Photometric Stereo with Twin-Fisheye Cameras

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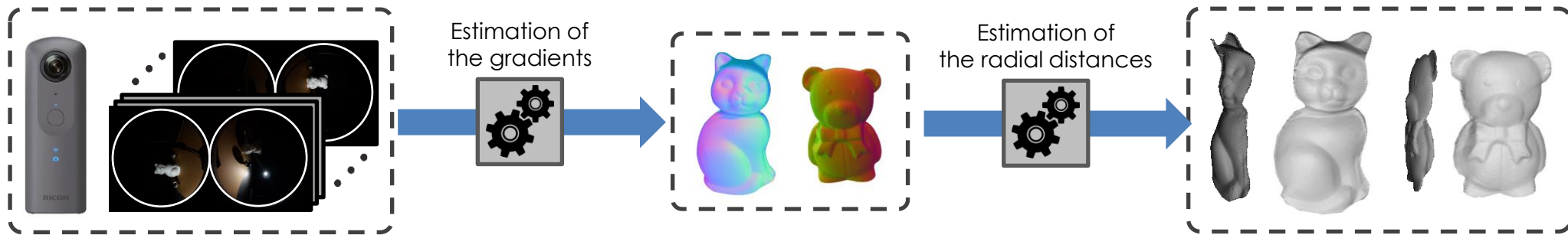
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ICPR'20

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


- Extension of the *spherical image irradiance equation* proposed in [Caracotte *et al.* CVIU'20], to fit the model of a twin-fisheye camera

