Rendering Synthetic Objects into Legacy Photographs

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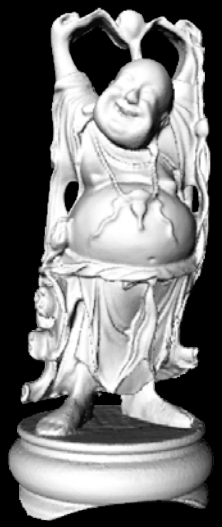
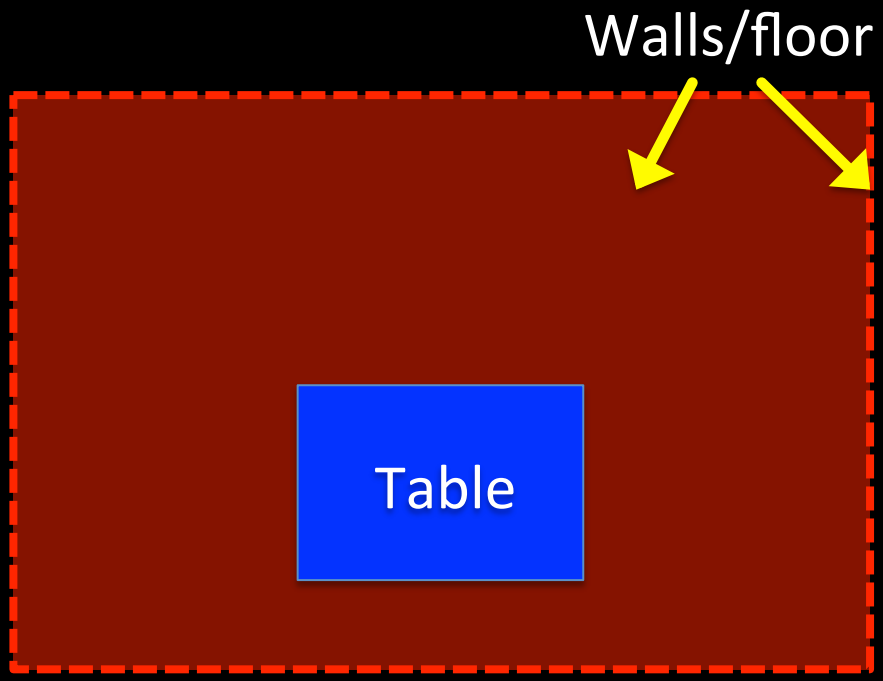


Challenges

- Estimate a physical scene model including:

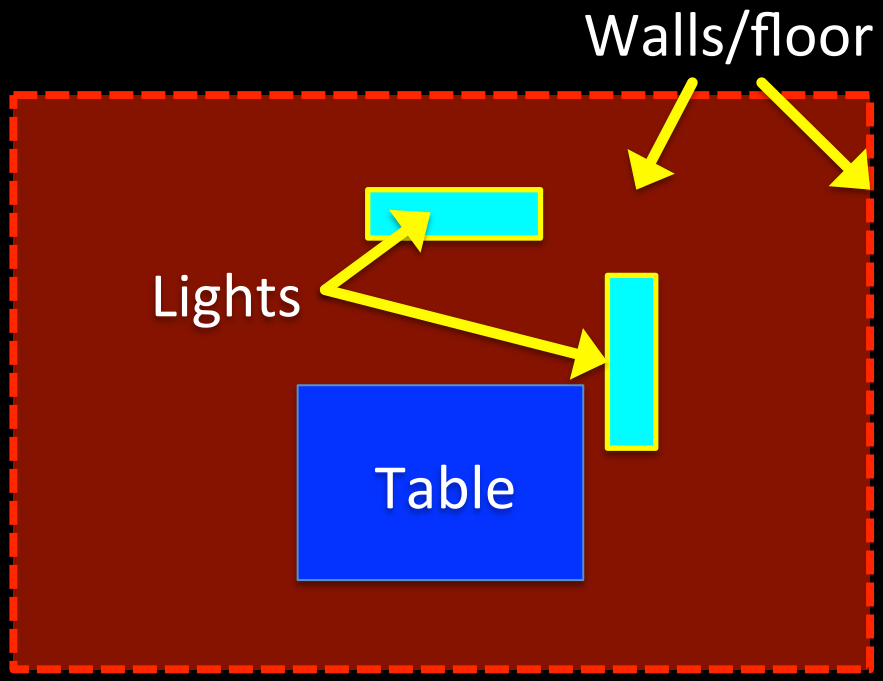
Challenges

- Estimate a physical scene model including:
  - Geometry
  - Surface properties



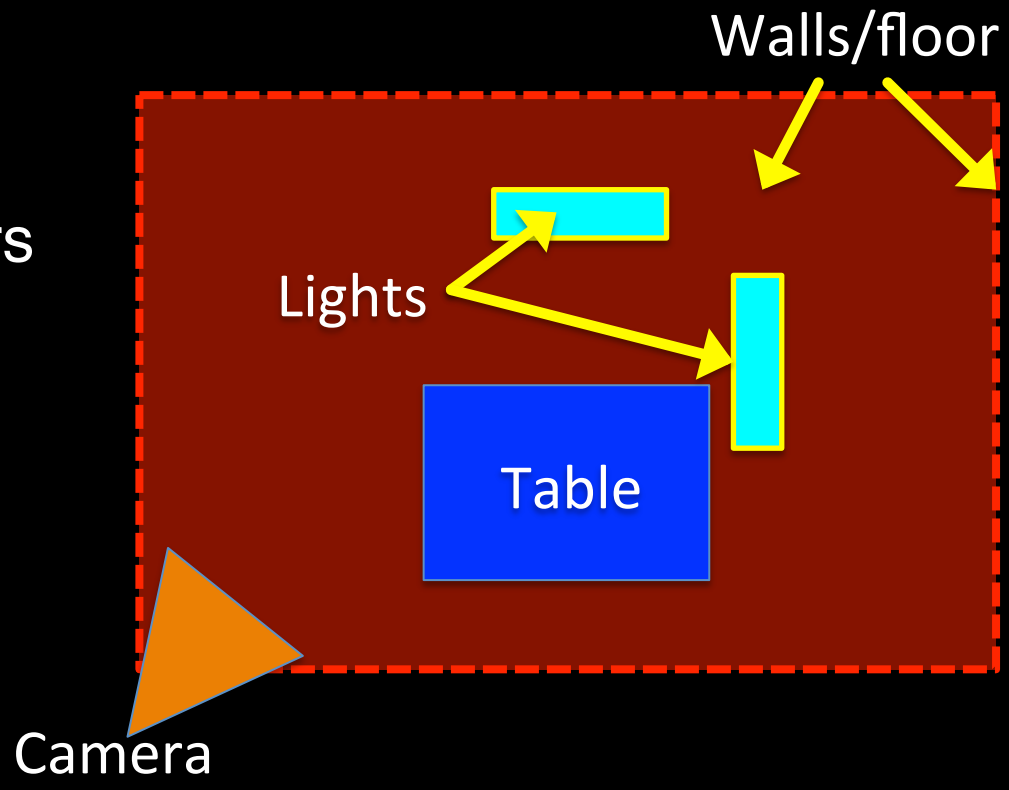
Challenges

- Estimate a physical scene model including:
  - Geometry
  - Surface properties
  - Lighting info



Challenges

- Estimate a physical scene model including:
  - Geometry
  - Surface properties
  - Lighting info
  - Camera parameters



Approaches with scene access

Manual authoring

[Fournier et al. ’93]

Approaches with scene access

Manual authoring

[Fournier et al. ’93]

Light probe, Inverse GI

[Debevec ’98, Yu et al. ‘99]

Approaches without scene access

Outdoor illumination

[Lalonde et al. ‘09]

Point source detection

[Wang and Samaras ’03, Lopez-Moreno et al. ‘10]

Goals

- ***Realistic insertion using a single LDR photo***

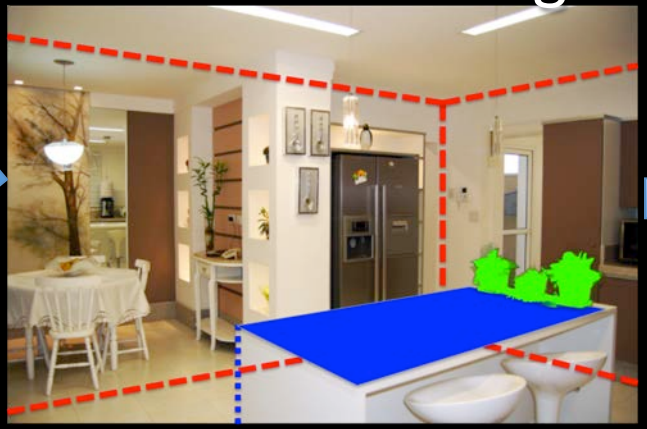
- Arbitrary lighting environments
- Intuitive, quick and easy to create content

