Visibility Streaming
for Network-based Remote Walkthroughs

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Remote network-based Walkthrough

Server

Client

Huge 3D model

Single frame of walkthrough
Remote Network-based Walkthrough

Network:
- low bandwidth
- inevitable network latency

Client
- low end thin computer
- interactive rate demand
- platform independent

Server
- huge model database
- multi-client demands

The Visibility of a view cell

Server

Sends the client a set of primitives valid for an entire neighborhood

Client

Renders independently all frames as long as the viewpoint is in the same neighborhood
The Visibility of Out-door scenes

Vast majority of the geometry in dense models is occluded from any single viewpoint.

The epsilon-visibility query

- Given a viewpoint the answer to an epsilon-visibility query is the set of all polygons visible from that viewpoint or from an epsilon-neighborhood of that point.
Out-doors scenes are much harder than In-doors scenes

No cells-and-portals

Conservative Viewspace Partitioning

The visibility set is valid for any view point within the view cell
Conservative Viewspace Partitioning

Resolving visibility of an object from some random view points does not guarantee a correct interpolation of the visibility for the entire view cell.

Instead of visibility interpolation occlusion interpolation may be used.

Strong Occlusion

- viewpoint1
- viewpoint2
- tested primitive
- strong Occluder
View Cell Occlusion Interpolation

Strong and weak Occluders

Strong occluder

Weak occluders
The method effectiveness

- the number of weakly occluded objects in each of our conservative visibility sets is relatively small, and
- we can construct the potentially visible sets efficiently (far more efficiently than it would have taken to compute the visibility set precisely).

The mathematical model

- Most occluded objects are strongly occluded
- Most objects are hidden
- An efficient view cell size
The mathematical model

Uniform distribution of spheres

Strong Occluder Analysis
Strong Occluder Analysis

- The majority of occluded objects are strongly occluded
- The vast majority of distant objects are strongly occluded
- View cells must be smaller than the occluding objects.

Optimizations

- **Space subdivision**
  - ray intersections by hierarchical ray traversal
- **Bounding boxes**
  - culls all polygons in an occluded box
- **Leading ray**
  - single ray traversal is sufficient to detect a strong Occluder
- **Redundant occluders**
  - an occluded object is a redundant Occluder
- **Shaft optimization**
  - rays not lying on the convex hull are redundant
  - for conservative occlusion
Optimizations (cont.)

![Diagram](image)

- View cell
- Tested polygon
- Strong occluder

Occlusion Test Models

- Dense (city A)
- Sparse (city B)

Total polygons: 21280
Occlusion results

<table>
<thead>
<tr>
<th></th>
<th>Dense</th>
<th>Sparse</th>
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<tr>
<td>total polygons</td>
<td>21280</td>
<td>21280</td>
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<tr>
<td>strongly occluded polygons</td>
<td>20062 (94%)</td>
<td>18713 (88%)</td>
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<tr>
<td>total boxes</td>
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<tr>
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<td>1954 (91%)</td>
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<td>first occluders</td>
<td>1427 (6.7%)</td>
<td>1225 (5.8%)</td>
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View cell ratio: 1/4

Strong occluders dominate occlusion of dense models

Optimizations results

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<thead>
<tr>
<th></th>
<th>Hierarchical model</th>
<th>bounding box</th>
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<th>redundant rays</th>
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<td>80</td>
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intersections tests

- ray/box               | -                  | 135 278     | 135 089             | 455 70         | 42414             |
- ray/polygon           | 517800             | 38648       | 38648               | 38648          | 38648             |

- times in milliseconds on SGI R4400
- model size = 21280 polygons
Cost effective analysis - the view cell size

- view cell size has great effect on the culling results
- smaller cells provide greater culling but are valid for a smaller area

<table>
<thead>
<tr>
<th>cell size</th>
<th>2.0x2.0</th>
<th>1.5x1.5</th>
<th>1.25x1.25</th>
<th>1.0x1.0</th>
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Conclusions

◆ Algorithm is suited for view space partitioning and occlusion culling of out-door scenes
◆ The vast majority of the occluded primitives has a strong occluder in dense models
◆ Neighborhood visibility superset may be regarded as a conservative aspect graph approximation of a given scene with much lower time and space complexity applicable for many computer graphics applications.

Open Problem

Non-convex occluders may be represented by a union of convex parts (not necessary disjoint)