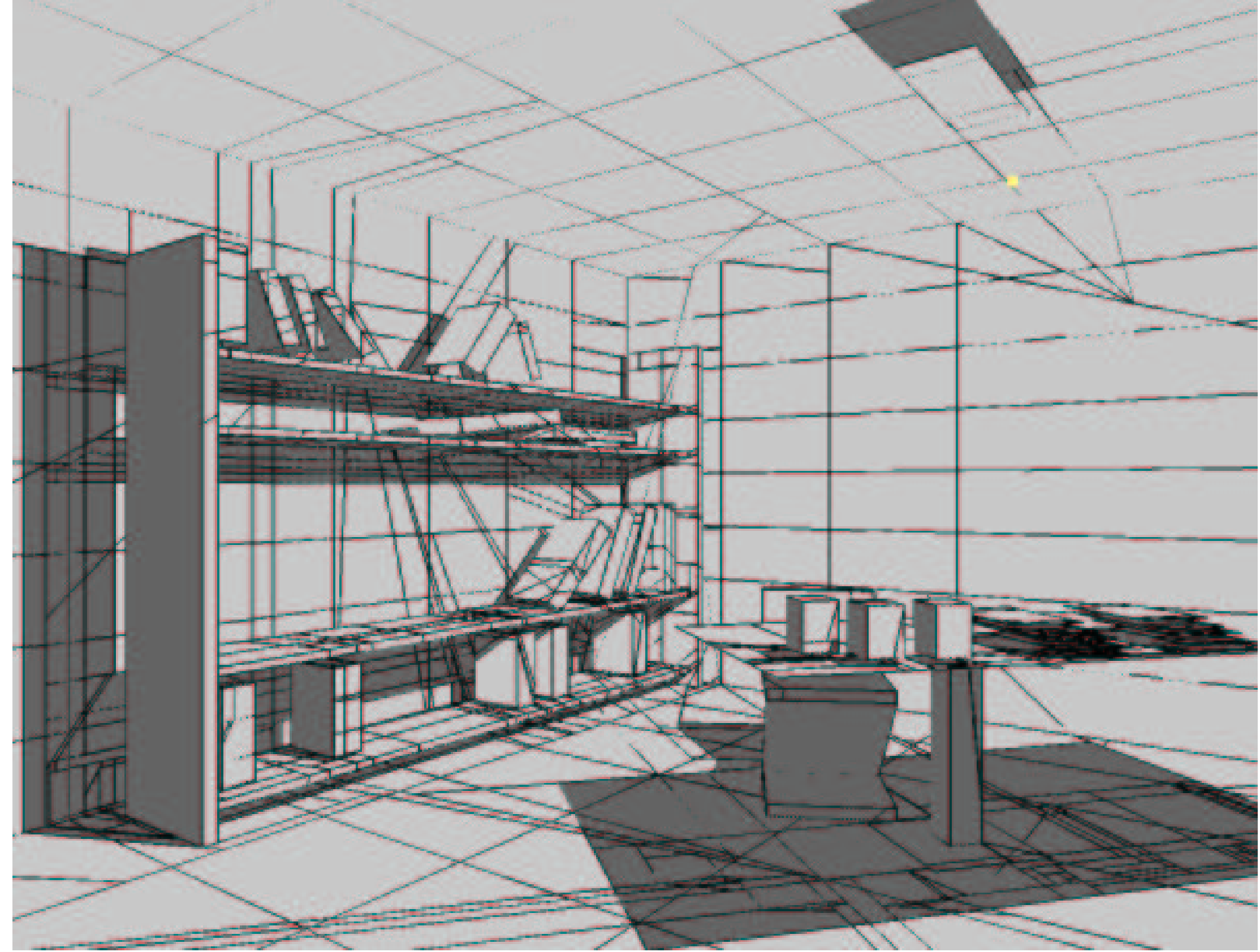
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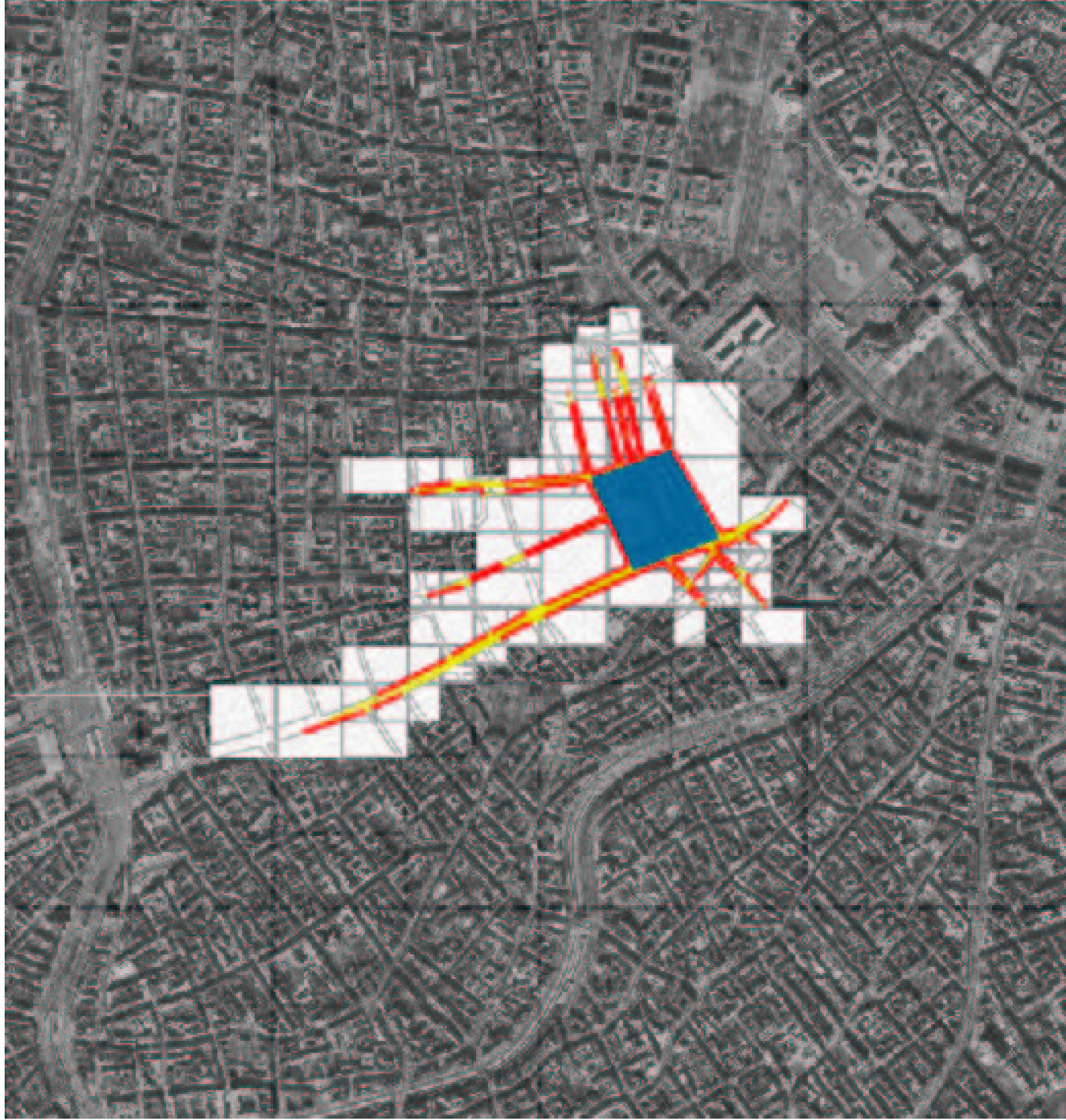
