Radiometric Calibration for Internet Photo Collections

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Problem

❑ Conventional radiometric calibration

- One accessible camera with controlled exposure times
- Fixed viewpoint, illumination
- The same camera setting (except for exposure time)

❑ Challenges using Internet images

- Multiple inaccessible cameras with uncontrolled settings
- Arbitrary viewpoints, illuminations
- Different camera settings (exposure time, white balance, ISO, etc.)

❑ Key idea

- Image formation model

$$B = f(I) = f\left(ct\rho\left(\mathbf{n}^T \int_{\Omega} L(\omega)\, d\omega\right)\right) = f(ct\rho(\mathbf{n}^T \bar{\mathbf{l}}))$$

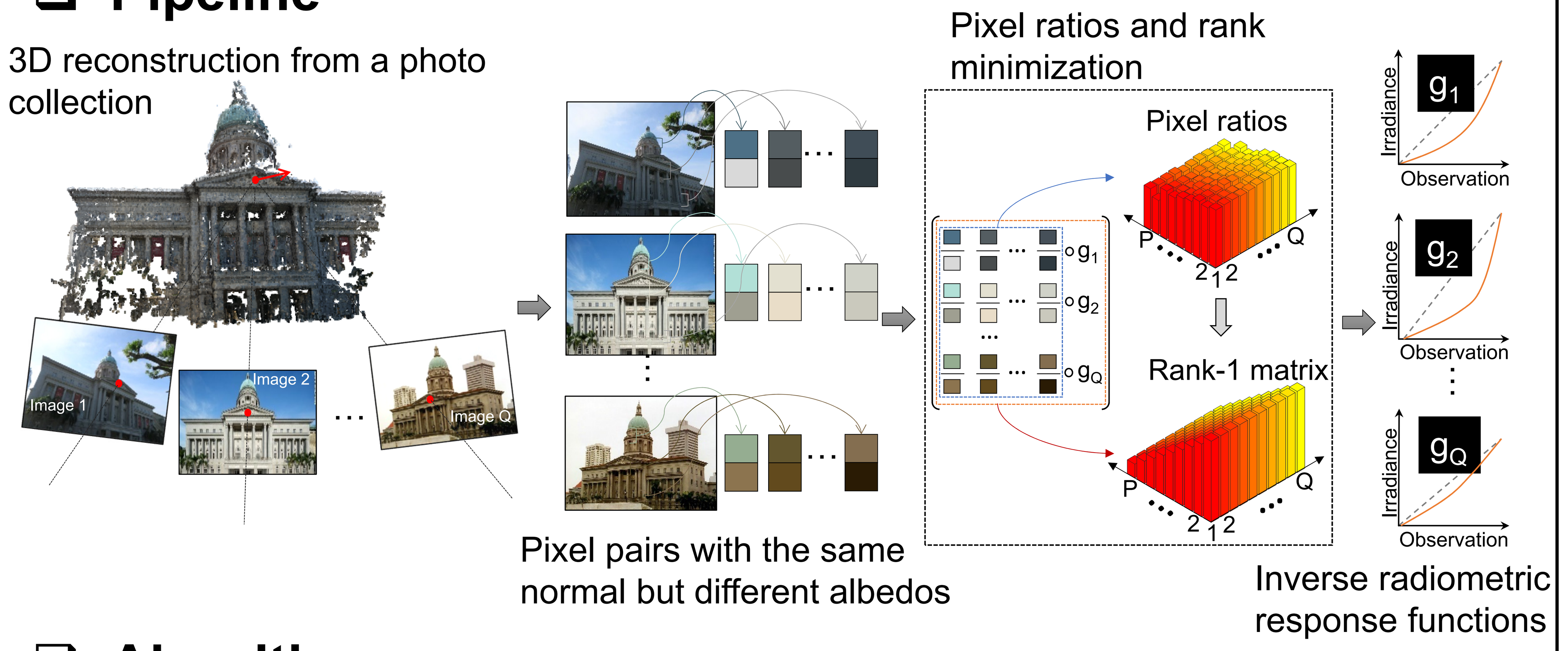
  - ✓ B – brightness, g/f – inverse/response function, c - white balance, t – exposure time, ρ – albedo, $\mathbf{n}$ – normal, $\bar{\mathbf{l}}$ – lighting integration over visible hemisphere Ω
- Key constraint
  - ✓ Ratio of pixel pairs with same normal and different albedos

