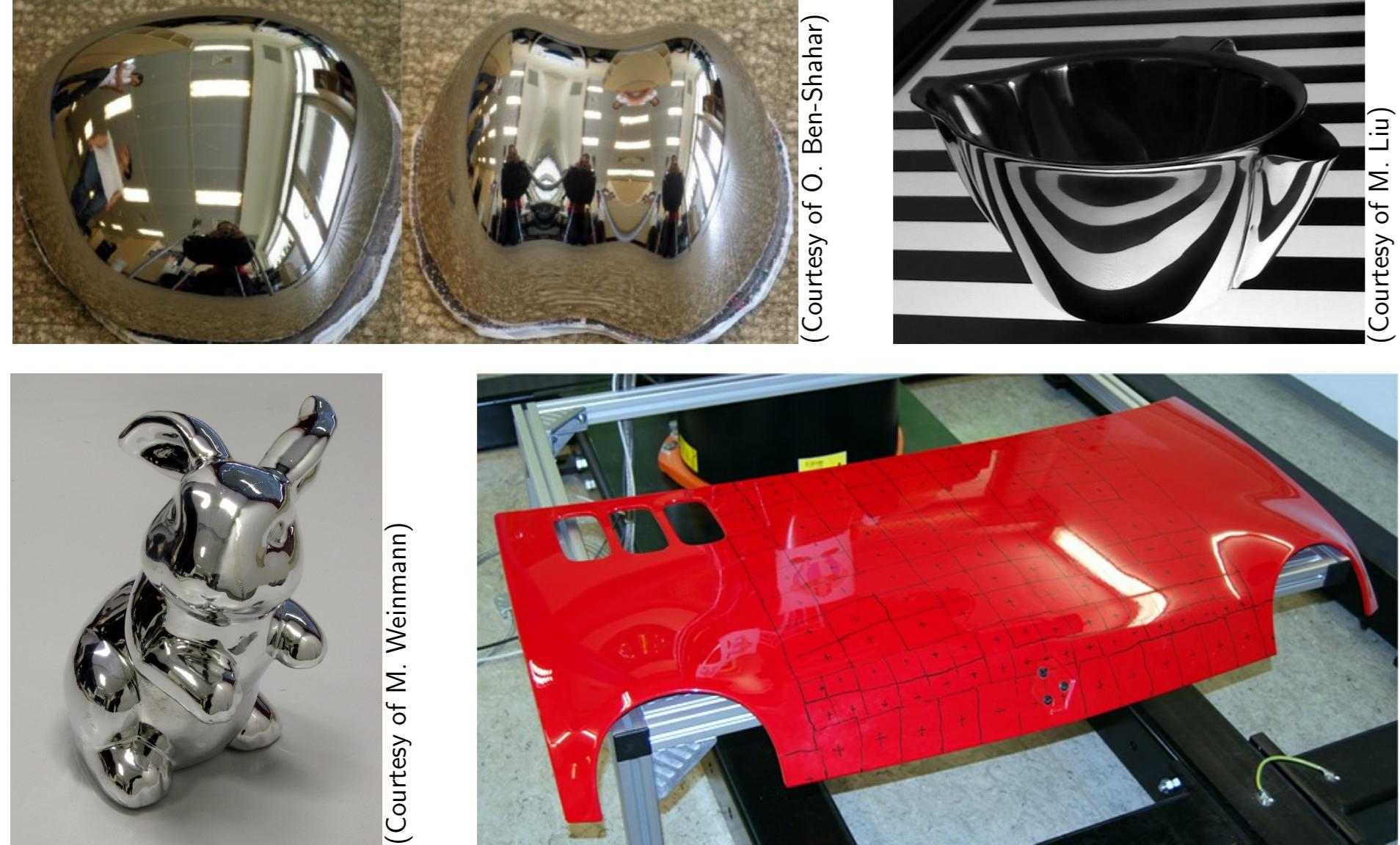


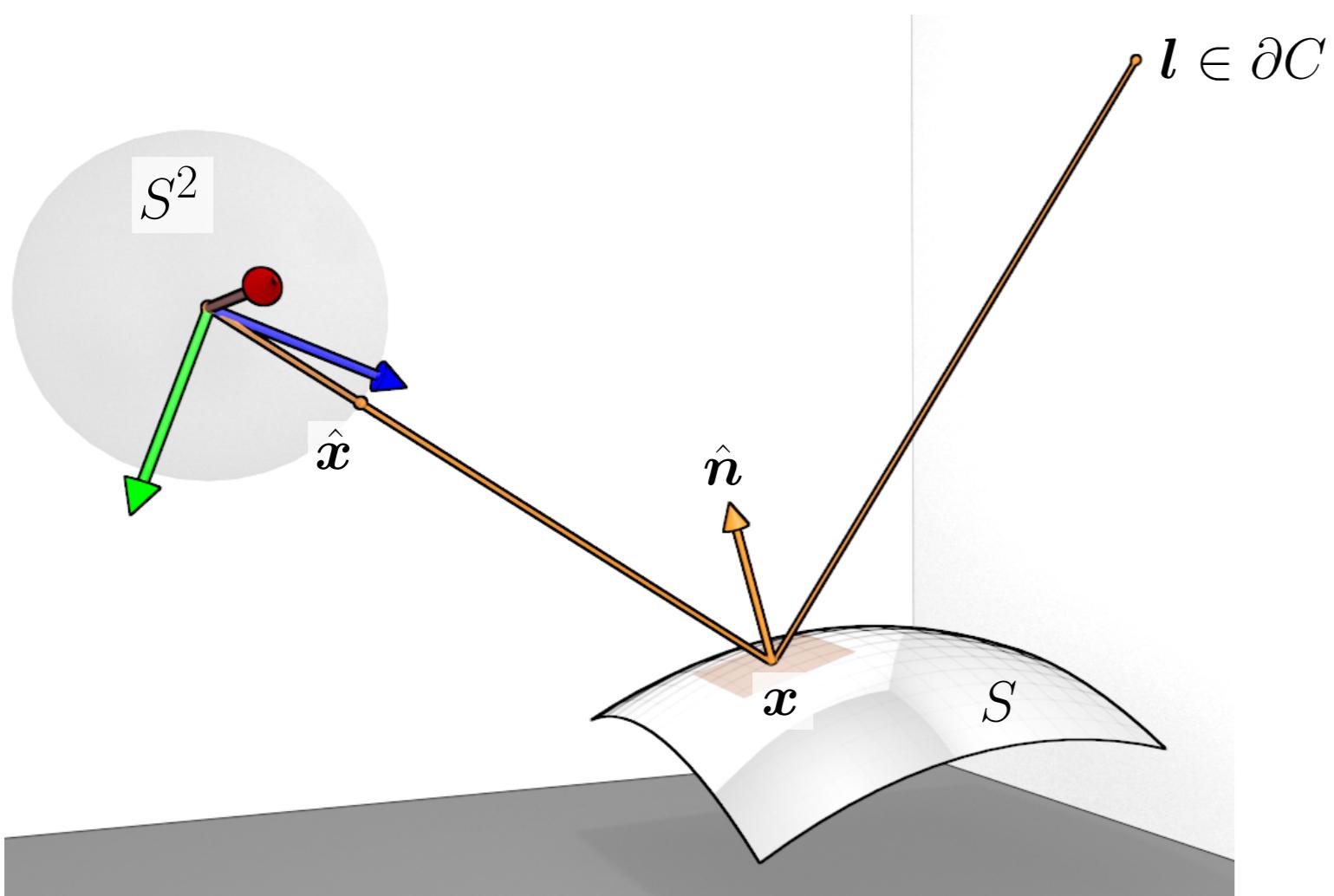
Objectives

- maximize reconstructable surface area
- handle high curvature
- minimize number of vantage points
- allow for dynamic camera placement



