

Visibility Problems for Walkthrough Applications

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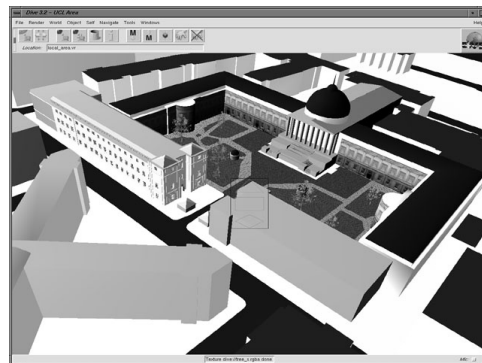
Tel-Aviv University

<http://www.cs.tau.ac.il/~dcor/>

Virtual Reality Applications

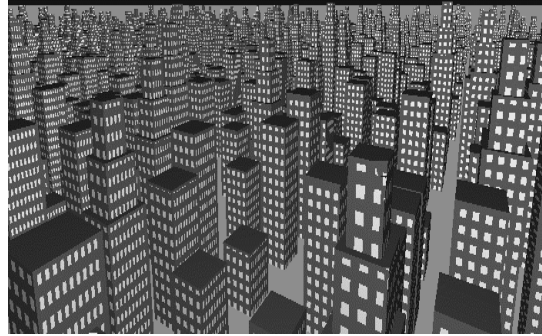
- ◆ The user "walks" interactively in a virtual polygonal environment.
Examples: model of a city, museum, mall, architectural design

The goal: to render an updated image for each view point and for each view direction in interactive frame rate



The Model

- ◆ Composed of 3D geometric objects - Lots of simple parts
- ◆ Large and complex - hundreds thousands or even millions of polygons



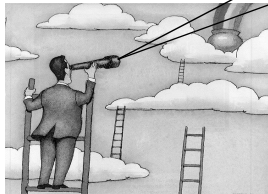
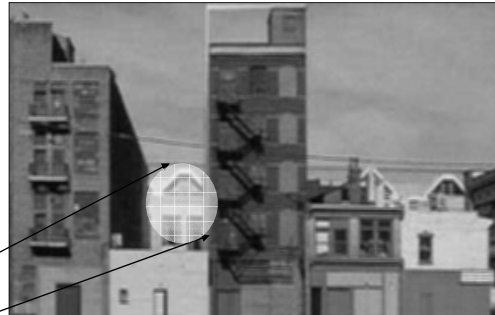
The Visibility Problem

- ◆ Selecting the (exact?) set of polygons from the model which are visible from a given viewpoint

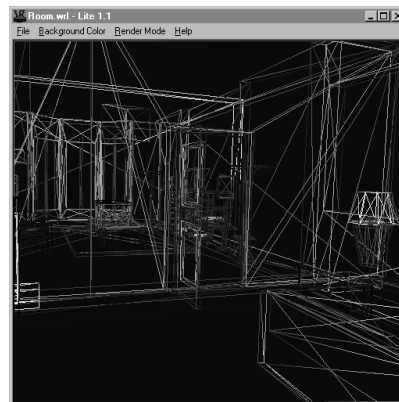
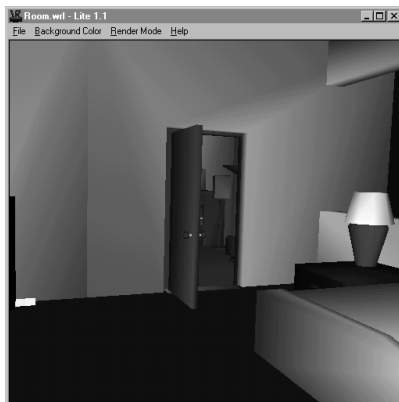


The Visibility Problem is important

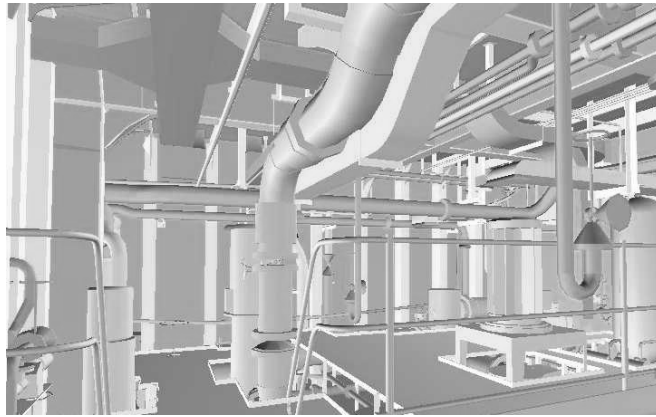
- ♦ Average number of polygons, visible from a viewpoint, is **much** smaller than the model size



Indoor scene



Oil-tanker ship



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Copying Machine



Outdoor scenes



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The Visibility Problem is not easy...

A small change of
the viewpoint might
causes large
changes in the
visibility



The Visibility Problem is not easy...

