Image-Based Rendering to Accelerate Interactive Walkthroughs

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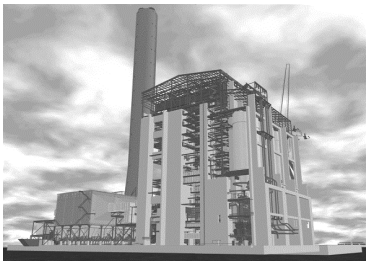
Lucent Technologies
Bell Labs Innovations

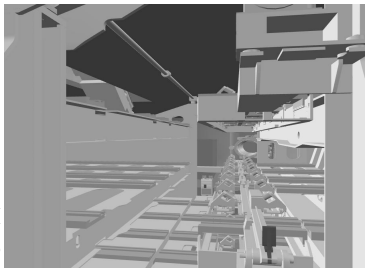
3D Models

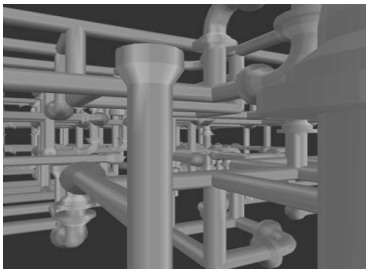
1.7M primitives



2.0M primitives

0.9M primitives

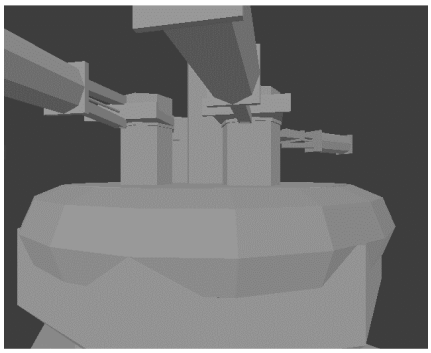




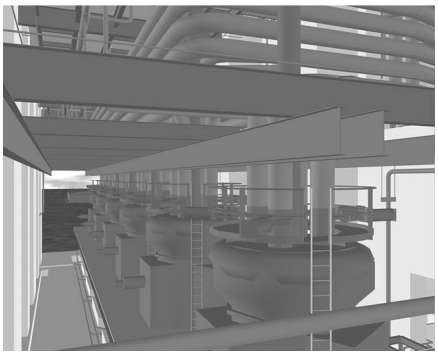
1.0M primitives

Why Use Images?

- Independent of scene complexity



640x480 pixels



640x480 pixels

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Flight Simulators

- Mid-1980's
  - E&S CT-6 one of first to use real-time photo textures
- Hand-selected objects:
  - Terrain, trees, airplanes, buildings, etc.
- 30-60 Hz
  - High visual fidelity

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Outline

- Replacing Geometry with Images
- Displaying Images
  - Texture-mapping and error metrics
  - Geometry and image warping
  - Meshes, Lightfield/Lumigraph
- Image Placement
  - Automatically Bounding Model Complexity
  - Cells and Portals
- Conclusions

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Replacing Geometry with Images

- Algorithm
  - Select subset of model
  - Create image of the subset
  - Cull subset and replace with image
- Why?
  - Image displayed in (approx.) constant time
  - Image reused for several frames

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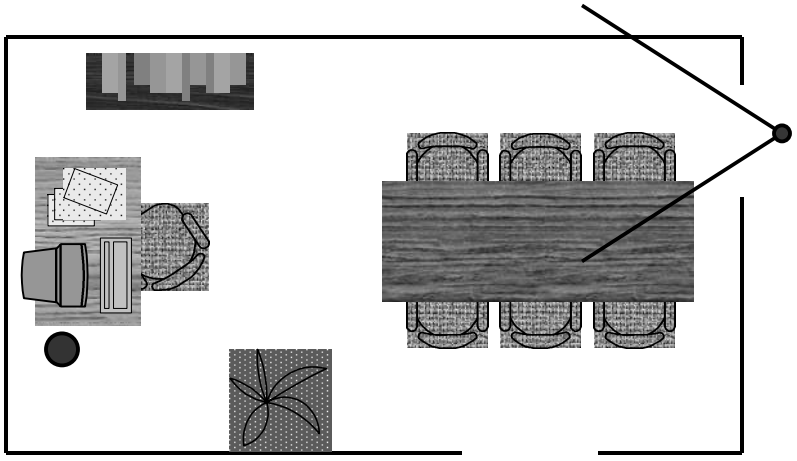
Simple Example



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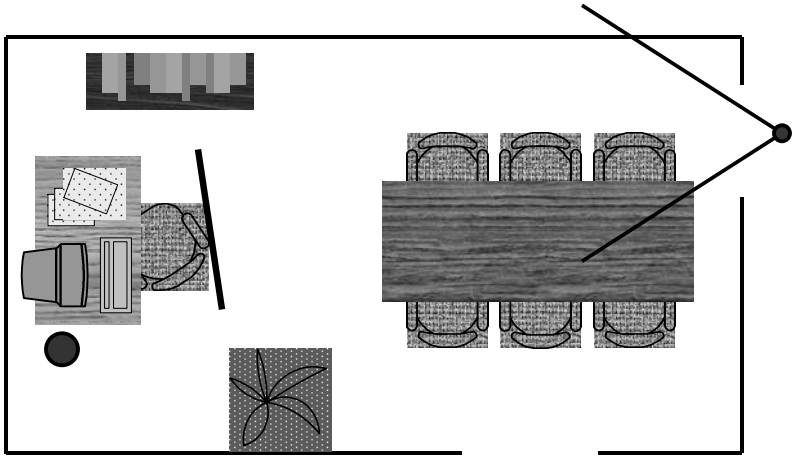
Simple Example



