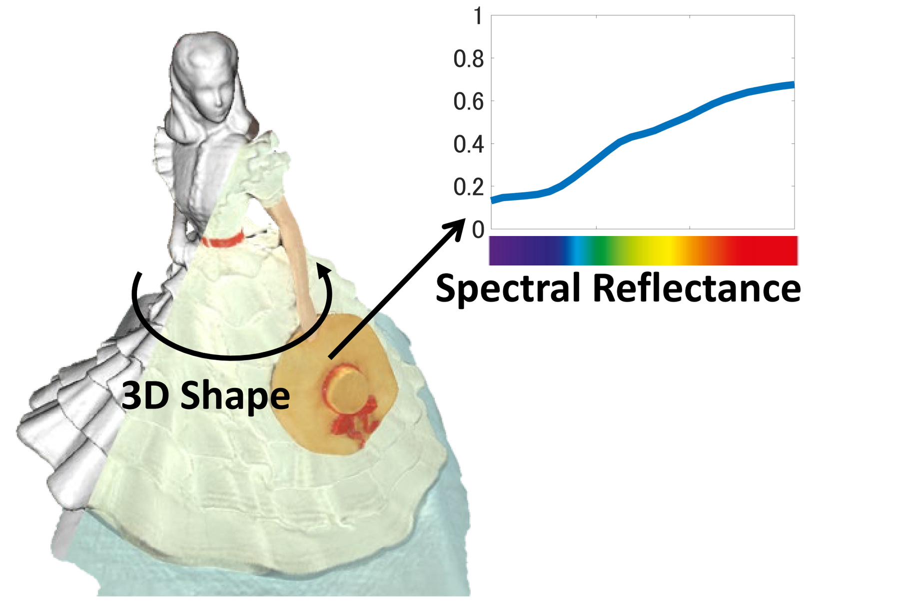
ICCV 2019 Seoul, Korea

Pro-Cam SSfM: Projector-Camera System for Structure and Spectral Reflectance from Motion

Chunyu Li, Yusuke Monno, Hironori Hidaka, and Masatoshi Okutomi
Tokyo Institute of Technology, Tokyo, Japan
東京工業大学 Tokyo Institute of Technology