A small change of the viewpoint might causes large changes in the visibility



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Far details

Close details

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Culling

Avoid processing polygons which contribute nothing to the rendered image

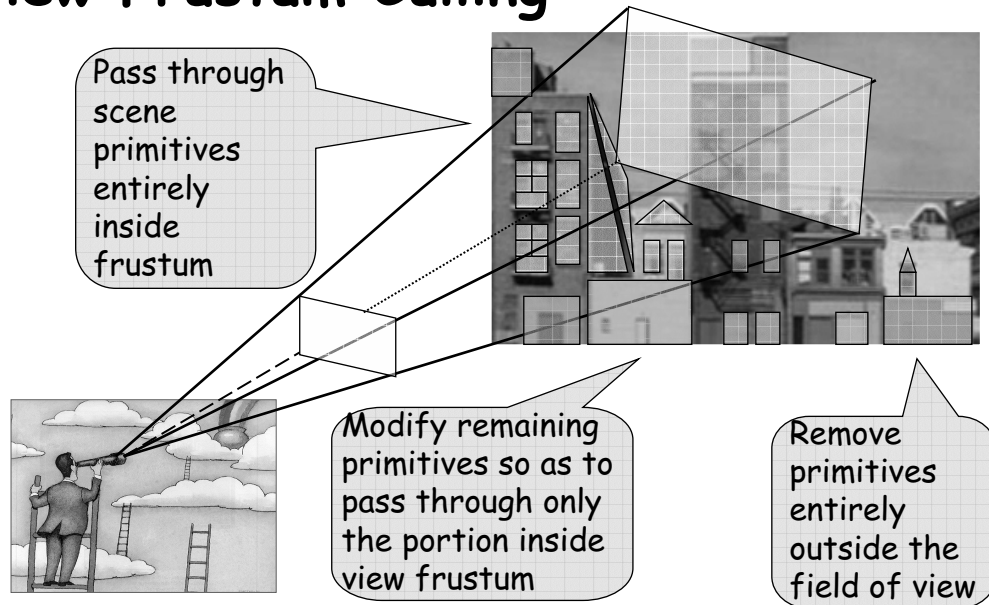
A primitive can be culled by:

View
Frustum
Culling

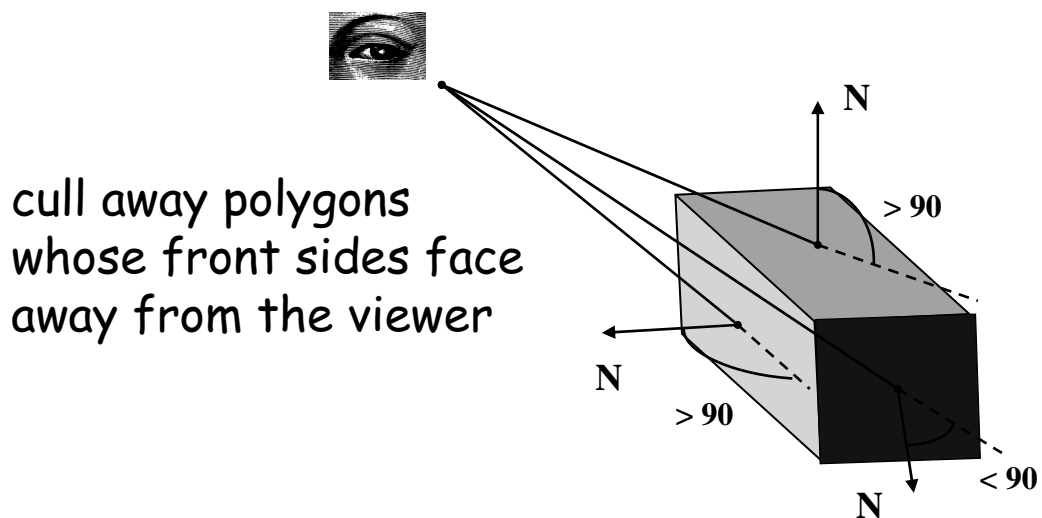
Back Face
Culling

Occlusion
Culling

View Frustum Culling



Backface Culling



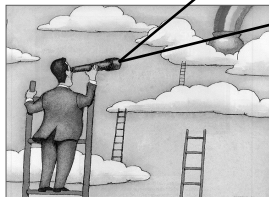


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Occlusion Culling

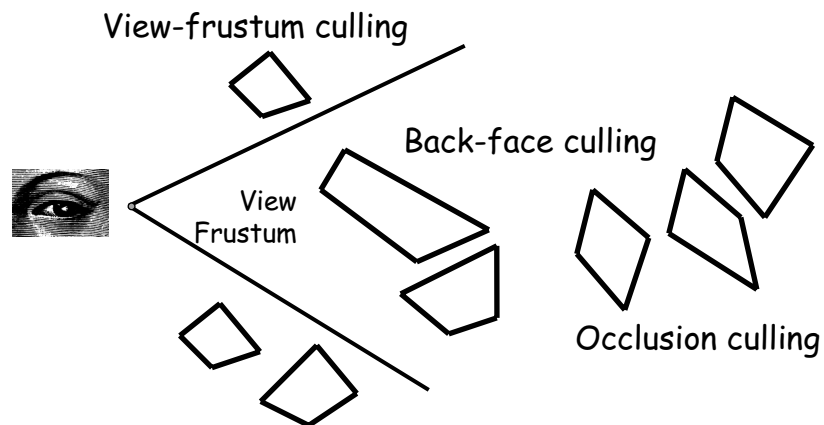
Cull the polygons occluded by other objects in the scene

