Image-Based 3D Photography Using Opacity Hulls

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The Goal: To Capture Reality

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- Fully-automated 3D models creation of real objects.
- Faithful representation of appearance for these objects.

Contributions

- A system to acquire complex 3D objects.
- Opacity Hull - a new shape representation.
- Algorithm for rendering 3D models from arbitrary viewpoints under arbitrary illuminations.

Outline

- Motivation and Contributions
- Background
- System
- Opacity Hulls and Surface Light Fields
- Surface Reflectance Fields
- Future Work and Conclusions

Previous Work

- Acquisition of 3D shape of real objects.
  - Contact digitizers – intensive manual labor.
  - Passive methods – require texture, Lambertian BRDF.
  - Active light imaging systems – restrict types of scanned materials.
- BRDF estimation, inverse rendering.
- Image based modeling and rendering.

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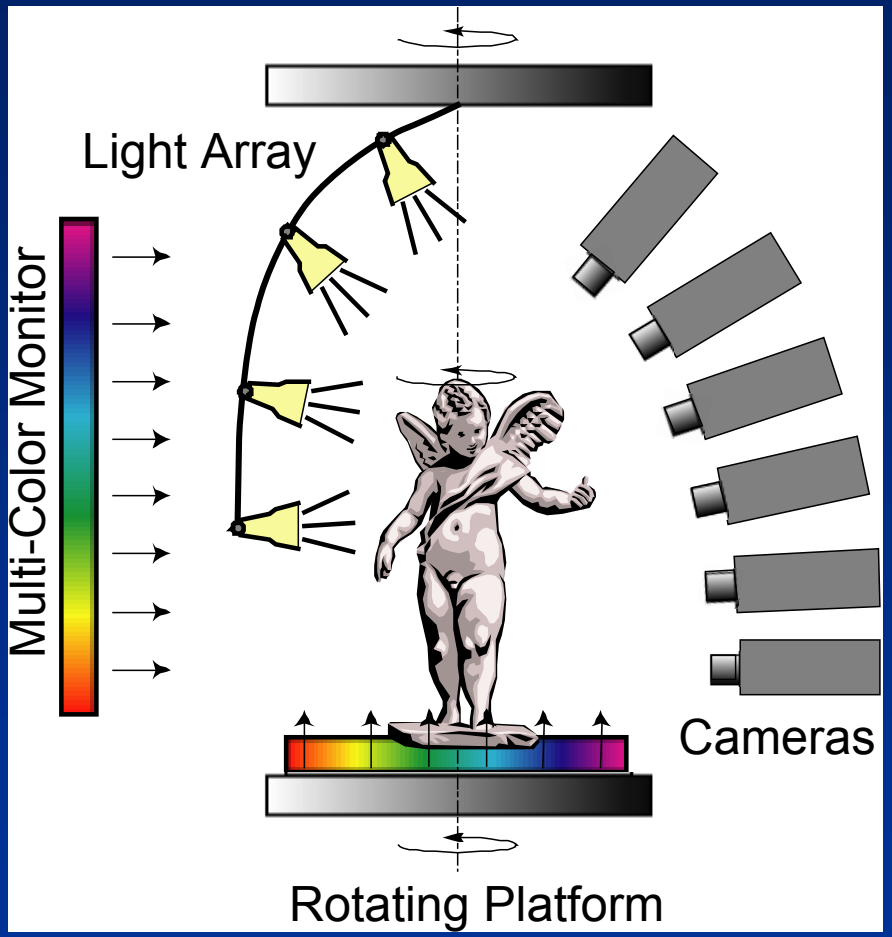
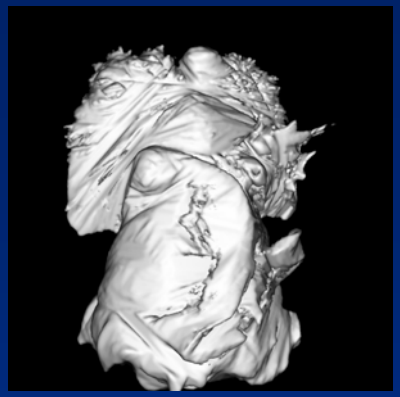
Acquisition System



