Photometric Stereo with Twin-Fisheye Cameras

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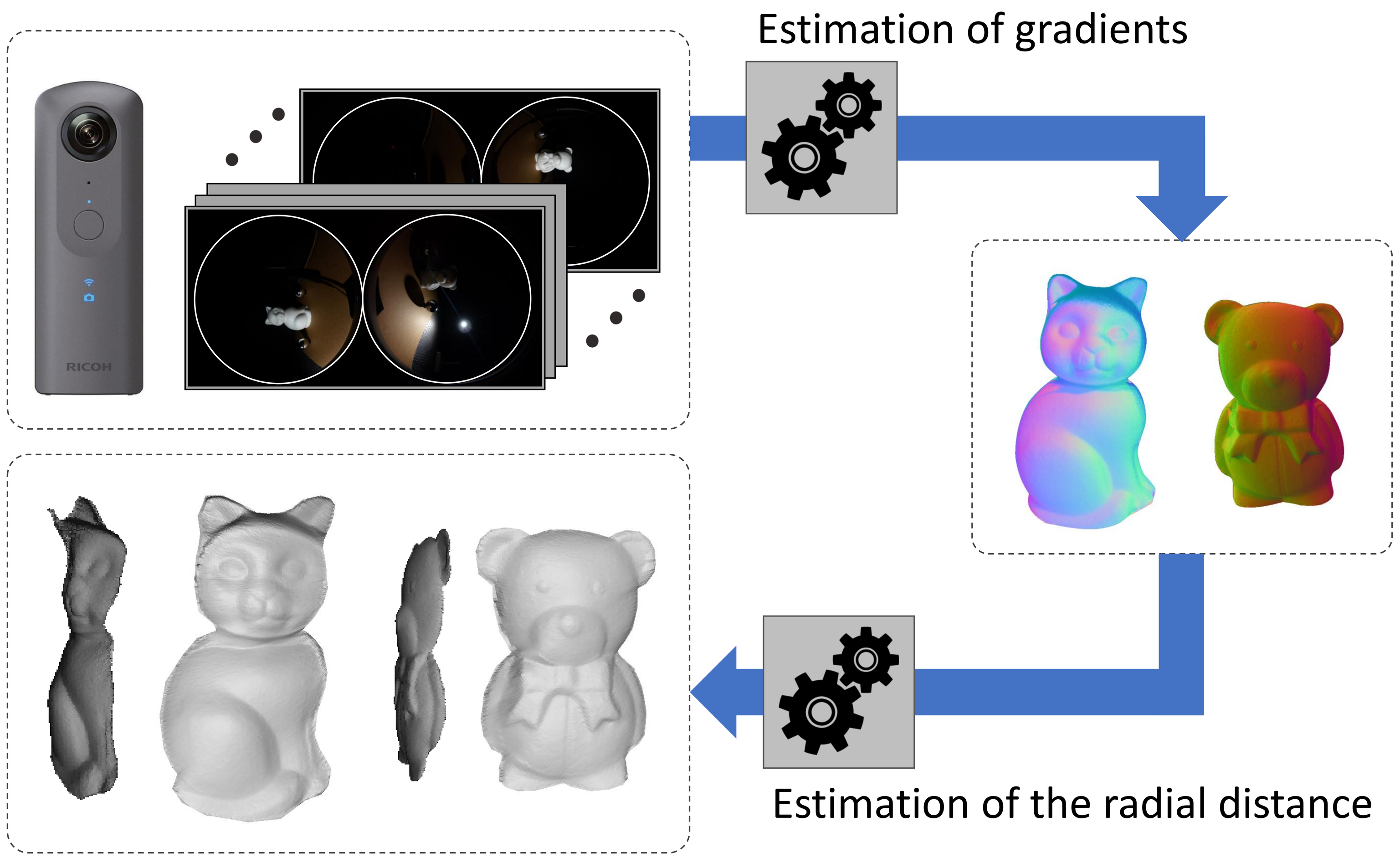
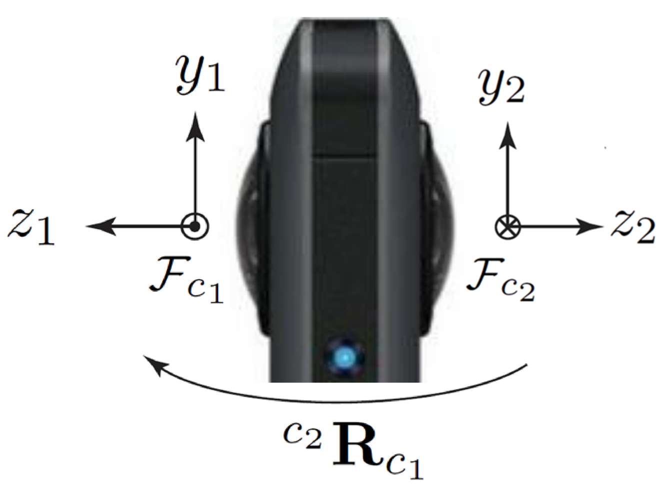
1. Objective and contributions