Very effective in densely occluded scenes



Global: involves interrelation between the polygons

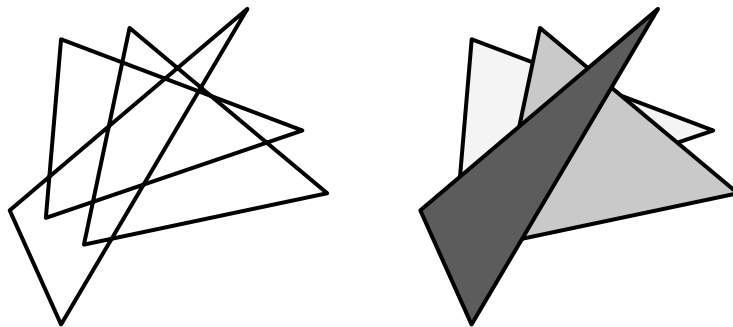
Visibility Culling



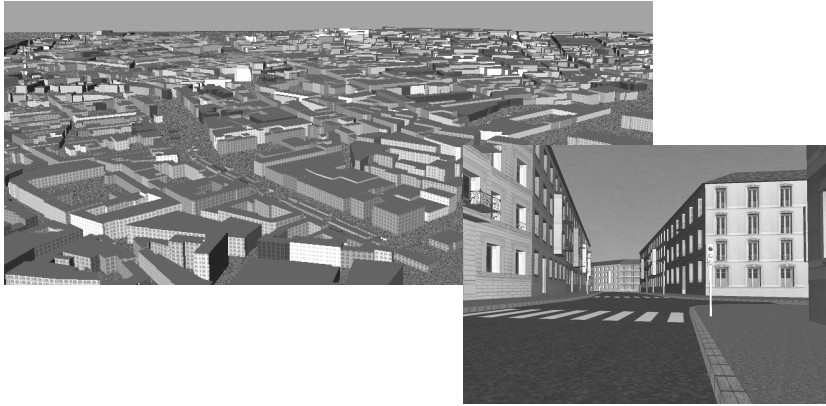
Hidden Surface Removal

Polygons overlap, so somehow, we must determine which portion of each polygon to draw (is visible to the eye)

Output
sensitive
algorithms



Visibility in real-time rendering

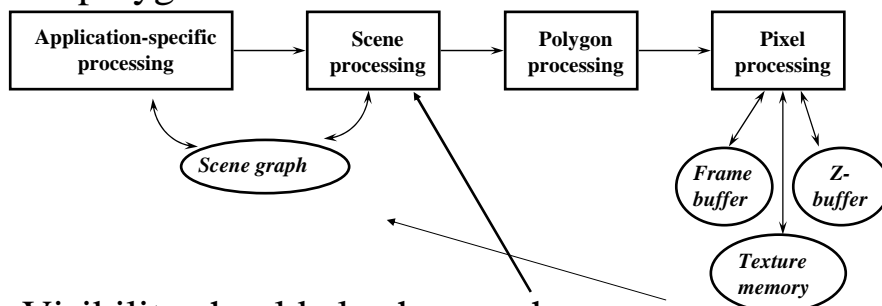


- interactively walk through a large model
- large model → millions of polygons → acceleration necessary (e.g. visibility)

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Why is the z-buffer not enough?

- Does not eliminate depth-complexity (overdraw)
- Does not eliminate vertex processing of occluded polygons



- Visibility should also happen here

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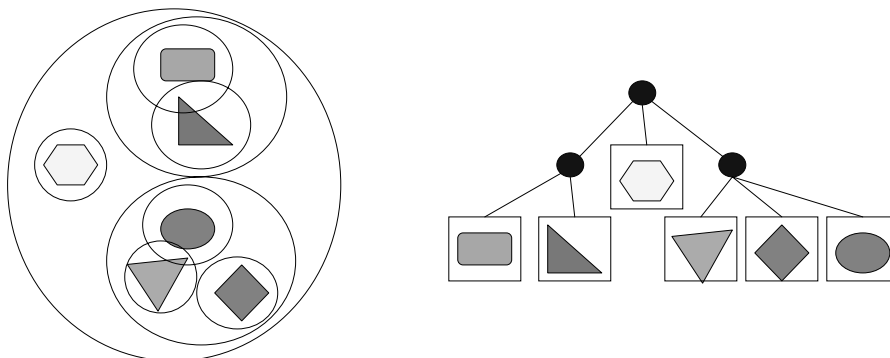
View-frustum culling