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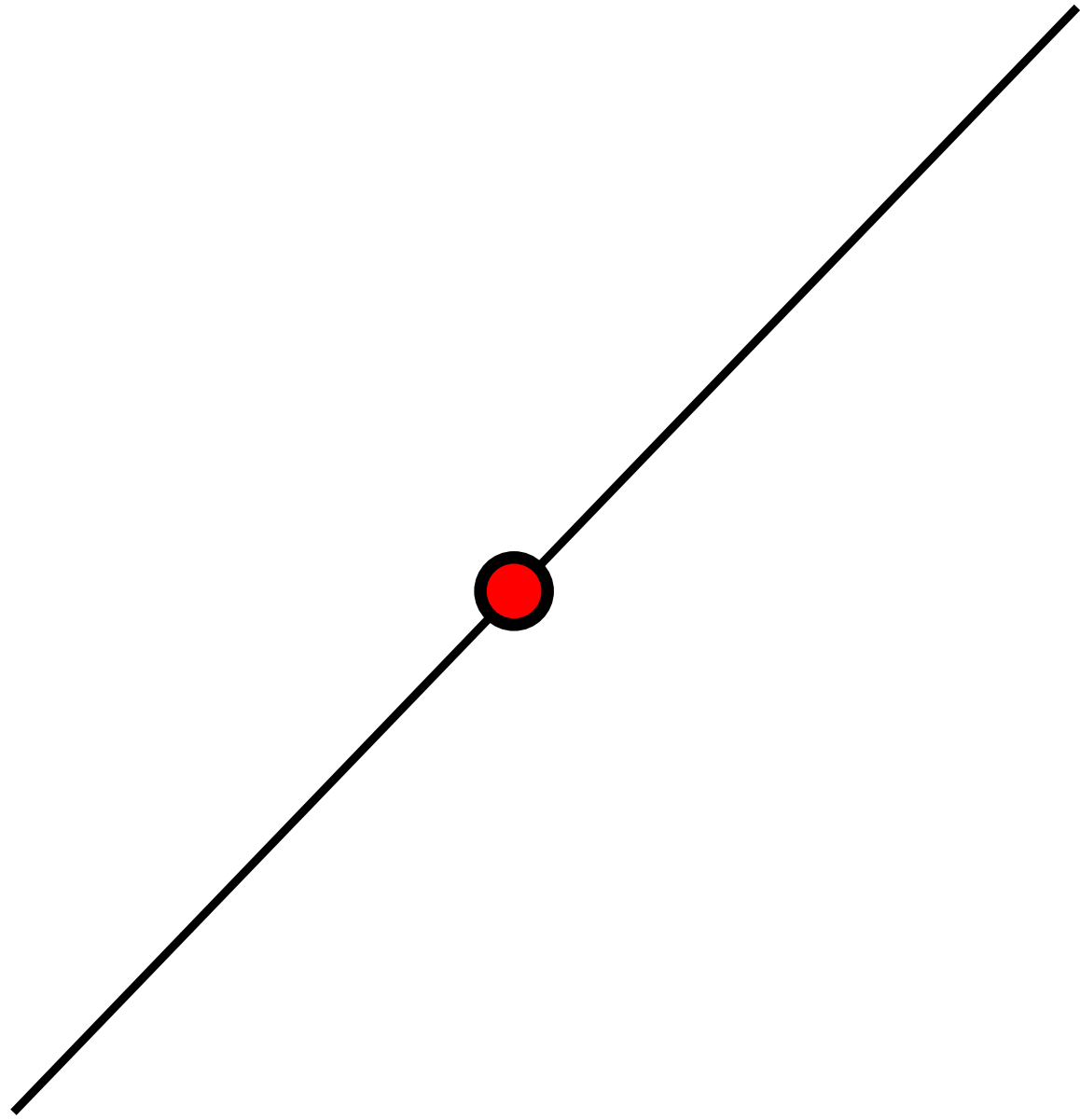
visibility from a point