Goal: design an omnidirectional photometric stereo algorithm for twin-fisheye cameras



- Extension of the *spherical image irradiance equation* proposed in [1], to fit the model of a twin-fisheye camera
- New reconstruction pipeline
- Real-world experiments with the Ricoh Theta V
- Mirror balls are used to estimate the direction of the light sources (we adapted the method in [2])

2. Modeling of the twin-fisheye camera



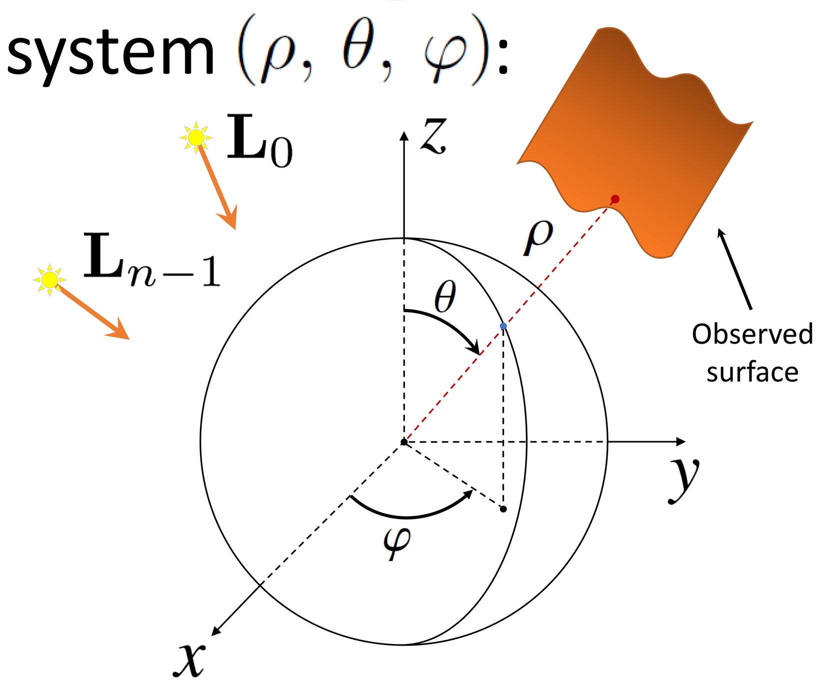
Use the same approach as in [3]

The translation vector between $\mathcal{F}_{c_1}$ and $\mathcal{F}_{c_2}$ is assumed to be zero

3. Spherical image irradiance equation

The *dual-fisheye* images are represented by using the spherical coordinate system $(\rho,\ \theta,\ \varphi)$:

$$\begin{cases} x = \rho \sin\theta \cos\varphi, \\ y = \rho \sin\theta \sin\varphi, \\ z = \rho \cos\theta. \end{cases}$$