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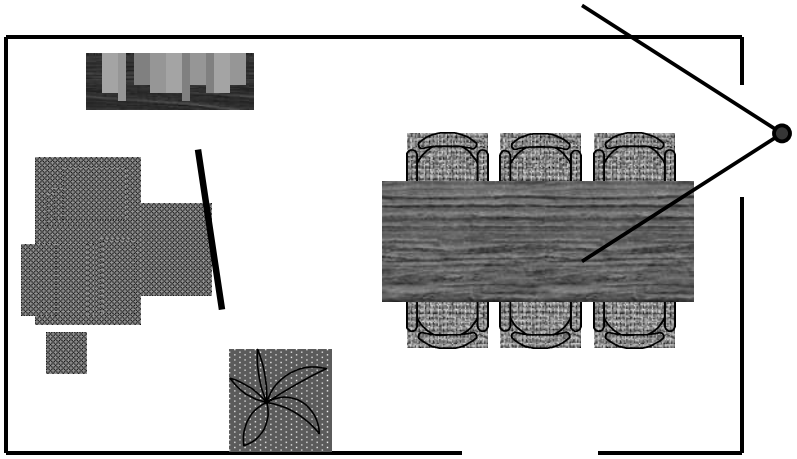
Simple Example



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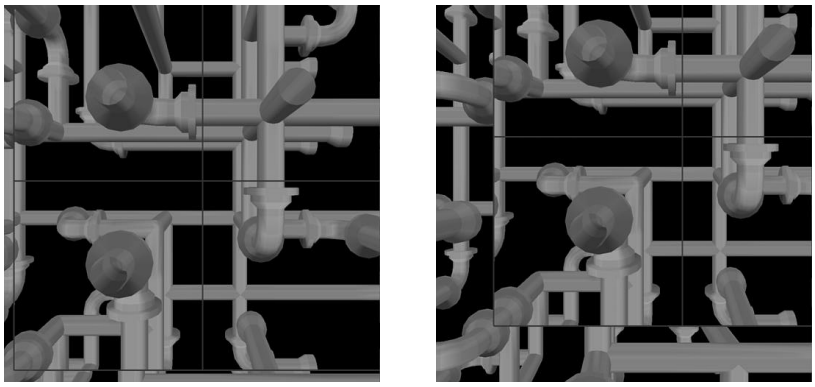
Geometric Discontinuity



- If we move from the center-of-projection, discontinuities appear at the border

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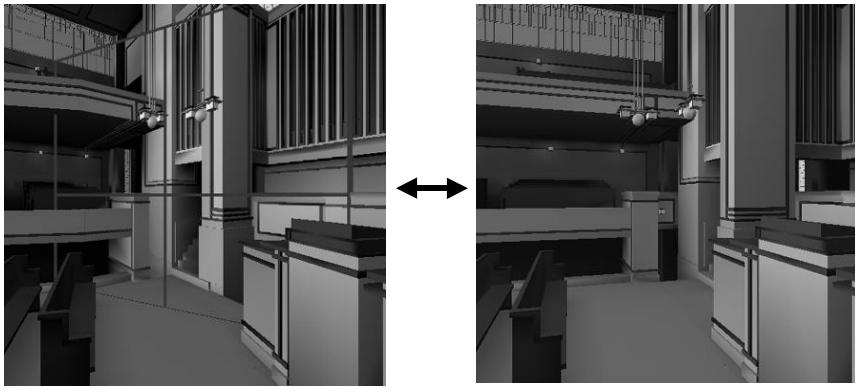
Temporal Discontinuity



- While moving, if we switch between geometry and image, a sudden *pop* occurs

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Approaches

- Geometric and Temporal Continuity
  - Error metrics
  - Geometry warping
  - Image warping
  - Lightfield/Lumigraph

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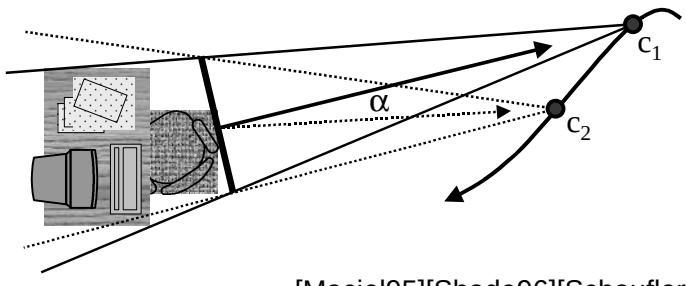
Error Metrics

- Use an *error metric* to control amount of discontinuity



[Maciel95][Shade96][Schaufler96]

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Error Metric

- Relies on “angular-deviation” measuring the visual quality of using the (same) image

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Video Segment I

- Pre-rendered Impostors
  - Maciel95
- Dynamic Image-Caching
  - Shade96, Schaufler96

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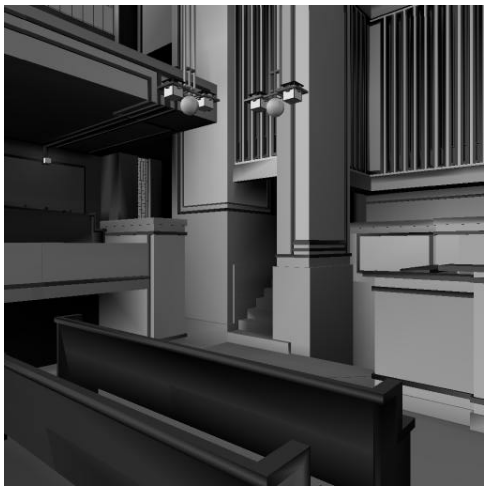
Geometry Warping



[Aliaga96]