$$\frac{g(B_1)}{g(B_2)} = \frac{I_1}{I_2} = \frac{ct\rho_1(\mathbf{n}^T\bar{\mathbf{l}})}{ct\rho_2(\mathbf{n}^T\bar{\mathbf{l}})} = \frac{\rho_1}{\rho_2}$$

- Major contributions
  - ✓ **Solved:** Simultaneously calibrate radiometric camera properties for a set of Internet images
  - ✓ **Potential:** Bring photometric techniques (3D modeling, scene analysis, etc.) from lab setup to big and wild data on the Internet

Solution

❑ Pipeline



❑ Algorithm

- Identify pixel pairs with same normal but different albedos in each image
  - ✓ Obtain surface normal from SfM + MVS
  - ✓ Discard pixel pairs whose brightness ratio are equal or close to 1
- Project 3D points of selected pixel pairs to each 2D image
- Optimization
  - ✓ Stack the ratio of selected pixel pairs as a matrix

$$\mathbf{A}_{Q\times P} = \begin{pmatrix} \frac{g_1(B_{11})}{g_1(B_{01})} & \frac{g_1(B_{21})}{g_1(B_{11})} & \cdots & \frac{g_1(B_{P1})}{g_1(B_{(P-1)1})} \\ \frac{g_2(B_{12})}{g_2(B_{02})} & \frac{g_2(B_{22})}{g_2(B_{12})} & \cdots & \frac{g_2(B_{P2})}{g_2(B_{(P-1)2})} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{g_Q(B_{1Q})}{g_Q(B_{0Q})} & \frac{g_Q(B_{2Q})}{g_Q(B_{1Q})} & \cdots & \frac{g_Q(B_{PQ})}{g_Q(B_{(P-1)Q})} \end{pmatrix}$$

  - ✓ Solve the problem via rank minimization

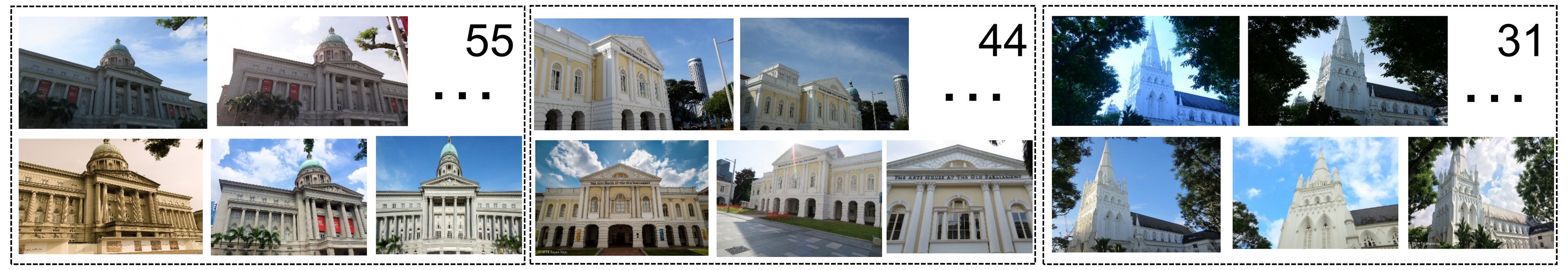
$$\{g_1^*, g_2^*, \dots, g_Q^*\} = \underset{\{g_1, g_2, \dots, g_Q\}}{\operatorname{argmin}} \ \operatorname{rank}(\mathbf{A})$$

  - ✓ Pairwise optimization - select two rows of $\mathbf{A}$ as "base" image pair and align all the other rows to the base in an incremental manner
- Output: Inverse response functions of all images up to the same exponential ambiguity