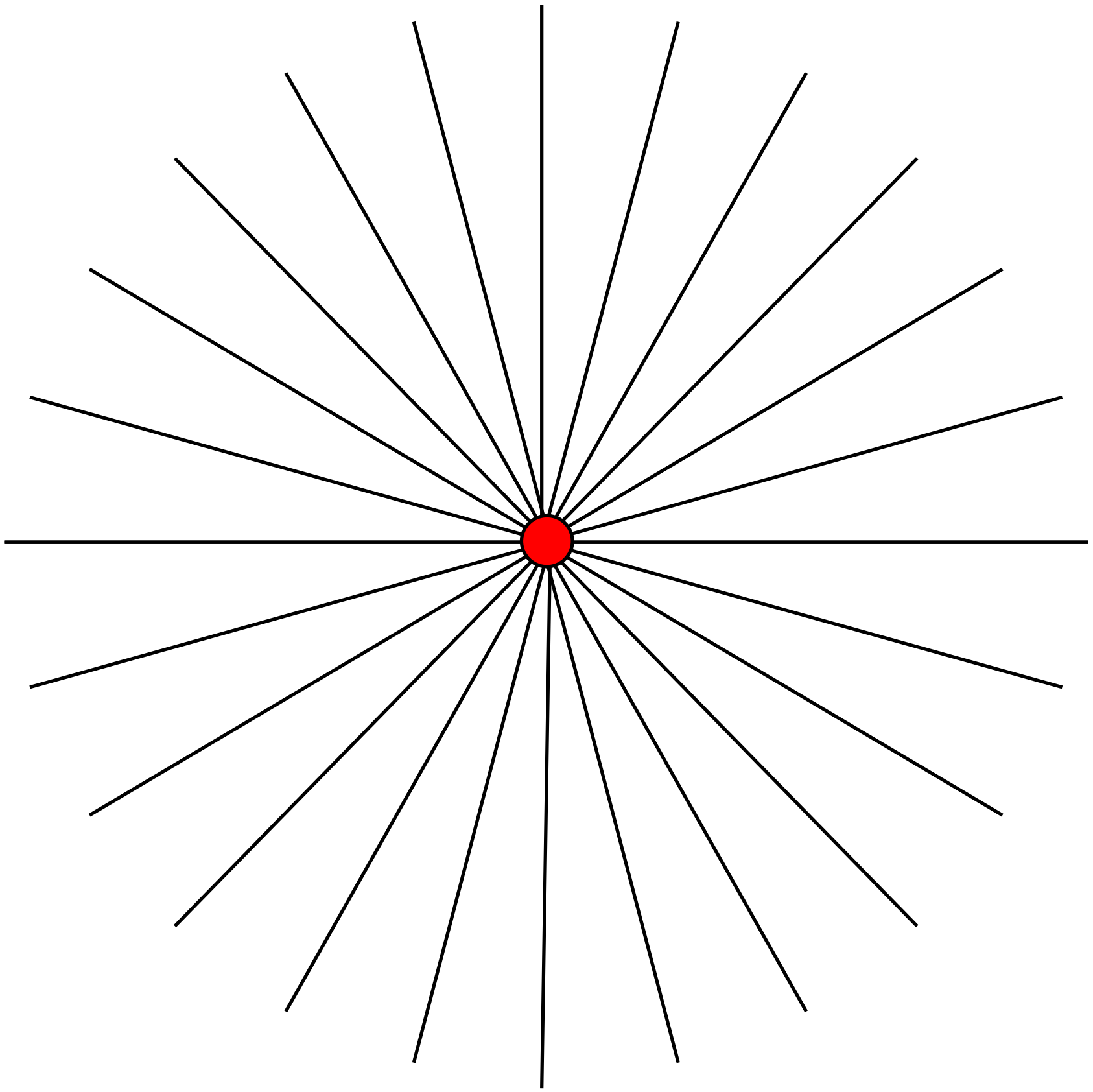


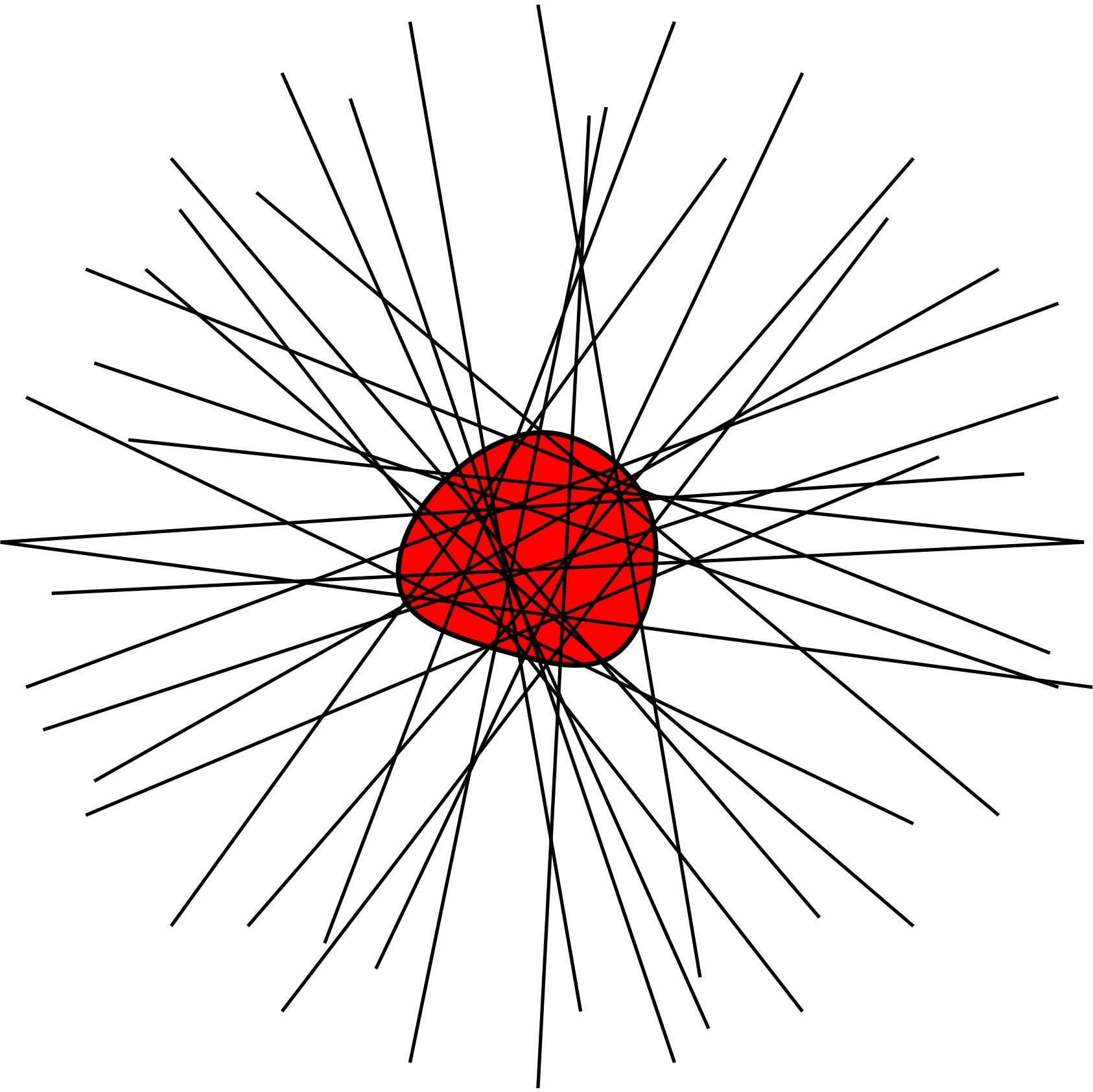




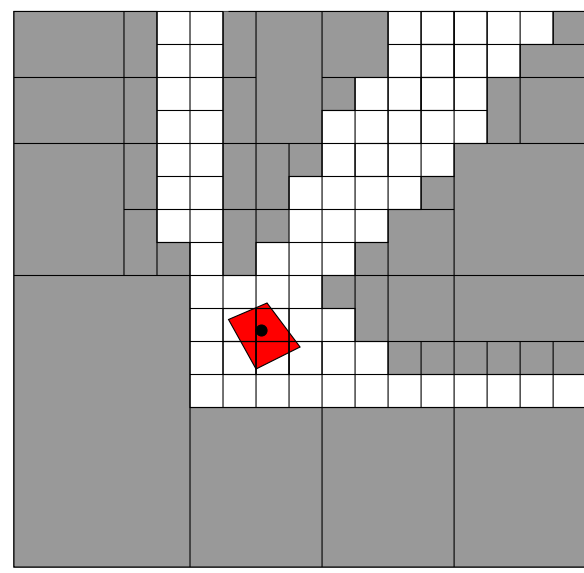
