Computational Photography

End of Semester

• Today is the last lecture!
• Friday is *office hours (in lecture room) + movie (TBA)*… (attendance optional)
• Quiz on Tuesday
  – Sample problems are posted on course website
• Final Project Presentations
  Fri May 8th, Tues May 12th
  – Attendance mandatory (please don’t be late!)
  – No laptops/phones/etc. allowed during your classmates’ presentations
  – You will be giving each other written feedback & peer grade
  – Ask good questions (participation grade)
• Presentation 10pts (peers)
• Project Report 20pts (instructor)
Final Presentation

- Summarize prior work as necessary
  - You don’t need to discuss papers we covered in class
- Be technical:
  - What were the challenges?
  - How did you solve them?
- Live demo / video / lots of images (depends on project)
  - Use plenty of examples (both of success & failure)
- Teams of 2:
  - Both should present & make it clear who did what
- Practice! & time yourself!
  - We have a tight schedule
  - I will stop you midsentence if you run over

Final Presentation Schedule

<table>
<thead>
<tr>
<th>Fri May 8th</th>
<th>Tues May 12th</th>
</tr>
</thead>
<tbody>
<tr>
<td>2:00 Matte &amp; Jeremy</td>
<td>2:00 Anthony &amp; Nick</td>
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<tr>
<td>2:25 Xitu &amp; Tim</td>
<td>2:25 Ben &amp; Jonathan</td>
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<tr>
<td>2:50 Andrew</td>
<td>2:50 Jim</td>
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<tr>
<td>3:05 Sam &amp; Kevin</td>
<td>3:05 Kyle &amp; Jay</td>
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<tr>
<td>3:20 Jaron</td>
<td>3:30 Rachel &amp; Michael</td>
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<tr>
<td>3:45 Brian &amp; Jesse</td>
<td>3:55 move to Ricketts 203!</td>
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<tr>
<td>4:10 Keaton</td>
<td>4:00 Robert</td>
</tr>
<tr>
<td>4:25 Karl &amp; Austin</td>
<td>4:15 David &amp; Dwight</td>
</tr>
<tr>
<td>4:50 done!</td>
<td>4:40 done!</td>
</tr>
</tbody>
</table>

Total time (including setup & questions):
15 min (individual), 25 min (team of 2)
Last Time?

- Texture Synthesis
- Markov Model
- Image Completion
- Volumetric Texture Synthesis

“I spent an interesting evening recently with a grain of salt.”

Reading for today:

- Coarse to fine completion
- Confidence & traversal order
- Search for best match over different scales, rotations, & resolutions (texture frequency)
- Compositing fragments

“Fragment-based image completion”, Drori, Cohen-Or, Yeshurun, SIGGRAPH 2003
• Fragment based image completion
  – Confidence values good idea
  – Math/algorithm easy to understand (but details for blending more complex)
  – Search for match with different translations & different rotations & different scales
    (unfortunately very expensive running time)
  – Slow
  – Like photoshop’s magic eraser
  – Description of limitations (3D things, lighting)
  – Carefully chosen examples
  – Lots of great results. Perspective wall example really impressive (demonstrates need for the rotations & scales!)
  – In the future will we be able to remove/repair even more complicated models?

• Texture synthesis by Non-Parametric Sampling
  – Results look natural, some artifacts
  – Difficult to read, a bit boring
  – Lots of probability notation

• Fast Texture Synthesis using Tree-structured Vector Quantization
  – Details in captions but not in regular text (more difficult to read), huge captions overall
  – Dependence on reader knowing TSVQ
    • Not guaranteed optimal, but fast and well spaced data, so “close-enough”
  – Pyramids for mipmapping
  – Some awkward results, loss of regularity
  – Good ideas for extensions (temporal synthesis)
  – Good table of symbols
Today

• Structure From Motion
• Multi-viewpoint Rendering
• Matting & Compositing
• Helmholtz Reciprocity
• Light Fields

Structure From Motion

• Input: Sequence of frames (e.g., video) of a moving object (or moving camera)
• Output: Approximate geometry of object & camera pose for each frame
• How?
  – Automatically detect features in each frame
  – Determine correspondences between features
  – Infer camera calibration & object geometry
• Humans do it all the time… but it’s a really hard problem!
Photo Tourism

Finding Paths through the World's Photos,
Snavely, Garg, Seitz, & Szeliski, SIGGRAPH 2008
Photo tourism: Exploring photo collections in 3D,
Snavely, Seitz, & Szeliski, SIGGRAPH 2006

Reading Comments

• Finding Paths through the World’s Photos
  – Computer vision + computer graphics
  – SIFT keypoints
  – What if people don’t take good photos?
  – Lighting adjustment & removal/separate treatment of foreground would improve the overall quality of the results
  – Resulting video is indeed helpful for exploring / understanding a new 3D environment
“Image Based Tree Modeling”, Tan et al., SIGGRAPH 2007

“Approximate Image-Based Tree-Modeling using Particle Flows”, Neubert et al., SIGGRAPH 2007

Figure 1: A tree is modeled using a set of input photographs. We show some examples of input and resulting 3D tree models. If image information is not available, e.g. the foliage is missing, the user is able to sketch it (right). The models approximate the input images while forming botanically plausible branching structures.
Image-Based Modeling and Photo Editing
Oh, Chen, Dorsey, & Durand, SIGGRAPH 2001

Figure 1: St Paul’s Cathedral in Melbourne. (a) Image segmented into layers (boundaries in red). (b) Hidden parts manually clone brushed by the user. (c) False-color rendering of the depth of each pixel. (d) New viewpoint and relighting of the roof and towers.