Goal

Acquisition of
- 3D shape
- Spectral reflectance

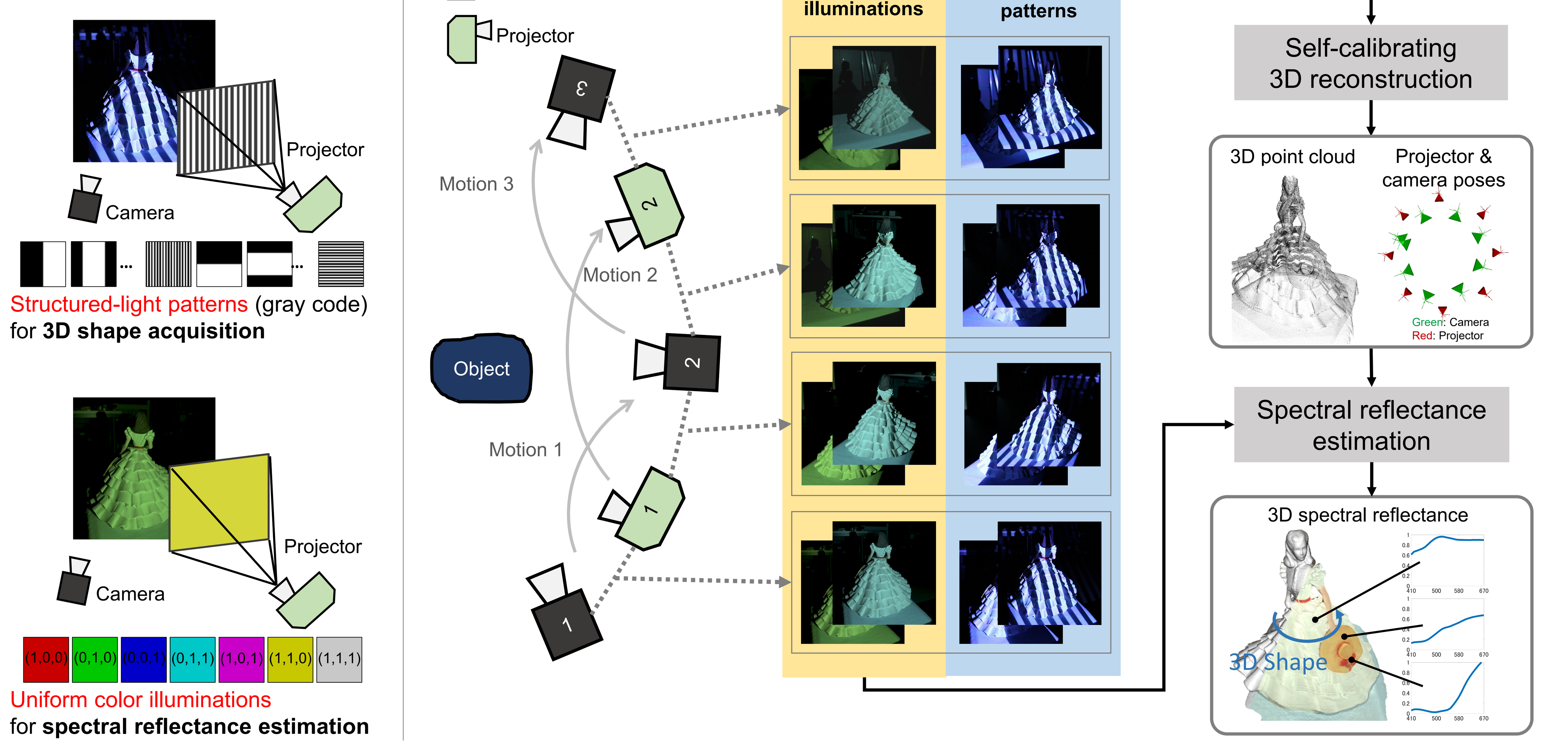


Contributions

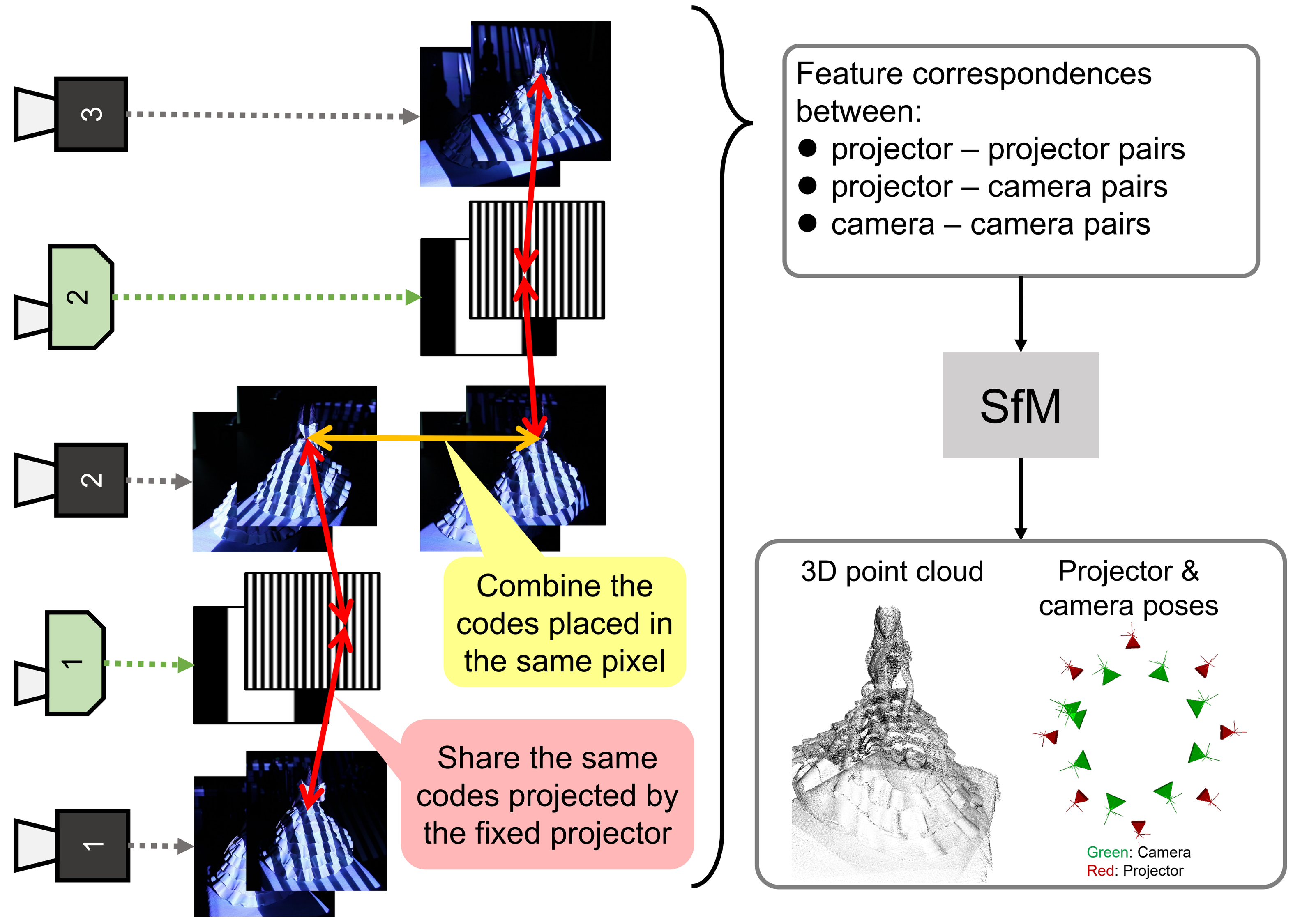
- Usage of standard camera and projector
- Self-calibrating 3D reconstruction
- Spectral reflectance estimation considering geometric information