System overview

Input image

Object insertion

Scene authoring



Scene synthesis

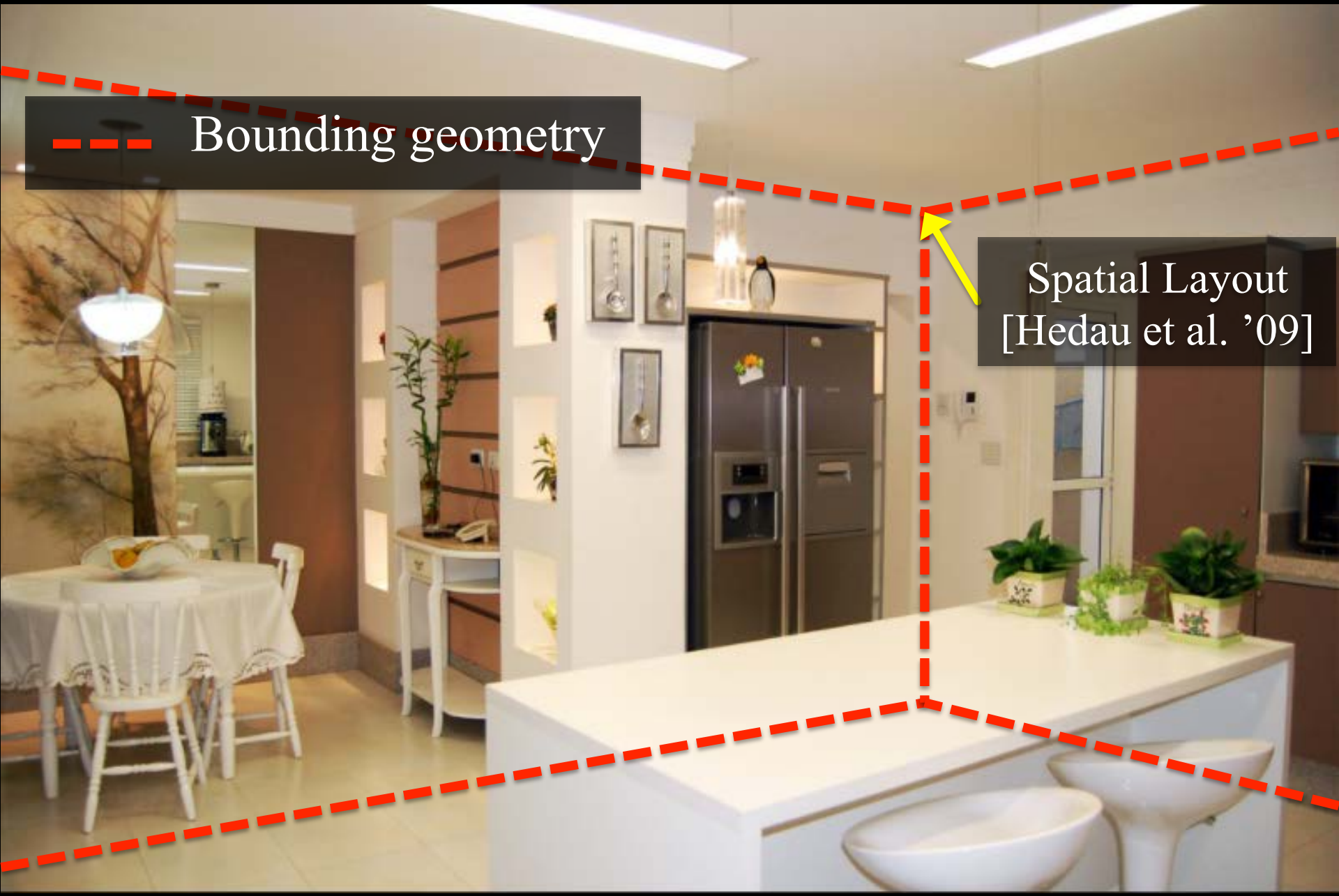
System overview

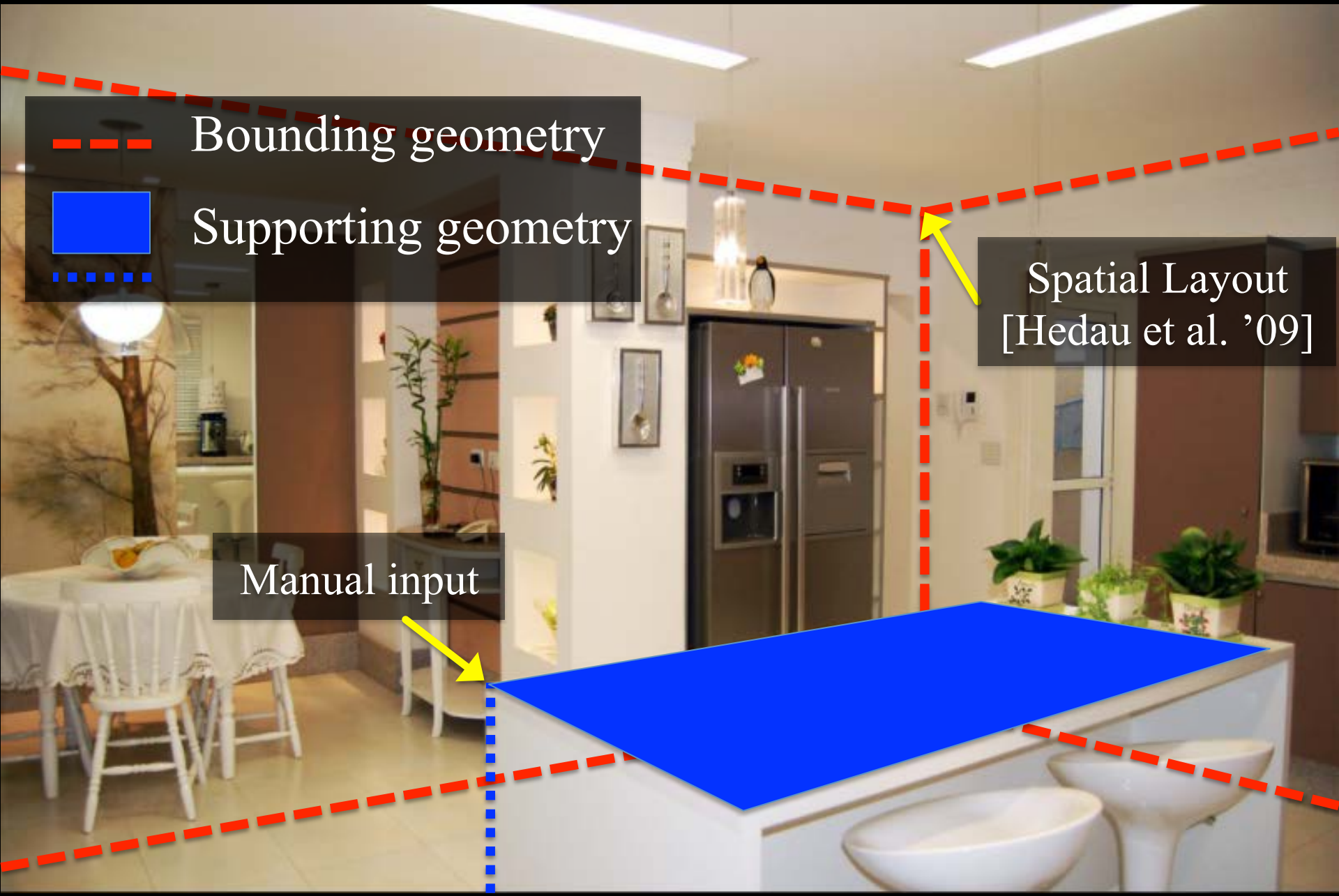
Input image

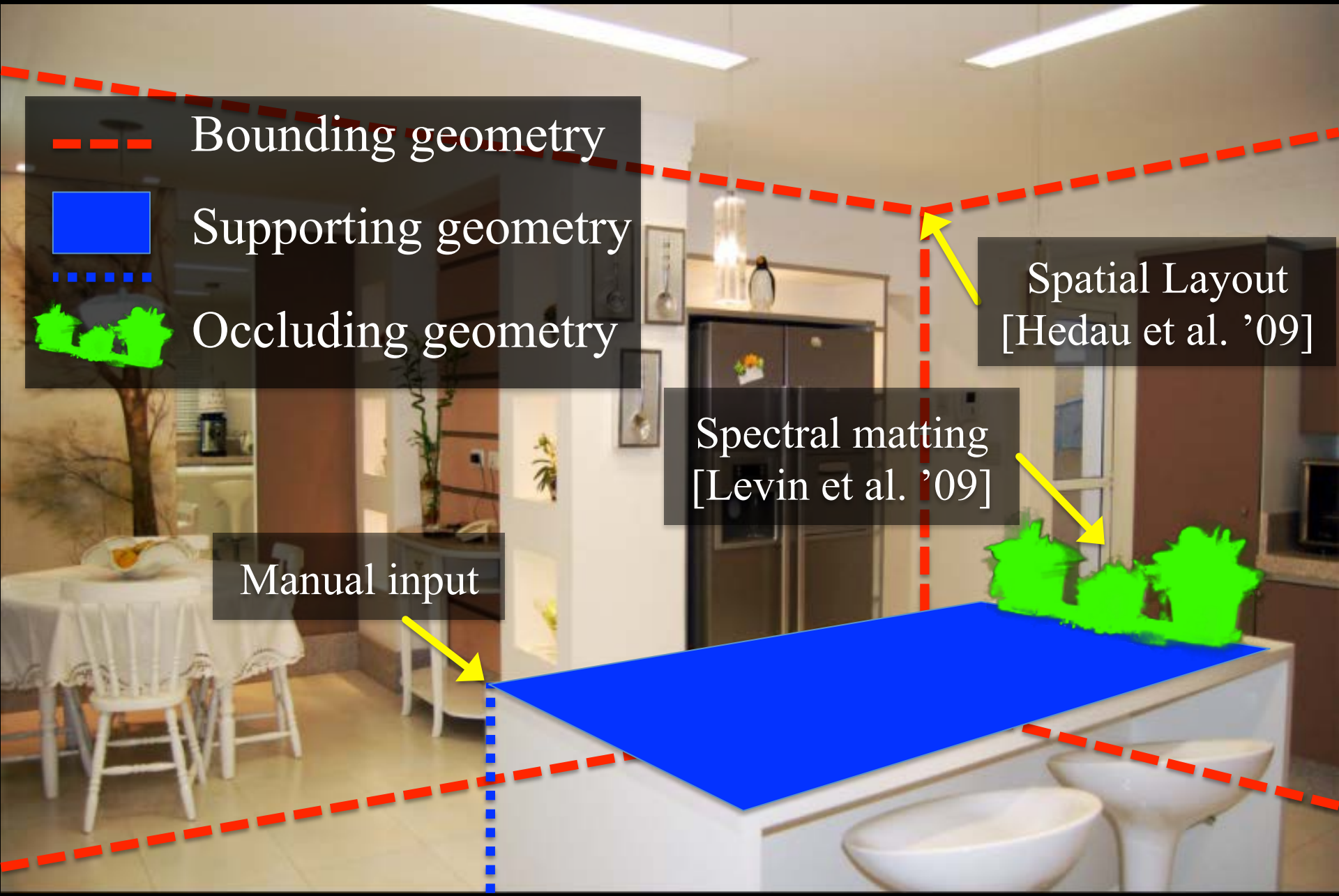
Object insertion

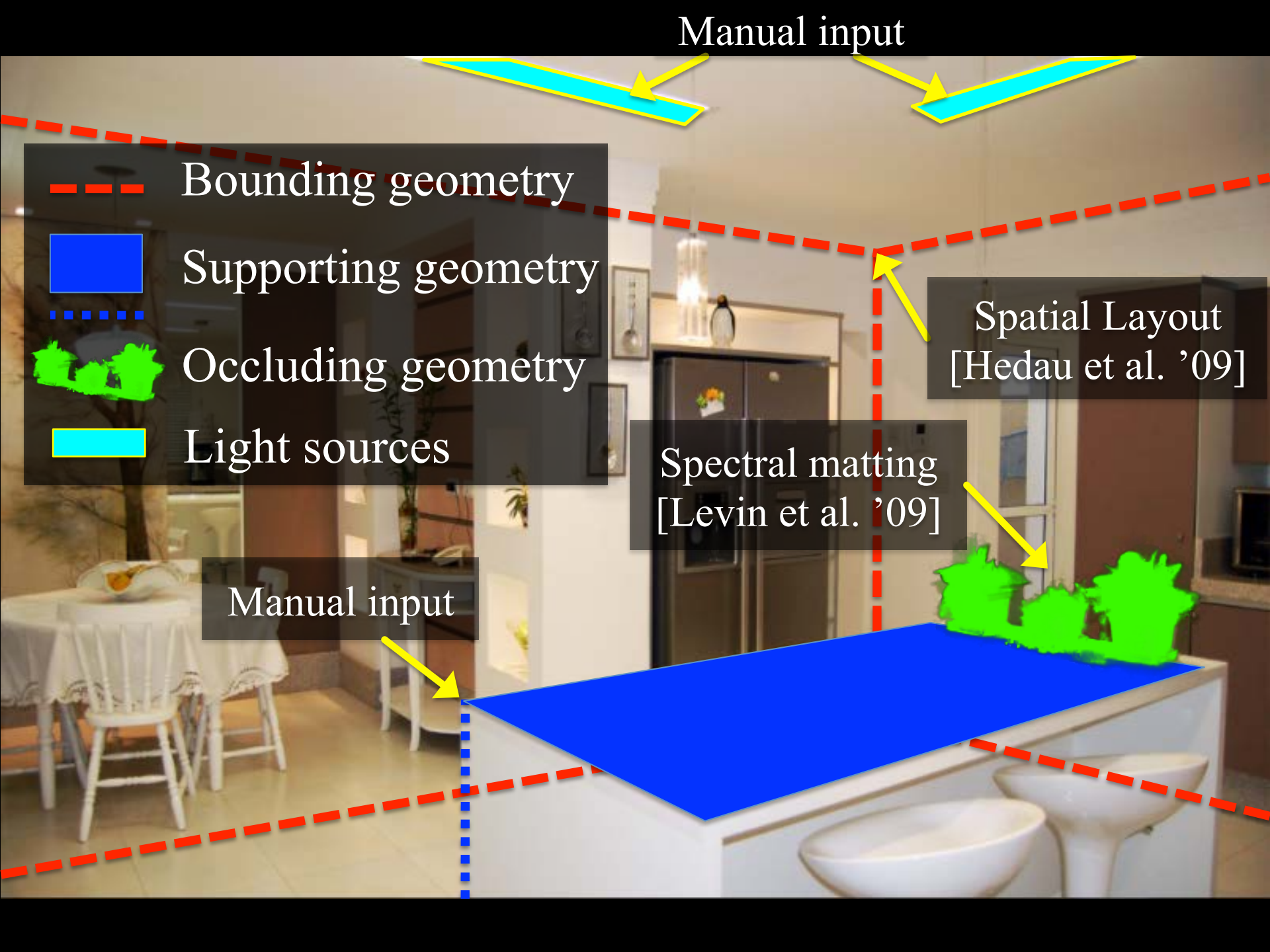
