Linearizing the Plenoptic Space

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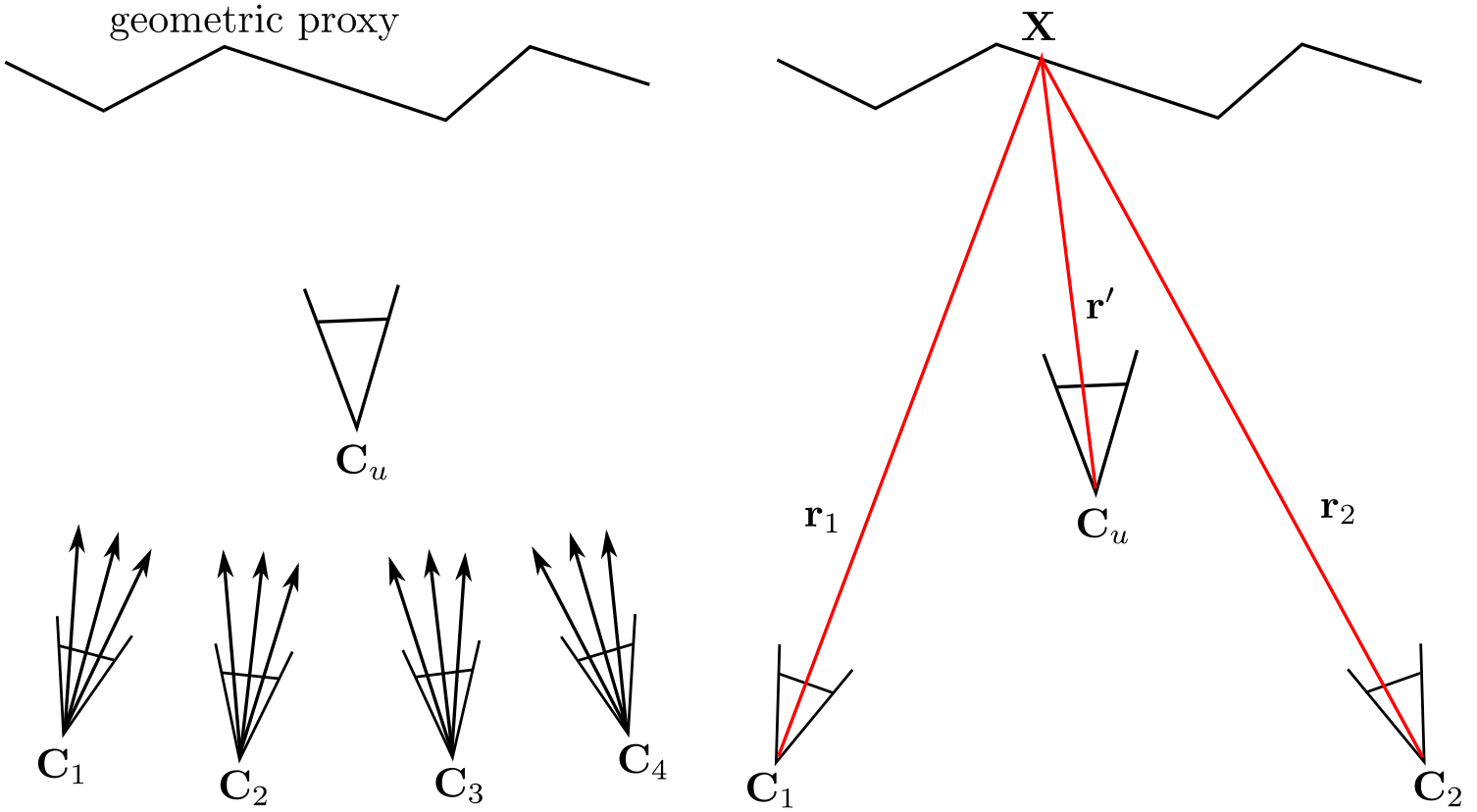
[1] LJK, Université Grenoble Alpes, France
[2] LIG, Université Grenoble Alpes, France





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.

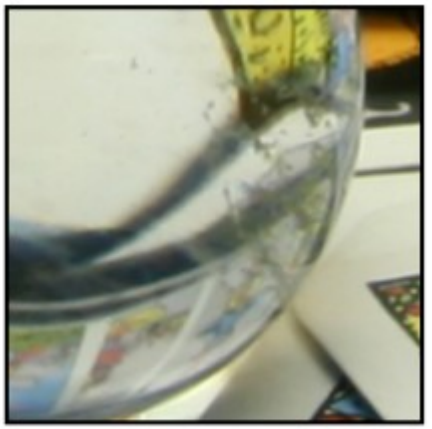


Motivations

- Proxy reconstruction may be a very hard problem.
- Proxy error, refractions, specularities ⇒ rendering artifacts.
- Modeling refractions, specularities (BRDF) → 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.