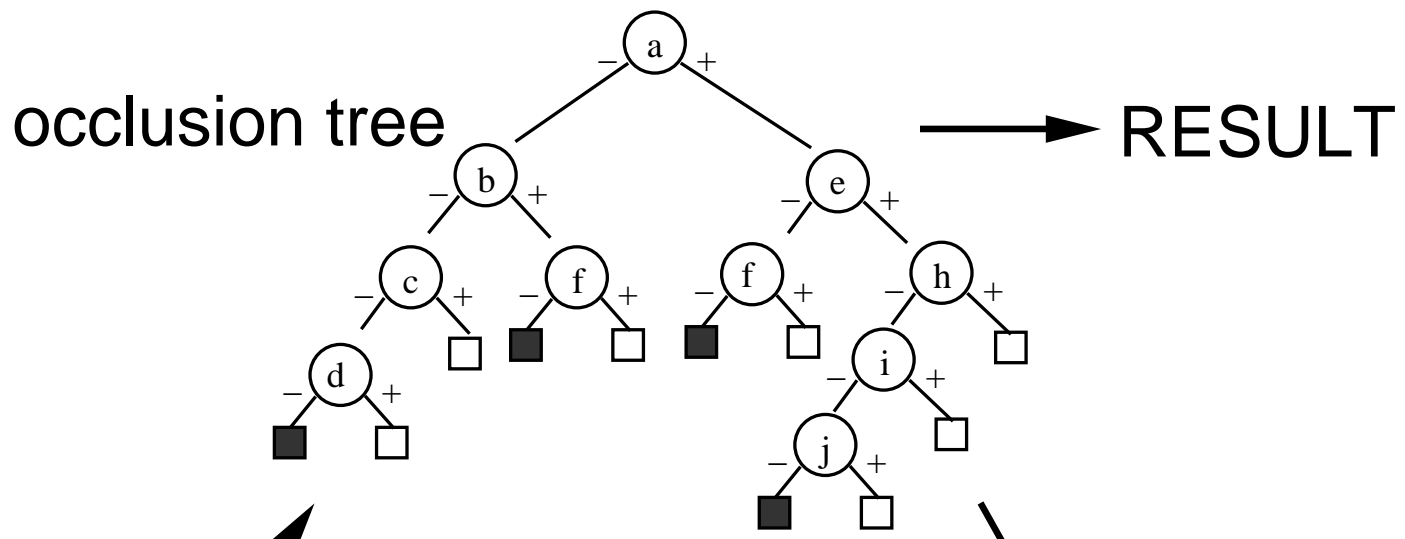
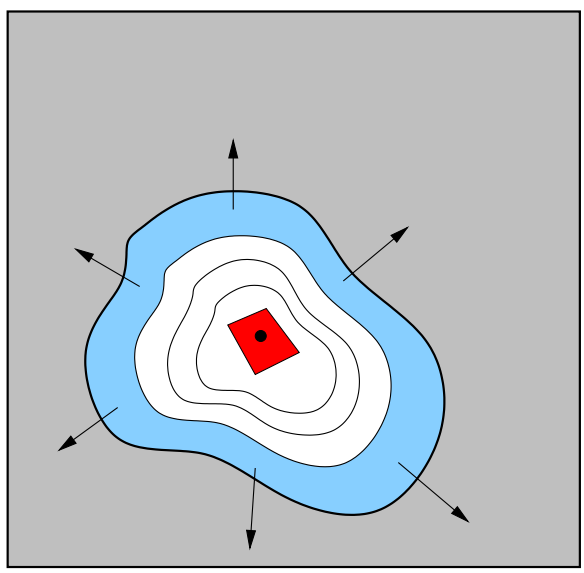








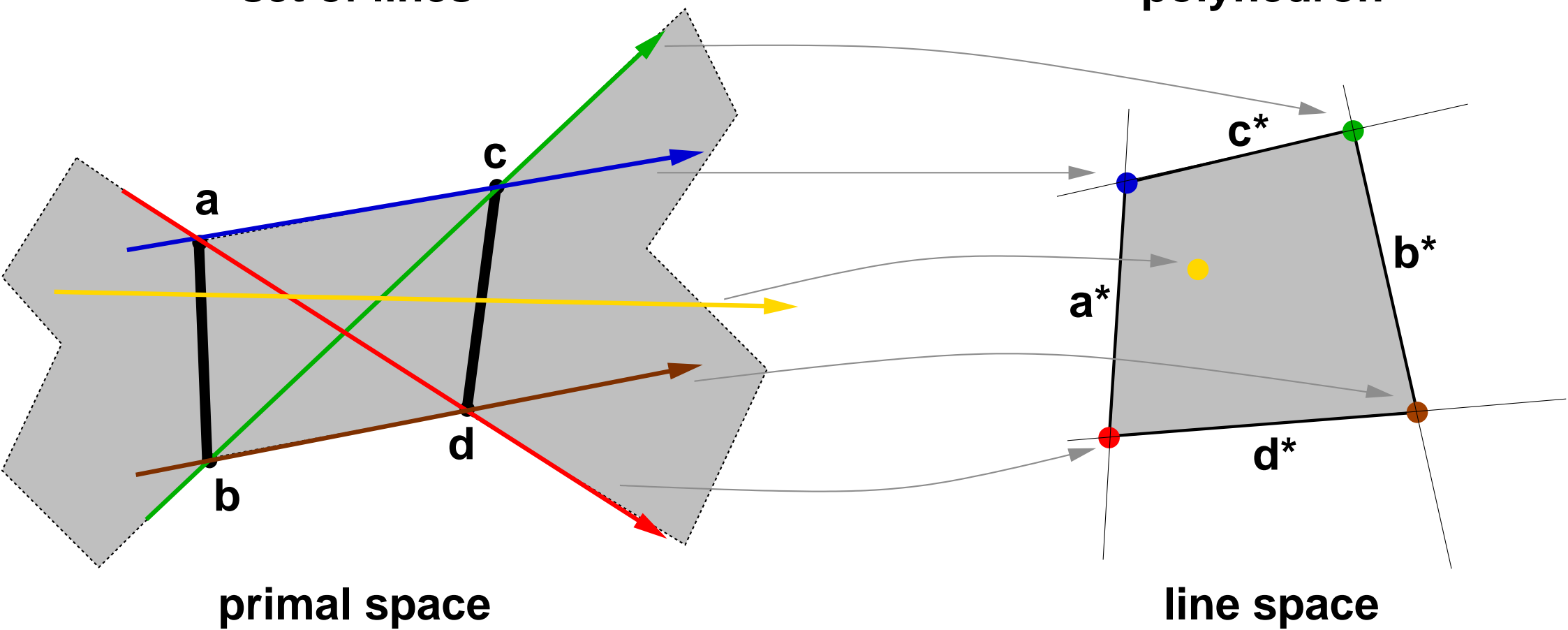