Spherical irradiance equation at point $(\theta,\ \varphi)$

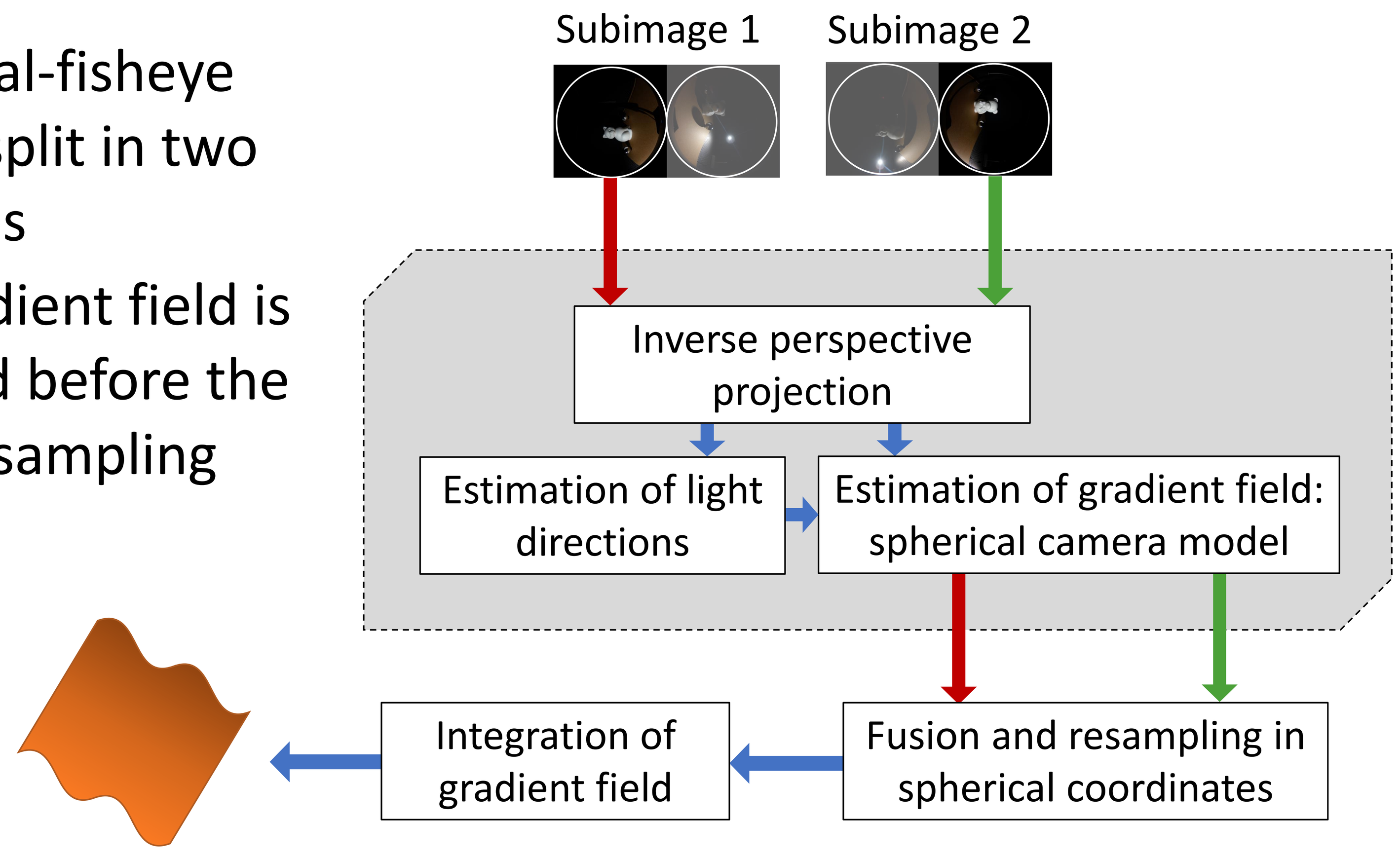
$$I_i(\theta,\ \varphi) = \frac{\overbrace{\alpha(\theta,\ \varphi)}^{\text{Albedo}}\ \overbrace{\mathbf{L}_i^T}^{\text{Direction of the } i\text{-th light source}}}{\|\mathbf{L}_i\|\sqrt{p^2 + \left(\dfrac{q}{\sin\theta}\right)^2 + 1}}\ \mathbf{R}_z(\varphi)\,\mathbf{R}_y(\theta) \begin{bmatrix} p \\ \dfrac{q}{\sin\theta} \\ -1 \end{bmatrix}$$