Scene authoring

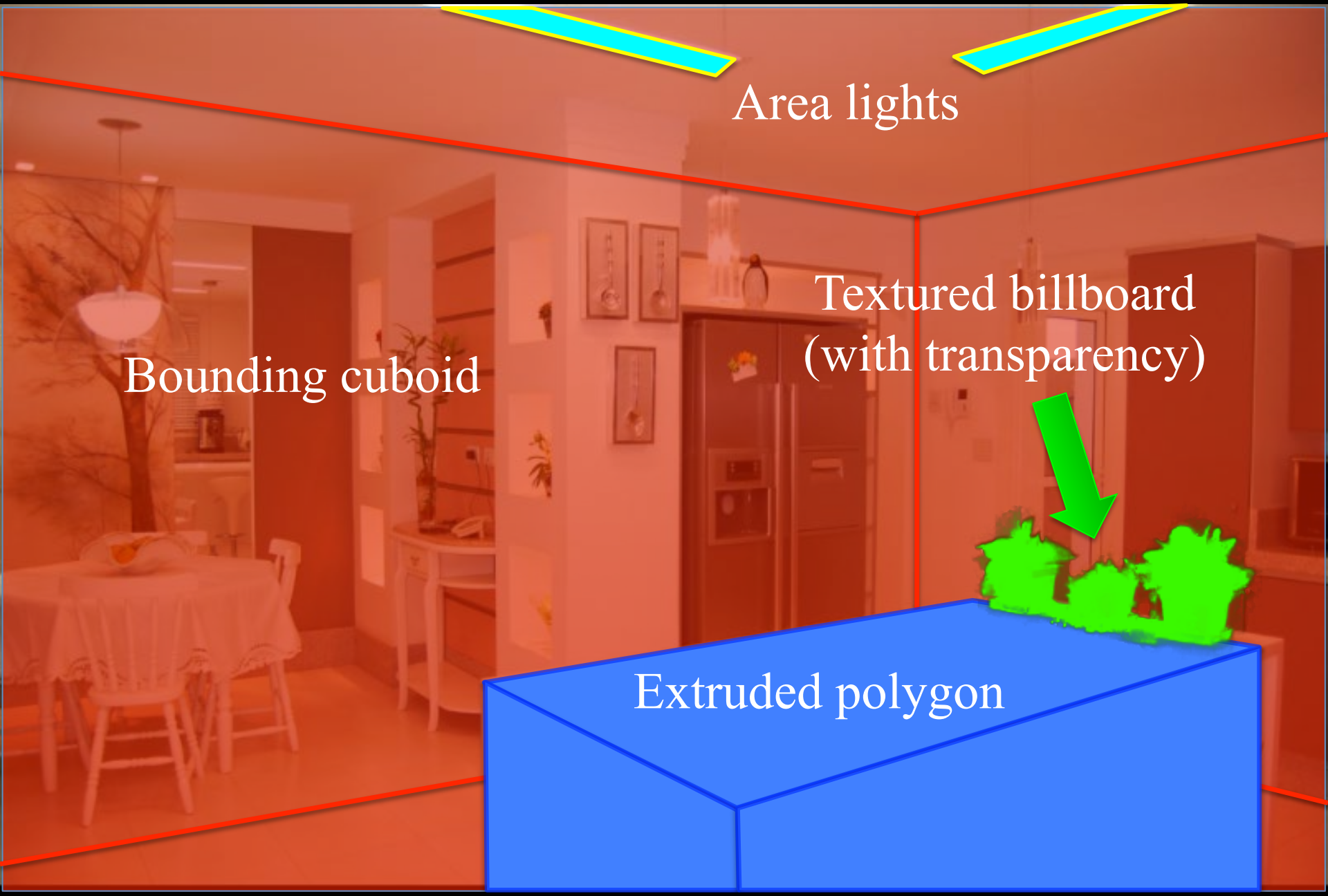
Scene synthesis

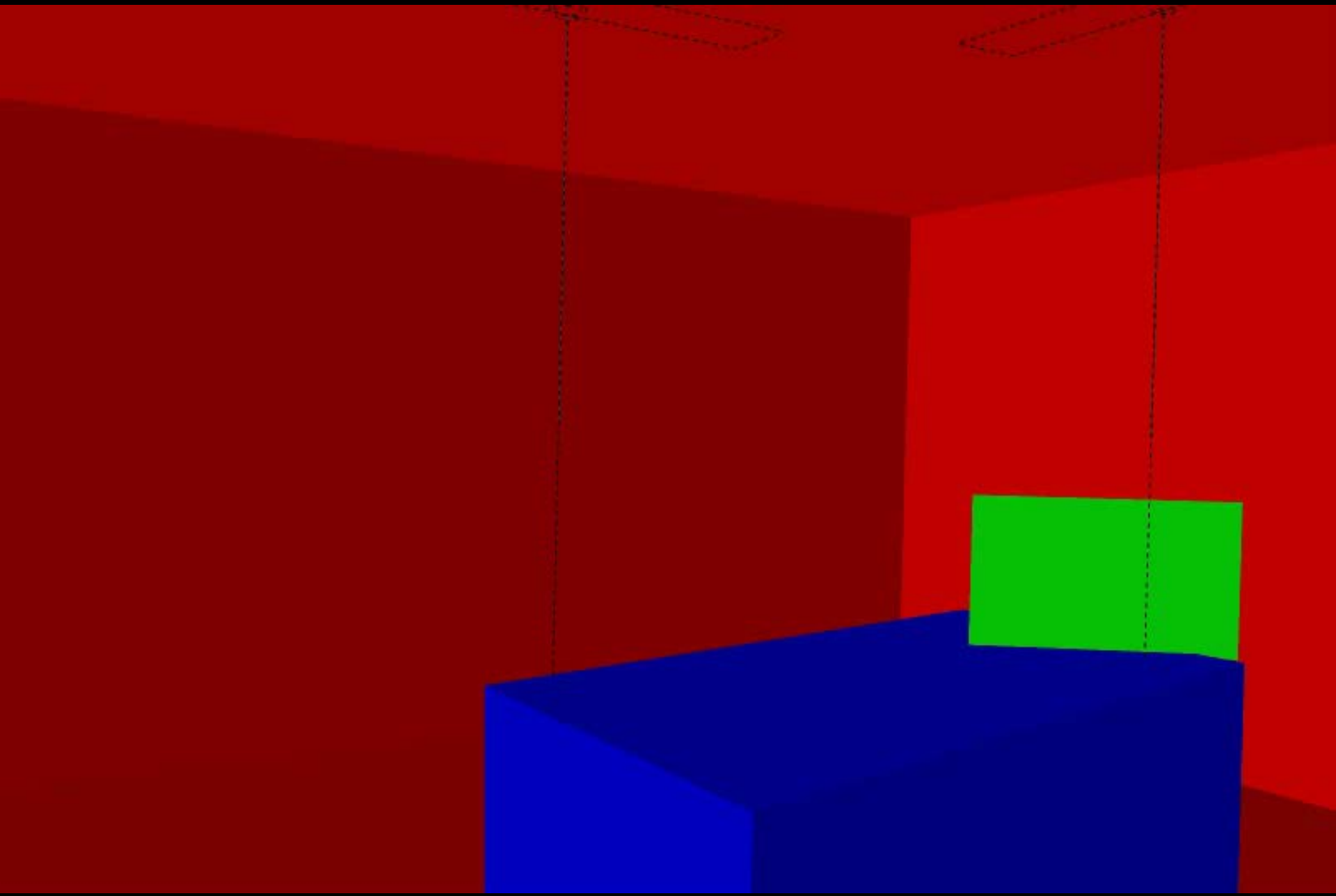

Bounding geometry
Spatial Layout
[Hedau et al. ’09]

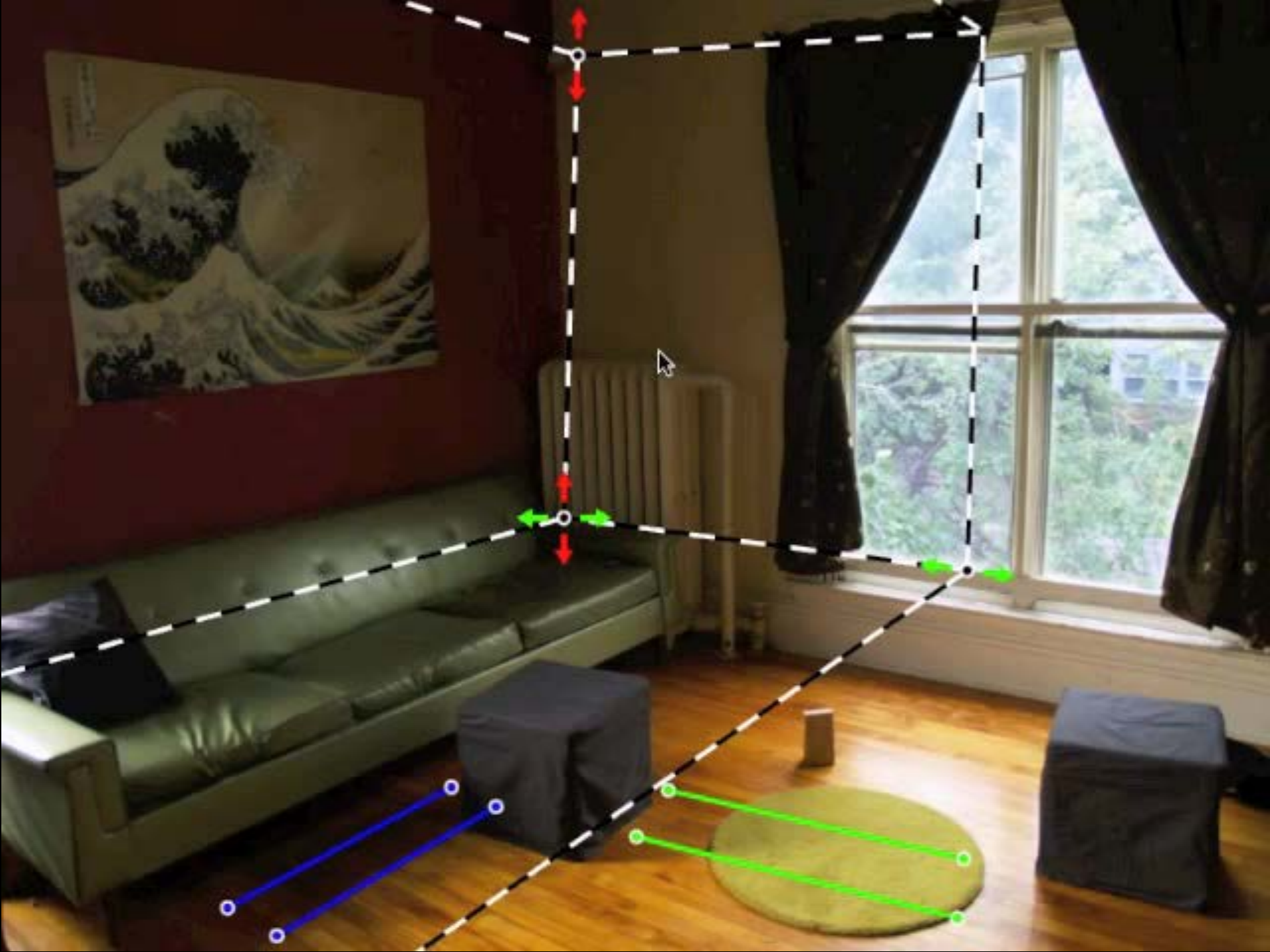

Bounding geometry
Supporting geometry
Spatial Layout
[Hedau et al. '09]
Manual input


