The image as a virtual stage

Adapted from slides by Kevin Karsch
Now

• Inserting objects into *legacy* photos
  – Uses single-view geometry and image-based lighting concepts
The polygonal mesh

- Discrete representation of a surface
  - Represented by vertices -> edges -> polygons (faces)
...into this
...into this
Insert these...
Inserting 3D objects into photographs

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

- **Arbitrary lighting environments**

- **Intuitive, quick and easy to create content**
  - Home planning/redecoration
  - Movies (visual effects)
  - Video games
Challenges

• Estimate a physical scene model including:
  – Geometry
  – Surface properties
  – Lighting info
  – Camera parameters
System overview

Input image

Object insertion

Scene authoring

Scene analysis
Overview of getting geometry and lighting
Remember Tour into the Picture? This is also a box model, but camera doesn’t have to face the back wall
- Three vanishing points
Bounding geometry

Supporting geometry

Manual input

Spatial Layout [Hedau et al. '09]
- Bounding geometry
- Supporting geometry
- Occluding geometry
- Light sources

Manual input

Spectral matting [Levin et al. ’09]

Spatial Layout [Hedau et al. ’09]
What the spatial layout provides
Extruded geometry, billboards enable occlusion
Box, supporting surfaces enable *object placement*
Box, extruded geometry, lighting enables *shadows*, *inter-reflections*, *caustics*
Camera geometry ensures correct *perspective*
Modeling occlusions
User-defined boundary

- Tedious/inaccurate
- How can we make this better?
Segmentation with graph cuts

\[
\text{Energy}(y; \theta, \text{data}) = \sum_i \psi_1(y_i; \theta, \text{data}) \sum_{i,j \in \text{edges}} \psi_2(y_i, y_j; \theta, \text{data})
\]
User-defined boundary
Refined segmentation
Spectral Matting
Spectral Matting

- Create NxN matrix describing neighboring pixel similarity (Laplacian matrix, L)
- Extract “smallest” eigenvectors of L
- Soft segmentation defined by linear combination of eigenvectors
  - Scribbles provide constraints to assign to foreground

[“Spectral Matting” Levin Rav-Acha Lischinski 2008]
Spectral matting
Spectral matting
Segmentations as “billboards”
Segmentations as “billboards”
Rendering via ray tracing

- Camera
- Image
- View Ray
- Light Source
- Shadow Ray
- Scene Object
Rendering via ray tracing

- Camera
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- Light Source
- View Ray
- Shadow Ray
- Scene Object
Insertion without relighting
...with relighting
Estimating light

• Light sources visible in images.
• Light sources not visible in images.
• Shafts.
Lighting estimation
Lighting estimation
Lighting estimation
Light refinement

Match original image to rendered image

\[
\text{argmin}_L E_{\text{render}}(L) + E_{\text{prior}}(L)
\]

Trust initial light parameters

Match rendered image with input

Input

Initial sources

Geometry

Reflectance

Refined sources
Initial light parameters
Refined light parameters
External light shafts
External light shafts
External light shafts

Shadow matting via Guo et al. [2011]
External light shafts

How to set direction of the shaft in 3D?
Setting light shaft direction

\[ x_2 = \begin{pmatrix} x_2 \\ y_2 \\ 1 \end{pmatrix} \]

\[ x_1 = \begin{pmatrix} x_1 \\ y_1 \\ 1 \end{pmatrix} \]
Light shaft result
Final composite

Additive differential technique [Debevec 1998]

composite = M.*R + (1-M).*I + (1-M).*(R-E)*c

$I$ (background)  \hspace{2cm} \text{composite}

$R$ (rendered)  \hspace{2cm} $E$ (empty)  \hspace{2cm} $M$ (mask)
Inserting objects

• Representation of geometry, materials and lights is now compatible with 3D modeling software

• Two methods of insertion/interaction
  – Novice: image space editing
  – Professional: 3D modeling tools (e.g. Maya)

• Scene rendered with physically based renderer (e.g. LuxRender, Blender’s Cycles)
Blender demo
Putting it all together (2011): Video

Summary

• We can accurately predict how a 3D object would look in a depicted scene by recovering
  – Viewpoint: camera matrix, single view geometry
  – Scene geometry: single-view geometry
  – Material: “intrinsic image approaches”
  – Lighting: solve for lights such that rendering reproduces image