- Eliminate polygons outside of the view frustum
- Hierarchical structuring
 - Bounding volume hierarchy
 - or any spatial data structure

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View-frustum culling

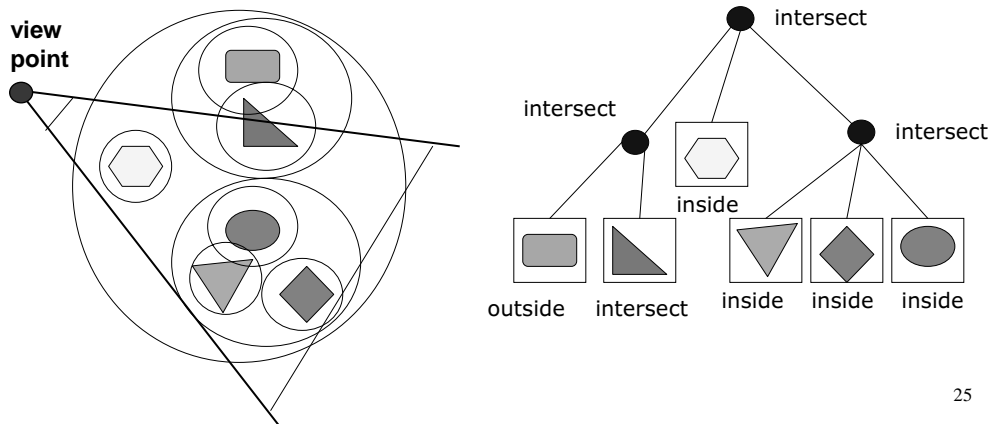
Hierarchy based on bounding volume



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View-Frustum Culling

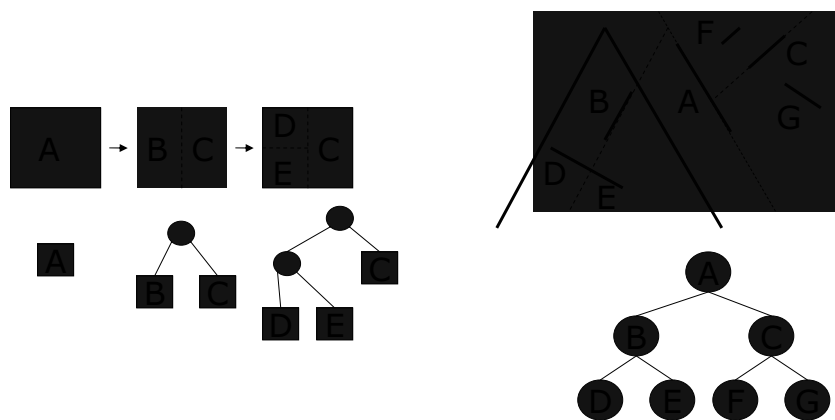
Hierarchical view-frustum culling based on bounding volume



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View-Frustum Culling

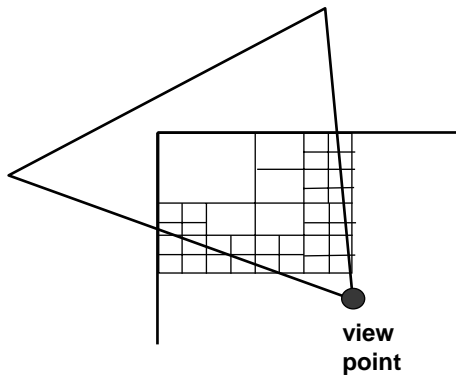
Hierarchical view-frustum culling using BSP(Binary Space Partitioning) Trees



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View-Frustum Culling

Hierarchical view-frustum culling using quadtree (octree)



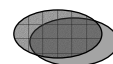
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Exact Visibility

Includes all the polygons which are at least partially visible and only these polygons.

Approximate Visibility

Includes most of the visible polygons plus maybe some hidden ones.