Bounding geometry
Supporting geometry
Occluding geometry
Spatial Layout
[Hedau et al. '09]
Spectral matting
[Levin et al. '09]
Manual input


Manual input
Bounding geometry
Supporting geometry
Occluding geometry
Light sources
Spatial Layout
[Hedau et al. '09]
Spectral matting
[Levin et al. '09]
Manual input


Area lights
Textured billboard
(with transparency)
Bounding cuboid
Extruded polygon





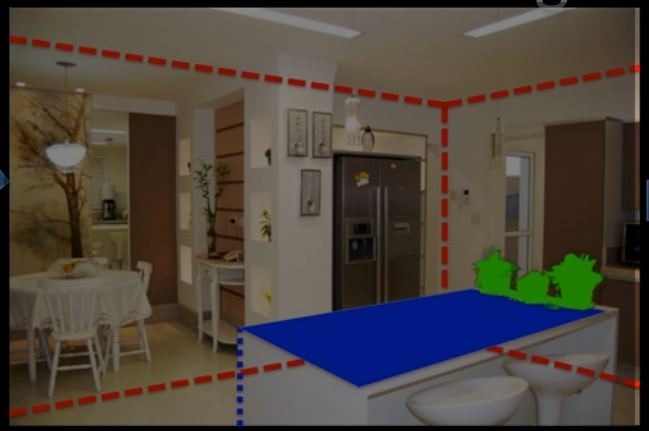

GOLFER

System overview

Input image

Object insertion

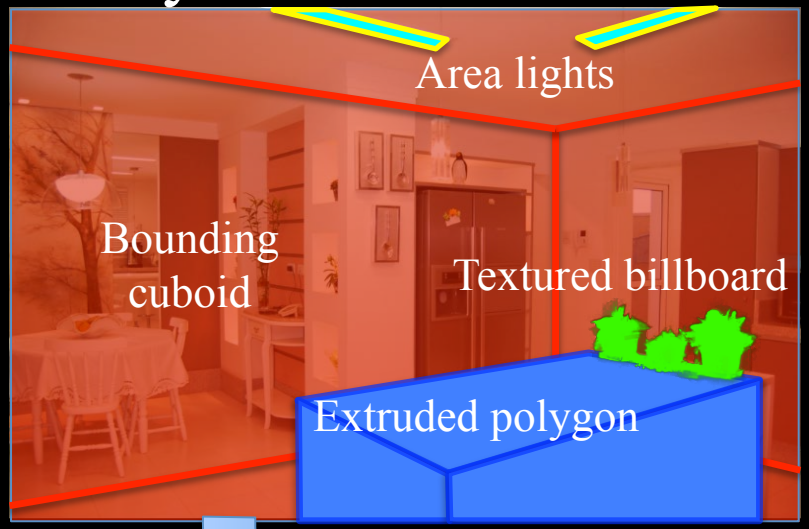
Scene authoring



Scene synthesis

Scene synthesis

Physical scene model



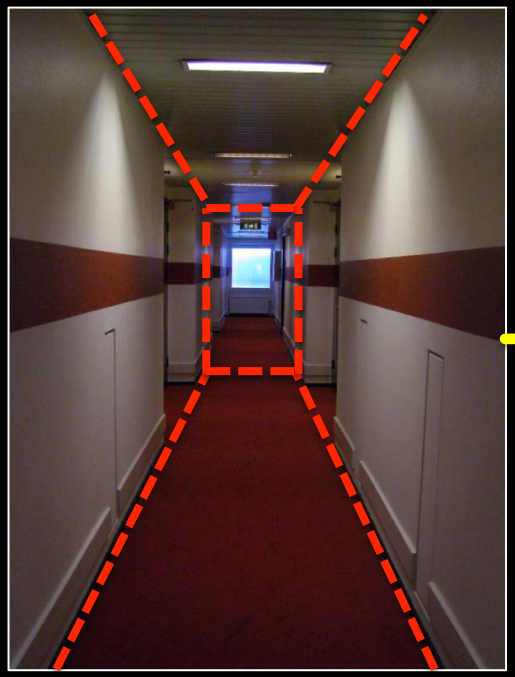
Rendered scene

Auto-material estimation
&
Auto-lighting refinement

Match input image and rendered scene

Material estimation

Input + geometry



Retinex-like decomposition

Lighting estimation

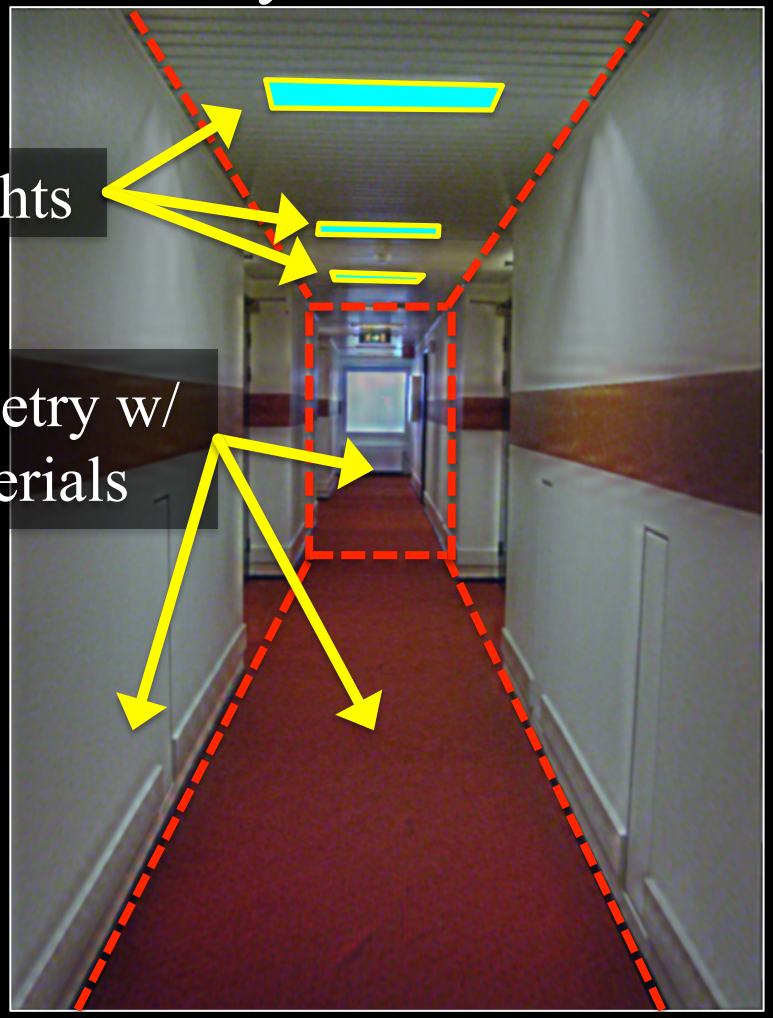
Input image

Physical model

Lighting estimation

Input image

Physical model



Lighting estimation

Input image

Rendered (initial)

Rendered (final)

Lighting estimation

$$\arg\min_{L} ||I - R(L)||$$

Input image

Rendered (initial)

Rendered (final)