where

$$p \triangleq \frac{1}{\rho}\frac{\partial\rho}{\partial\theta} = \frac{\partial \ln\rho}{\partial\theta}, \qquad q \triangleq \frac{1}{\rho}\frac{\partial\rho}{\partial\varphi} = \frac{\partial \ln\rho}{\partial\varphi}$$

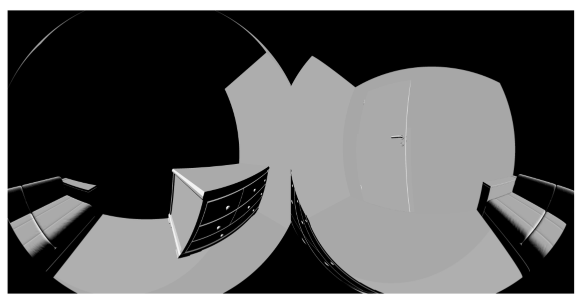
4. Reconstruction pipeline

- Each dual-fisheye image is split in two subimages
- The gradient field is estimated before the spatial resampling

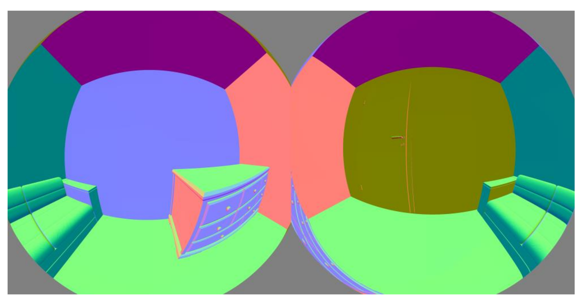


5. Experimental validation

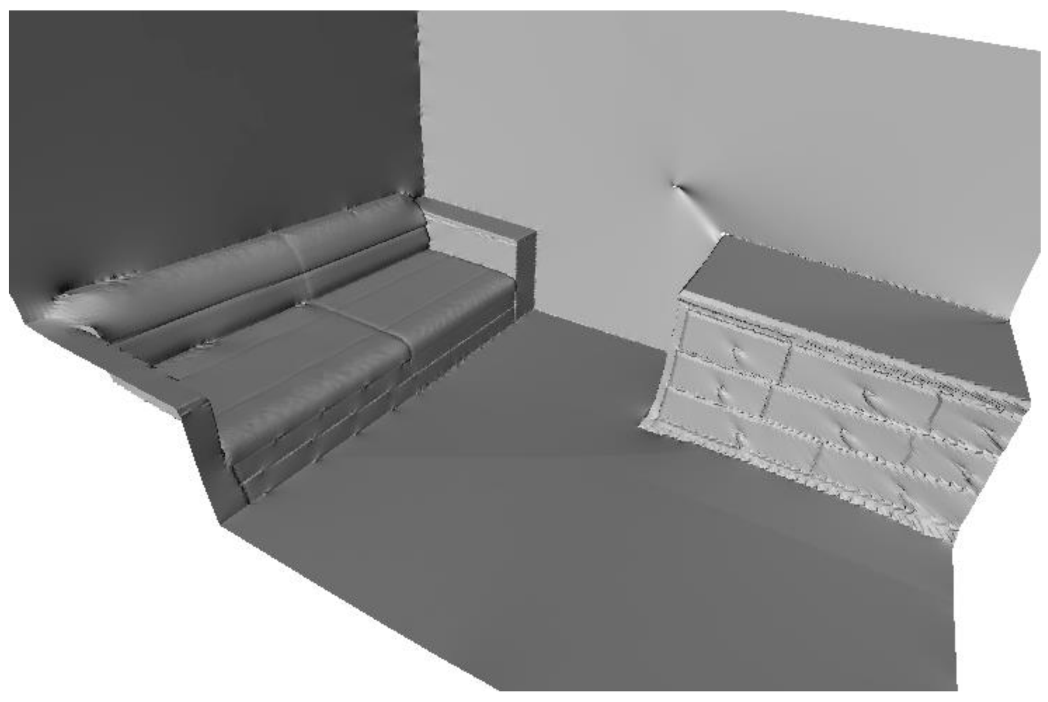
5.1. Simulation experiments



Example of input image

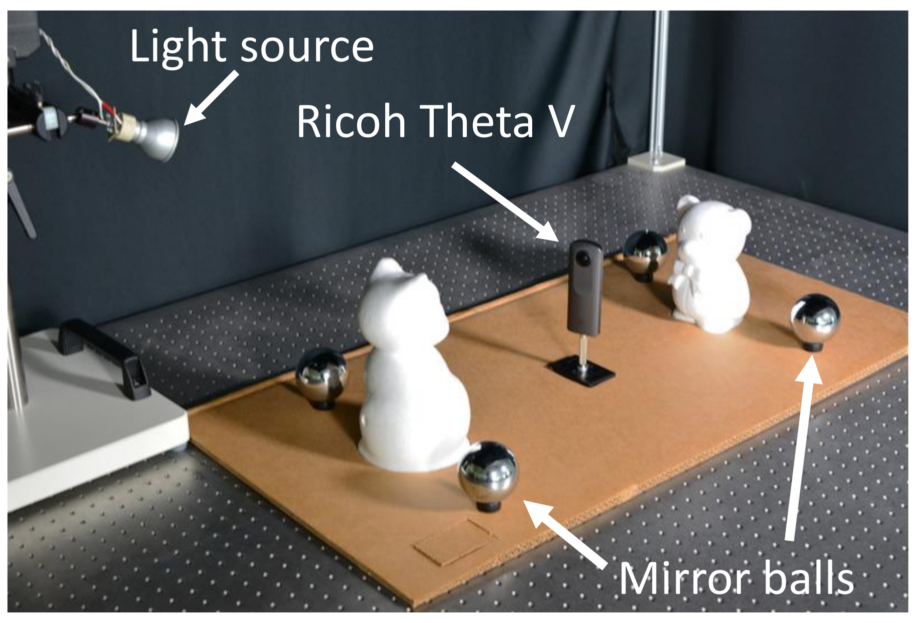


Estimated normal vectors in false colors



Half of the final 3D reconstruction of the scene *Room*

5.2. Real-world experiments



Experiment setup

3D reconstruction of *Cat* and *Teddy Bear*

- Input images: 12 for *Cat* and 11 for *Teddy Bear*

6. Future work

- Take light attenuation into account
- Validation using an outdoor scene under natural illumination conditions

References:

[1] *Photometric stereo with central panoramic cameras*, J. Caracotte, F. Morbidi, E. Mouaddib, Comput. Vis. Image Und., vol. 201, December 2020.

[2] *Camera and light calibration from reflections on a sphere*, D. Schnieders, K.-Y. Wong, Comput. Vis. Image Und., vol. 117, n. 10, pp. 1536–1547, 2013.

[3] *Spherical Visual Gyroscope for Autonomous Robots using the Mixture of Photometric Potentials*, G. Caron, F. Morbidi, in Proc. IEEE Int. Conf. Robot. Automat., pp. 820–827, 2018.

Source code & dataset (free download):

home.mis.u-picardie.fr/~fabio/PhotoSphere.html

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