Linearizing the Plenoptic Space

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Goal: synthesize a new view

- Capture/sample the 4D space of rays.
- Use them to reconstruct the missing rays (geometry and color).
- Gold standard method: estimate a geometric proxy, warp rays.
Motivations

- Proxy reconstruction may be a very hard problem.
- Proxy error, refractions, specularities $\Rightarrow$ rendering artifacts.
- Modeling refractions, specularities (BRDF) $\Rightarrow$ assume particular capturing device and *a priori* knowledge of the material.
- Handle sparse/unstructured light field.
- Goal: not render but model for local light field behavior.
Light Field Distortion

- Geometrical distortion (breaks the epipolar geometry).
- Violates the Lambertian assumption.
- Need for more complex geometric and photometric models.
Related Work

- Reconstructing reflective and specular scenes.
  - P. Zhou et al. ICIP ’13, ICIMCS ’14.
  - A. Sulc et al. VMV ’16.
  - Adato et al. PAMI ’10.
- Reconstructing refractive and transparent scenes
  - G. Wetzstein et al. ICCV ’11.
  - E. Iffa et al. SPIE ’12.
Key concepts

- Plenoptic space: space of rays, geometry (4D) and color (3D).
- **Visual point**: set of associated rays.

Adelson et Bergen, '91
Light Field Representation

Light slab parametrization, Levoy et Hanrahan '96.

Epipolar Plane Image (EPI)
Reconstructing the Light Field

- Geometric model

- Photometric model
Overview of the Method

- Plenoptic space sampling.
- Ray parameterization.
- Model fitting.
- Model selection.
- Rendering.
Sampling the Plenoptic Space

- Ray correspondences: optical flow.
- For each **visual point**: set of rays (geometry and color).
- For each ray: uncertainty propagation.
Linearizing the Plenoptic Space

- Geometric and photometric linear models of the visual point: 3g, 4g, 6g, 3p, 9p.
- Weight each contribution by the propagated uncertainty of the measurement.
- Non-linear least square optimization: we maximize the likelihood of the parameters (probability of obtaining the data samples given the estimated parameters).
Model selection

- For each visual point, pick the right model without overfitting.
- Bayesian Information Criterion (BIC):
  - + number of parameters
  - + number of samples
  - + final value of the cost function (likelihood of the estimated parameters).
- Chosen model: minimizes the BIC.

result (3g + 3p)
Rendering a novel camera

• Ray: Intersection between the reconstructed visual point $P$ and the novel camera $C$.
• Color: deduced from the reconstructed ray and the fitted photometric model.
Results

Tarot fine
PSNR: 35.03 DSSIM: 16

Tarot coarse
PSNR: 26.34 DSSIM: 64

original image    result    absolute difference    fitting quality
Results

<table>
<thead>
<tr>
<th>Original Image</th>
<th>Result</th>
<th>Absolute Difference</th>
<th>Fitting Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bracelet</td>
<td>PSNR: 39.93 DSSIM: 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td>PSNR: 35.01 DSSIM: 272</td>
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</tbody>
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Results

original view  3g + 3p  3g + 9p  4g + 9p  6g + 9p
Video
Summary

• Most IBR methods require geometric proxy.
• Proxy imperfections cause rendering artifacts.
• Estimating geometry: cumbersome and fails when:
  – Lambertian assumption violated.
  – Rays do not follow rules of parallax.
• **Contribution:** locally approximate the plenoptic space, captured from unstructured camera configuration, using **visual points**.
• Better reconstruction of specularities and transparencies.
Future work

- Fit non-linear models (quadratic).
- Include a temporal dimension (video, non-static scenes).