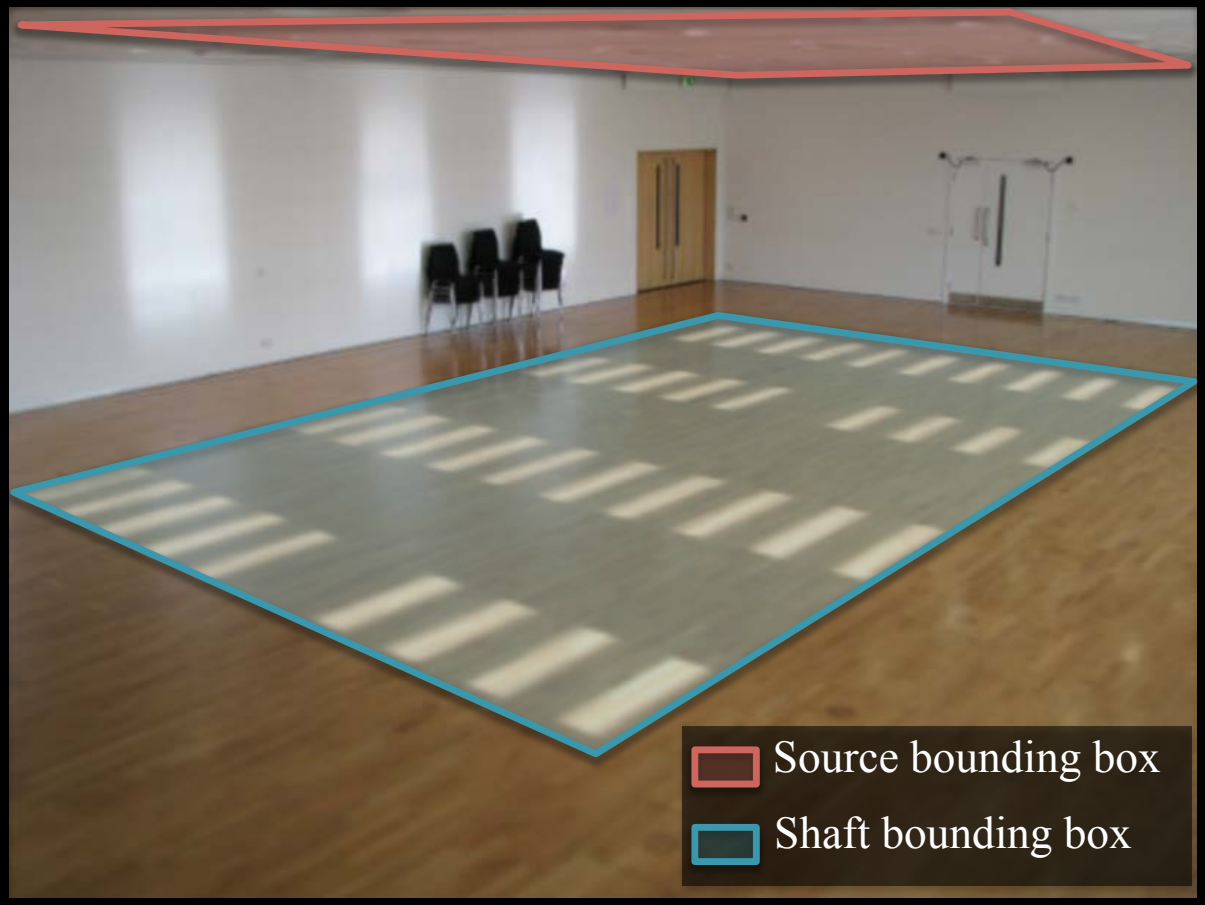
Lighting estimation

Result using **initial** lights

Result using **refined** lights

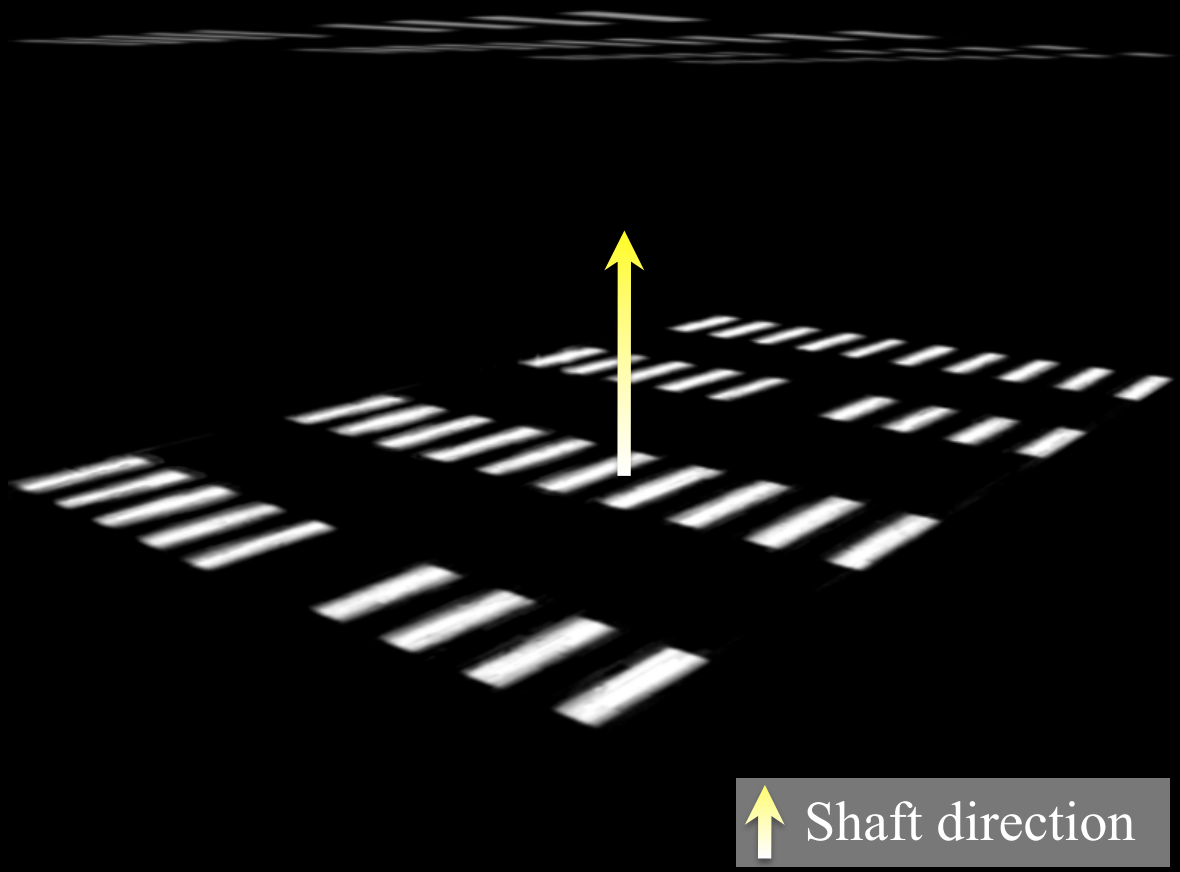
External lighting

External lighting



External lighting

Shadow matting via [Guo et al. ‘11]

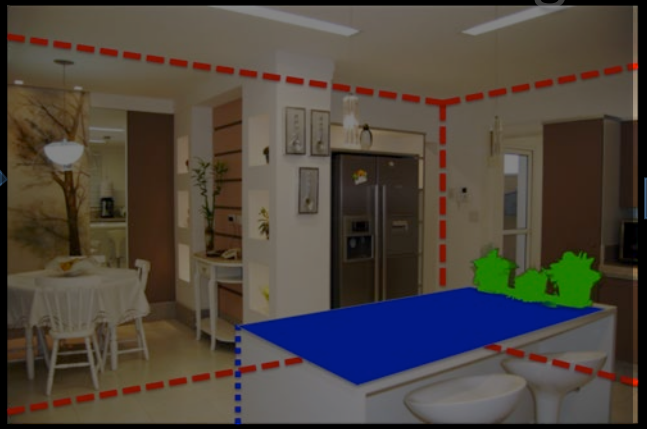


System overview

Input image

Object insertion

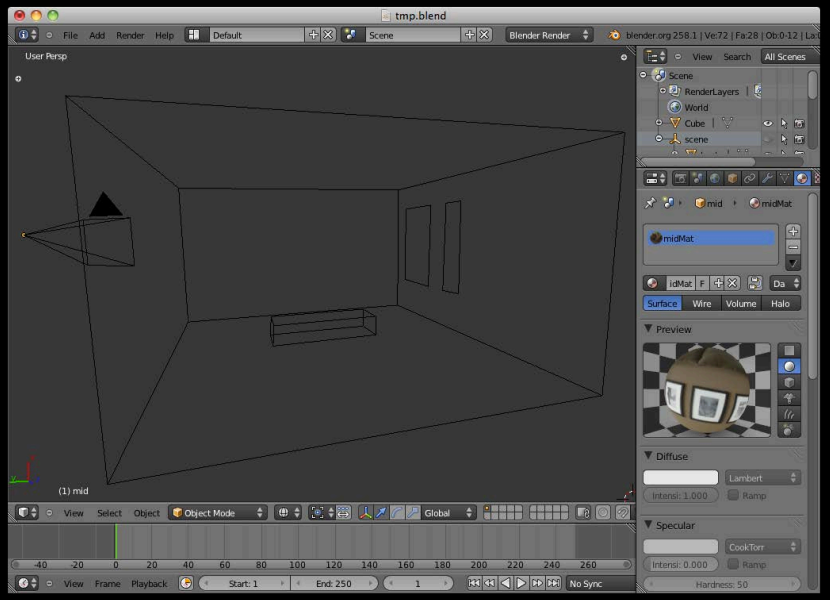
Scene authoring



Scene synthesis

Inserting objects

- Load scene into 3D modeler
- Insert objects, animations
- Render with any physically based renderer



tmp.blend

Scene

Blender Render

blender.org 258.1 | Ve:72 | Fa:28 | Ob:0-12 | La:0

View Search All Scenes

Scene

RenderLayers

World

Cube

scene

mid midMat

midMat

idMat F Da

Surface Wire Volume Halo

Preview

Diffuse

Lambert

Intensi: 1.000 Ramp

Specular

CookTorr

Intensi: 0.000 Ramp

Hardness: 50

(1) mid

View Select Object Object Mode Global

-40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260

View Frame Playback Start: 1 End: 250 1 No Sync

Scene graph

tmp.blend

Scene

Blender Render

blender.org 258 | Ve:72 | Fa:28 | Ob:0-12 | La:0

View Search All Scenes

Scene

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World

Cube

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mid midMat

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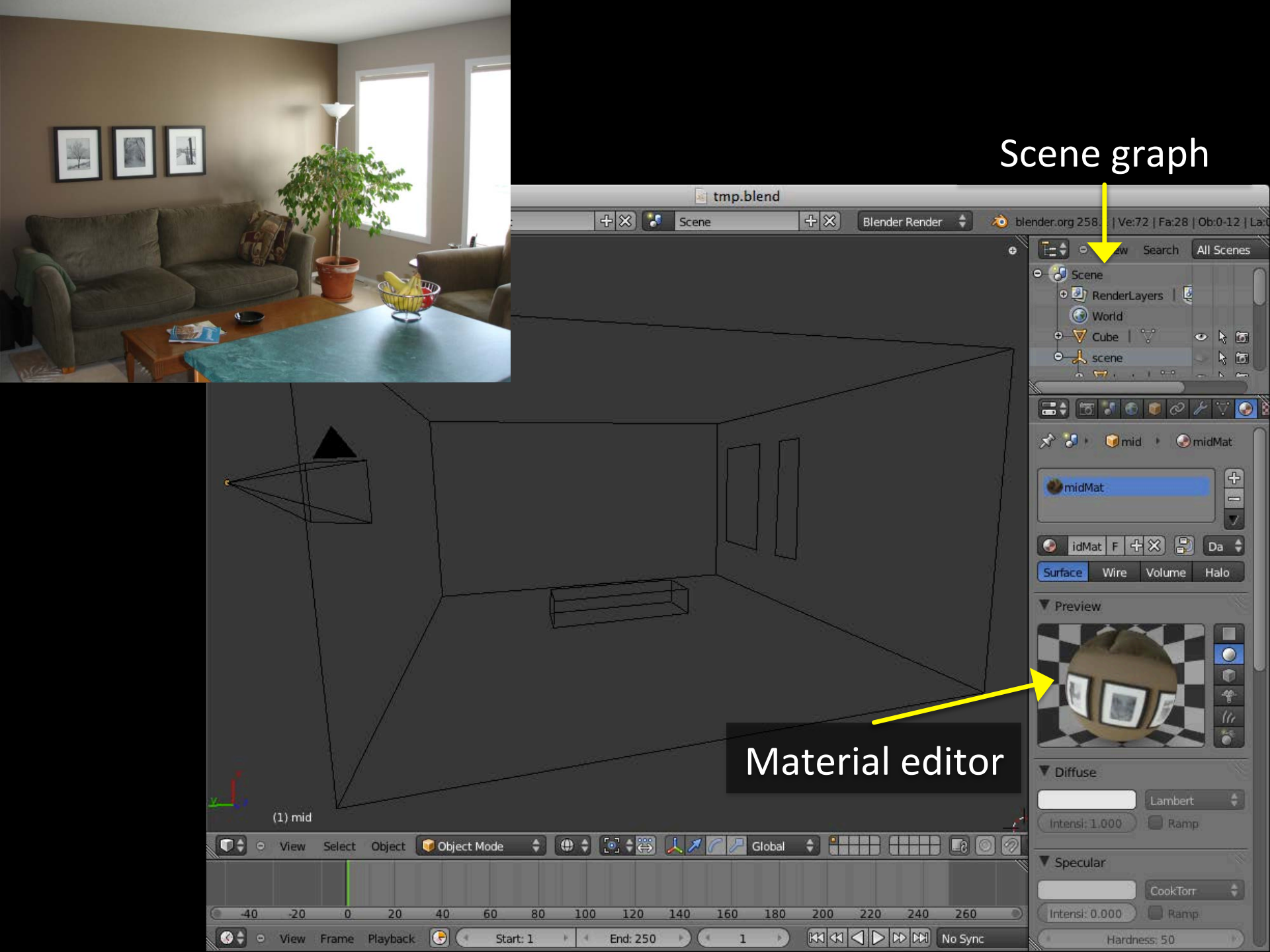
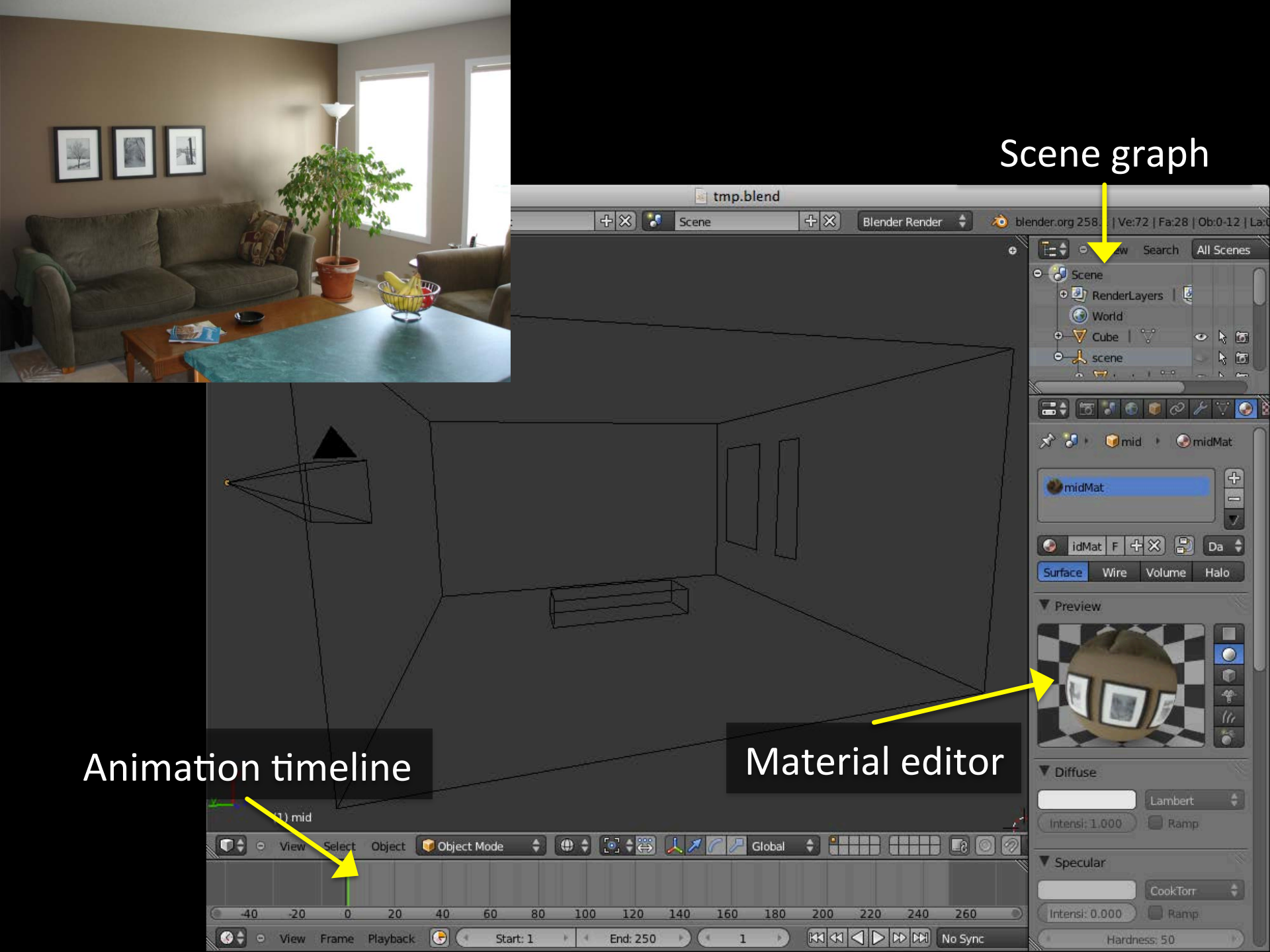
-40 -20 0 20 40 60 80 100 120 140 160 180 200 220 240 260