tarot ball – Stanford LF archive

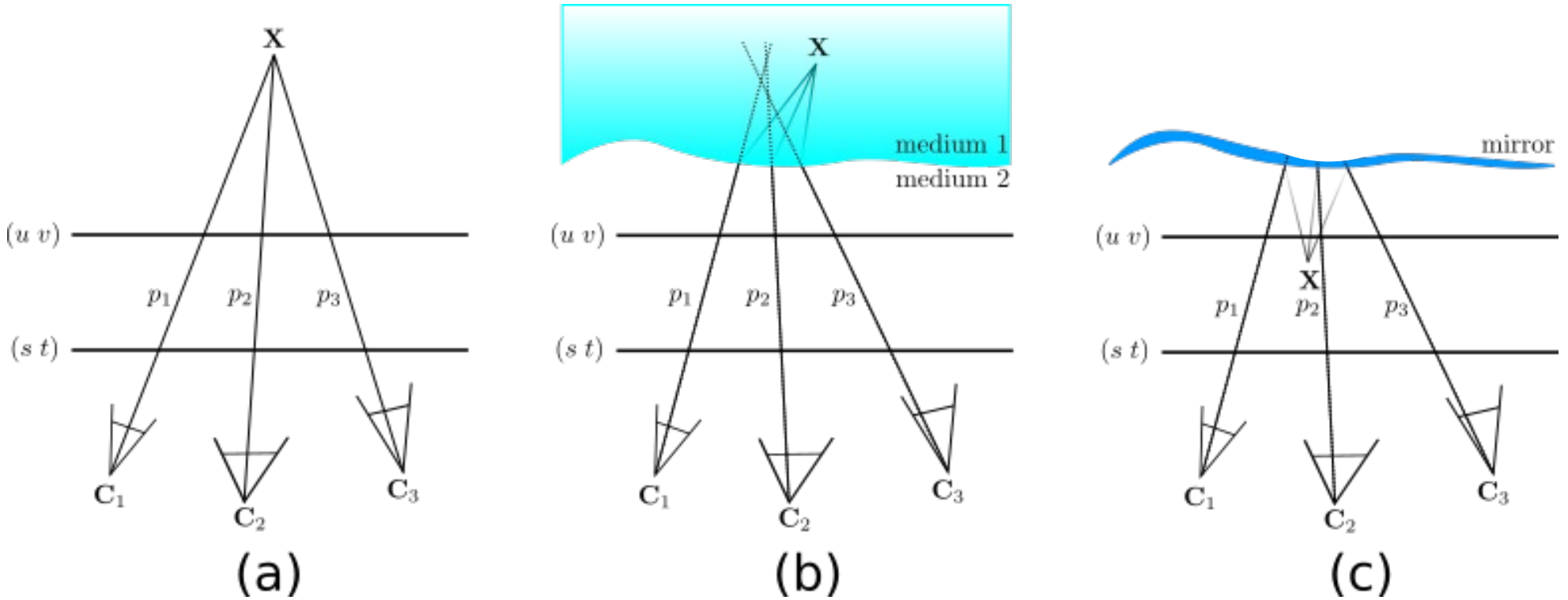


close-up – GT



rendered image

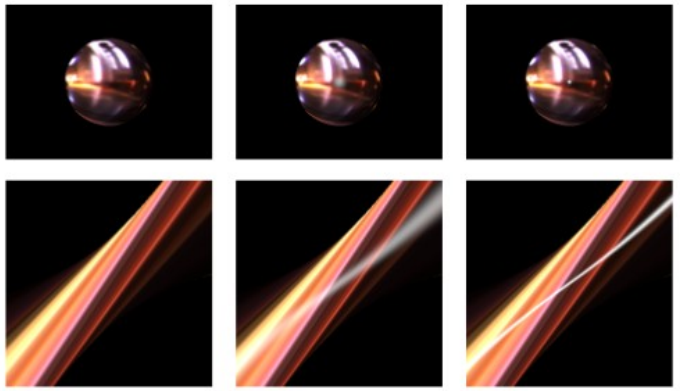
Light Field Distortion



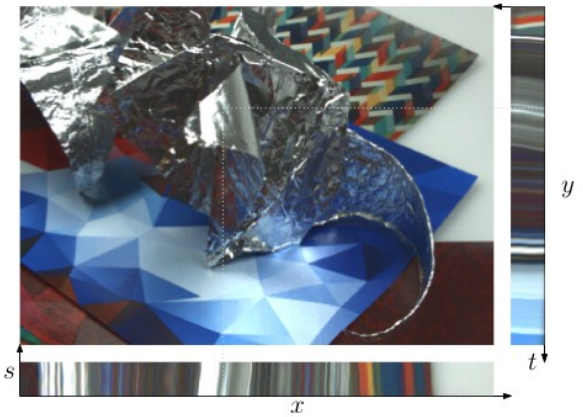
- Geometrical distortion (breaks the epipolar geometry).
- Violates the Lambertian assumption.
- Need for more complex geometric and photometric models.

Related Work

- Reconstructing reflective and specular scenes.



P. Zhou et al. ICIP '13, ICIMCS ’14.

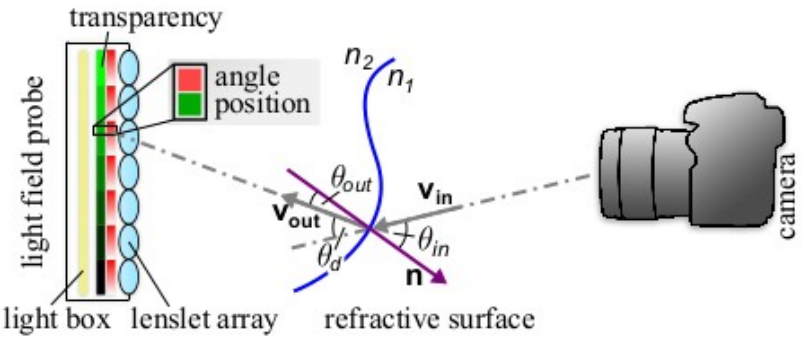


A. Sulc et al. VMV '16.

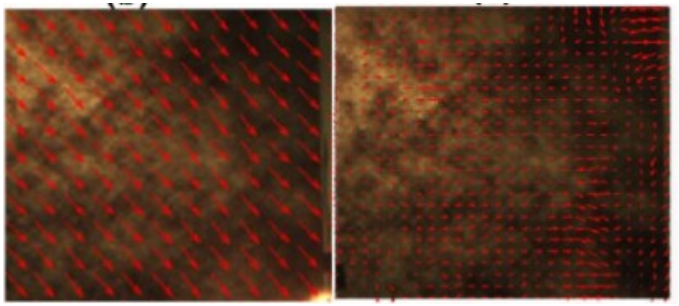


Adato et al. PAMI ’10.