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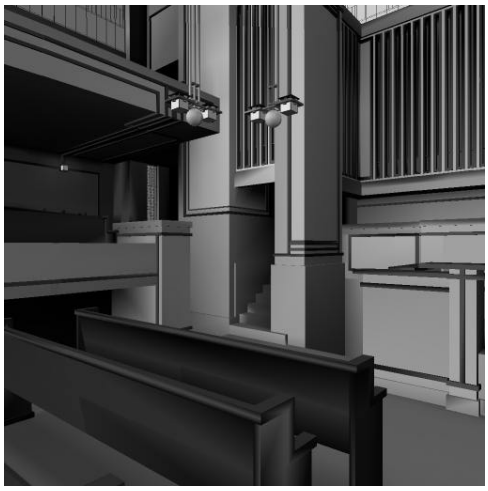
Geometry Warping



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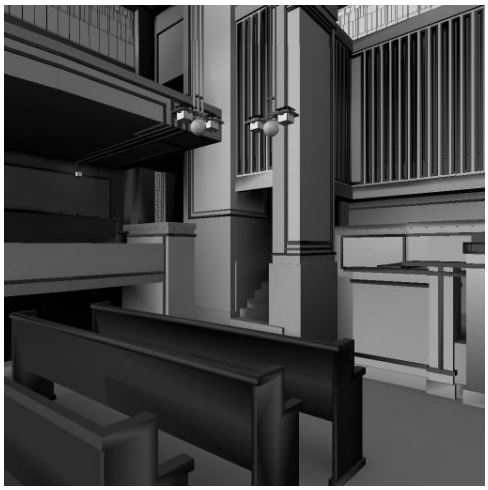
Geometry Warping



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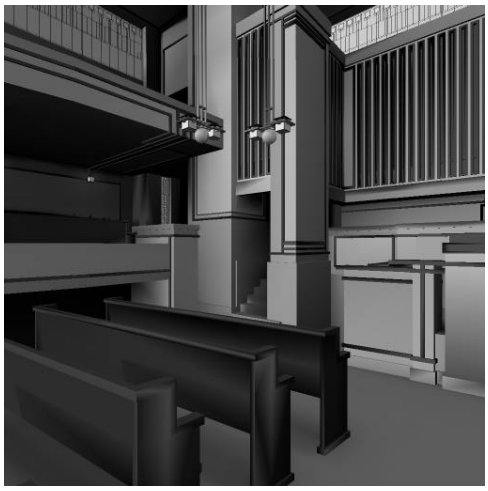
Geometry Warping



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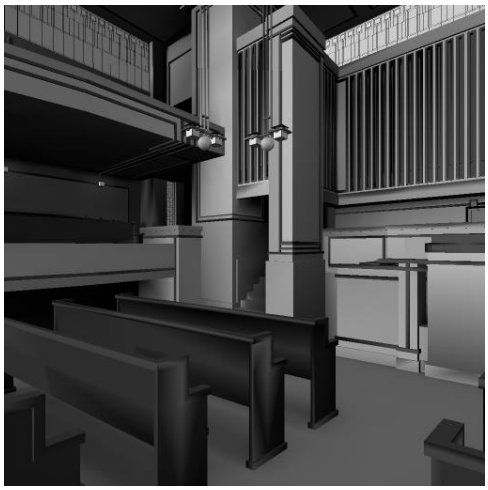
Geometry Warping



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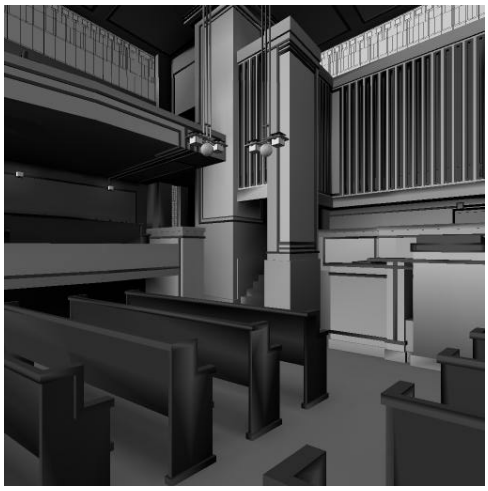
Geometry Warping



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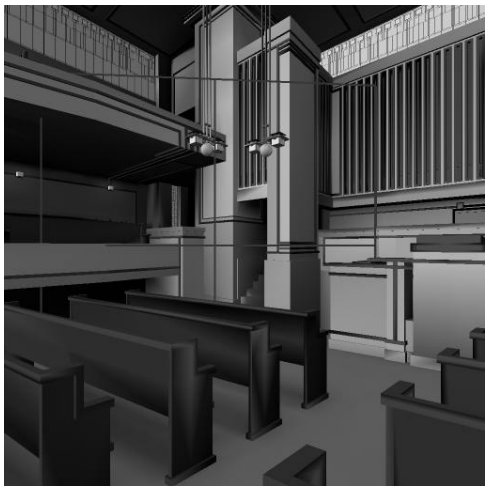
Geometry Warping



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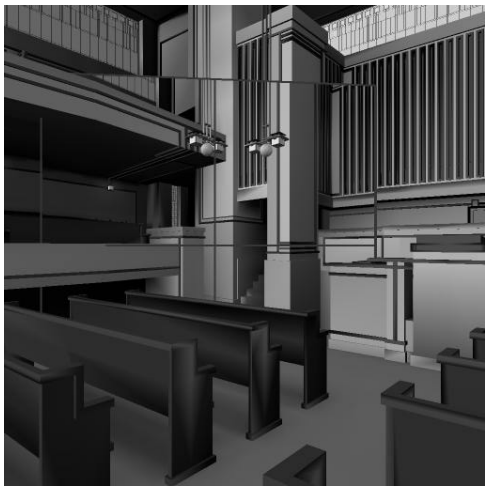
Geometry Warping