Conservative Visibility

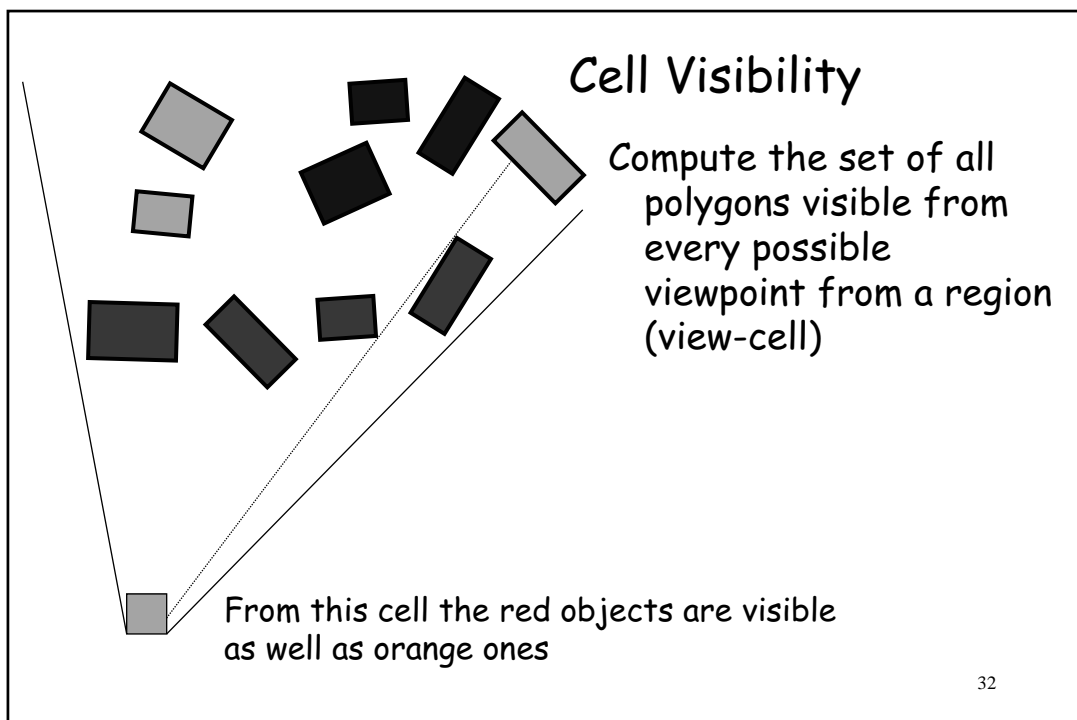
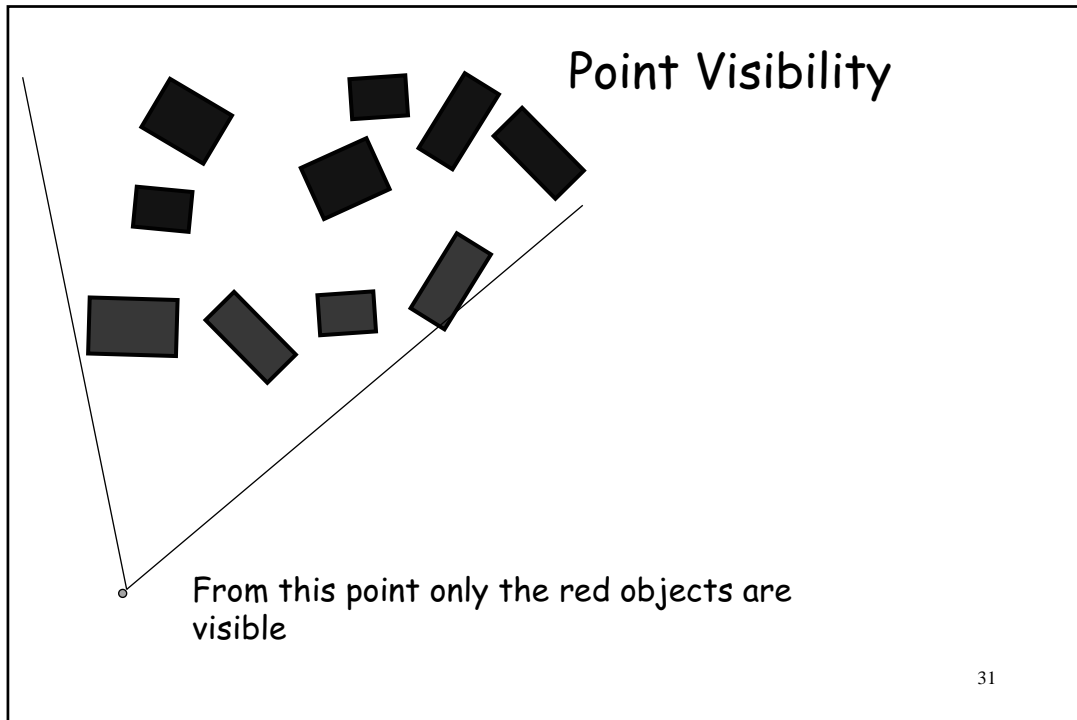
Includes at least all the visible objects
plus maybe some additional invisible
objects



May classify invisible object as visible
but may never classify visible object as
invisible

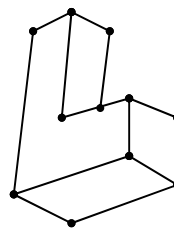
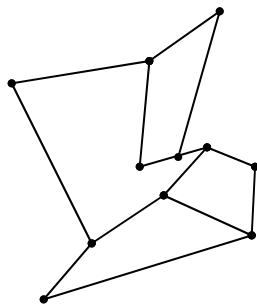
What is visible?