- New reconstruction pipeline

- Mirror balls are used to estimate the direction of the light sources

- Real-world experiments with the Ricoh Theta V

- The translation vector between $\mathcal{F}_{c_1}$ and $\mathcal{F}_{c_2}$ is assumed to be zero
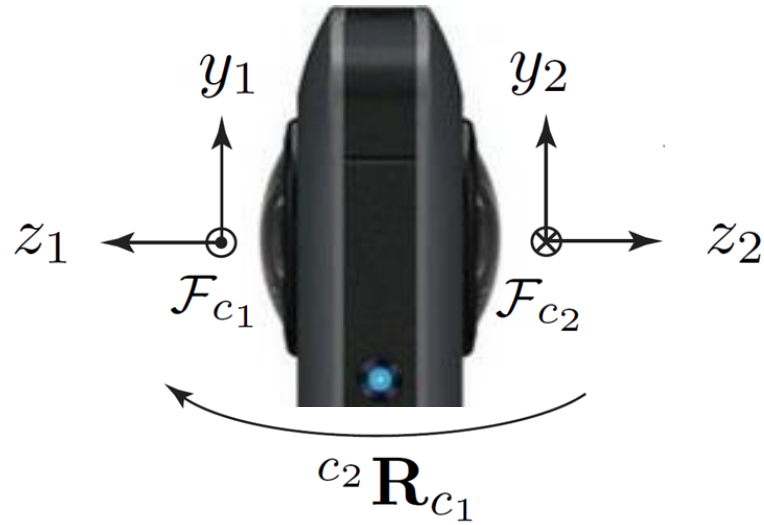
Coordinate frames of the two fisheye lenses
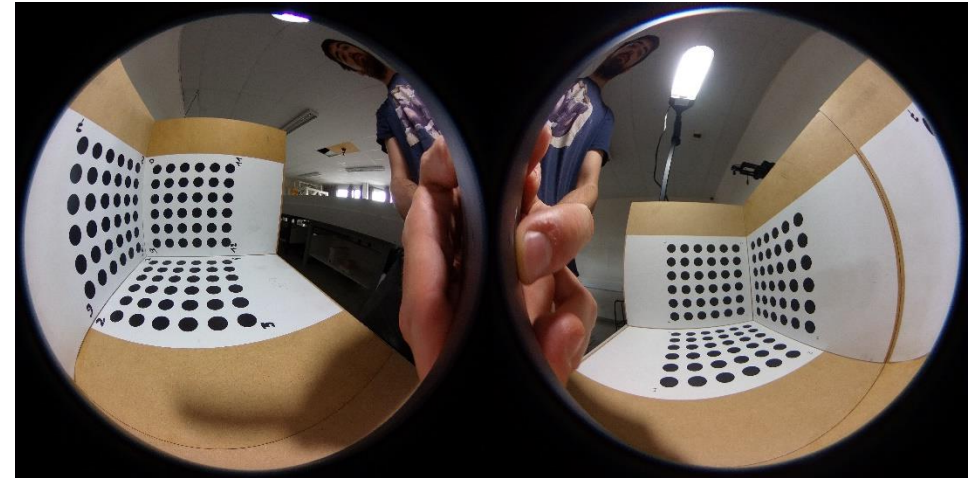
Example of input images used
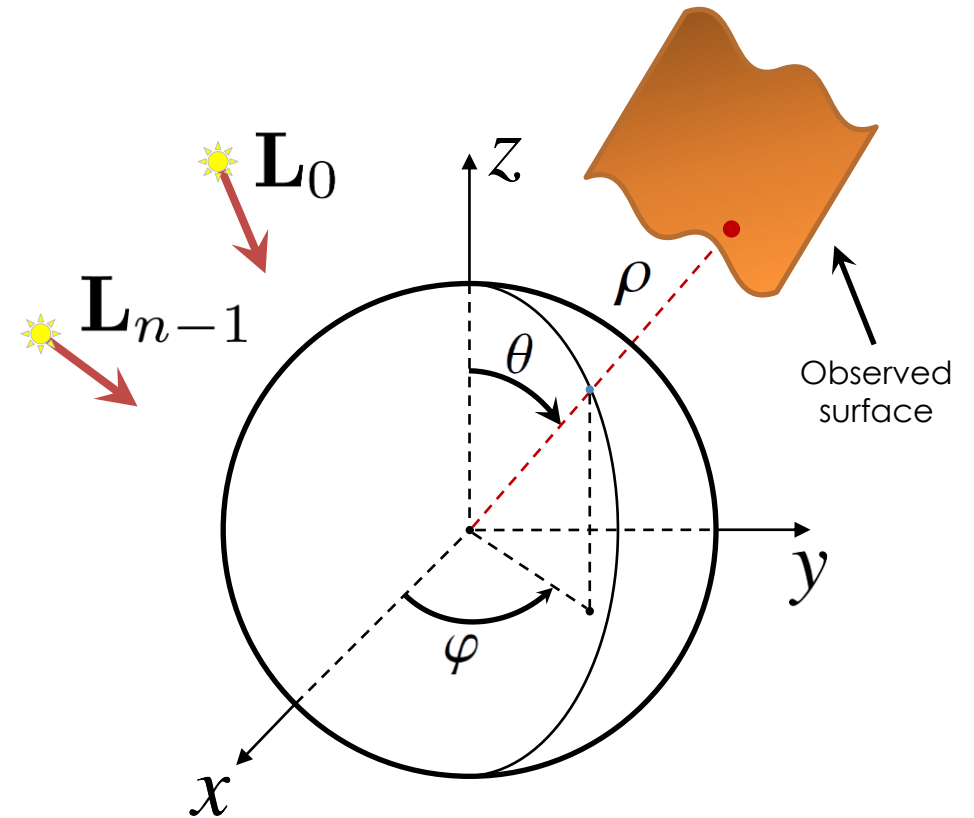in the calibration process

- The *dual-fisheye* images are represented using the spherical coordinate system (ρ, θ, φ):