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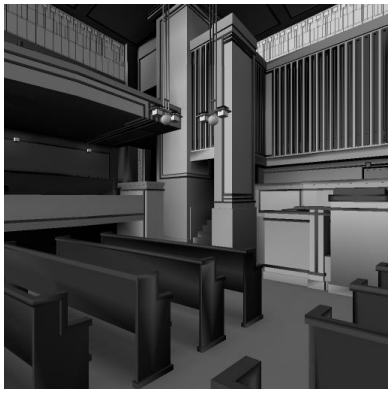
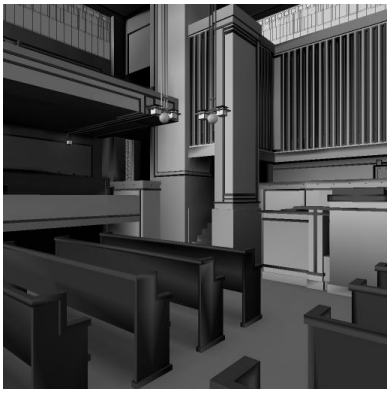
Geometry Warping



Surrounding geometry warped
(incorrect perspective)



Correct perspective

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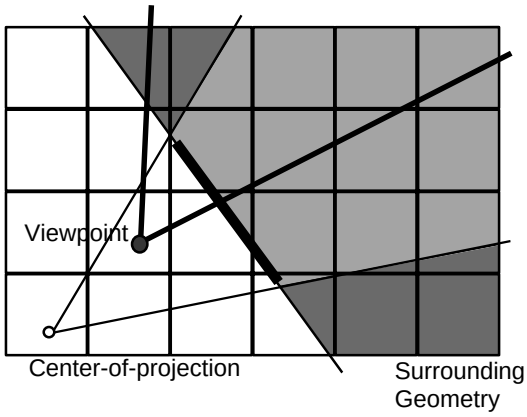
Geometry Warping

- Surrounding geometry warped to match image



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Video Segment II

- Geometry Warping
  - Aliaga96

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Image Warping

- Change the image itself
  - Re-project the image to the current viewpoint
    - [Chen93][McMillan95][Max95][Shade98]
  - Display image as a (simplified, textured) mesh
    - [Darsa97][Sillion97]

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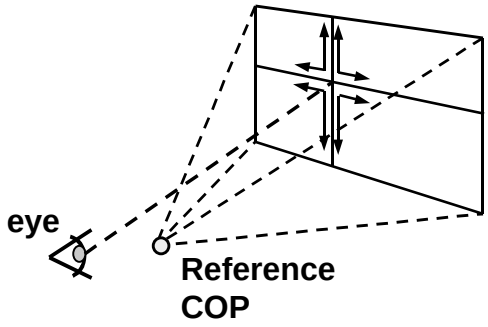
Image Warping



- A raster scan of each sheet produces a back-to-front ordering of warped pixels

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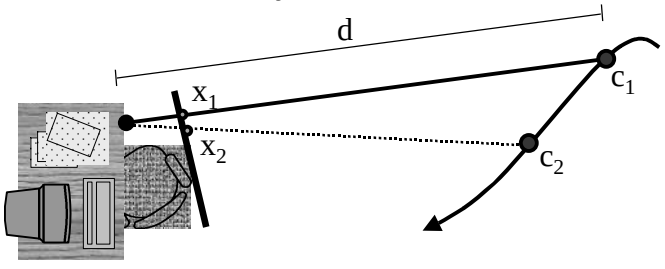
Image Warping

- McMillan and Bishop's Warping Equation

$$x_2 = \underbrace{\delta(x_1)\, P_2^{-1}\,(c_1 - c_2)}_{\textit{Move pixels based on distance to eye}} + \underbrace{P_2^{-1}\, P_1\, x_1}_{\textit{\sim Texture mapping}}$$



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Example...

- Image outlined in yellow
- Viewed from image's center-of-projection

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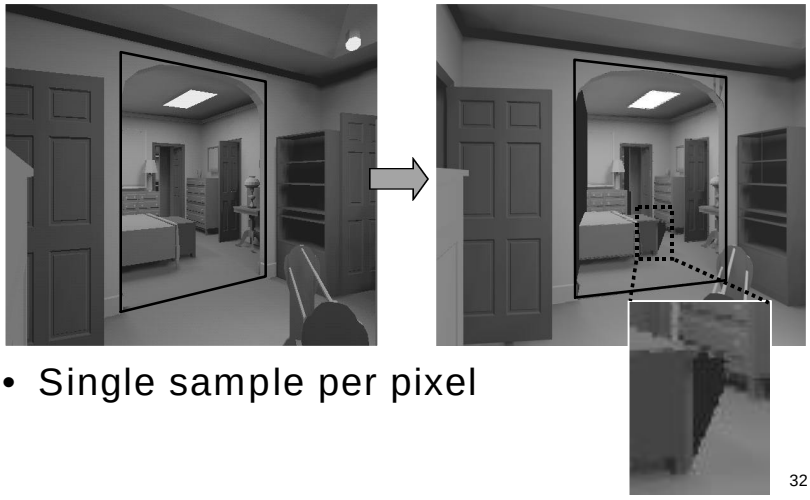
3D Image Warp



- Single sample per pixel

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Layered Depth Image Warp

- Multiple samples per pixel
  - Previous occlusions are filled-in [Popescu98]

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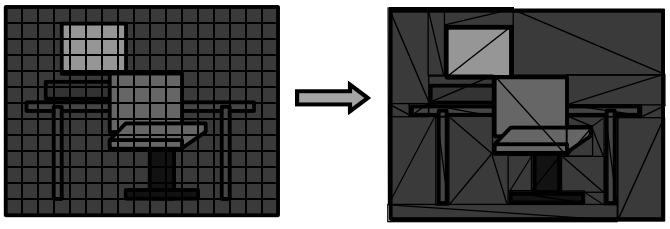
Meshes