“Video Matching”,
Sand & Teller, SIGGRAPH 2004

Figure 10: Texture-illuminance decoupling. (a) Input image. (b) Initial illuminance estimation using simple Gaussian filtering. (c) Initial texture estimation, note the artifacts corresponding to shadow boundaries. (d) Texture computed using bilateral filtering.
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Multi-Viewpoint Panoramas

“Photographing long scenes with multi-viewpoint panoramas”, Agarwala, Agrawala, Cohen, Salesin, & Szeliski, SIGGRAPH 2006
Multi-Viewpoint Panoramas

• Like many non-photorealistic rendering methods, this paper aims to mimic the style of a particular artist or style of art

• Well designed user interface:
  – Most components automated
  – User can adjust dominant plane, view selection, seams, & inpainting
Multi-Perspective Rendering

J. Yu & L. McMillan
“A Framework for Multiperspective Rendering”
Eurographics Symposium on Rendering 2004

Opening Scene from Disney’s Pinocchio
Photo Montage

• David Hockney

http://www.hockneypictures.com/photos/photos_collages_05_large.php
Questions?

Today

- Structure From Motion
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- Matting & Compositing
- Helmholtz Recipocity
- Light Fields
“Environment Matting and Compositing”
Zongker, Werner, Curless, & Salesin, SIGGRAPH 1999
Today

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- Light Fields

Helmholtz Reciprocity

- BRDF is symmetric: % of light reflected from direction $i$ off surface point $p$ to direction $j$ is the same as the % of light reflected from direction $j$ off surface point $p$ to direction $i$
Helmholtz Reciprocity

“Dual Photography”, Sen, Chen, Garg, Marschner, Horowitz, Levoy, & Lensch, SIGGRAPH 2005

“Dual Photography”, Sen, Chen, Garg, Marschner, Horowitz, Levoy, & Lensch, SIGGRAPH 2005

Figure 16: Dual photography with indirect light transport. (a) A projector illuminates the front of a playing card while the camera sees only the back of the card and the diffuse page of the book. An aperture in front of the projector limits the illumination only onto the card. The card was adjusted so that its specular lobe from the projector did not land on the book. Thus, the only light that reached the camera underwent a diffuse bounce at the card and another at the book. (b) Complete camera view under room lighting. The back of the card and the page of the book are visible. It seems impossible to determine the identity of the card from this point of view simply by varying the incident illumination. To acquire the transport matrix, a 3 x 3 white pixel was scanned by the projector and 5742 images were acquired to produce a dual image of resolution 66 x 87. (c) Sample images acquired when the projector scanned the indicated points on the card. The dark level has been subtracted and the images gamma-corrected to amplify the contrast. We see that the diffuse reflection changes depending on the color of the card at the point of illumination. After acquiring the T matrix in this manner, we can reconstruct the dual image (d). It shows the playing card from the perspective of the projector being indirectly lit by the camera. No contrast enhancement has been applied. Note that the resulting image has been automatically antialiased over the area of each projector pixel.
Today

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• Light Fields

Light Fields

Plenoptic Modeling: An Image-Based Rendering System, McMillan & Bishop, SIGGRAPH 1995


Light Field Rendering, Levoy & Hanrahan, SIGGRAPH 1996
Unstructured Lumigraph Rendering”
Buehler et al. SIGGRAPH 2001

Figure 1: When available, approximate geometric information should be used to determine which source rays correspond well to a desired ray.

Figure 2: When a desired ray passes through a source camera center, that source camera should be emphasized most in the reconstruction.

Figure 7: A visualized color blending field. Camera weights are computed at each pixel. This example is from the “hallway” dataset.
**Light Field Camera**

- *After* taking the photograph, we can:
  - Adjust focus
  - Change viewpoint
  - Change illumination
  - & more?

Light Field Photography with a Hand-Held Plenoptic Camera, Ng, Levoy, Bredif, Duval, Horowitz, & Hanrahan, Stanford Tech Report, 2005

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“Coded Rolling Shutter Photography: Flexible Space-Time Sampling” Gu, Hitomi, Mitsunaga, & Nayar, ICCP 2010
Global Shutter vs. Rolling Shutter plus Coded
Interlaced vs. Staggered
Skew Compensation
High Speed Photography
Interpolation of High Resolution
High Dynamic Range
Adaptive Row-wise Auto Exposure
Simulation ➔ Prototype Camera Hardware

“Coded Rolling Shutter Photography: Flexible Space-Time Sampling” Gu, Hitomi, Mitsunaga, & Nayar, ICCP 2010

Yeah! Last lecture!!