View Frame Playback Start: 1 End: 250 1 No Sync


Scene graph
tmp.blend
Scene
Blender Render
Search
All Scenes
RenderLayers
World
Cube
scene
mid
midMat
Surface
Wire
Volume
Halo
Preview
Material editor
Diffuse
Lambert
Intensi: 1.000
Ramp
Specular
CookTorr
Intensi: 0.000
Hardness: 50
(1) mid
View
Select
Object
Object Mode
Global
Frame
Playback
Start: 1
End: 250
No Sync


Scene graph
tmp.blend
Scene
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Search
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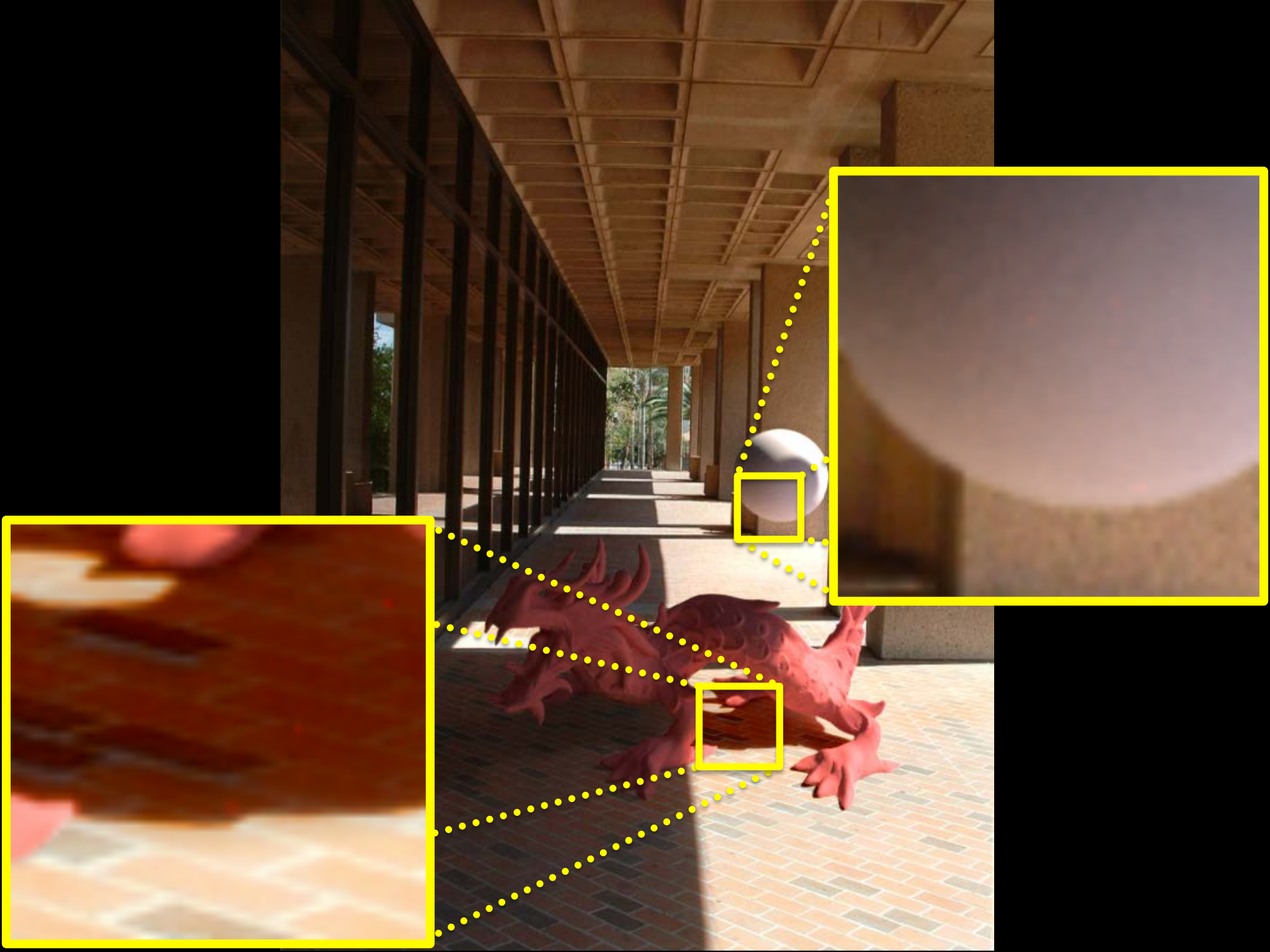
Surface
Wire
Volume
Halo
Preview
Diffuse
Lambert
Specular
CookTorr
Material editor
Animation timeline
View
Select
Object
Object Mode
Global
Frame
Playback
Start: 1
End: 250
No Sync

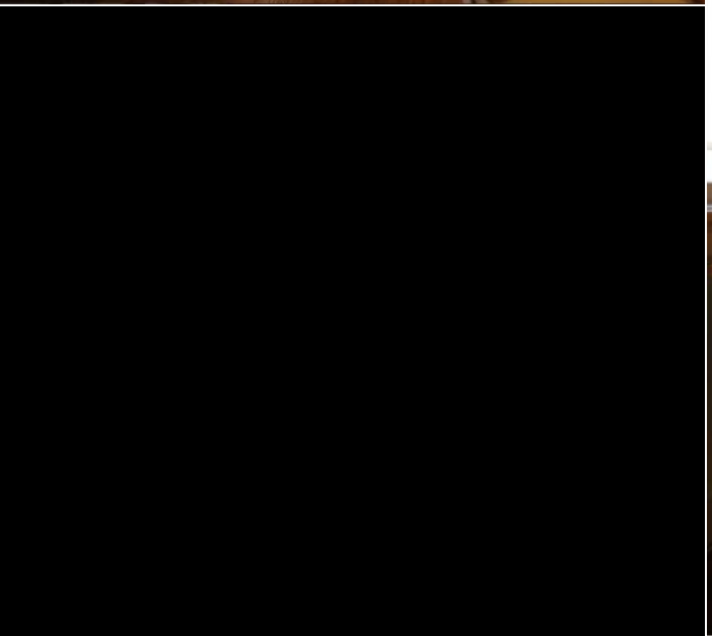
Final composite

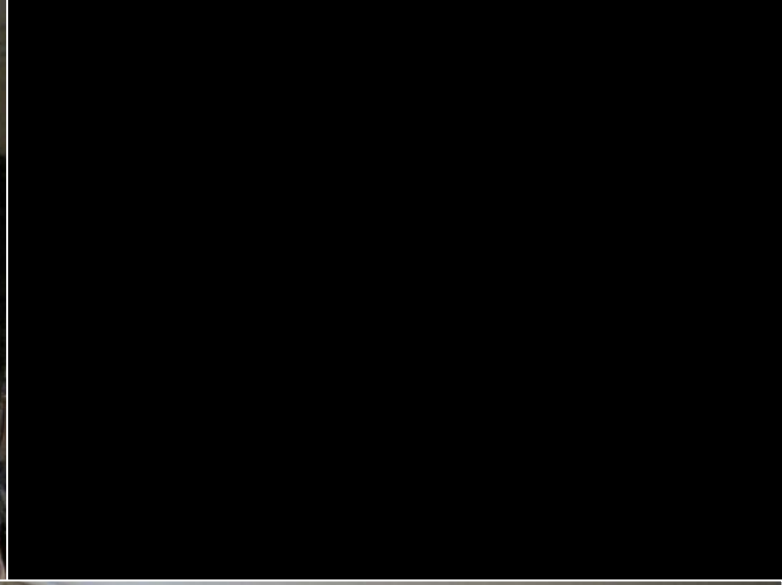
Additive differential technique [Debevec '98]

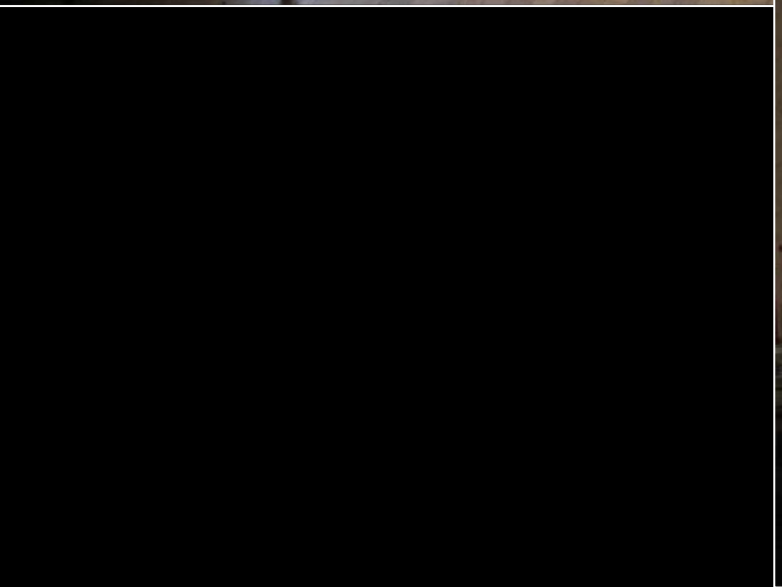
$$\mathcal{I}_{final} = M \odot \mathcal{I}_{obj} + (1 - M) \odot (\mathcal{I}_b + \mathcal{I}_{obj} - \mathcal{I}_{no\_obj})$$