Overview

The projector has two functions:



Self-calibrating 3D reconstruction



Spectral reflectance estimation considering shading

Cost function: $\underset{\boldsymbol{\alpha}_k}{\operatorname{argmin}}\ \underbrace{E_{ren}(\boldsymbol{\alpha}_k)}_{\text{Rendering term}} + \gamma \underbrace{E_{ssm}(\boldsymbol{\alpha}_k)}_{\text{Spectral smoothness term}}$

k: 3D point index
c: Camera view index
$\mathcal{V}(k)$: The visible camera set for k-th point
$y^{obs}_{k,c}$: The observed image intensity

Rendering term:

$$E_{ren}(\boldsymbol{\alpha}_k) = \sum_{c\in\mathcal{V}(k)} \frac{\left\| \boldsymbol{y}^{obs}_{k,c} - \boxed{\boldsymbol{y}_{k,c}(\boldsymbol{\alpha}_k)} \right\|_2^2}{|\mathcal{V}(k)|}$$

Rendered model:

$$\boldsymbol{y}_{k,c}(\boldsymbol{\alpha}_k) = s\, \boldsymbol{C}^{\mathrm{T}}\, \boldsymbol{L}\, \boldsymbol{r}_k$$

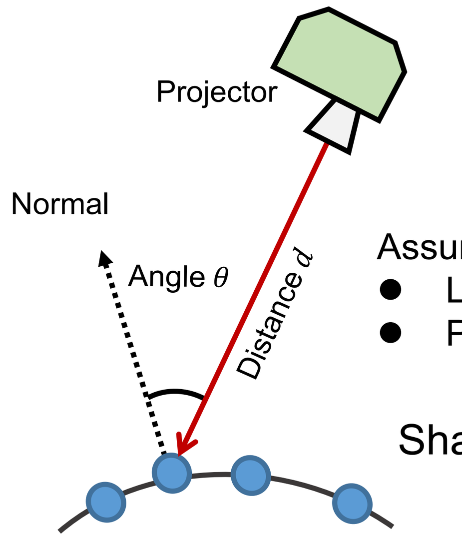
$$\begin{pmatrix} \hat{y}_R \\ \hat{y}_G \\ \hat{y}_B \end{pmatrix} = s$$

Shading | Camera sensitivity (31) | Illumination (31) | Spectral reflectance (31)