- (Simplified) Textured Depth Mesh
  - Per-pixel depth creates mesh that approximates 3D parallax effects
  - Image is texture-mapped onto mesh



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Video Segment III

- 3D Image Warping
  - McMillan95
- Textured Meshes
  - Darsa97, Sillion97

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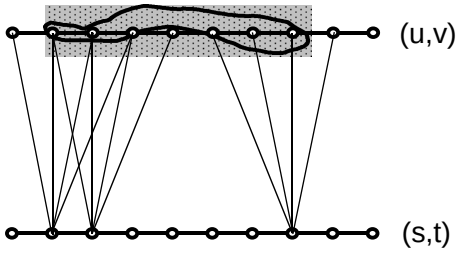
Lightfield/Lumigraph

- Flow of light at all positions and directions
  - [Levoy96][Gortler96]
- Large number of images are used as 2D slices of a 4D light function



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Video Segment IV

- Light field
  - Levoy96
- Lumigraph
  - Gortler96

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Automatic Image-Placement

- As a preprocess
  - Select geometry to replace with an image in order to limit the number of primitives to render for any frame
- At run time
  - Display selected geometry as a (depth) image
  - Render remaining geometry normally

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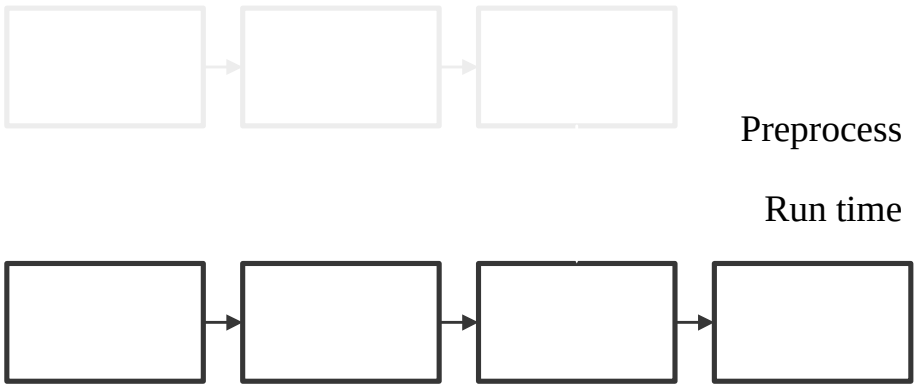
Automatic Image-Placement



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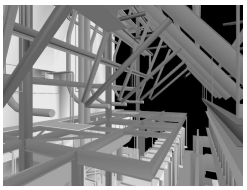
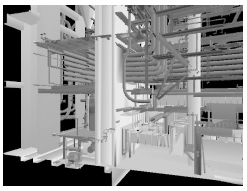
Example Rendering