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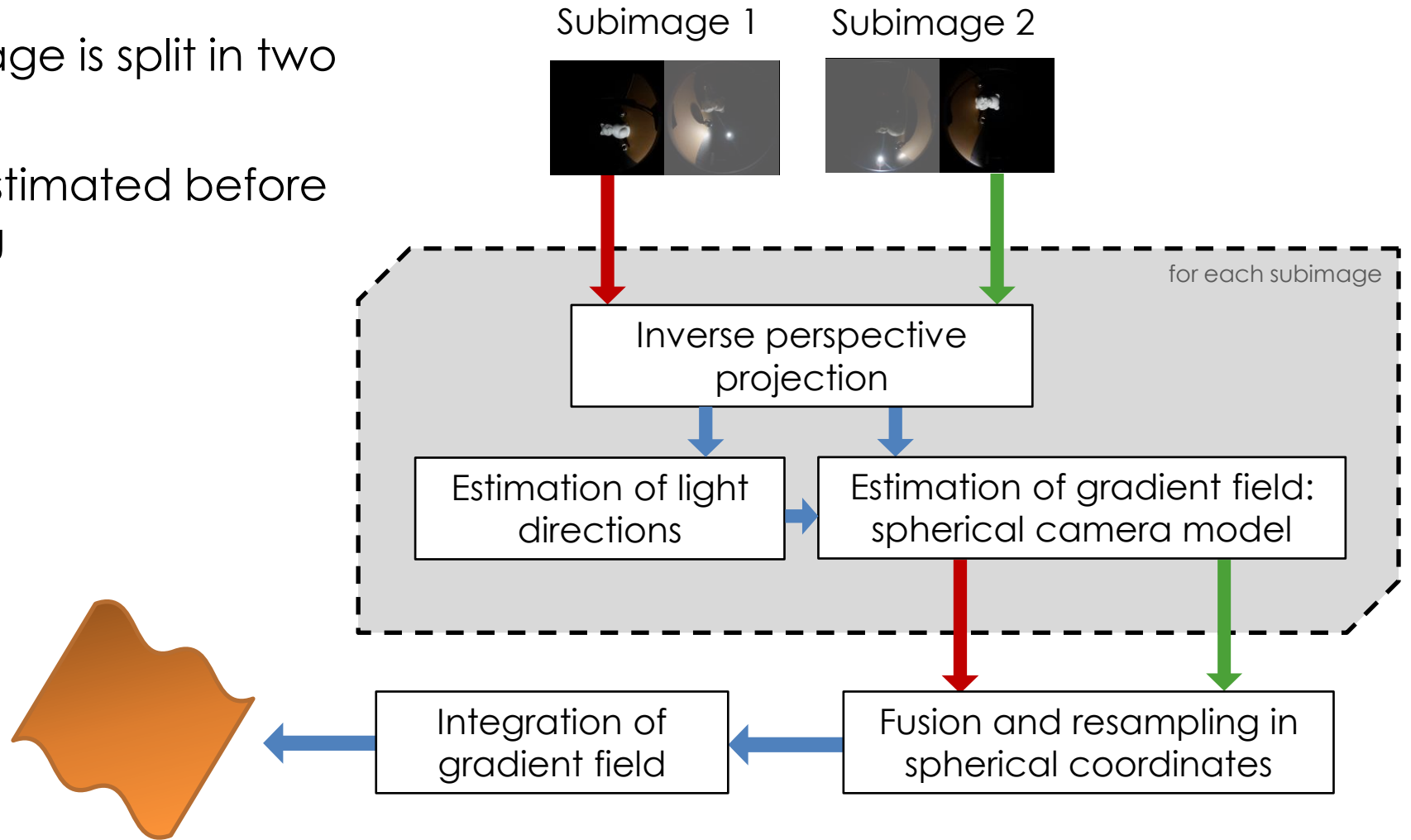
$$I_i(\theta, \varphi) = \frac{\overset{\text{Albedo}}{\alpha(\theta, \varphi)} \overset{\substack{\text{Direction of the} \\ i\text{-th light source}}}{\mathbf{L}_i^T}}{||\mathbf{L}_i|| \sqrt{p^2 + \left(\frac{q}{\sin\theta}\right)^2 + 1}} \mathbf{R}_z(\varphi)\, \mathbf{R}_y(\theta) \begin{bmatrix}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

where

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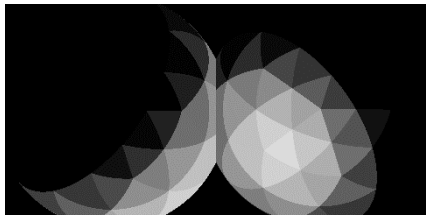
Reconstruction pipeline