approximate
occlusion
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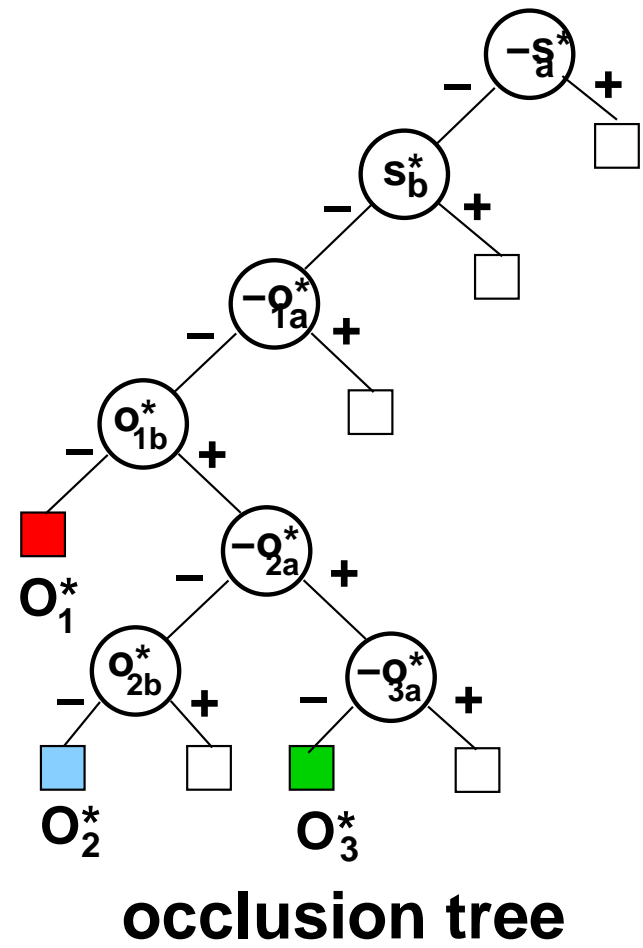