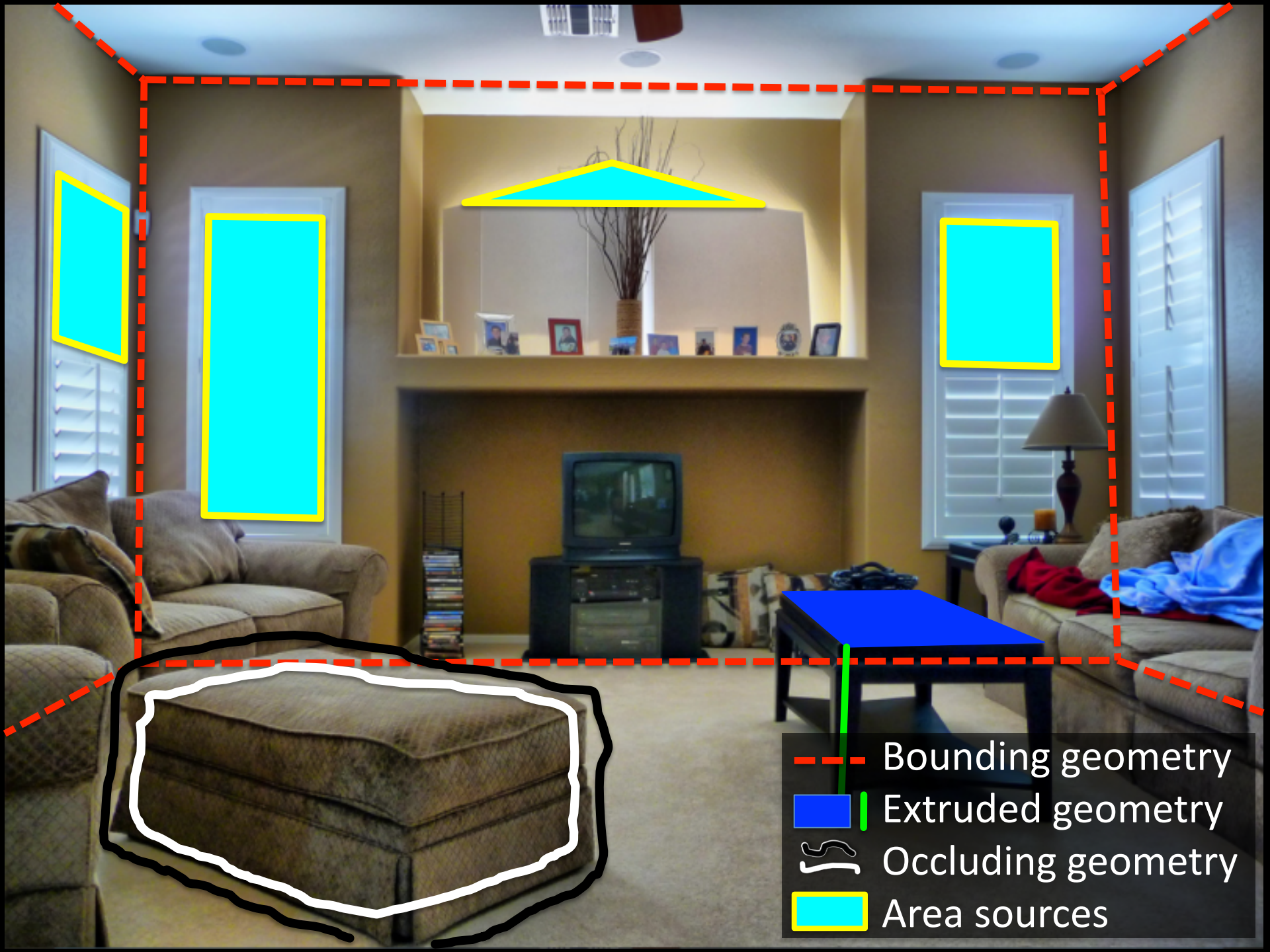
Results

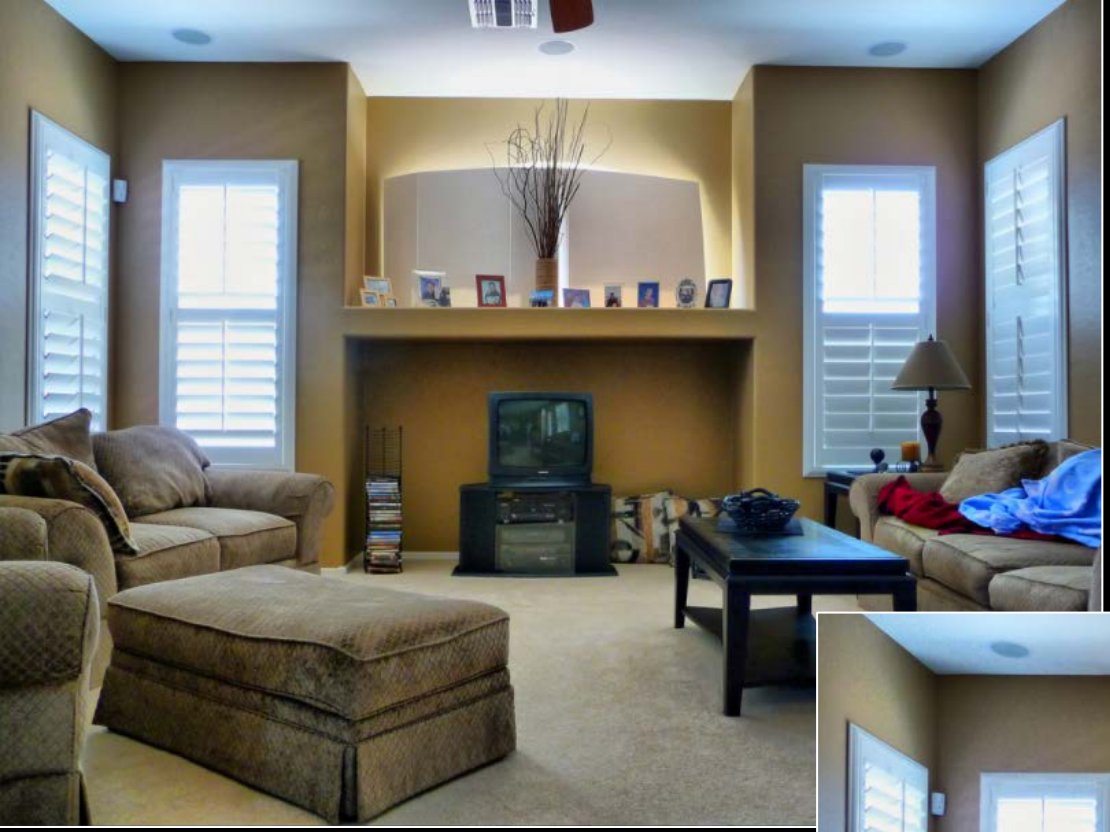








Bounding geometry
Extruded geometry
Occluding geometry
Area sources

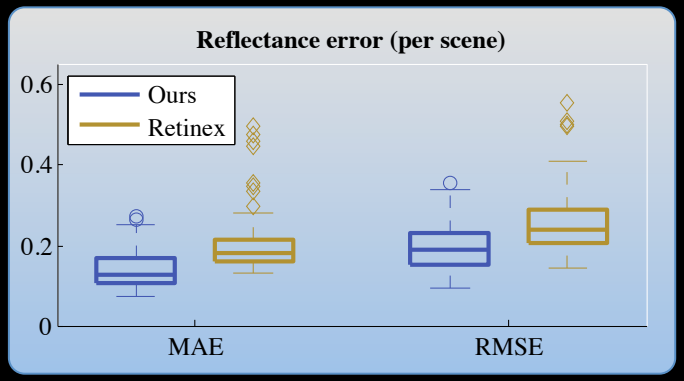


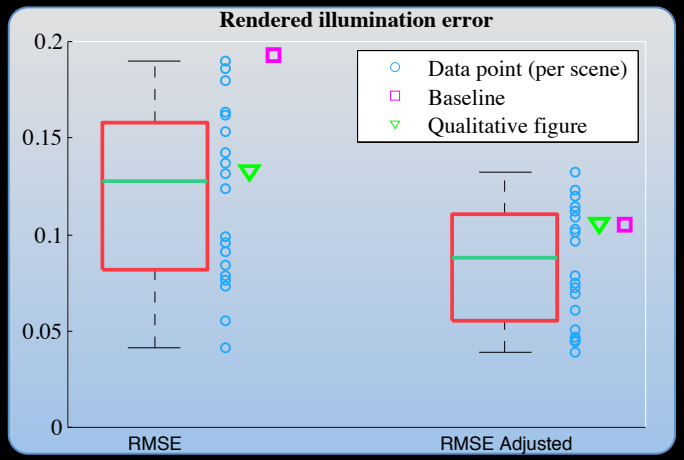
Quantitative Evaluation

- Collected ground truth illumination and reflectance datasets

- Our reflectance method outperforms Retinex

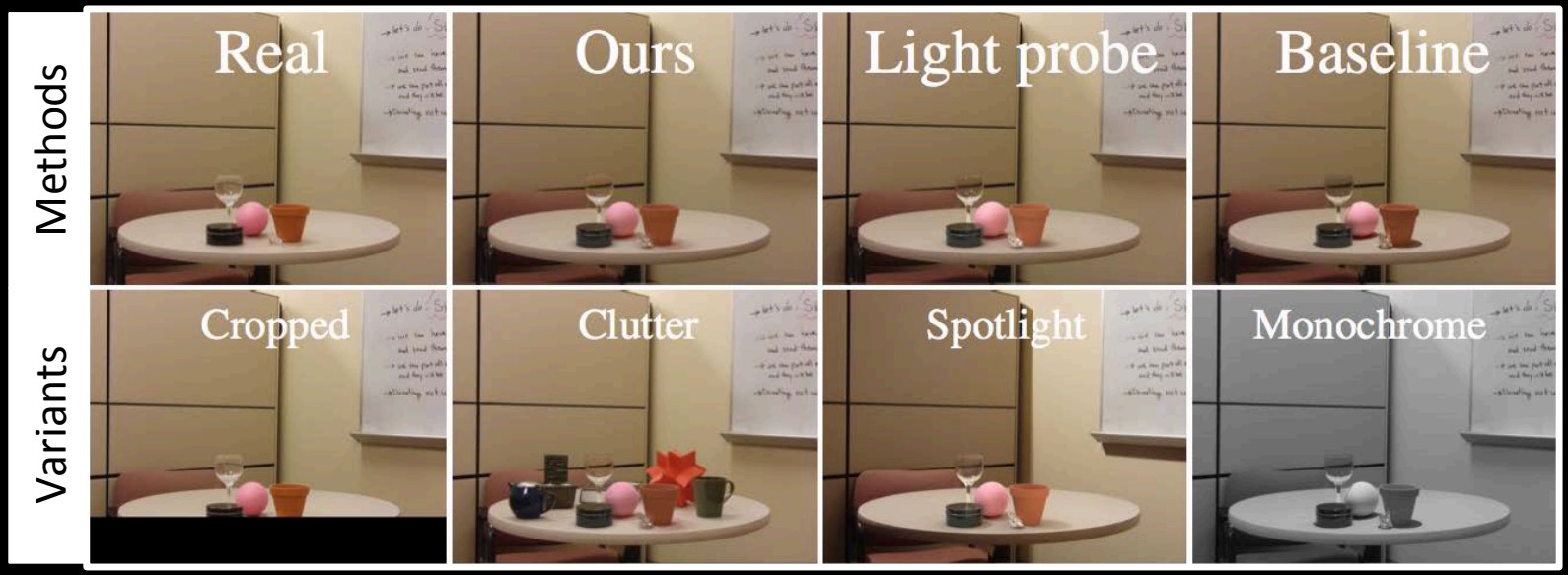
- Our renderings more accurate than baseline





User study

- How does our method compare to real images?
- How does our method compare to other insertion techniques?
- Two-alternative forced choice: choose the *most realistic* image from each image pair

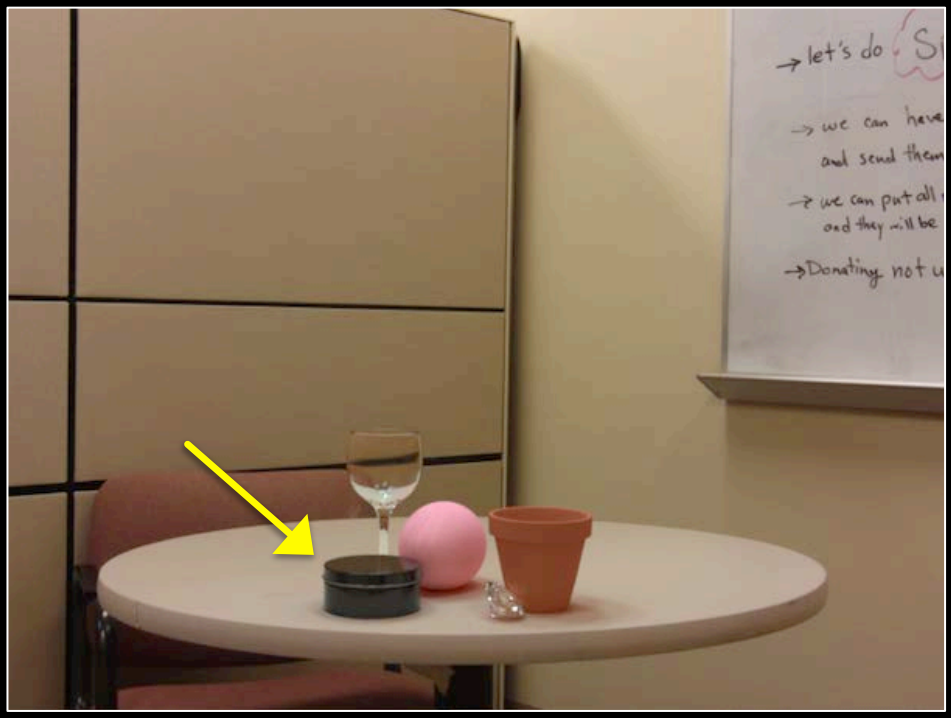



→ let's do
→ we can
and send
→ we can put
and they will be
→ Donating


→ let's do
→ we can
and send
→ we can put
and they will be
→ Donating

Table reflection?

