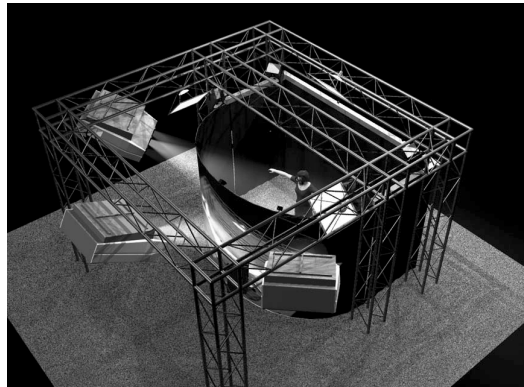


Hybrid Rendering for Collaborative, Immersive Virtual Environments

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Outline

- Rendering techniques
 - GBR, IBR and HR
- From images to models
- Novel view generation
- Putting it all together
 - Image-based Visual Hulls
- Hybrid Rendering in VR?

Rendering techniques

- Geometry-based Rendering
 - simulation of light's interaction with objects in a scene
 - based on *geometric models, lighting ...*
- Image-based Rendering
 - (partial) reconstruction of the plenoptic function
 - based on *images*

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by Matthias Zwicker

Rendering techniques

Geometry-based Rendering

- Scene Scene description in terms of geometry, surface properties, lighting conditions
- Discretization Sampling (tessellation) optimized regarding *geometric properties*
- Representation Set of *primitives* (polygons, textures, light sources)
↓
- Image Synthesis **Conventional Rendering**

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Rendering techniques

GBR [2]

- Rendering cost dependent on scene complexity and lighting
- Visual realism due to texture mapping
 - different techniques available (see GDV I)
- Overhead if rendering primitives are smaller than screen resolution
- Requires 3D surface representation

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by Matthias Zwicker

Rendering techniques

Image-based Rendering

- Scene
Scene description in terms of the plenoptic function
- Discretization
Sampling optimized regarding *screen resolution*
- Representation
Set of *n-dimensional samples*
- Image Synthesis
↓
Reconstruction

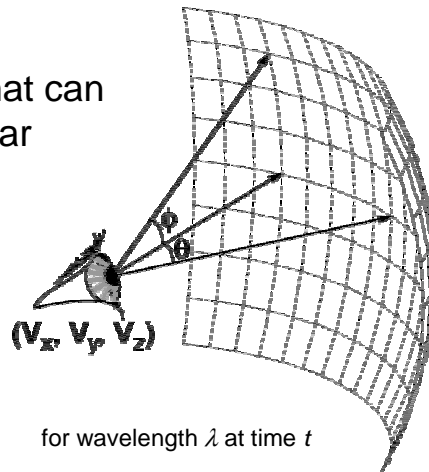
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Rendering techniques

IBR [2]

- The plenoptic function
 - describes everything that can be seen from a particular viewing position

$$I = P(x, y, z, \theta, \rho, \lambda, t)$$



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Rendering techniques

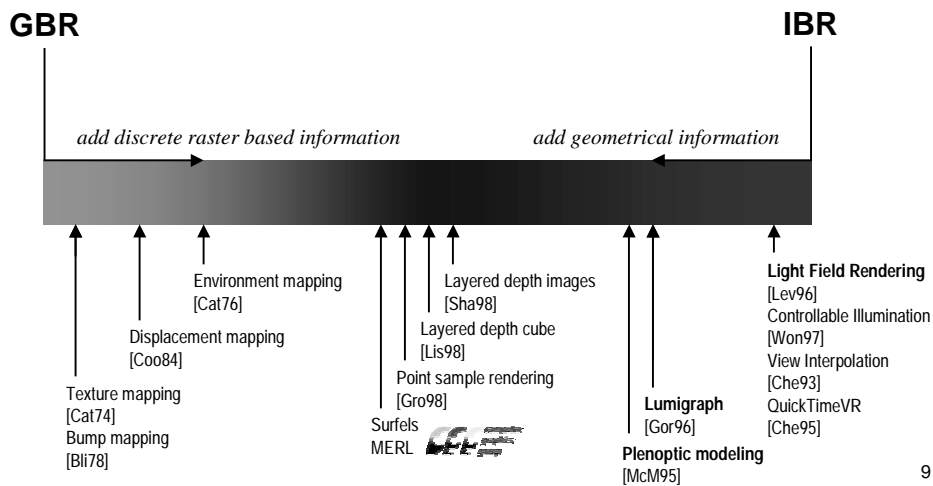
IBR [3]