Geometry

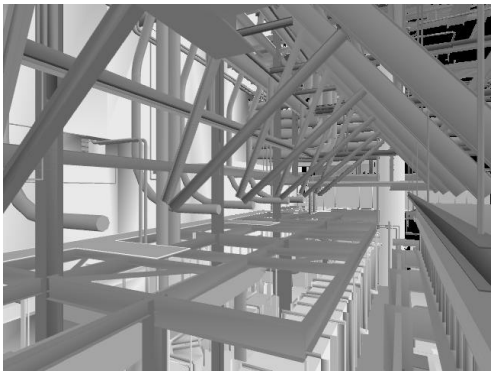


+



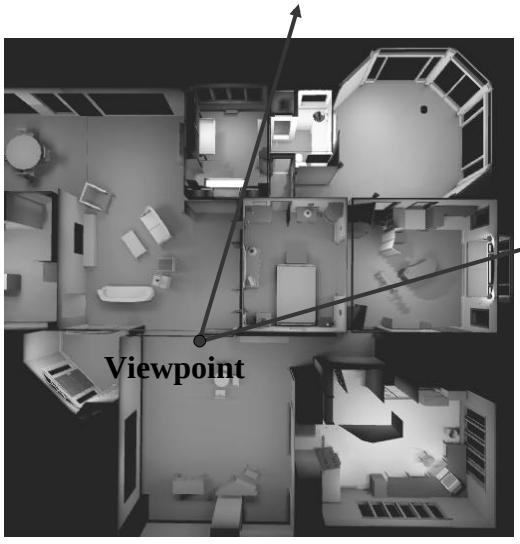
Image

=



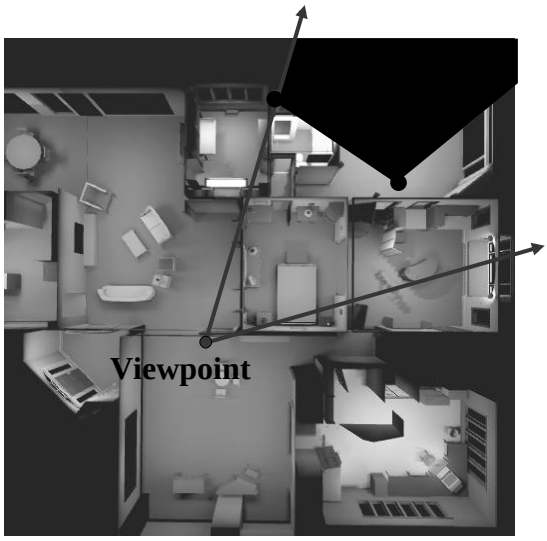
Final Scene

Key Observation



- Example model
- Too much geometry in view frustum

Key Observation



- Geometry is replaced by image to limit the number of primitives to render

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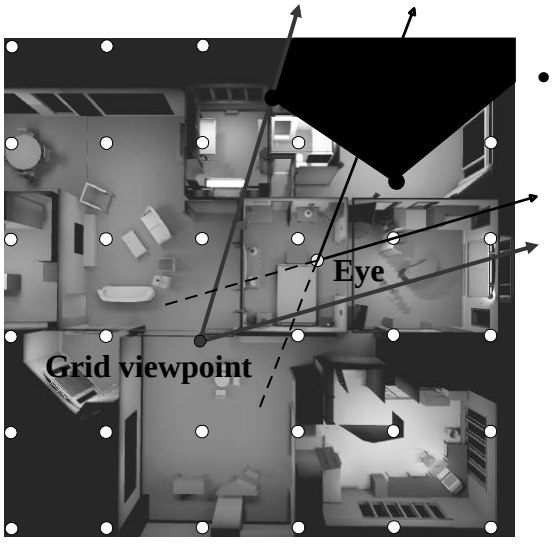
Key Observation



- Less geometry is in the view frustum from the eye than the one from the grid viewpoint

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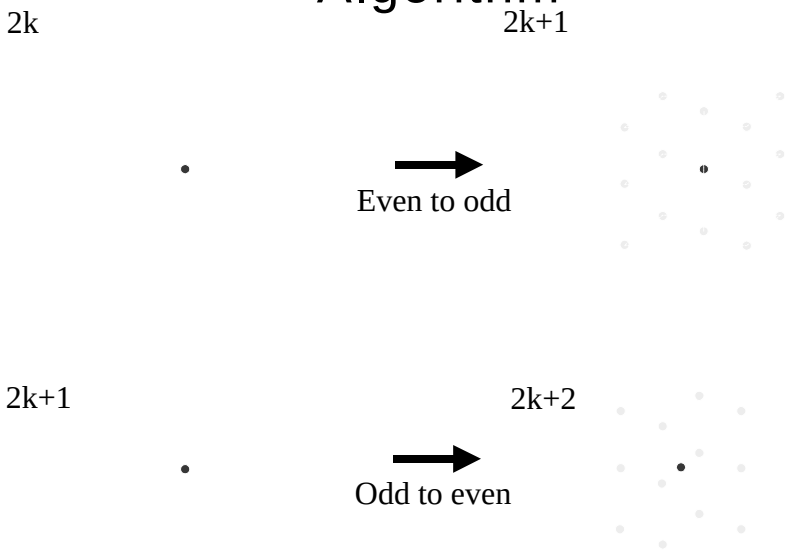
Recursive Subdivision Algorithm



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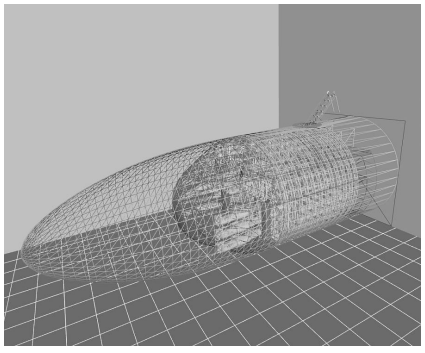
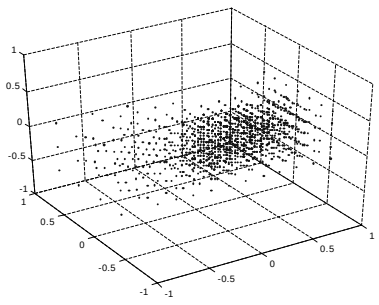
Example Grid



Wireframe rendering



3D grid of 1557 viewpoints

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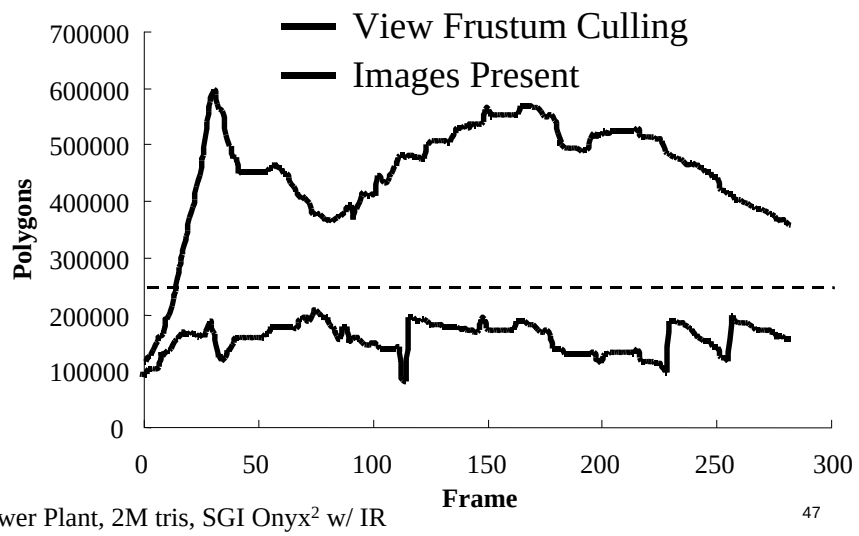
Sample Path