Table reflection?



Photographer reflection?

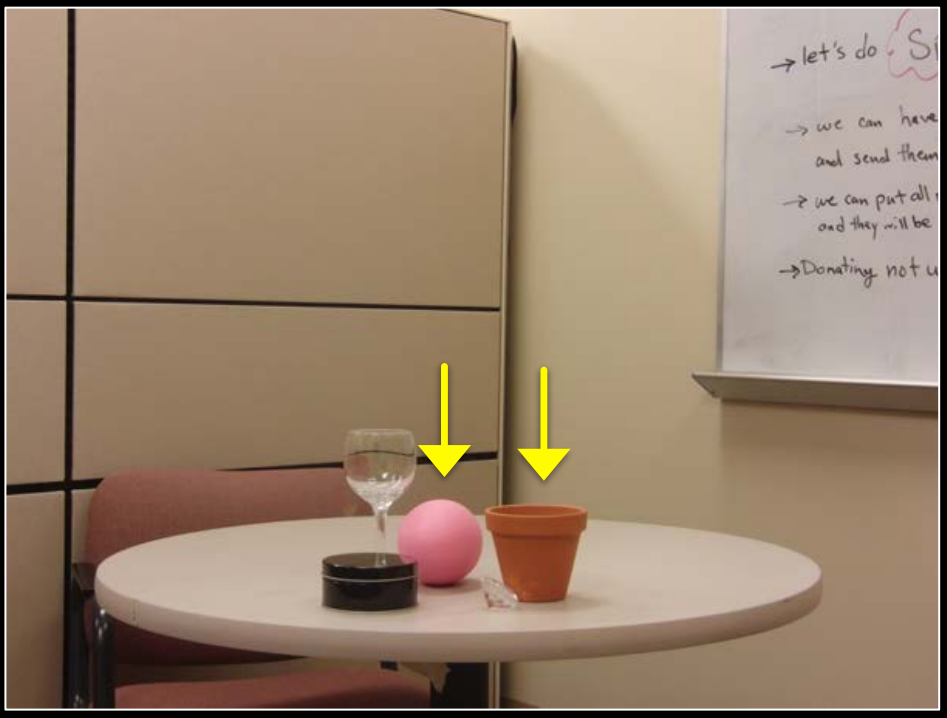


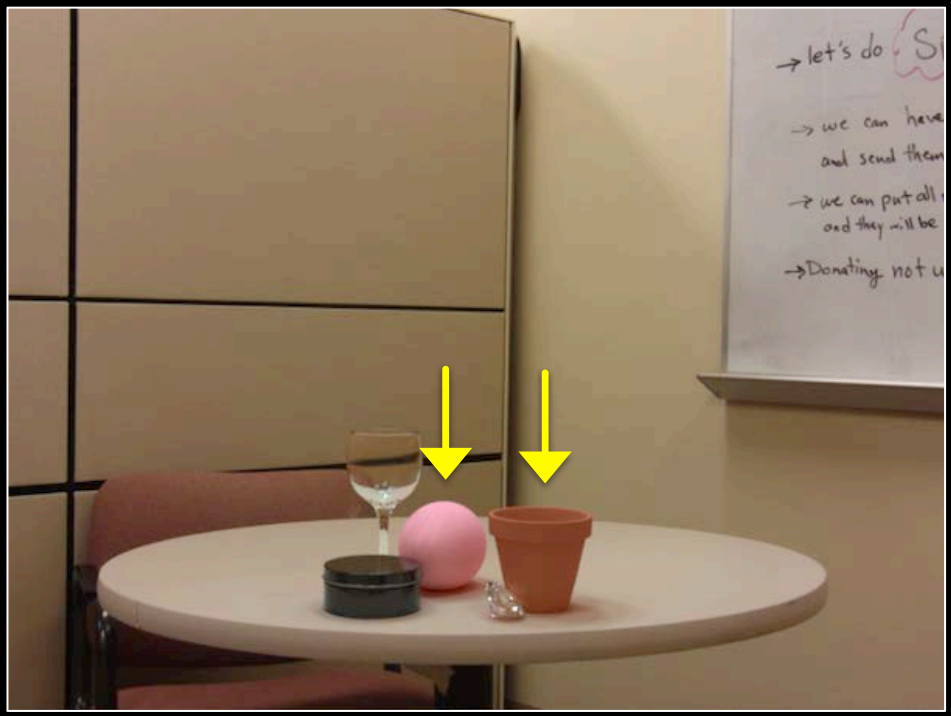
Table reflection?

Too dark?

Photographer reflection?

Table reflection?

Too dark?



Photographer reflection?

Too bright?

Table reflection?

Too dark?

Fake object?

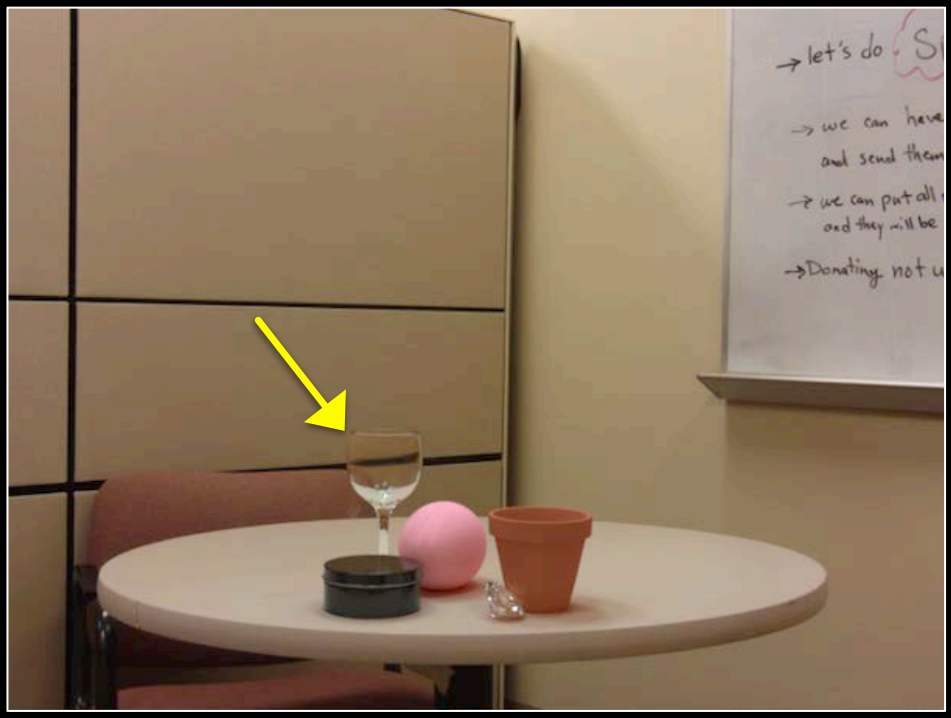
Photographer reflection?

Too bright?

Table reflection?

Too dark?

Fake object?



Photographer reflection?

Too bright?

Glass IOR?

Table reflection?

Too dark?

Fake object?

No shadows?

Photographer reflection?

Too bright?

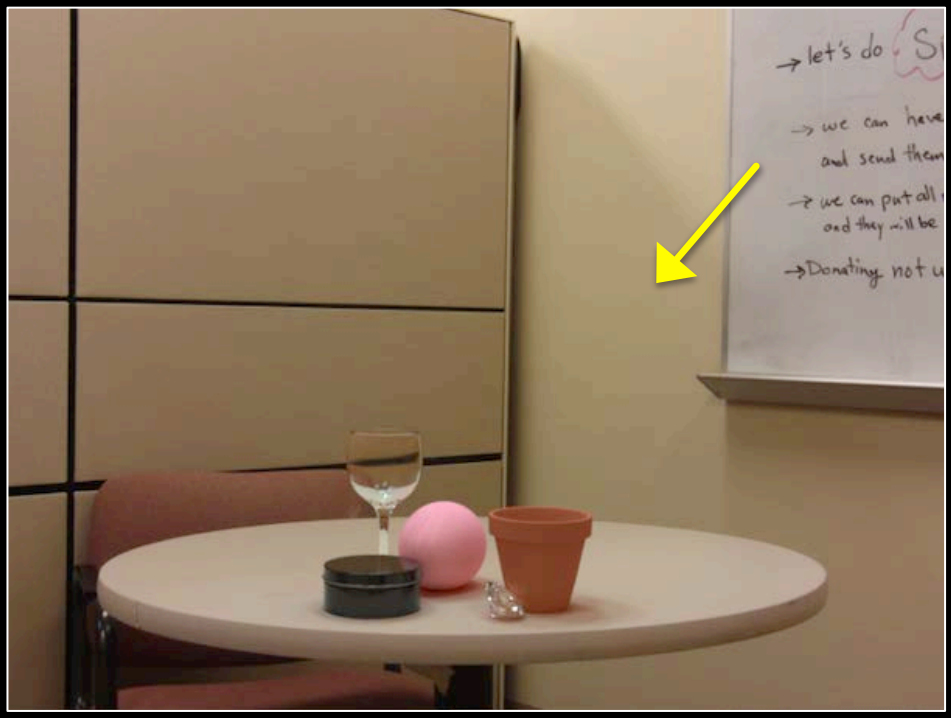
Glass IOR?

Table reflection?

Too dark?

Fake object?

No shadows?



Photographer reflection?

Too bright?

Glass IOR?

Rendering noise?

Table reflection?

Too dark?

Fake object?

No shadows?

Photographer reflection?

Too bright?

Glass IOR?

Rendering noise?

(post-session commentary!)

Table reflection?

Too dark?

Fake object?

No shadows?

Photographer reflection?

Too bright?

Glass IOR?

Rendering noise?

(post-session commentary!)

Study results

- All three methods are highly realistic
- Our method fooled people more than *our* implementation of the light probe
  - Rankings may change depending material acquisition method
- *Important conclusion*: our method is a plausible alternative if scene is **not accessible**

Future work

- Single image material estimation
- Extend to legacy *videos*
- Image-to-image insertion
- More automation
  - Geometry [Saxena et al. ‘08, Lee et al. ’10, Liu et al. ‘10]
  - Lighting [Wang and Samaras ’03, Lopez-Moreno et al. ‘10]

Conclusion

- Quick, easy method for inserting objects into legacy images
  - Interactively obtain 3D scene with minimal input
- Scene refinement compensates for inaccuracy in geometry and material estimates
- Output compatible with popular modeling tools and physically based renderers

Thanks!

Online demo will be available soon!

http://kevinkarsch.com/publications/sa11.html