Acquisition Process

Alpha Mattes



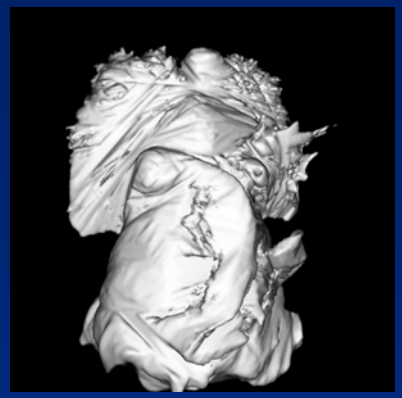
Visual Hull

Surface Lightfield

Surface Reflectance Fields

Acquisition Process

Alpha Mattes



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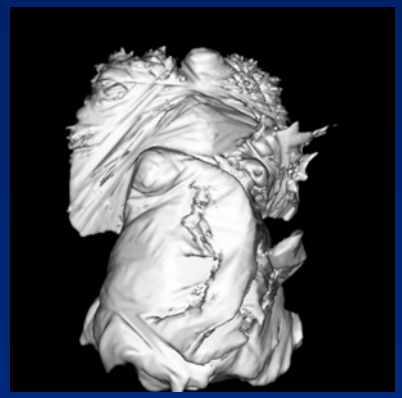

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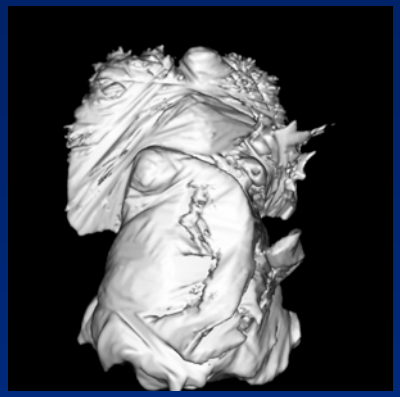

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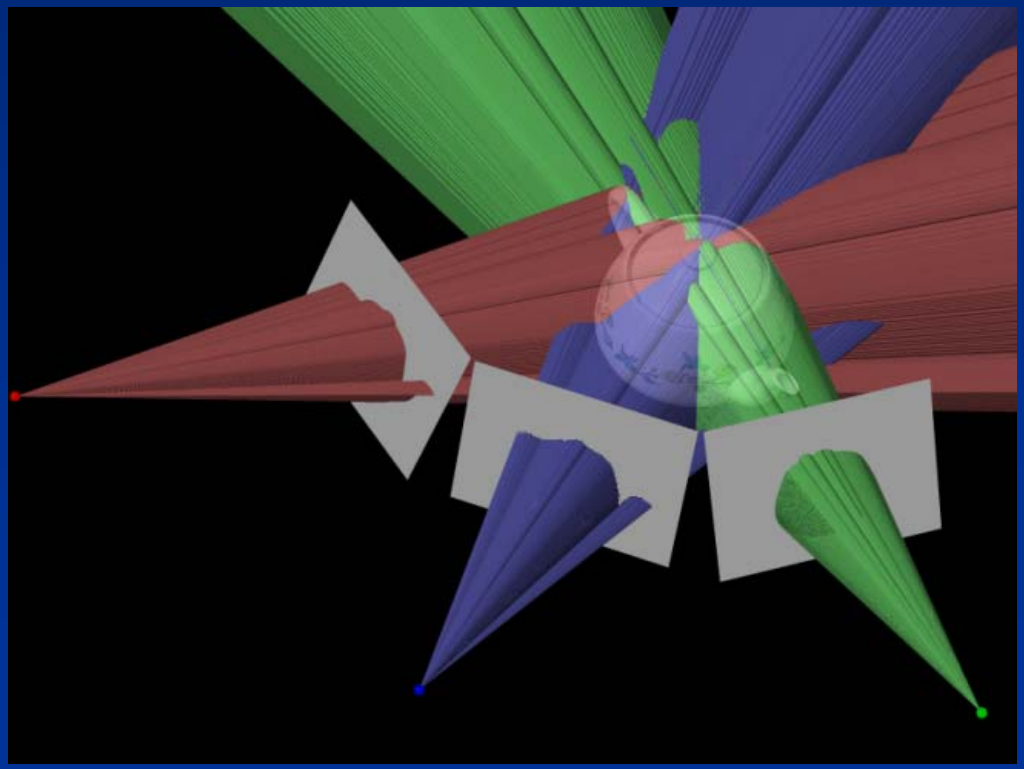
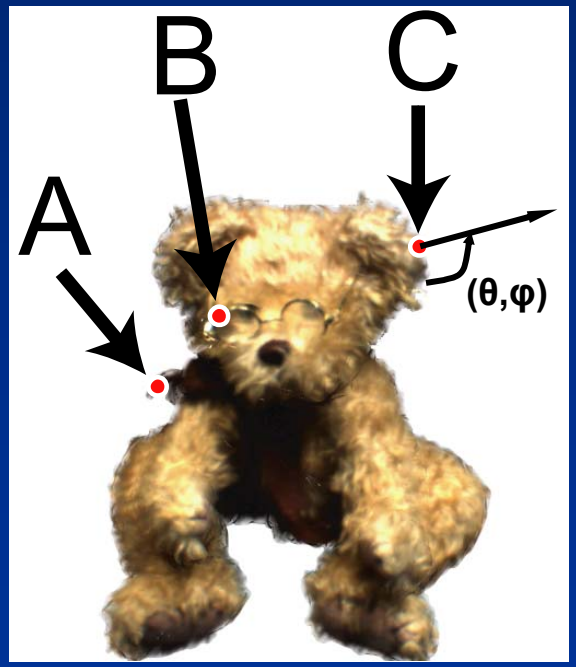
Geometry Representation