What is Occluded?



The Aspect Graph

Isomorphic graphs

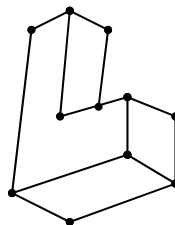
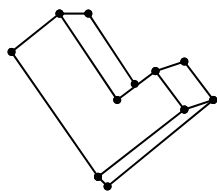


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The Aspect Graph

◆ ISG – Image Structure graph

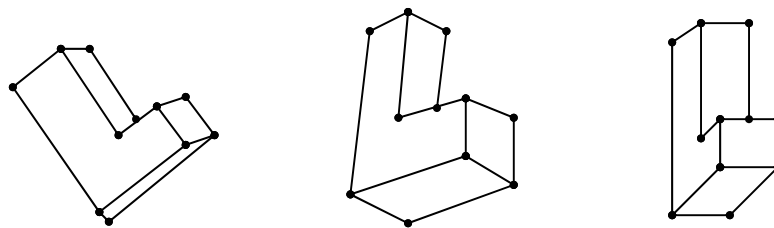
The planner graph, defined by the outlines of an image, created by projection of a polyhedral object, in a certain view direction



The Aspect Graph (Cont.)

◆ Aspect

Two different view directions of an object have the same aspect iff the corresponding Image Structure graphs are isomorphic



The Aspect Graph (Cont.)

◆ VSP – Visibility Space Partition

- ◆ Partitioning the viewspace into maximal connected regions in which the viewpoints have the same view or aspect

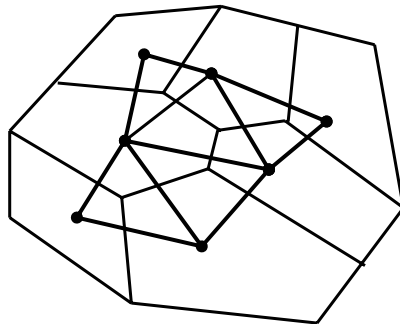
◆ Visual Event

A boundary of a VSP region called a VE for it marks a change in visibility

The Aspect Graph (Cont.)

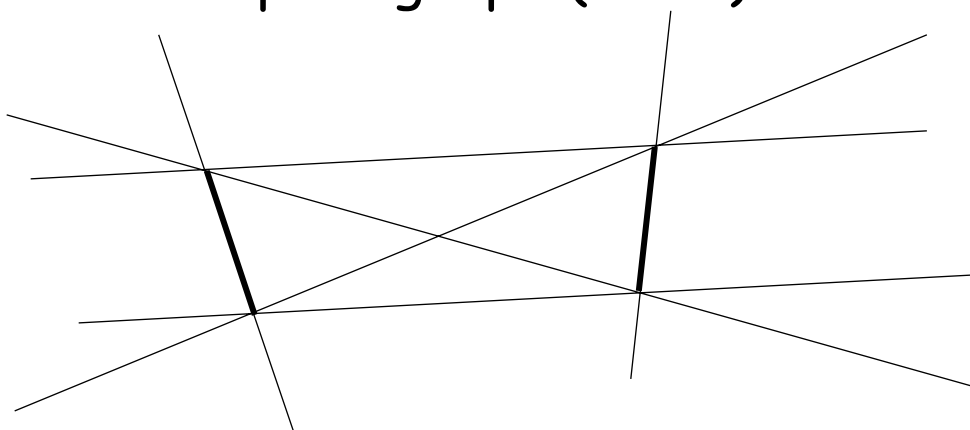
◆ Aspect Graph

- ◆ A vertex for each region of the VSP
- ◆ An edge connecting adjacent regions



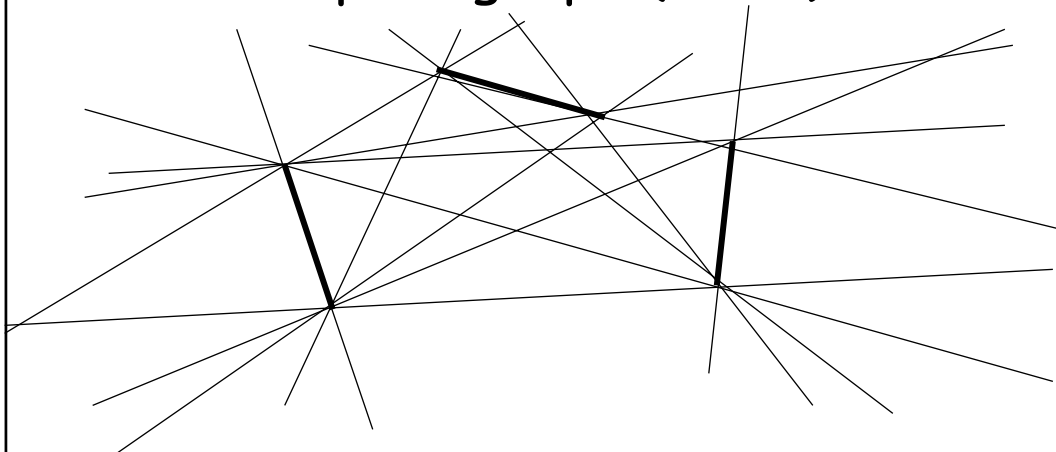
Regions of the VSP are not maximal but maximal connected regions.