Power Plant, 2M tris, SGI Onyx^2 w/ IR

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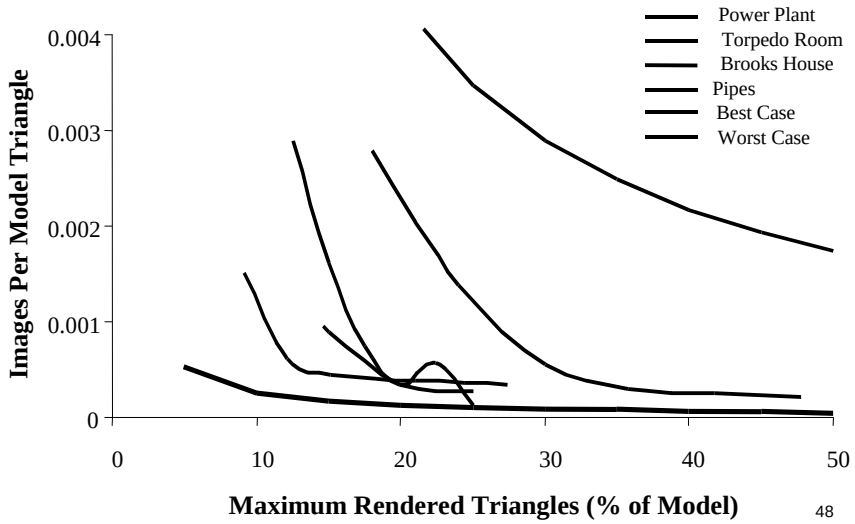
Images Per Triangle



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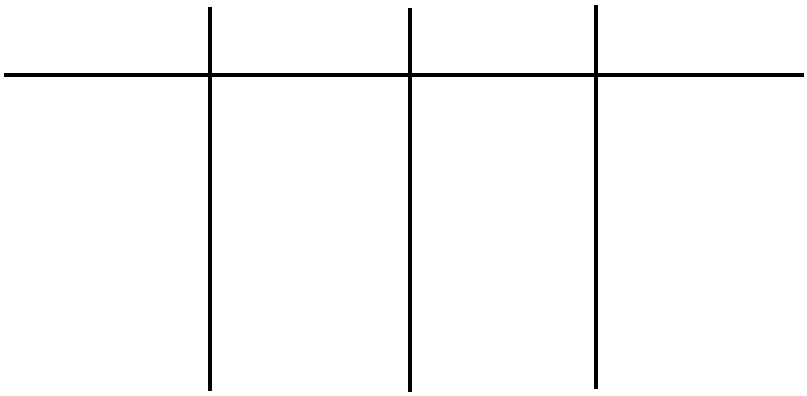
Preprocessing Summary



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Video Segment V

- Automatically Bounding Geometric Complexity by Using Images
  - Aliaga99

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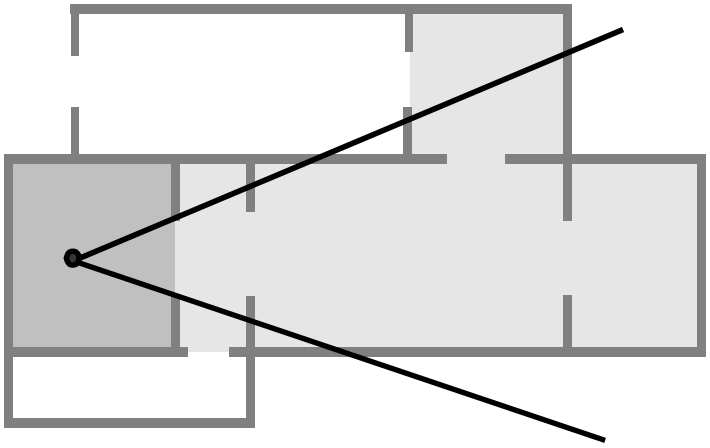
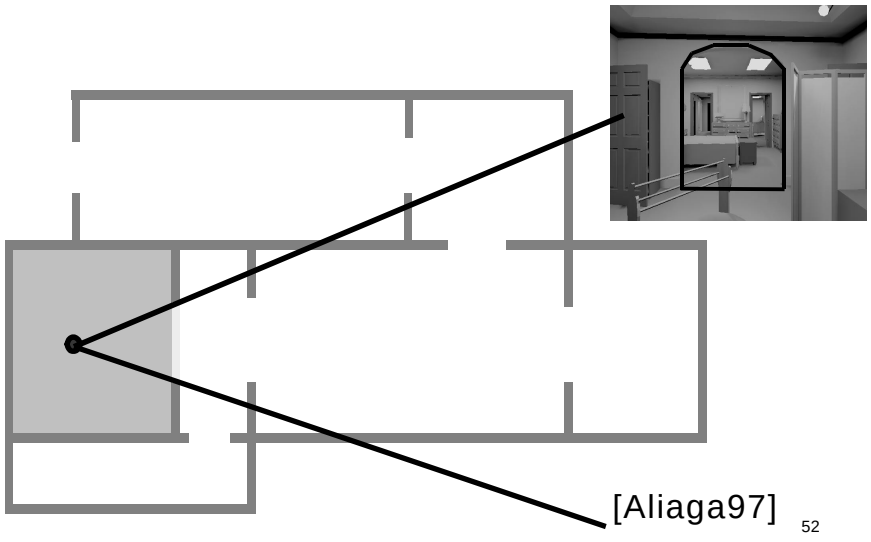
Cells and Portals