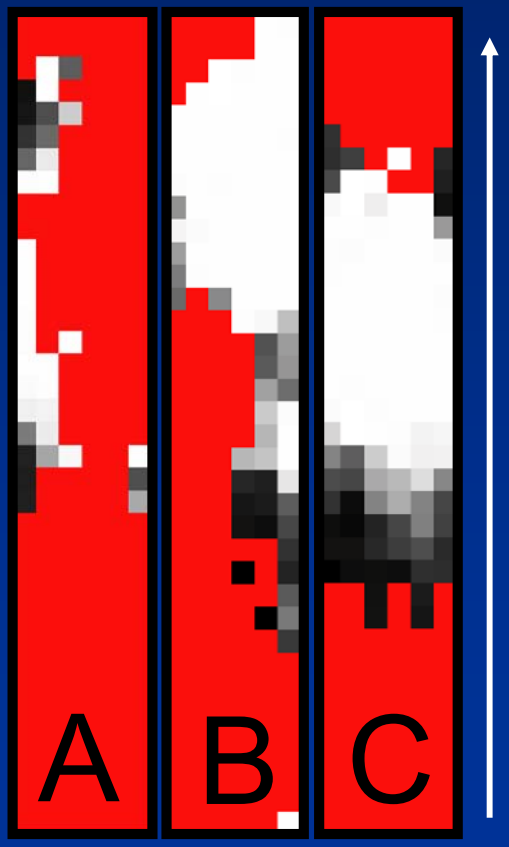
- Visual Hull - the maximal object consistent with a given set of silhouettes.
- Visual Hull can be computed robustly.



Opacity Hull

- We assign a (view-dependent) opacity to each ray originating on a point of the visual hull.





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Red = invisible
White = opaque
Black = transparent

Example

Photo

Example

Photo

Visual Hull

Example

Photo

Visual Hull

Opacity Hull

Example

Photo

Surface Light Field

Visual Hull

Opacity Hull

Results Video

Opacity Hull - Discussion

- View dependent opacity vs geometry trade-off.
- Sometimes acquiring the geometry is not possible.
- Sometimes representing true geometry would be very inefficient.
- Opacity hull stores the “macro” effect.