- Rendering cost independent of scene complexity
- No geometric model needed
- Improved realism through real world data

- Large storage requirements
- Limited flexibility (eg. lighting, reflectance)

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Rendering techniques Hybrid Rendering



Rendering techniques Hybrid Rendering [2]

- Combination of IBR and GBR
 - Extraction of **geometric** information from images
 - Extraction of **texture** information from images
- Rendering from novel views using available information

From images to models

- Geometric information from multiple images
 - (partial) reconstruction of 3D models
- Number of different techniques:
 - volumetric models from silhouettes
 - 3D surface points from stereo correspondence

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From images to models

Volumetric models

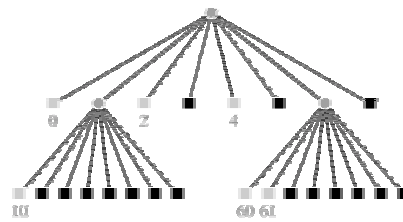
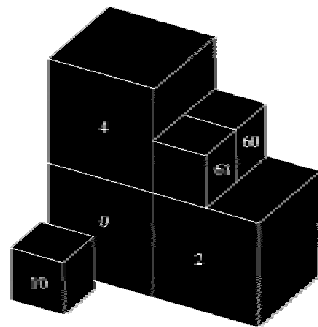
- 3D volumetric model from silhouettes
 - extract binary silhouette using blue-screen (chroma-keying) technique
 - each silhouette + camera center defines enclosing conic region of space
 - intersection of cones \Rightarrow bounding volume
 - octree construction in hierarchical coarse-to-fine fashion: *cube subdivisions*

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From images to models

Volumetric models [2]

- Octree example and representation

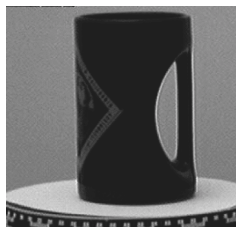


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From images to models

Volumetric models [3]

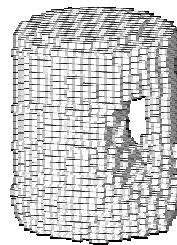
- Results



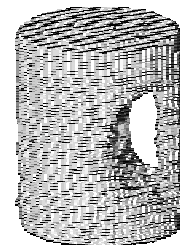
Input image



silhouette image
(non-white areas are considered part of object)



lower-res octree model
(5 levels)



higher-res octree model
(6 levels)

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From images to models

Volumetric models [4]

- Advantages
 - simple to implement
 - fast execution
 - complete (closed) surface
- Disadvantages
 - only produces *line hull* (no cavities)
 - possible misclassification in silhouette extraction
 - limited resolution

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From images to models

3D surface points

- Integration of depth maps into a complete 3D model
 - Computation of dense *disparity maps* from pairs of images using correlation
 - Backprojection into object space
- Convert to 3D points lying on the surface of the object

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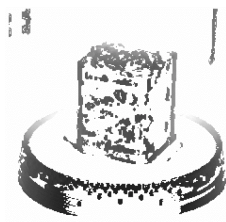
From images to models

3D surface points [2]