[Airey90, Teller91, Luebke95] 51

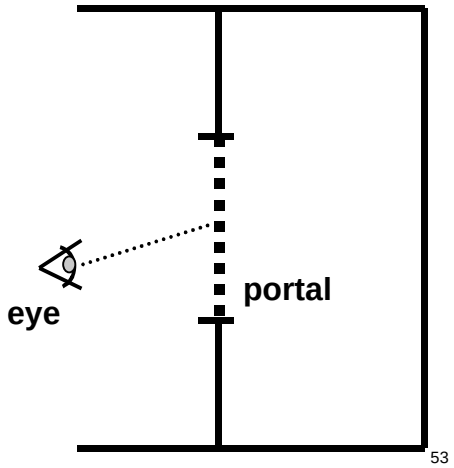
Portal Images



[Aliaga97] 52

Creating Portal Images

Ideal portal image would be one sampled from the current eye position



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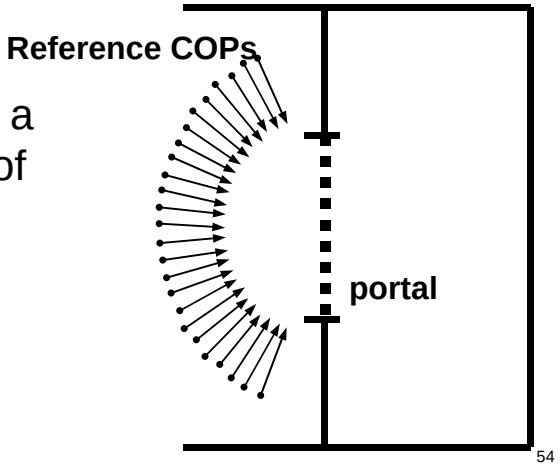
Creating Portal Images

Display one of a large number of pre-computed images (~120)



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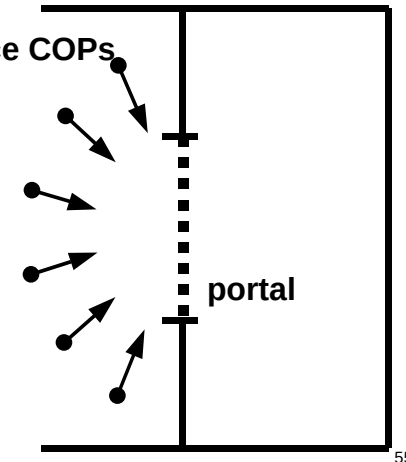
Creating Portal Images

or…

Warp one of a much smaller number of reference images



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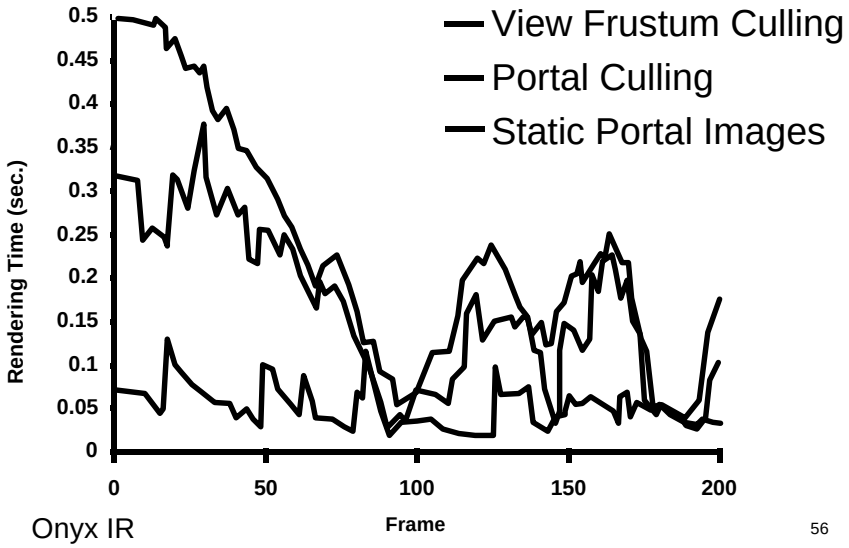
Brooks House



Onyx IR

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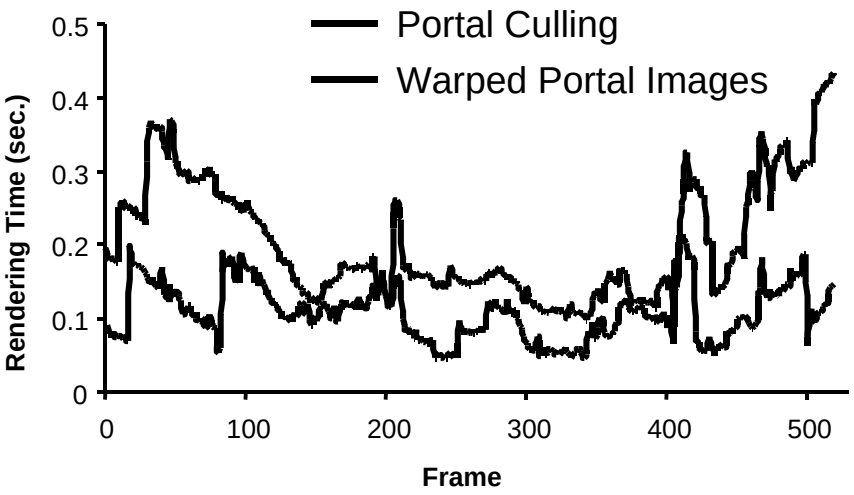
Brooks House



Onyx IR

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Video Segment VI

- Architectural Walkthroughs using Portal Images
  - Aliaga97, Rafferty98

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Image Quality

- What about measuring quality?
  - *Need a perceptual quality metric!*

- We know
  - Texture-mapping: bad perspective, small distortions believable (geometry warping)
  - IBR: correct perspective, disocclusions
  - Meshes: stretching of skins

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Limitations

- Diffuse illumination
  - Deferred shading?
- Static models
  - Incremental updating?
- Cannot sample all visible surfaces
  - Smarter reconstruction/resampling?
- Can only sample surfaces at a fixed resolutions
  - Multi-resolution reference images?

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Acknowledgments

- Authors of the Video Segments
- Models
  - Discreet Logic, UNC Walkthrough Group
- UNC-Chapel Hill
  - Walkthrough, PixelFlow, ImageFlow
- NSF, NIH, DARPA
- Lucent Technologies Bell Labs

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