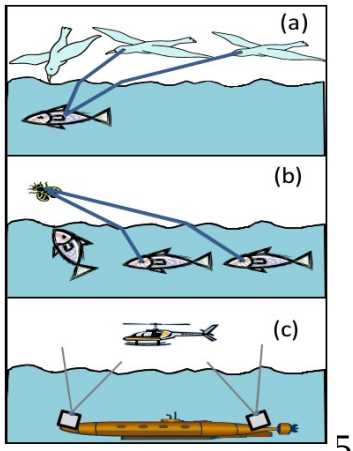
- Reconstructing refractive and transparent scenes



G. Wetzstein et al. ICCV '11.



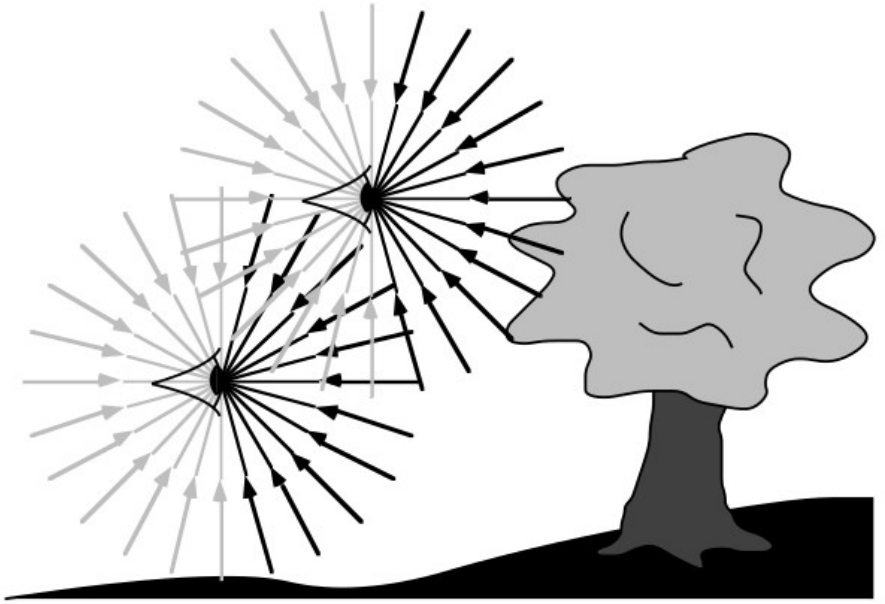
E. Iffa et al. SPIE '12.