Aspect graph (Cont.)



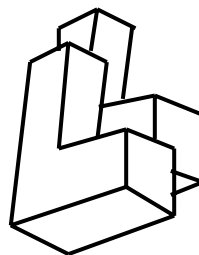
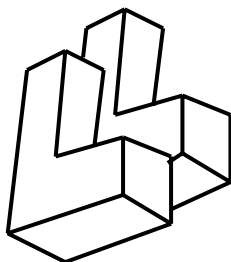
2 polygons - 12 aspect regions

Aspect graph (Cont.)

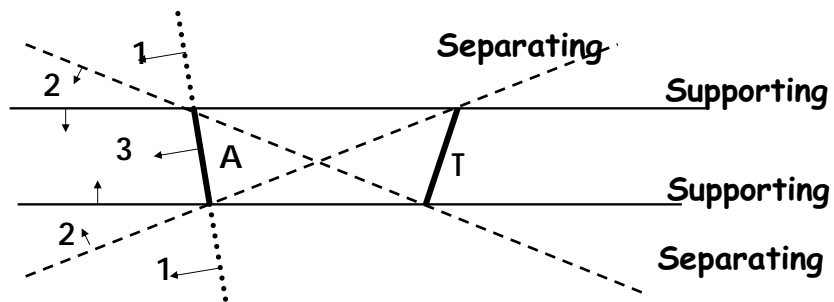


3 polygons - "many" aspect regions

Different aspect regions can have
equal sets of visible polygons



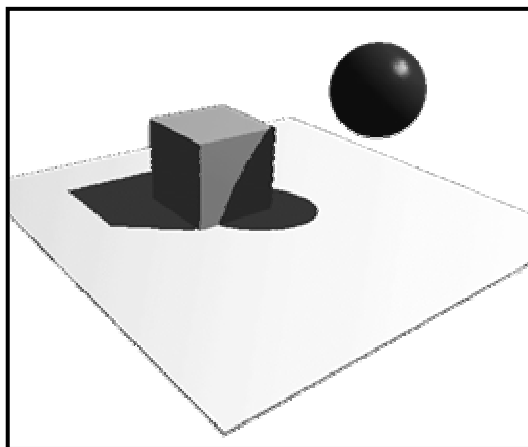
Supporting & Separating Planes



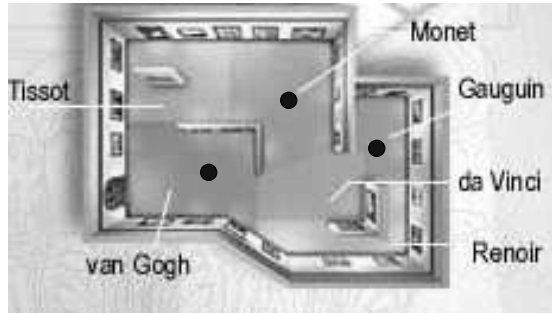
T is not occluded in region 1
T is partially occluded in region 2
T is completely occluded in region 3

A - occluder
T - occludee

Visibility from the light source



The Art Gallery Problem



See: <ftp://ftp.math.tau.ac.il/pub/~daniel/pg99.pdf>

Classification of visibility algorithms

- Exact vs. Approximated
- Conservative vs. Exact
- Precomputed vs. Online
- Point vs. Region
- Image space vs. Object space
- Software vs. Hardware
- Dynamic vs. Static scenes

Idea: 2.5D Occlusion Culling

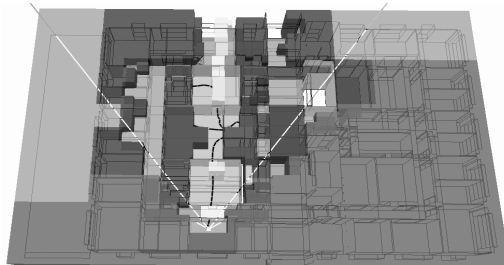


- Buildings are occluders, connected to the ground
- → 2.5D visibility algorithms
 - Occluder is a function $f(x,y) = z \rightarrow 2.5D$