- Each dual-fisheye image is split in two subimages

- The gradient field is estimated before the spatial resampling

Subimage 1   Subimage 2

for each subimage

Inverse perspective projection

Estimation of light directions

Estimation of gradient field: spherical camera model

Fusion and resampling in spherical coordinates
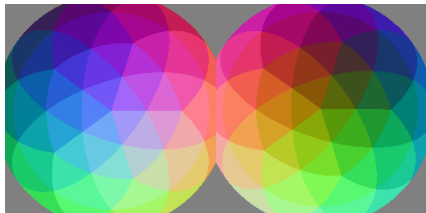
Integration of gradient field
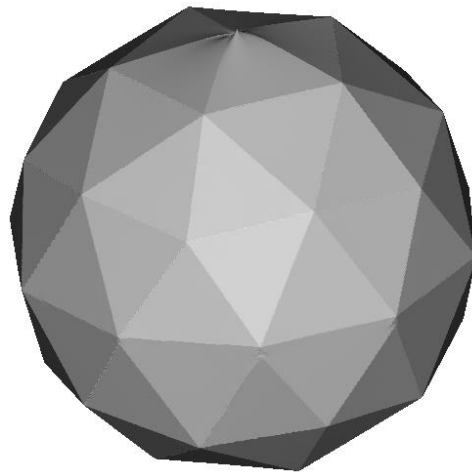
- Simulation experiments