K. Maeno et al. CVPR '13.

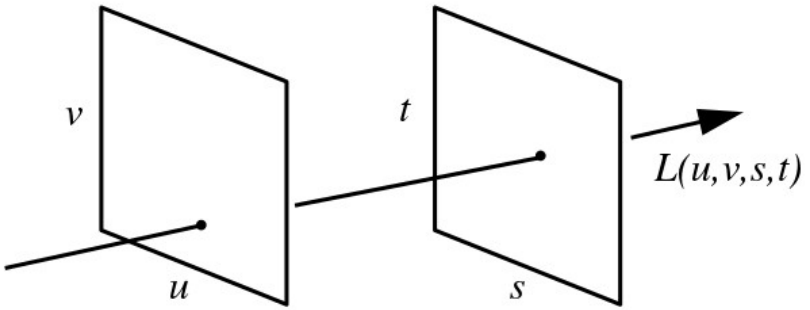
Key concepts

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

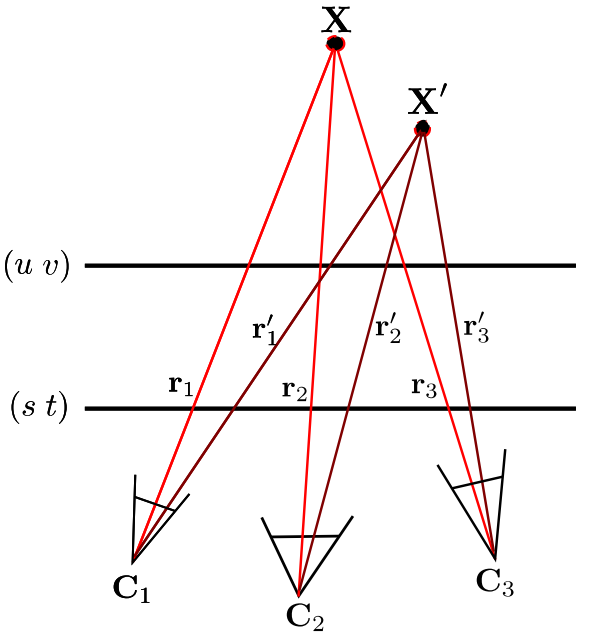


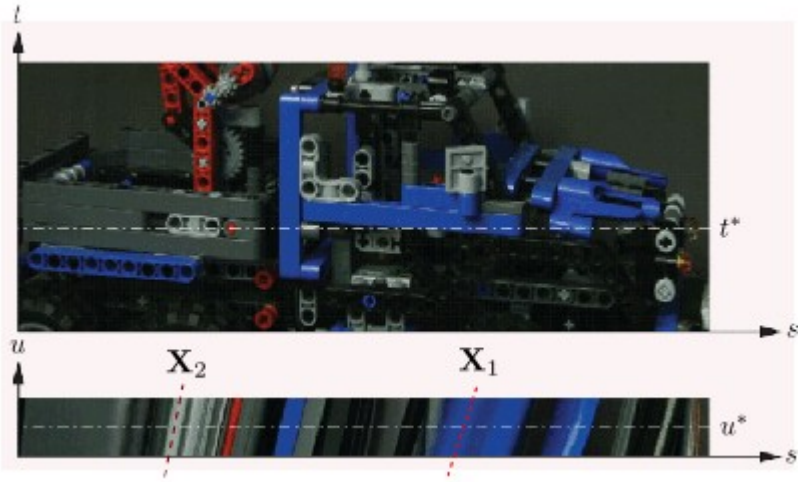
Adelson et Bergen, '91

Light Field Representation

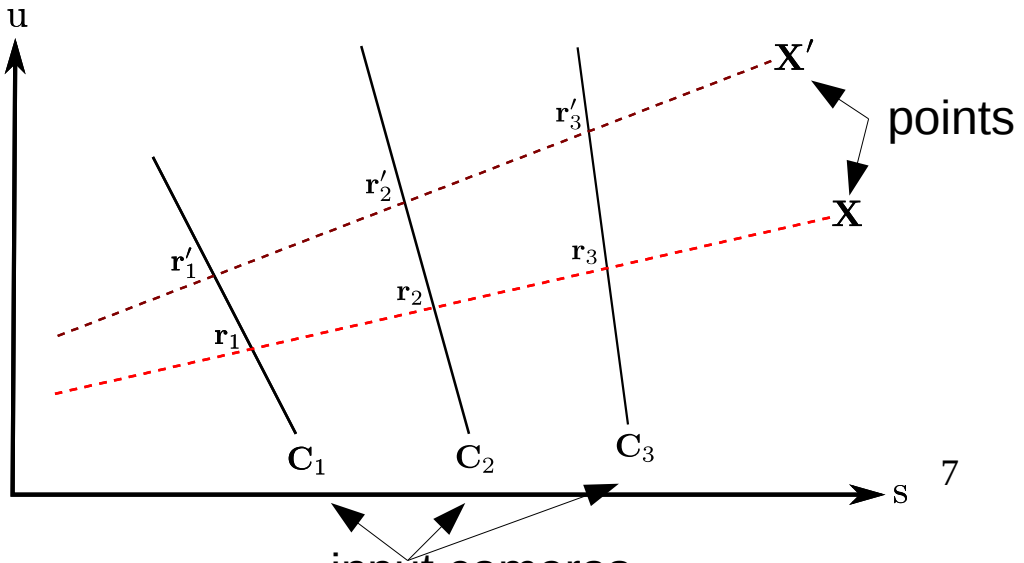


Light slab parametrization,
Levoy et Hanrahan '96.



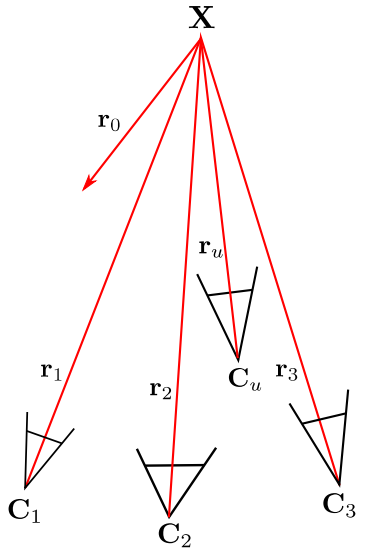


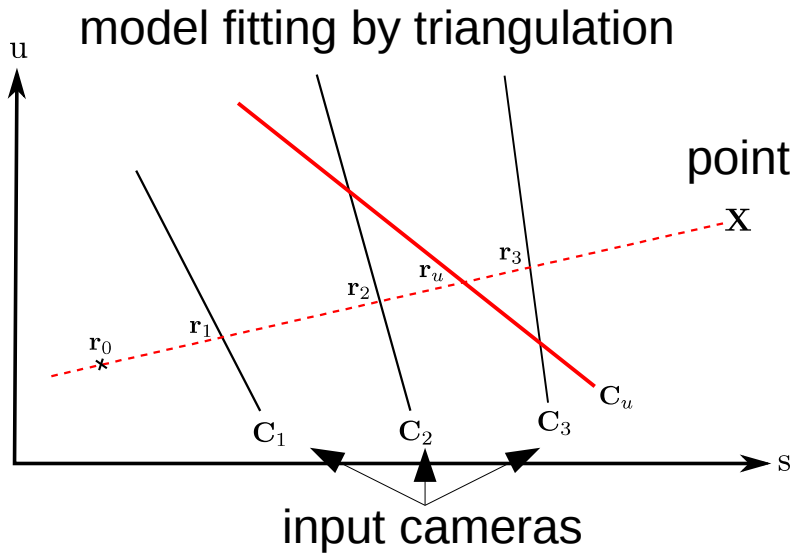
Epipolar Plane Image (EPI)