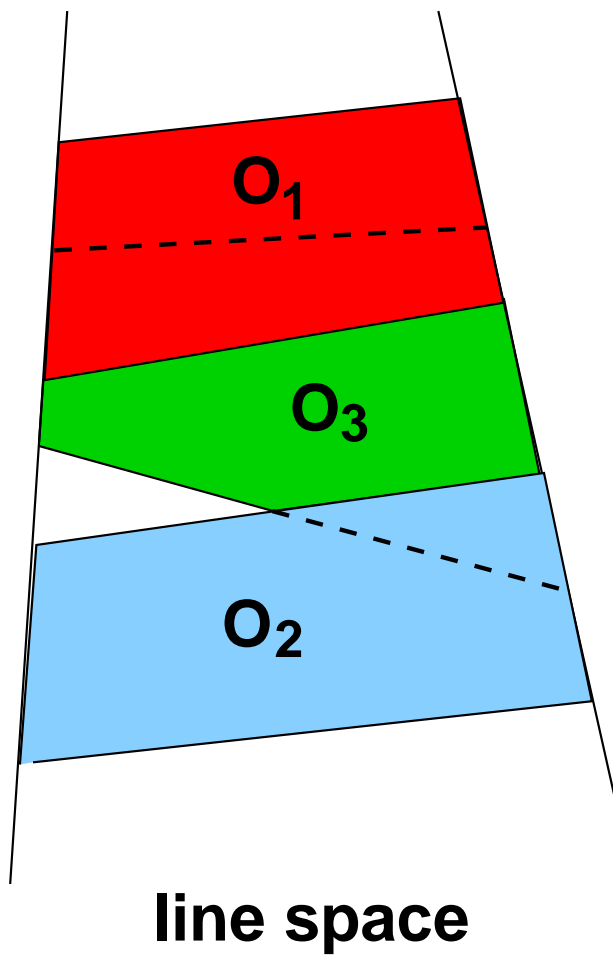
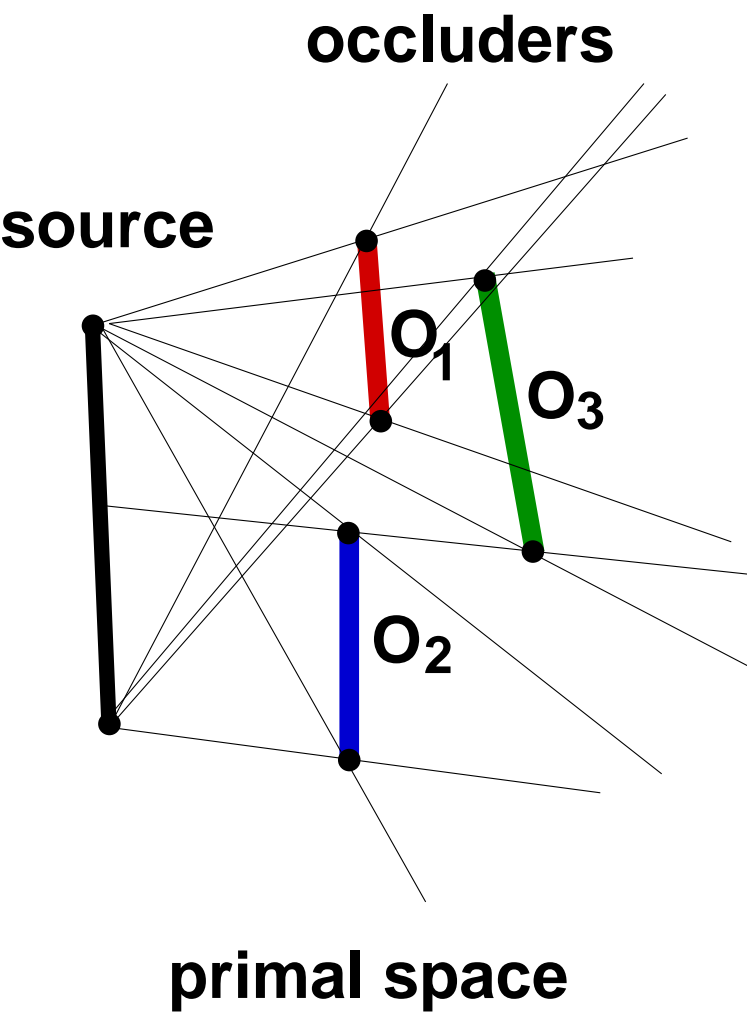


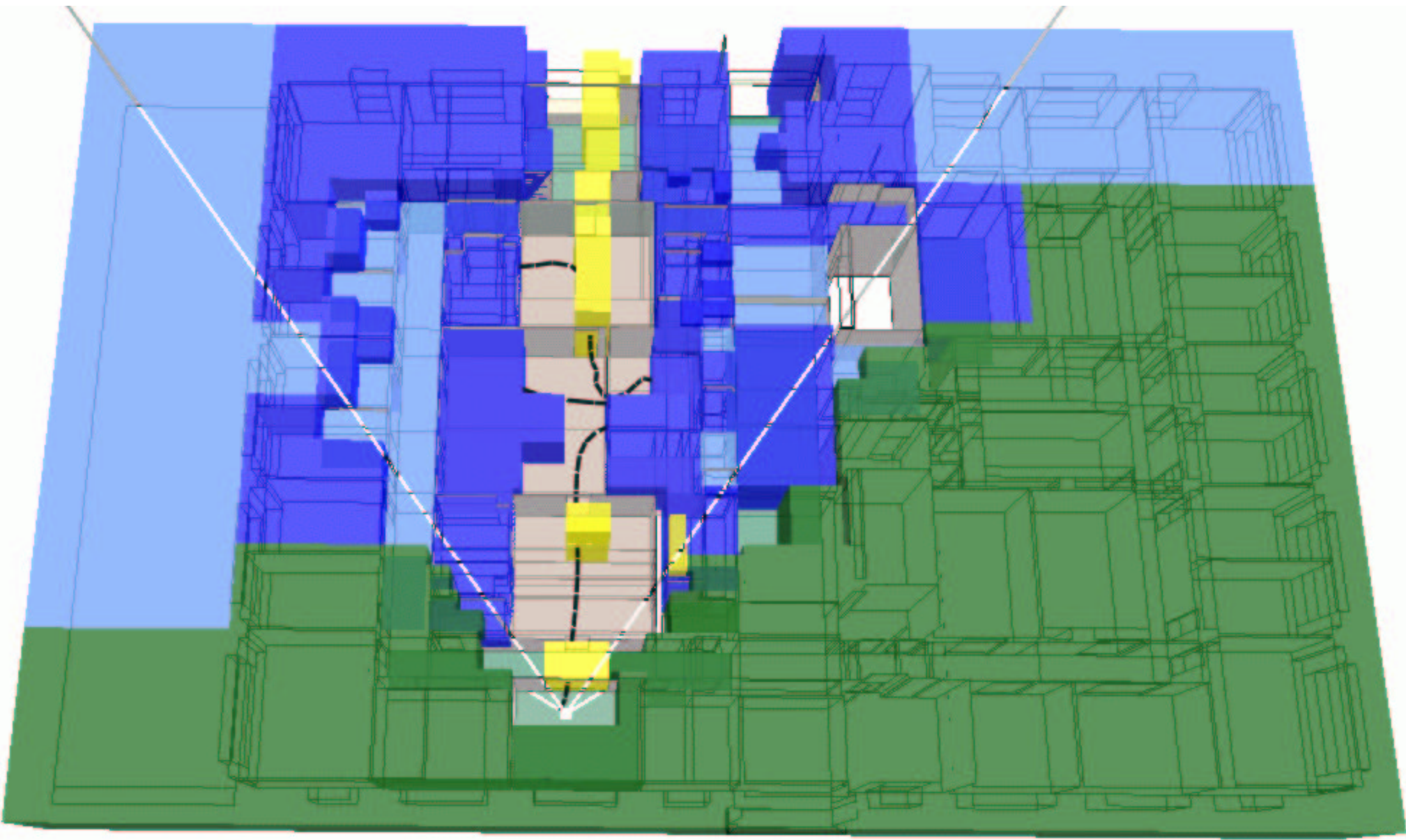