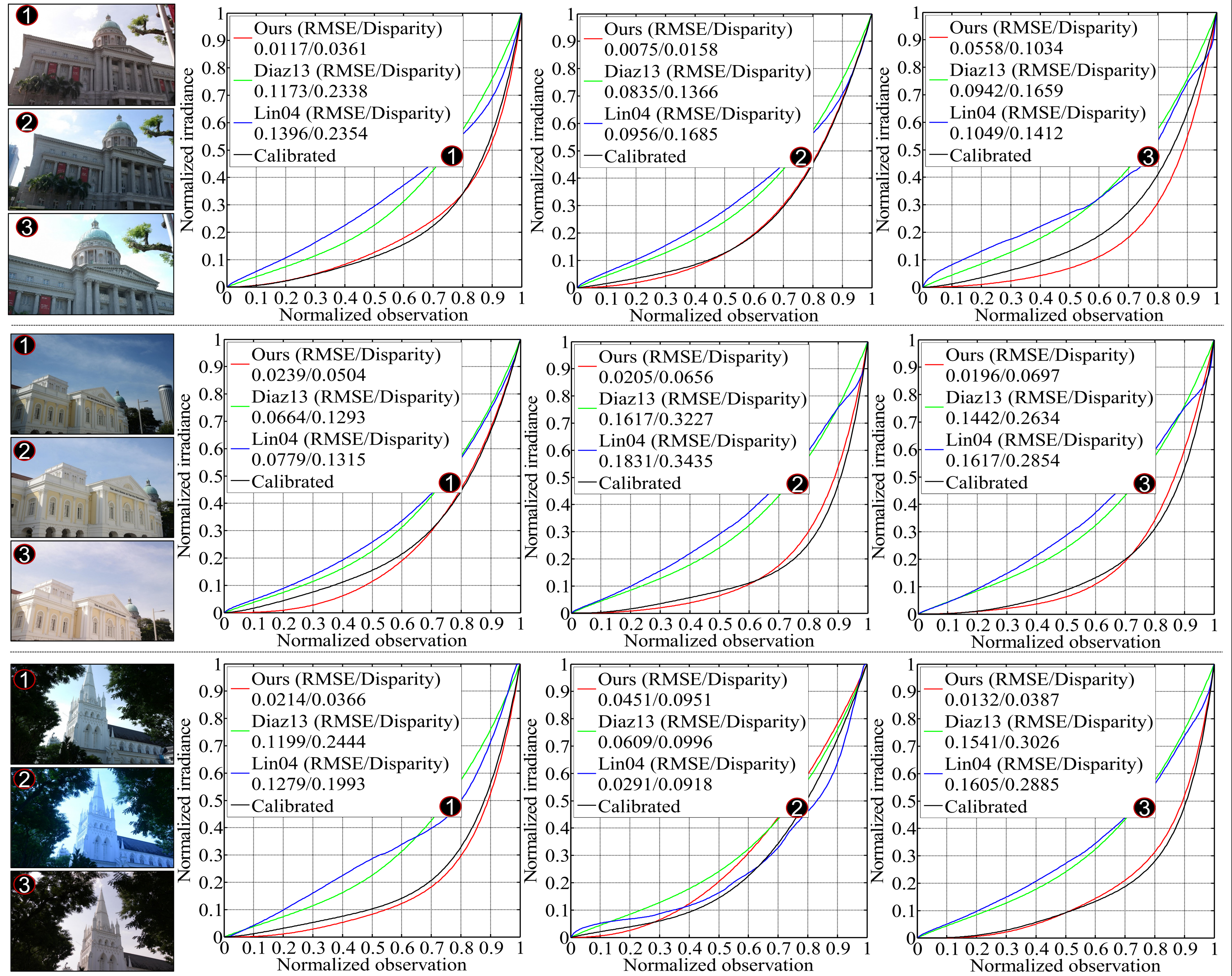
Verification

❑ Dataset

- Three real datasets containing mixture of Internet photos and images captured using controlled cameras



❑ Result



[Diaz13] M. Diaz, et al., Estimating photometric properties from image collections, JMIV13
[Lin04] S. Lin, et al., Radiometric calibration from a single image, CVPR04