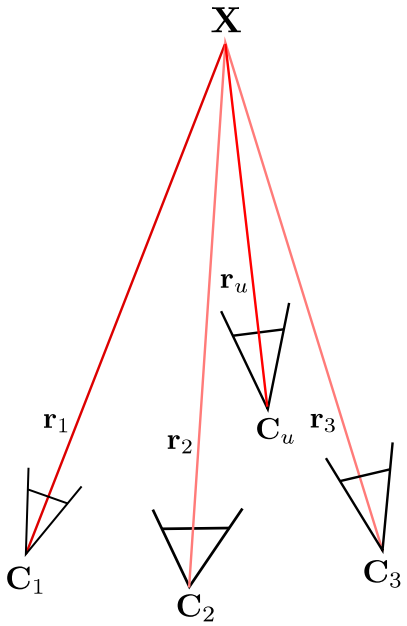
Reconstructing the Light Field

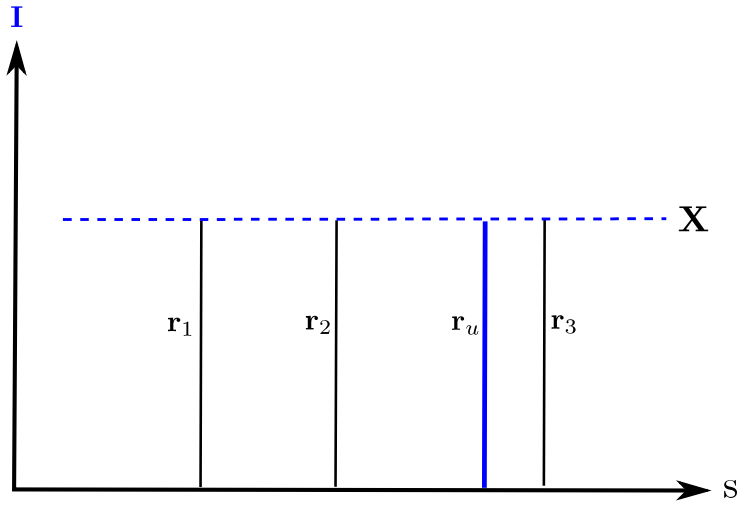
- Geometric model





- Photometric model



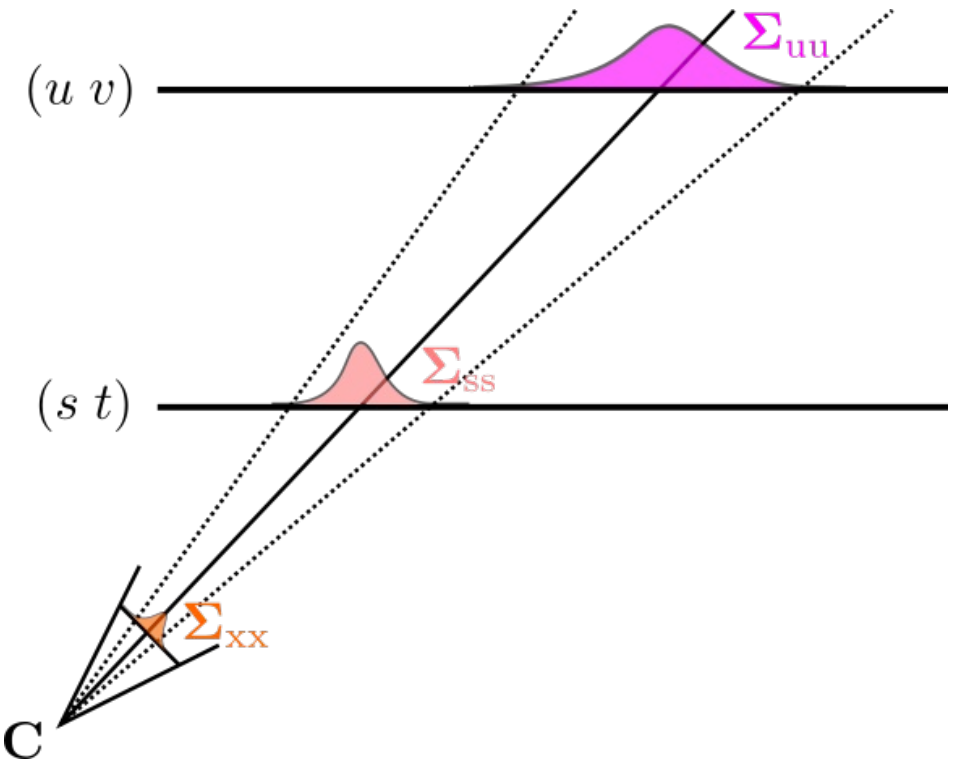


Overview of the Method

- Plenoptic space sampling.
- Ray parameterization.
- Model fitting.
- Model selection.
- Rendering.

