Special Topics: Image-based Rendering

Computer Graphics
CMU 15-462/15-662
So—why haven’t we “solved” graphics yet?
The “Mustache” controversy

Justice League (2017)
Budget: 300 Million USD
Graphics is still hard!

- Creating photorealistic images from scratch takes a lot of effort
- Hard to recreate complex geometry and lighting effects found in photos like this:
IDEA: What about replacing geometry and reflectance models with photos?
The “Bullet Time” Effect

Bullet Time Effect: Behind the Scenes

The Matrix
Image-based Rendering

- Skip modeling geometry and material reflectance properties
- Instead, capture sets of photos (e.g., with different viewpoints or under different illumination) that can be used to render novel images of a scene
  - light field rendering: *photorealistically* change camera viewpoint or other parameters (e.g., focus)
  - image-based relighting: generate *photorealistic* images under synthetic illumination conditions

http://graphics.stanford.edu/projects/lightfield/
Light Field Rendering (with synthetic images)

"Light Field Rendering", Mark Levoy and Pat Hanrahan
Light Field Rendering (with real images)

Lytro Illum Camera
Image-based Relighting

Relighting Results for Optical Arnoldi

Number of photos: 40

"Optical Computing for Fast Light Transport Analysis", O’Toole and Kutulakos
Image-based Relighting

Observation #1

\[
\text{photo with 120 Watt light source} = 2 \times \text{photo with 60 Watt light source} = 2 \times (\text{photo taken with light source emitting } a \times b \text{ Watts}) = a \times (\text{photo taken with light source emitting } b \text{ Watts})
\]
Image-based Relighting

Observation #2

photo with lights 1 & 2 turned on

=  

photo with light 1 turned on

+  

photo with light 2 turned on

photo taken under two light sources = sum of photos taken under each source individually
Image-based Relighting

Observation #2

photo taken under two light sources = sum of photos taken under each source individually
Image-based Relighting

Observation #2

photo taken under two light sources =
sum of photos taken under each source individually
Image-based Relighting

- Simple set of rules can be used to predict the appearance of a scene based on previously-captured images:
  - photo taken with light source emitting $a \times b$ Watts = $a \times$ (photo taken with light source emitting $b$ Watts)
  - photo taken under two light sources = sum of photos taken under each source individually

- We can come up with a complete set of “rules” for working with images $u$, $v$, and $w$ (all lit by different light sources):

<table>
<thead>
<tr>
<th>For all vectors $u$, $v$, $w$ and scalars $a$, $b$:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- $u + v = v + u$</td>
</tr>
<tr>
<td>- $u + (v + w) = (u + v) + w$</td>
</tr>
<tr>
<td>- There exists a zero vector “0” such that $v + 0 = 0 + v = v$</td>
</tr>
<tr>
<td>- For every $v$ there is a vector “$-v$” such that $v + (-v) = 0$</td>
</tr>
<tr>
<td>- $1v = v$</td>
</tr>
<tr>
<td>- $a(bv) = (ab)v$</td>
</tr>
<tr>
<td>- $a(u + v) = au + av$</td>
</tr>
</tbody>
</table>
| - $(a + b)v = av + bv$                             | (Looks familiar!)
Image-based Relighting

Generate new photos by computing weighted combination of images!

(e.g., adding the red channel of image 1 and the blue channel of image 2)
Light Stage 1 from USC: ICT

Source: http://www.pauldebevec.com/Research/LS/
Light Stage 6 from USC: ICT

Source: [http://vgl.ict.usc.edu/Research/RHL/](http://vgl.ict.usc.edu/Research/RHL/)
Mobile Light Stage from USC: ICT

Source: http://gl.ict.usc.edu/Research/PresidentialPortrait/
CG Avatars from Facebook Reality Labs
Want to learn more?

  - Spring 2020: Tuesdays & Thursdays, 1:30pm - 2:50pm

- Shape from Shading
- Illumination Estimation
- Texture Modeling
- Photometric Stereo
- Color Constancy
- Reflection Separation
- Stereo
- Motion