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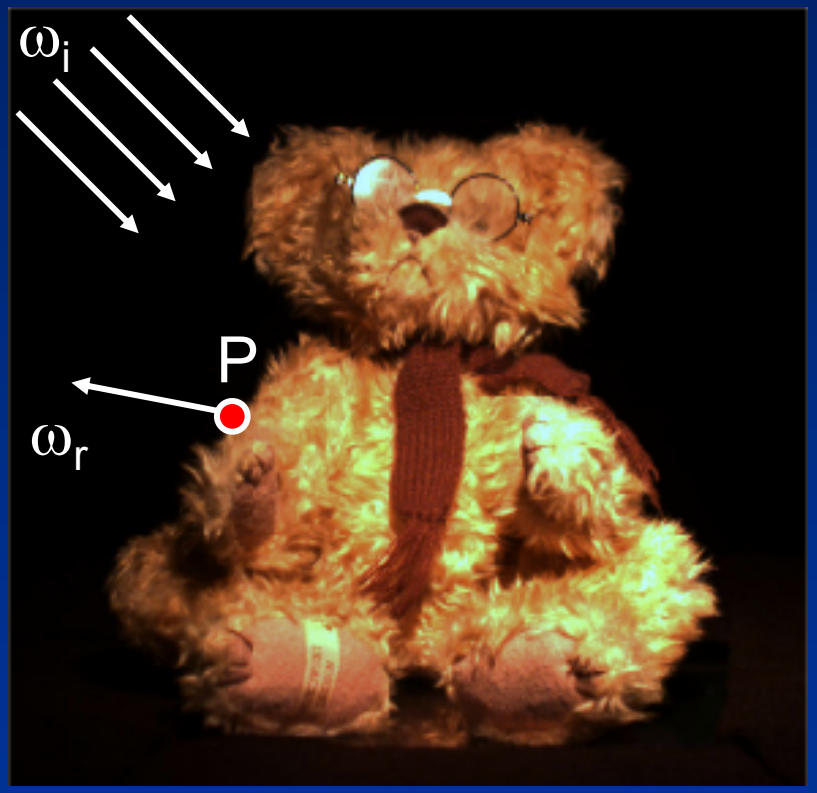
Surface Reflectance Field

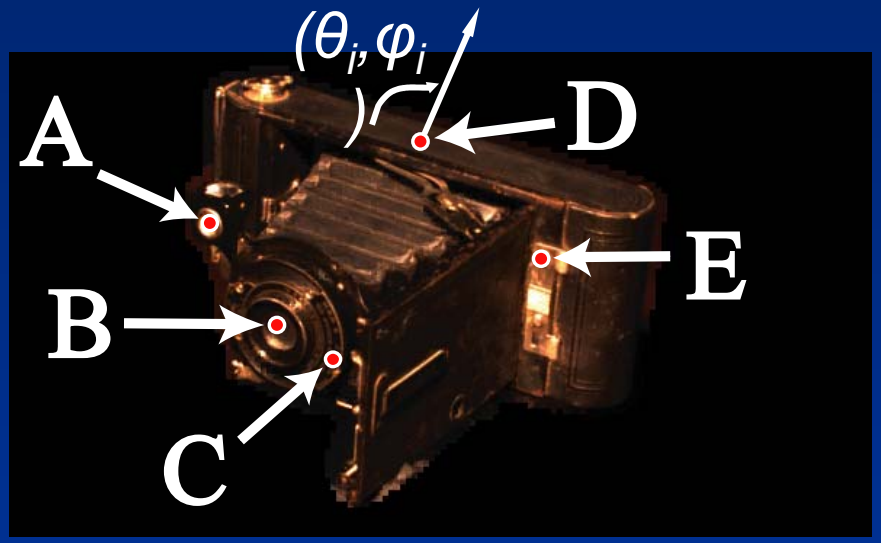
- 6D function: $R(P, \omega_i, \omega_r) = R(u_r, v_r; \theta_i, \Phi_i; \theta_r, \Phi_r)$