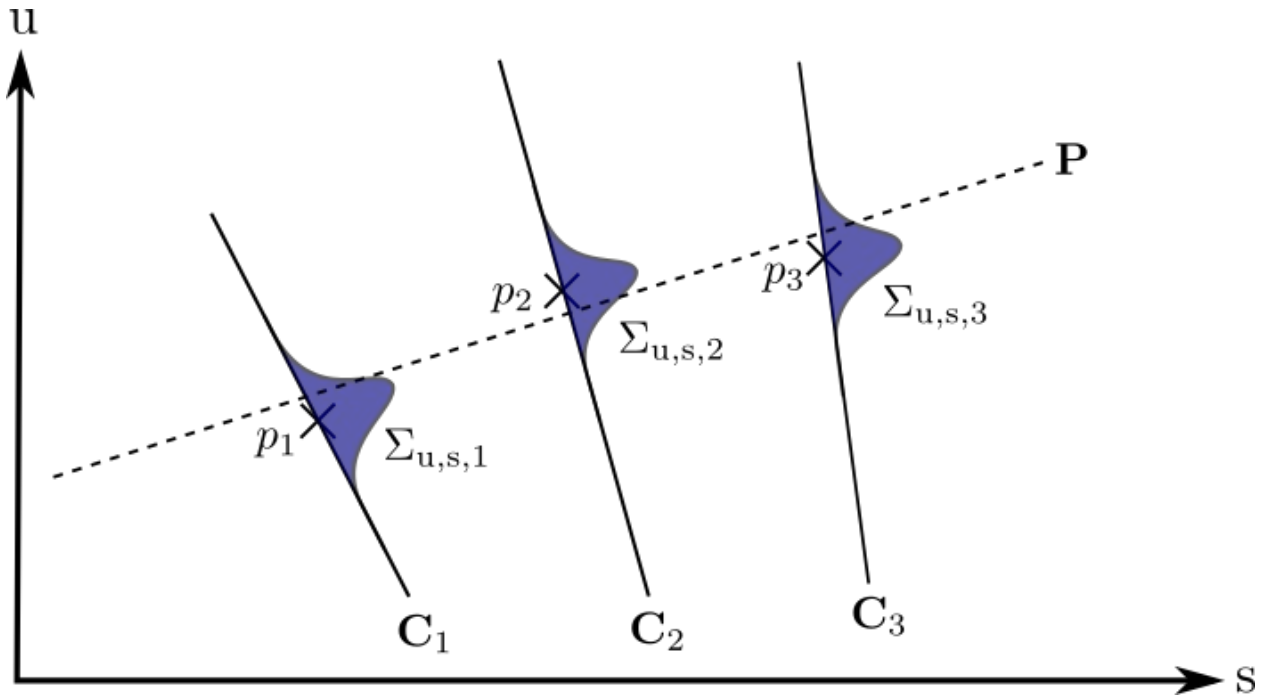
Sampling the Plenoptic Space

- 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):

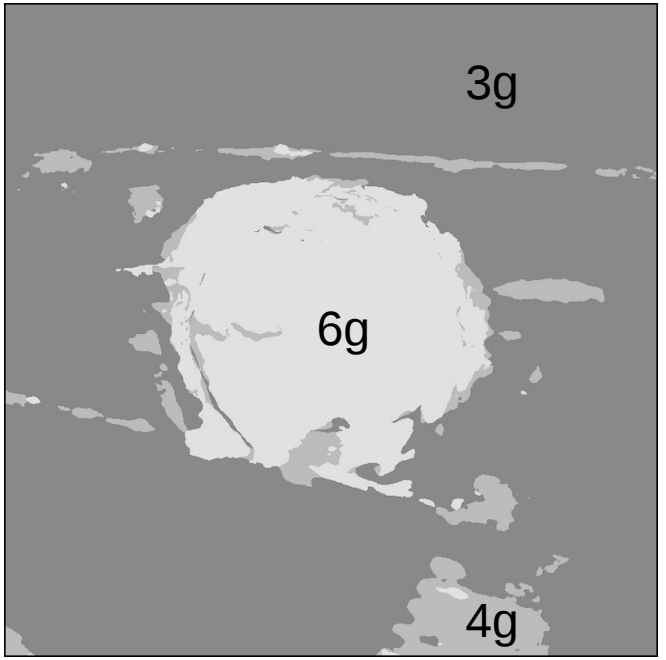
  + number of parameters

  + number of samples

  + final value of the cost function (likelihood of the estimated parameters).
- Chosen model: minimizes the BIC.



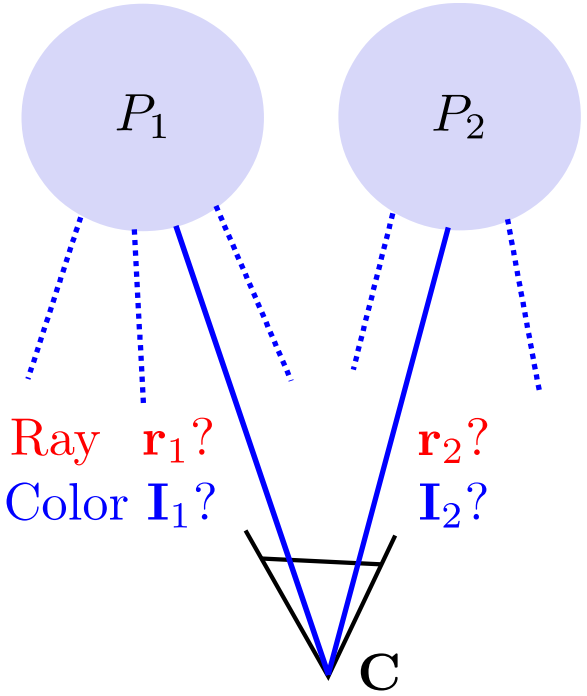
result (3g + 3p)