$\boldsymbol{r}_k$ is expressed with 8 basis:

$$\boldsymbol{r}_k \approx \boldsymbol{B}\boldsymbol{\alpha}_k = \underbrace{\left[\ \cdots \ \right]}_{\text{Basis}} \begin{pmatrix} a_1 \\ a_2 \\ \vdots \\ a_8 \end{pmatrix}$$

Shading model:

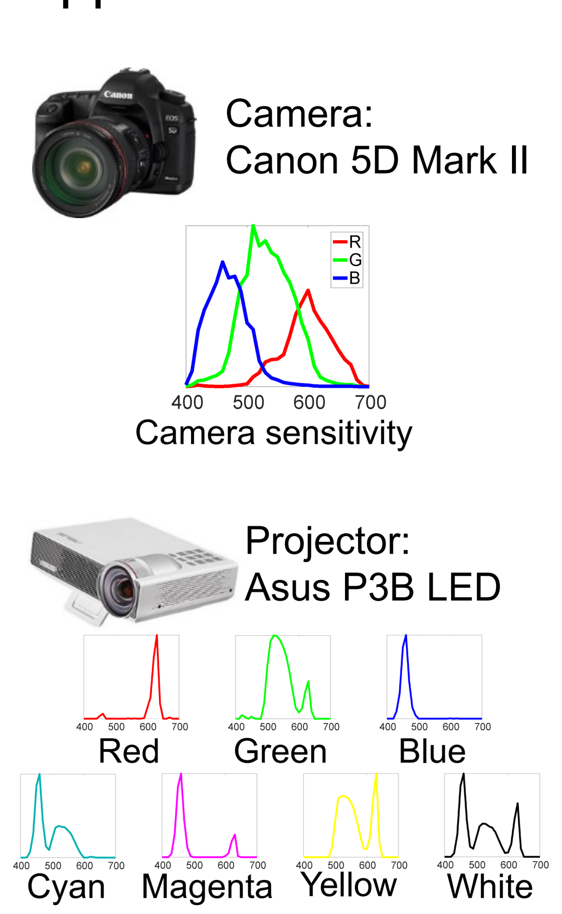


Assumption:
- Lambertian reflection
- Point light source