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Object space

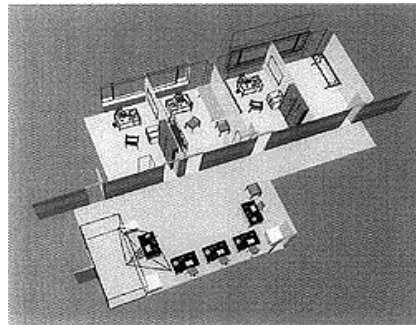
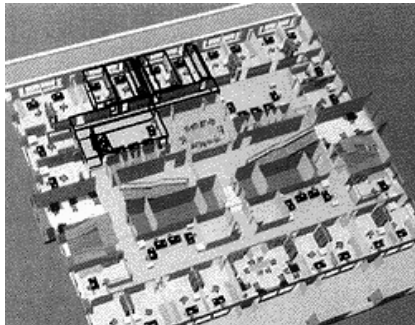
- [Bittner98]
 - kd tree and BSP trees
 - Works fine, all sorts of occluder fusion
- Using thousands of occluders is slow



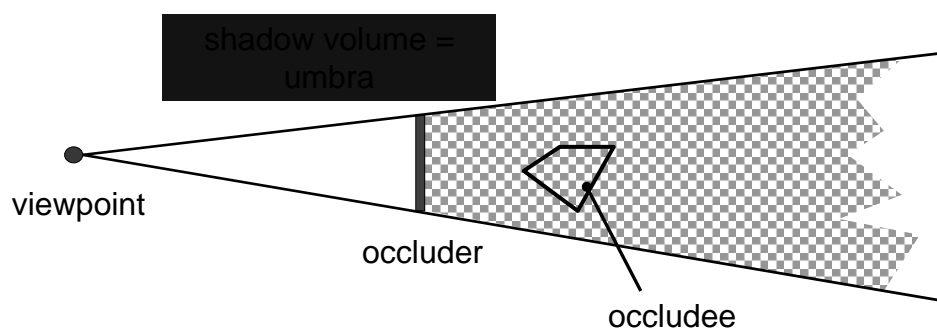
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Cells and Portals

- Architectural walkthroughs
- Structure scene into
 - Cells (mainly rooms)
 - Portals (mainly doors)

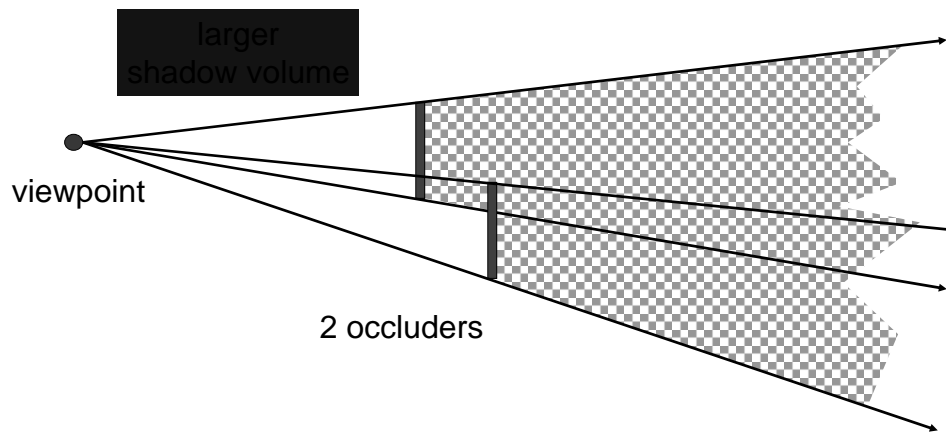


Visibility from a point



- Terms: occluder, occludee, shadow volume, umbra

Visibility from a point

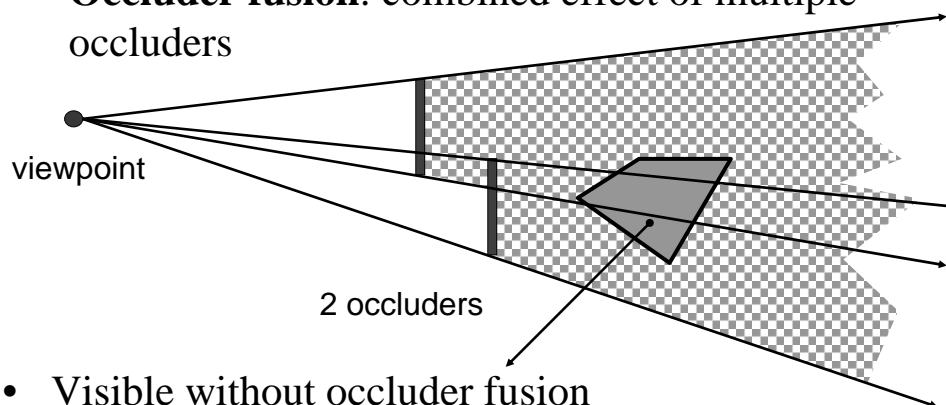


Complete shadow volume for occluder occ_1, \dots, occ_n
= union of all individual shadow volumes

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Occluder Fusion

- **Occluder fusion:** combined effect of multiple occluders



- Visible without occluder fusion
- Invisible with occluder fusion

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Visibility is important and interesting

- Only a small fraction of the scene is visible from a given point.
- Small changes in the view point can cause large changes in the visibility

Thanks for Listening