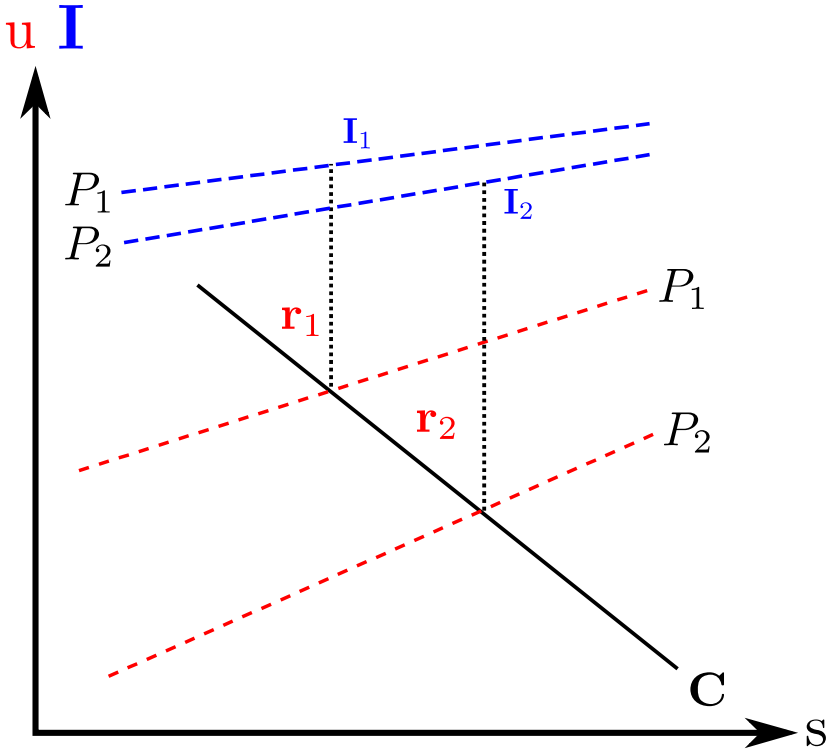


per visual point model selection

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





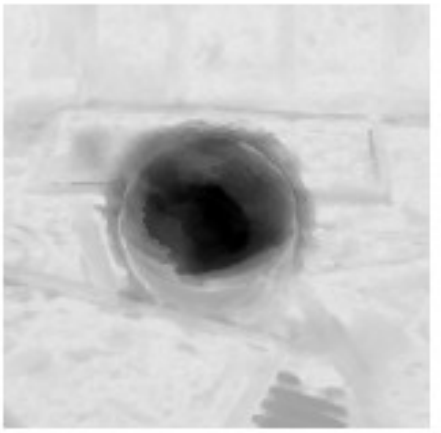


Tarot coarse



PSNR: 26.34 DSSIM: 64





original image

result

absolute difference

fitting quality

Results

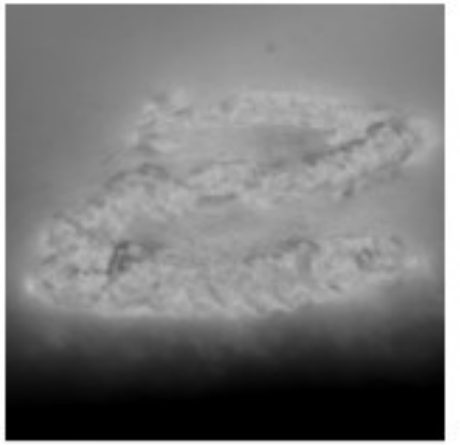


Bracelet



PSNR: 39.93 DSSIM: 5