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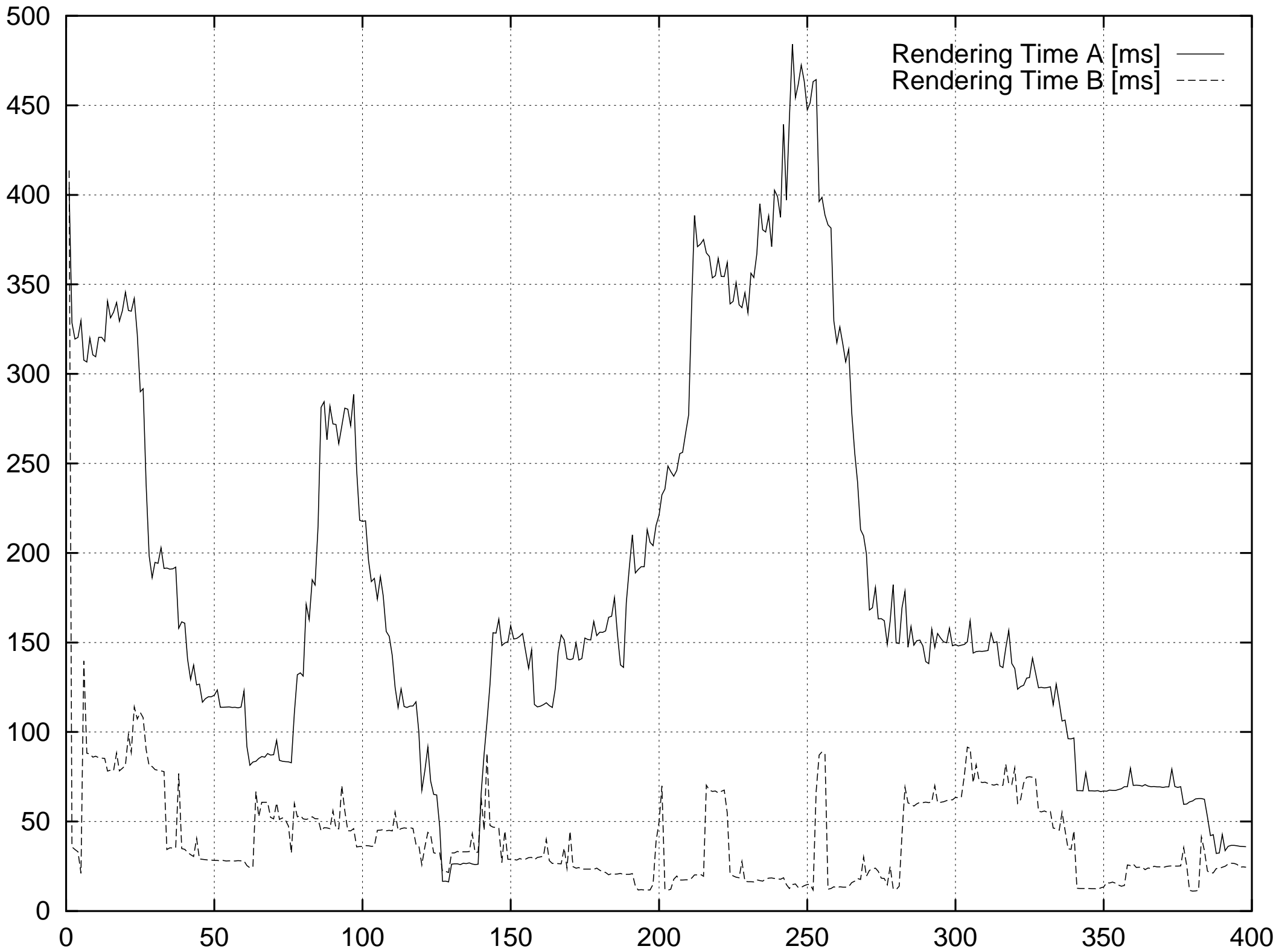
set of lines