Geodesic Polyhedron

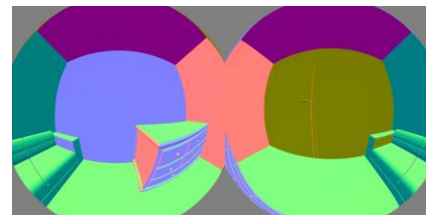Example of input image

Estimated normal vectors
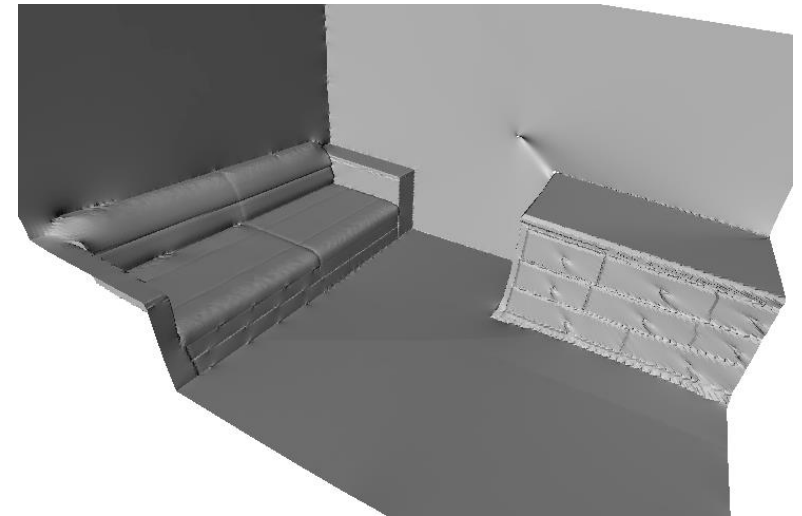in false colors

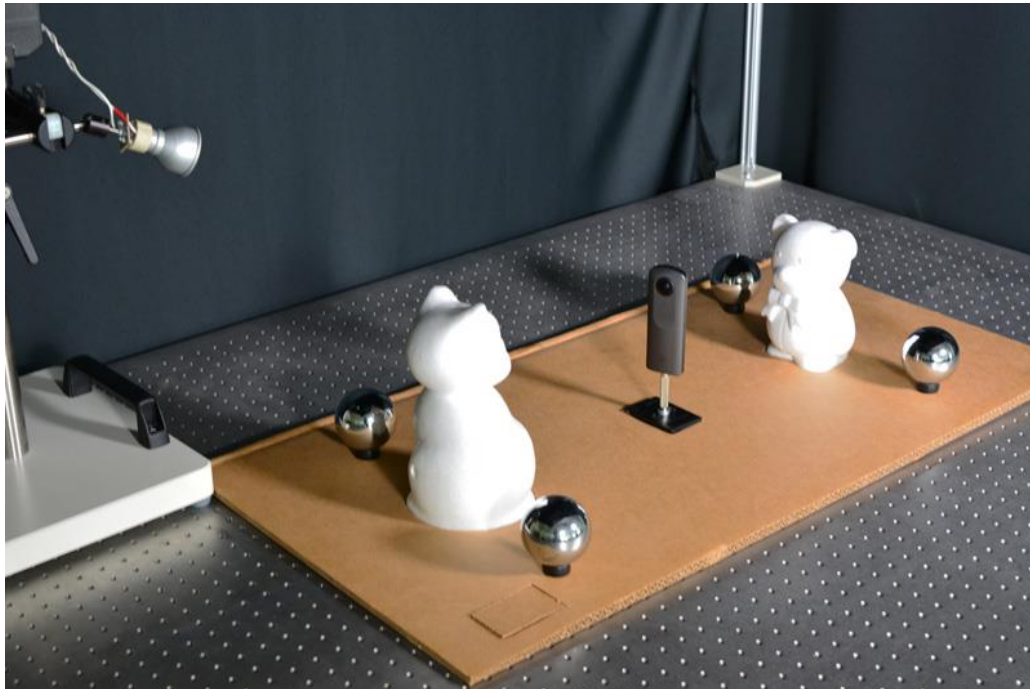3D reconstruction (external view)

Room

Example of input image

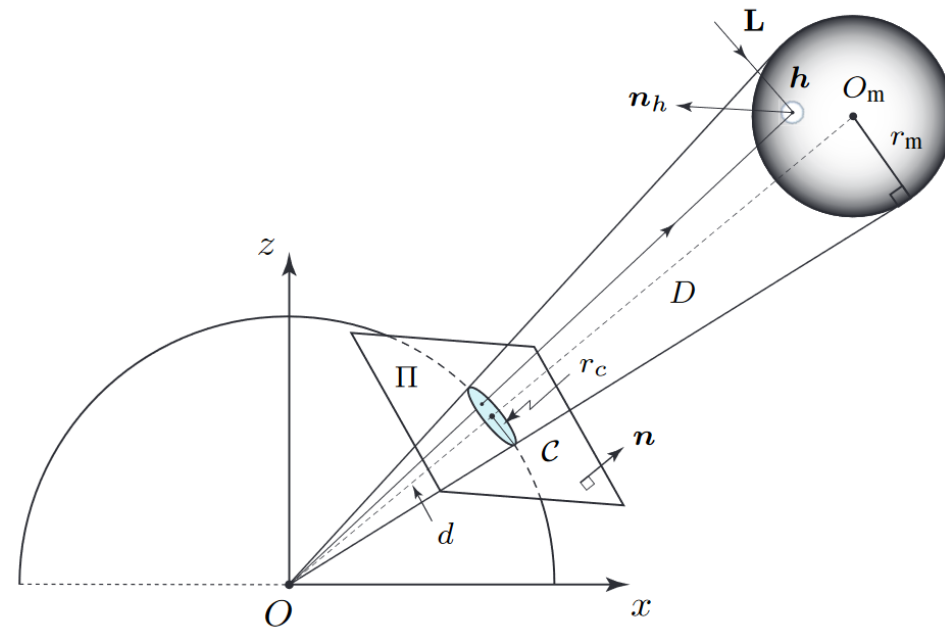Estimated normal vectors
in false colors

Half of the final 3D reconstruction

- Setup for the experiments and estimation of the light direction

Experimental material

Estimation of light direction using a mirror ball

- Real-world experiments

Example of input image

Normal vectors in false colors

Albedo estimation [Schneiders & Wong, CVIU'13]

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

- Take light attenuation into account

- Validation using an outdoor scene under natural illumination conditions

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Thank you for watching!

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