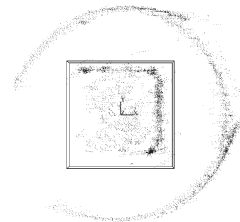
■ Results



first image
in sequence



depth map
from flow
(darker is nearer)



top view of
3D point cloud

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From images to models

3D surface points [3]

■ Advantages

- gives detailed surface estimates
- multi-view aggregation improves accuracy

■ Disadvantages

- fails in textureless areas
- sparse, incomplete surface

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Novel view generation

- Ray Databases
 - Light Field Rendering [Levoy et al.]
 - The Lumigraph [Gortler et al.]
- Image Warping
 - transforming the points of one image to their appropriate position in another image [McMillan & Bishop]

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Novel view generation

Light Field Rendering

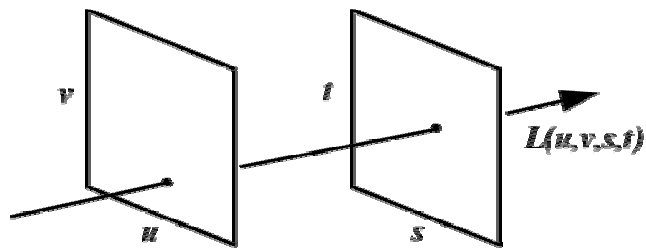
- Pure IBR technique
 - no depth information
- 4D approximation of plenoptic function
- Database of rays
- Quadrilinear interpolation for novel views
- Large arrays of images needed

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Novel view generation

Light Field Rendering [2]

- Sampling on rays
 - light slab
 - regular grid of intersection points



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Novel view generation

Light Field Rendering [3]

- Results

Demo

Interactive
Light Field Viewer

program and light field data set:
Stanford Computer Graphics Laboratory

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Novel view generation

The Lumigraph

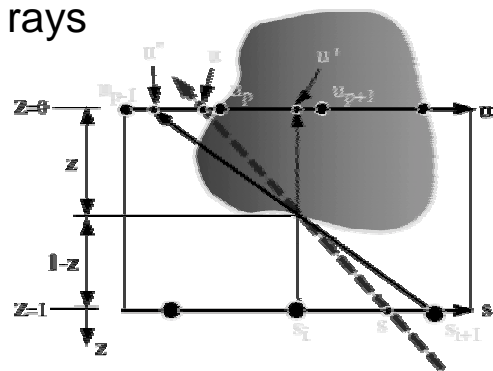
- Close to the Light Field approach
 - but geometric information for depth correcting images
 - ⇒ volumetric model
- Real-world acquisition with hand-held camera
- Discretization with coeff. and basis functions
- Lumigraph construction similar to multi-dimensional *scattered data approximation*
 - hierarchical algorithm: **splat - pull - push**

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Novel view generation

The Lumigraph [2]

- Depth correction of rays



intersection at:
$$u' = u + (s - s_i) \frac{z}{1 - z}$$

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Novel view generation

The Lumigraph [3]

■ Results

no depth correction



with depth correction



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Novel view generation

Image Warping

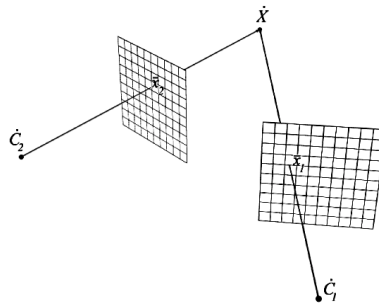
- Mapping points from a reference image to a desired image
 - depth information or correspondences needed
- Not a one-to-one mapping
 - thus resolving *visibility* is needed
- Reconstruction so that transformed points appear continuously in desired image

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Novel view generation

Image Warping [2]

- Specification of a 3D point



$$\dot{X} = \dot{C}_1 + t_1 \mathbf{P}_1 \bar{x}_1 = \dot{C}_2 + t_2 \mathbf{P}_2 \bar{x}_2$$

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Novel view generation

Image Warping [2]