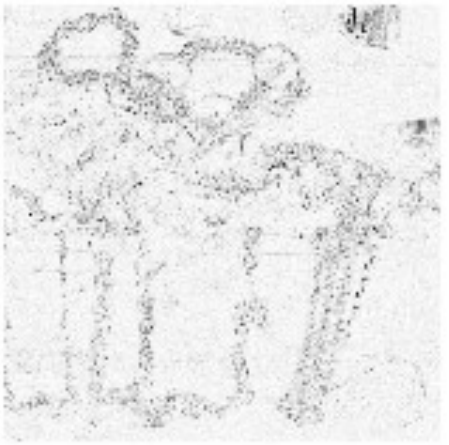


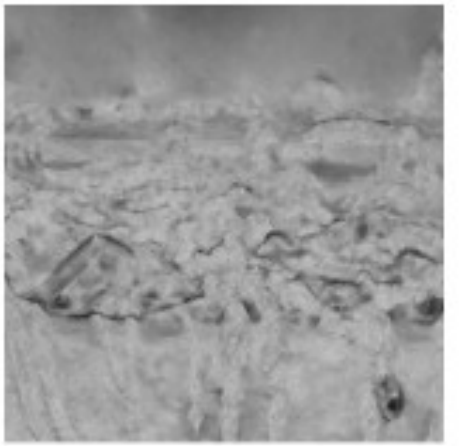


Chest



PSNR: 35.01 DSSIM: 272





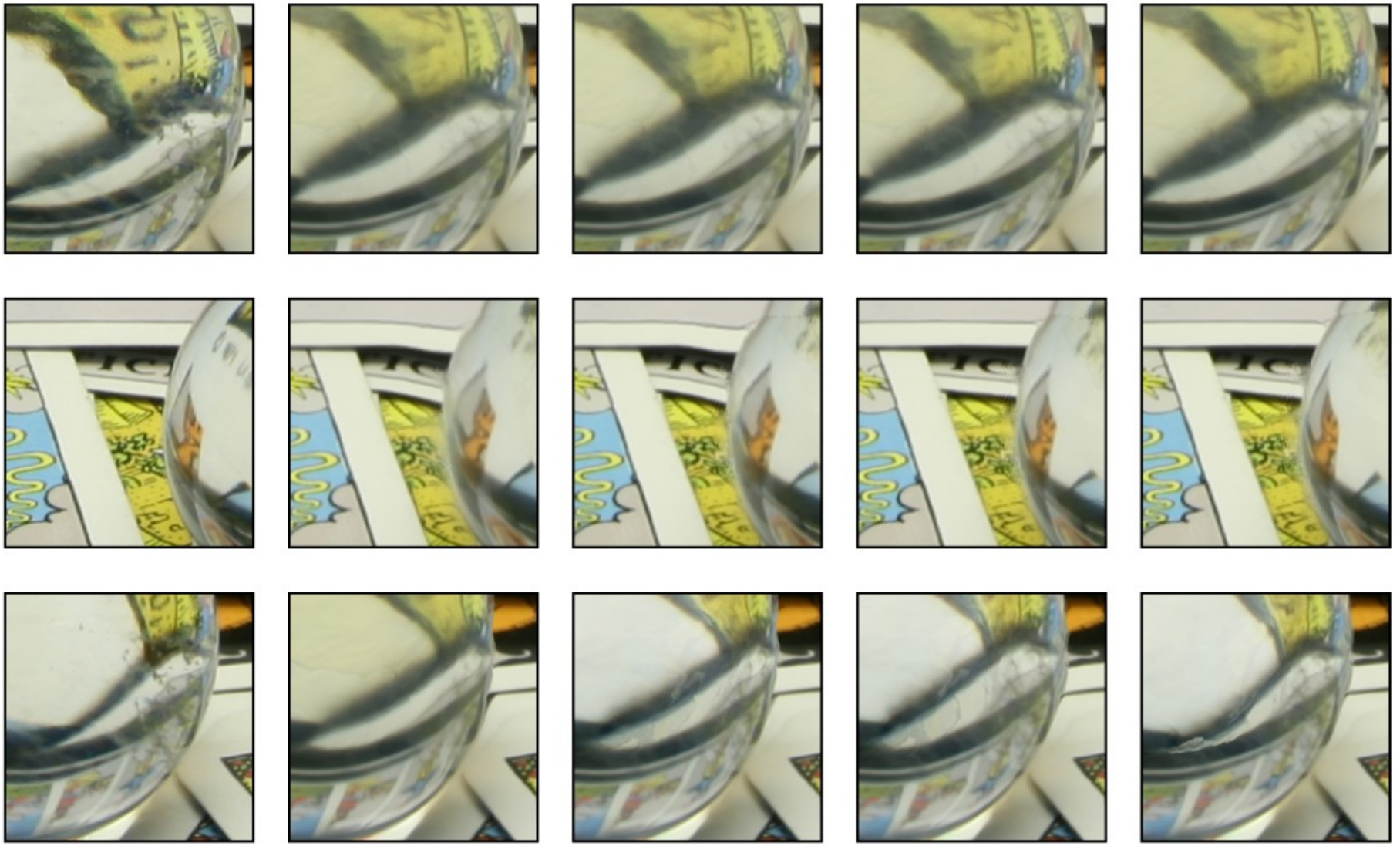
original image

result

absolute difference

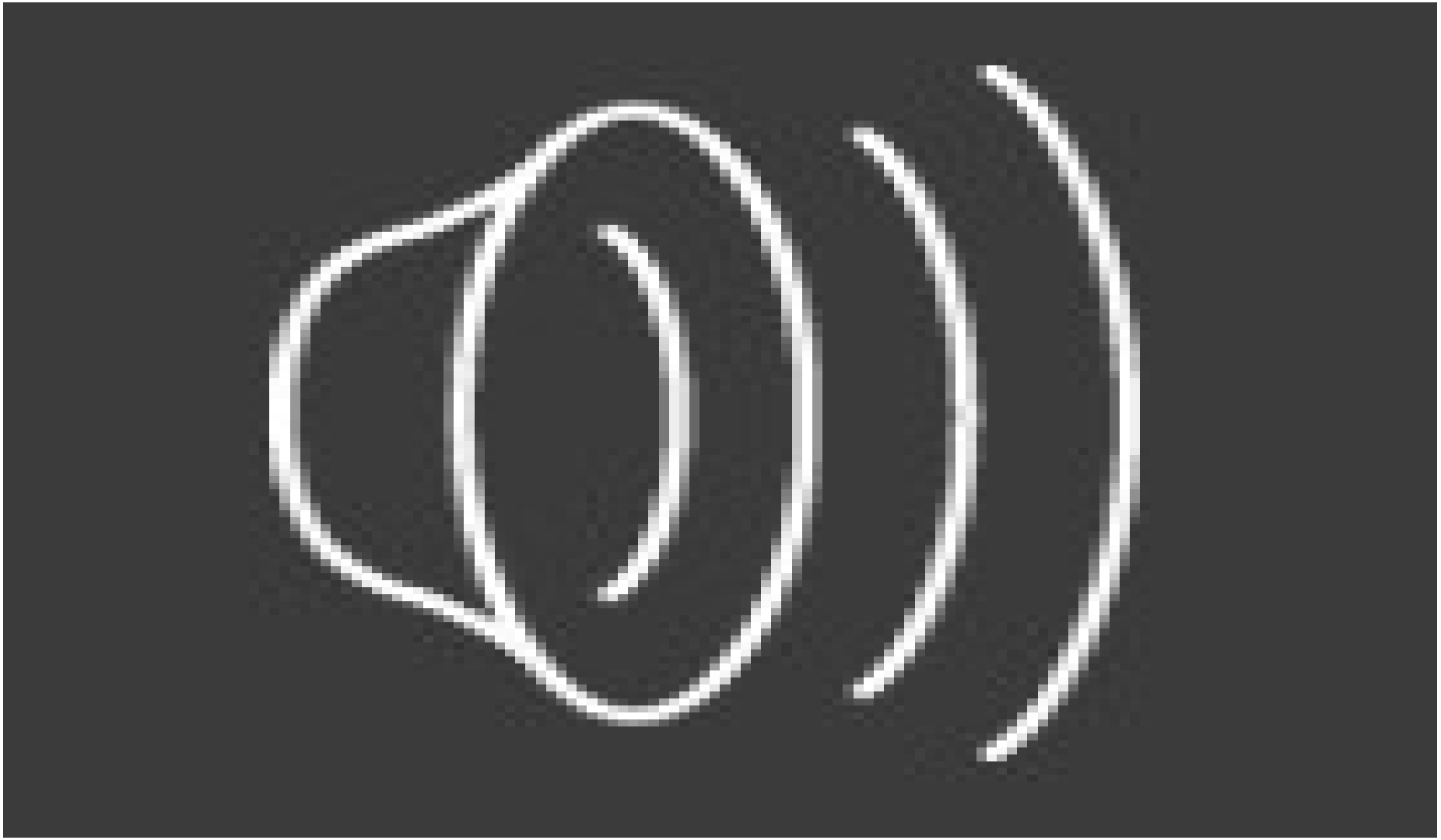
fitting quality

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).



original view | $3g + 3p$ | $3g + 9p$ | $4g + 9p$ | $6g + 9p$