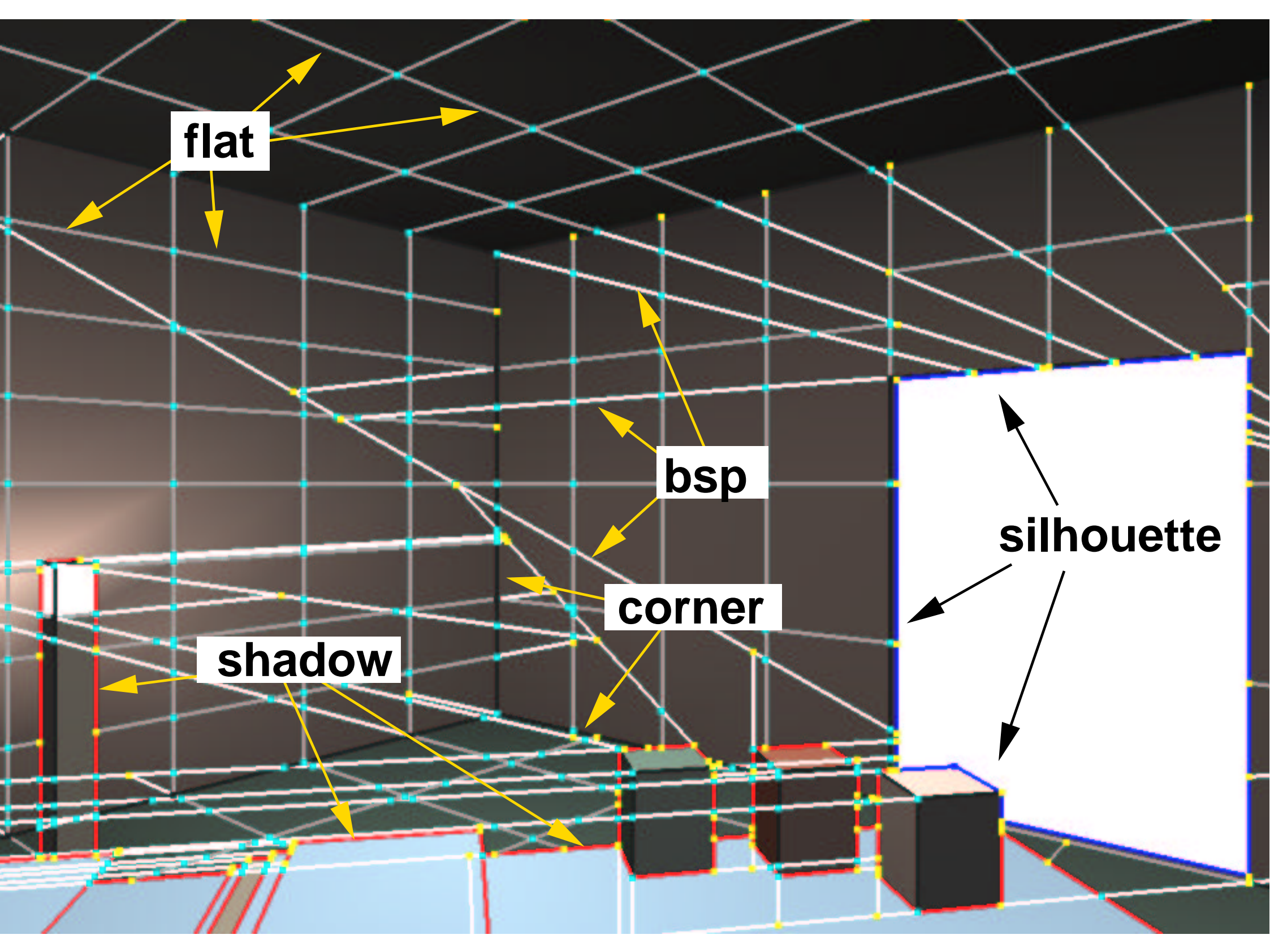
polyhedron

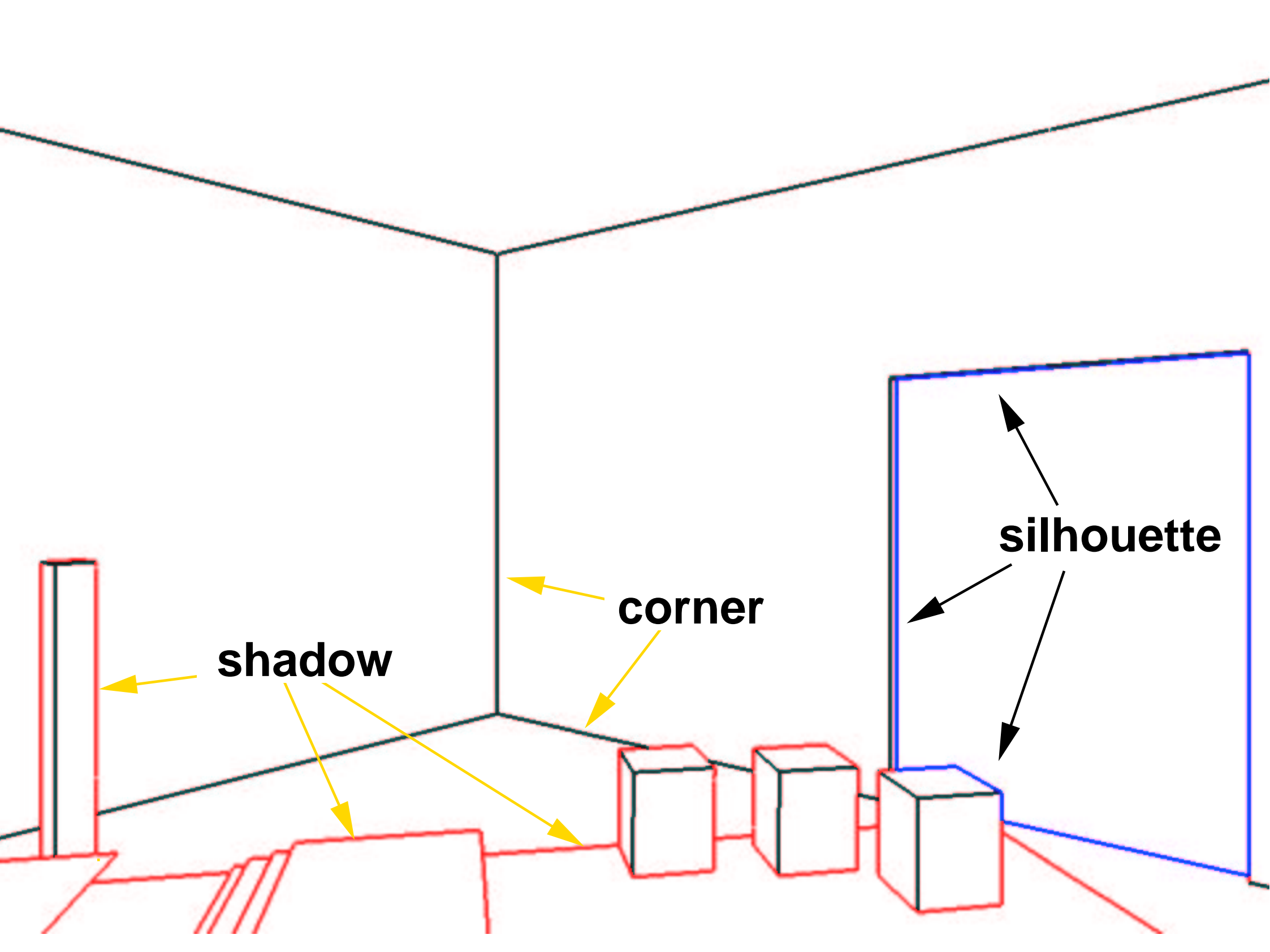












shadow

corner

silhouette