- Planar image-warping equation

generalized disparity

$$\bar{x}_2 \doteq \delta(\bar{x}_1) \mathbf{P}_2^{-1} (\dot{C}_1 - \dot{C}_2) + \mathbf{P}_2^{-1} \mathbf{P}_1 \bar{x}_1$$

per pixel shift proportional to
disparity in direction of epipole

planar projective
transformation

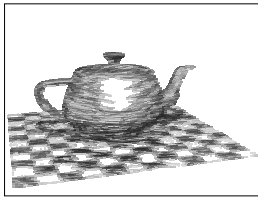
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Novel view generation

Image Warping [3]

■ Results

reference image
(note: only *one* image)



disparity data
(stored as gray scale image)



Demo

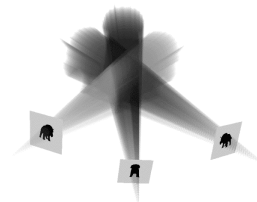
Image Warping Applet
MIT, Leonard McMillan

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Putting it all together:

Image-based Visual Hulls

- The Visual Hull
 - intersection of silhouette volumes seen from multiple points of view
- Image-based representation
 - silhouette image with occupancy intervals at every pixel
 - stored as pairs of real numbers
 - third dimension is continuous



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Putting it all together:

Image-based Visual Hulls [2]

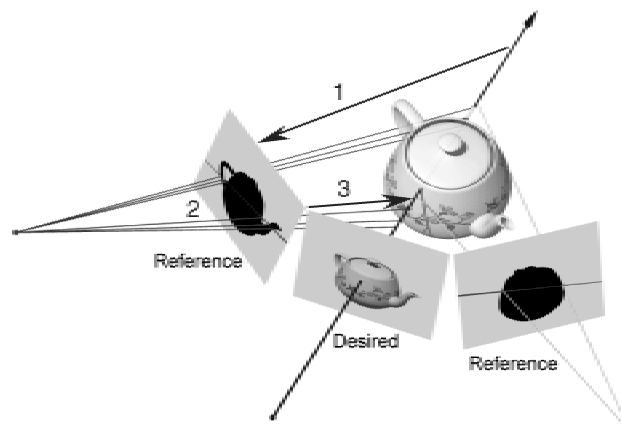
■ Creating Image-based Visual Hulls

- 1 projection of the desired 3D viewing ray onto a reference image
- 2 determination of the intervals where the projected ray crosses the silhouette
- 3 lift back these intervals onto the desired ray where they can be intersected with intervals from other reference images

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Putting it all together:

Image-based Visual Hulls [3]



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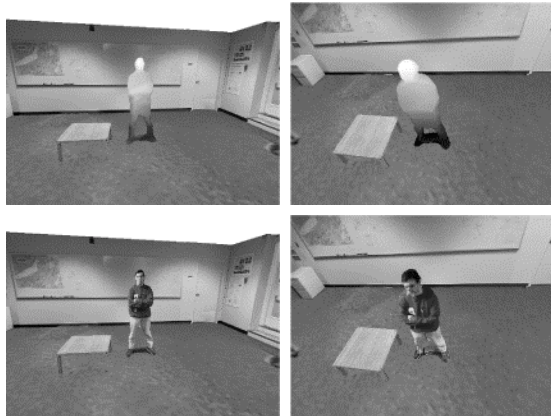
Putting it all together:

Image-based Visual Hulls [4]

■ Results



base: 4 segmented reference images



upper: **depth maps** of the computed visual hulls
lower: **shaded renderings** from the same viewpoint

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Putting it all together:

Image-based Visual Hulls [5]



MIT Visual Hull Project

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Hybrid Rendering in VR?

- Rendering humans in VR?
- Two possibilities:
 - video-based avatars
 - billboarding
 - no occlusion detection
 - real humans
 - texture and geometric information from video streams
- ...and we want real humans!

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