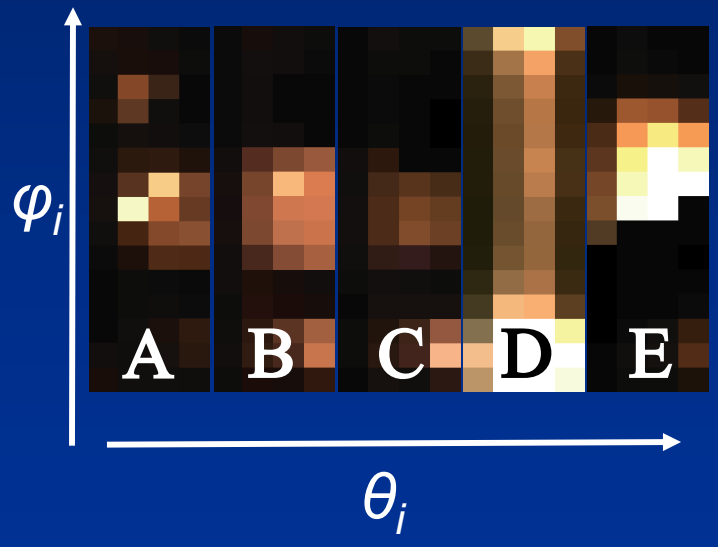


- Assumes directional illumination at infinity.

Reflectance Function

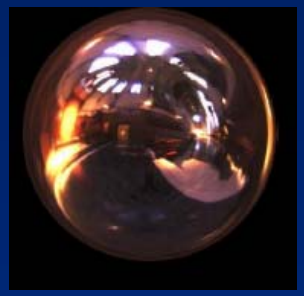
- [Debevec et al., 00][Hawkins et al. 01][Malzbender et al. 01]
- 4D function: $R_{xy}(\omega_i) = R(x, y; \theta_i, \Phi_i)$





- We use multiple viewpoints and 3D geometry.

1st Step: Relighting



New
Illumination

Down-sample

Surface reflectance field

x

=

V0

V1

V2

… Vn

2nd step: View Interpolation

- Interpolate opacity and radiance.
  - Unstructured lumigraph interpolation

    [Buehler et al., 01]
  - View-dependent texture mapping

    [Debevec 98].
- From new viewpoint, for each surface point, find four nearest acquired viewpoints.

Results Video

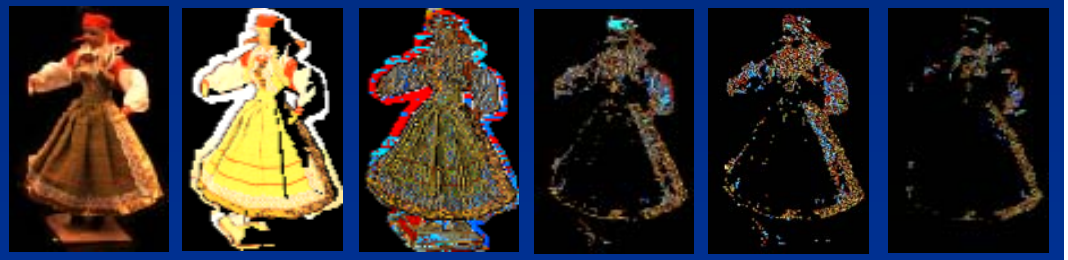
Surface Reflectance Fields

- Work without accurate geometry.
- Surface normals are not necessary.
- Capture more than reflectance
  - Inter-reflections
  - Subsurface scattering
  - Refraction
  - Dispersion

Compression

- Subdivide images into 8 x 8 pixel blocks.
- Keep blocks containing object (avg. compression 1:7)
- PCA Compression (avg. compression 1:10)

PCA →



Results

Results

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Future Work

- Better compression
- Real-time rendering
- Refractive & transparent objects

  [Matusik et al., EGRW 2002]

Refractive & Transparent Objects

[Matusik et al., EGRW 2002]

Conclusions

- Our system is able to capture and render any type of object.
- Opacity hulls combined with surface reflectance fields/lightfields provide realistic 3D graphics models.
- Our models can be seamlessly inserted into new environments.

Acknowledgements

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