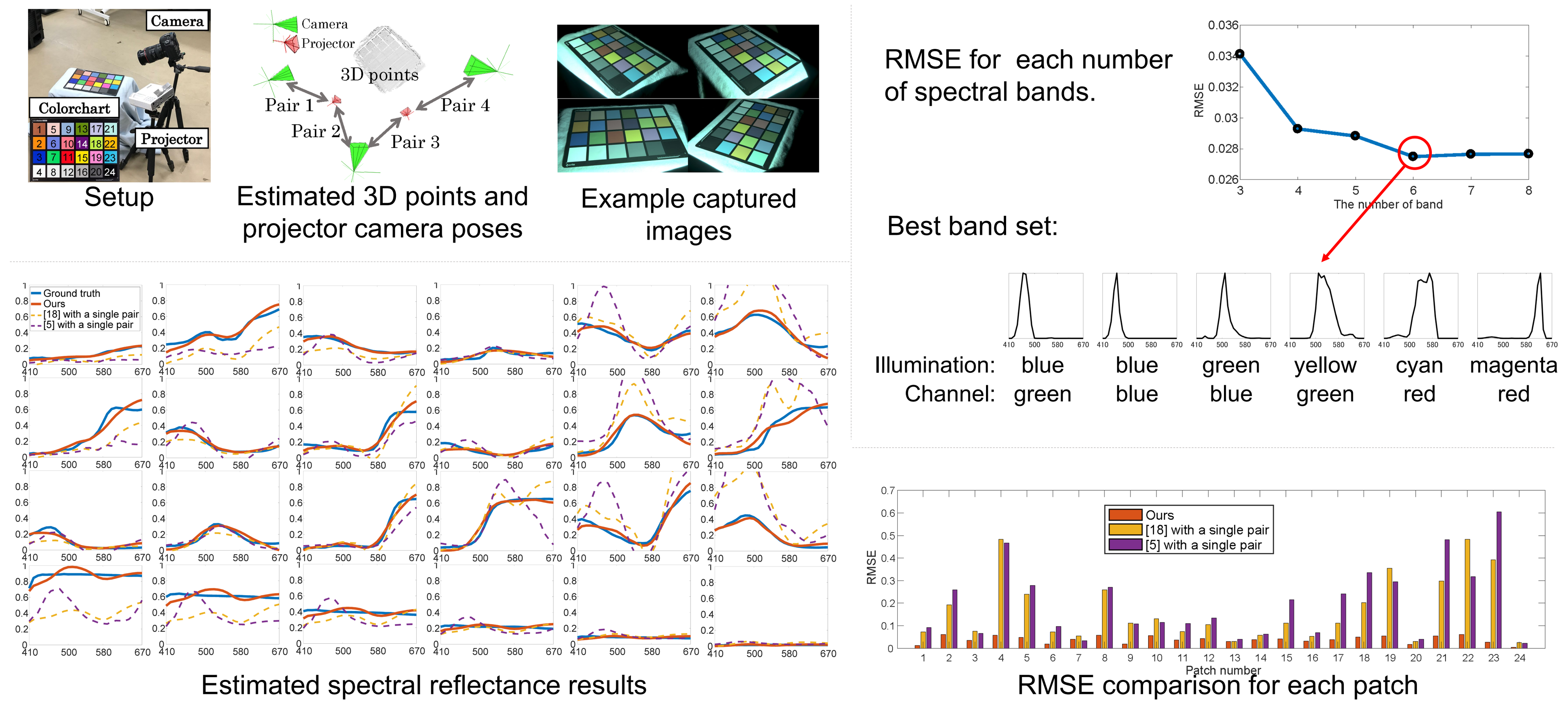
Shading $s = \frac{\cos\theta}{d^2}$

Experiment and results

Apparatus

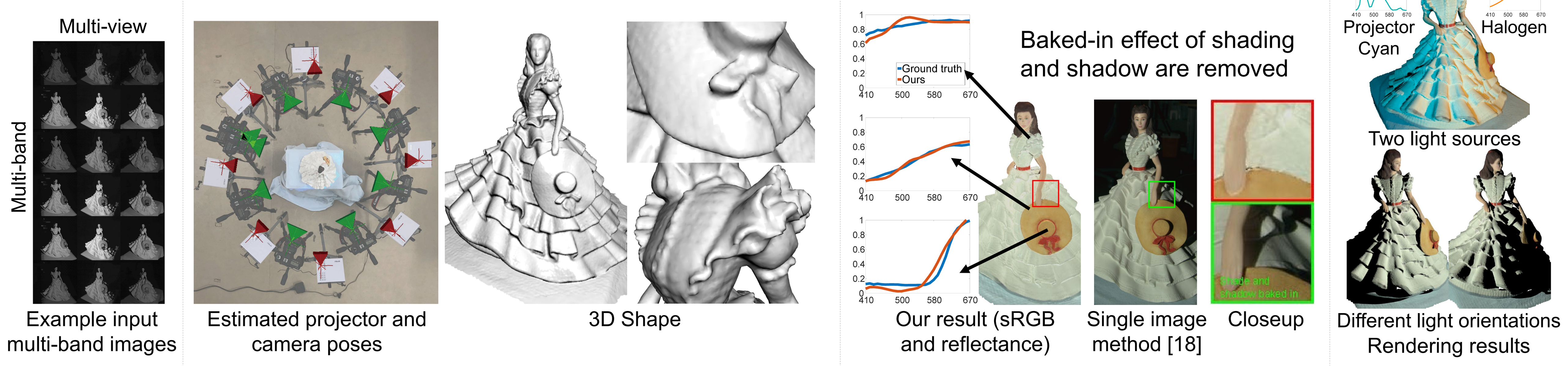


Colorchart results

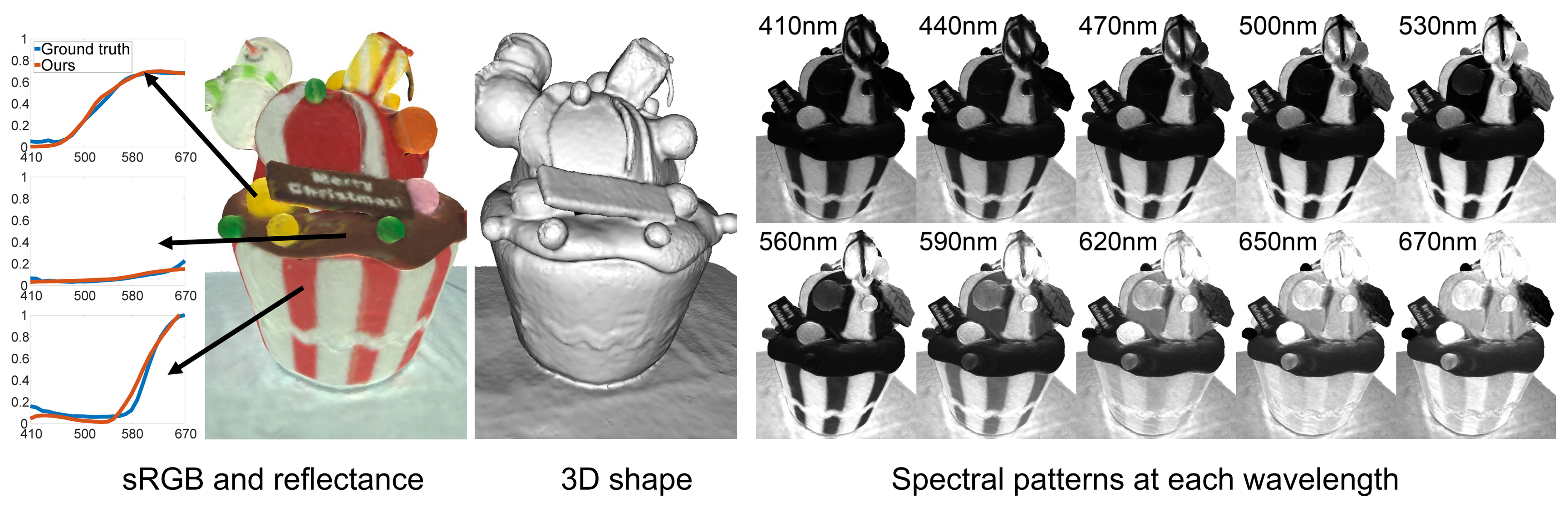


Real object results

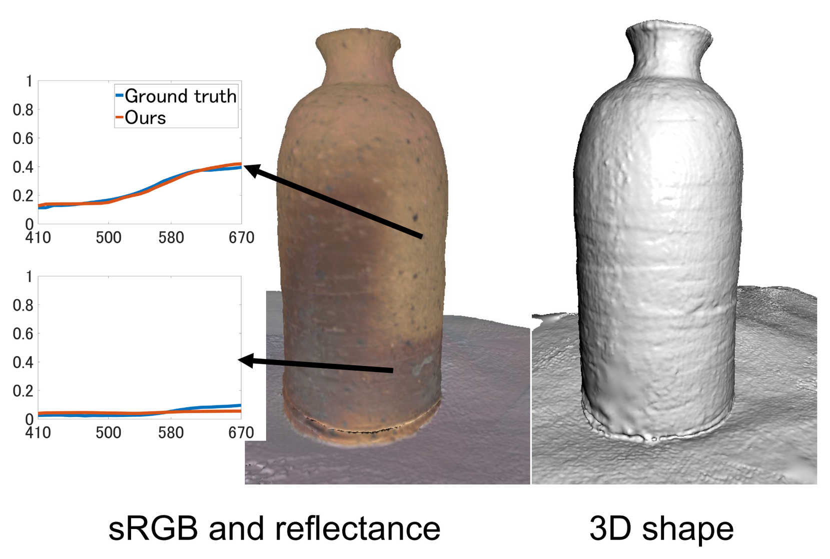
A clay sculpture



A stuffed toy



A ceramic vase



Reference
[5] Boaz Arad and Ohad Ben-Shahar. Sparse recovery of hyperspectral signal from natural RGB images. Proc. of European Conf. on Computer Vision (ECCV), pages 19–34, 2016.
[18] Shuai Han, Imari Sato, Takahiro Okabe, and Yoichi Sato. Fast spectral reflectance recovery using DLP projector. Int. Journal of Computer Vision, 110(2):172–184, 2014.

Project Homepage