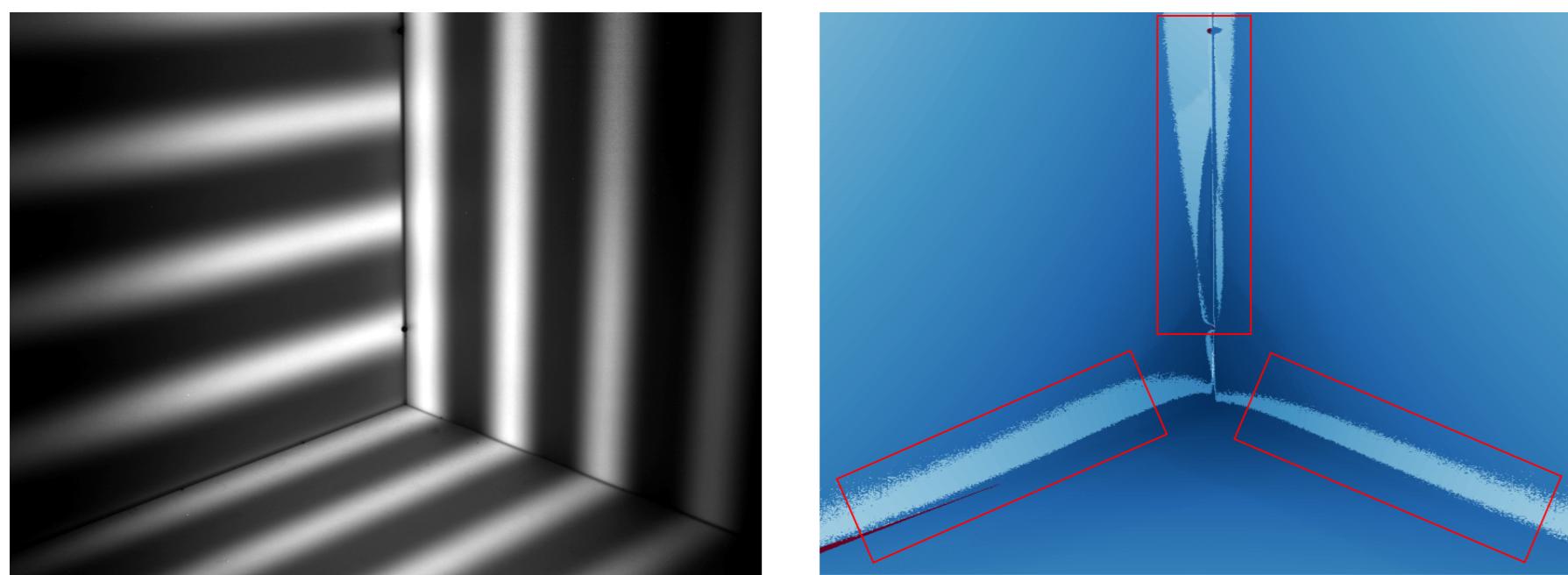
Optical coding

- geometry of reflection:

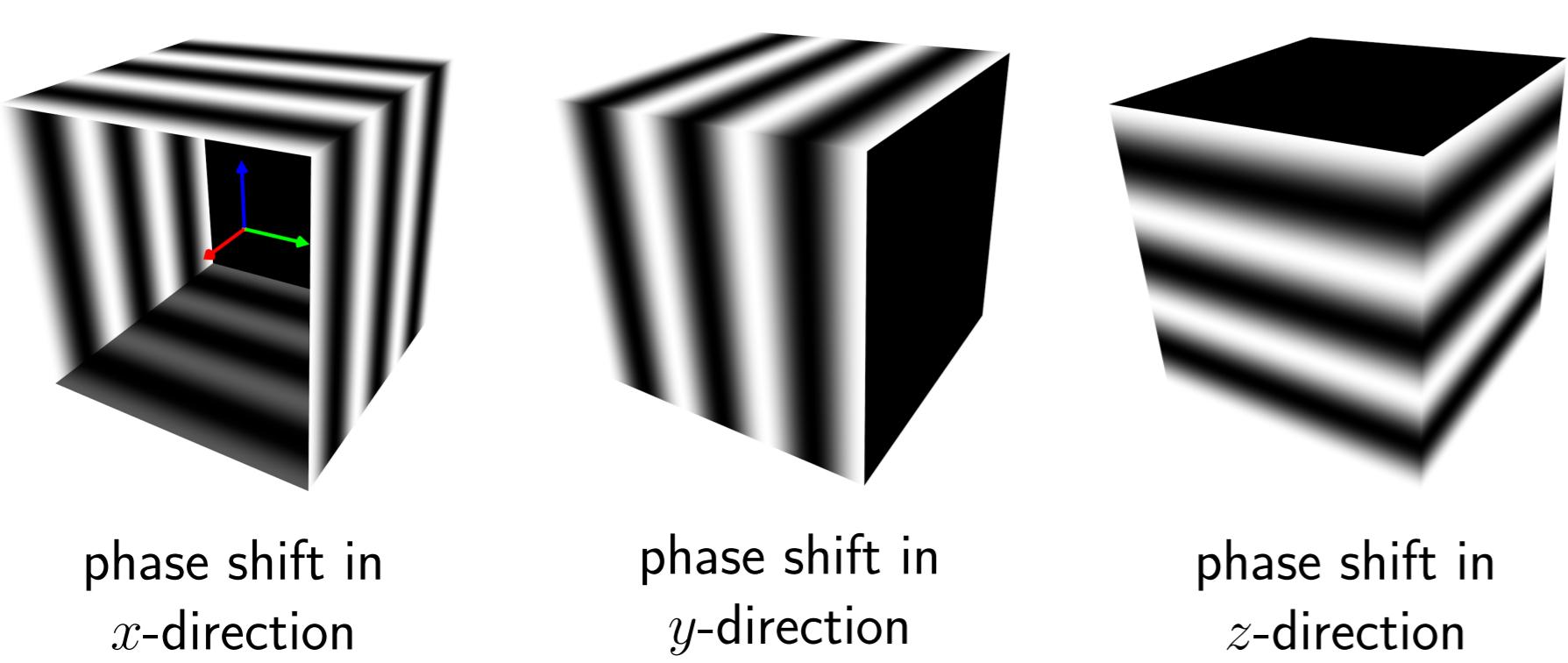


- $-\hat{x} \in \mathbb{S}^2$: view vector
- S : specular surface
- x : point on S
- \hat{n} : normal at x
- l : scene point which appears under \hat{x} (*light map*)

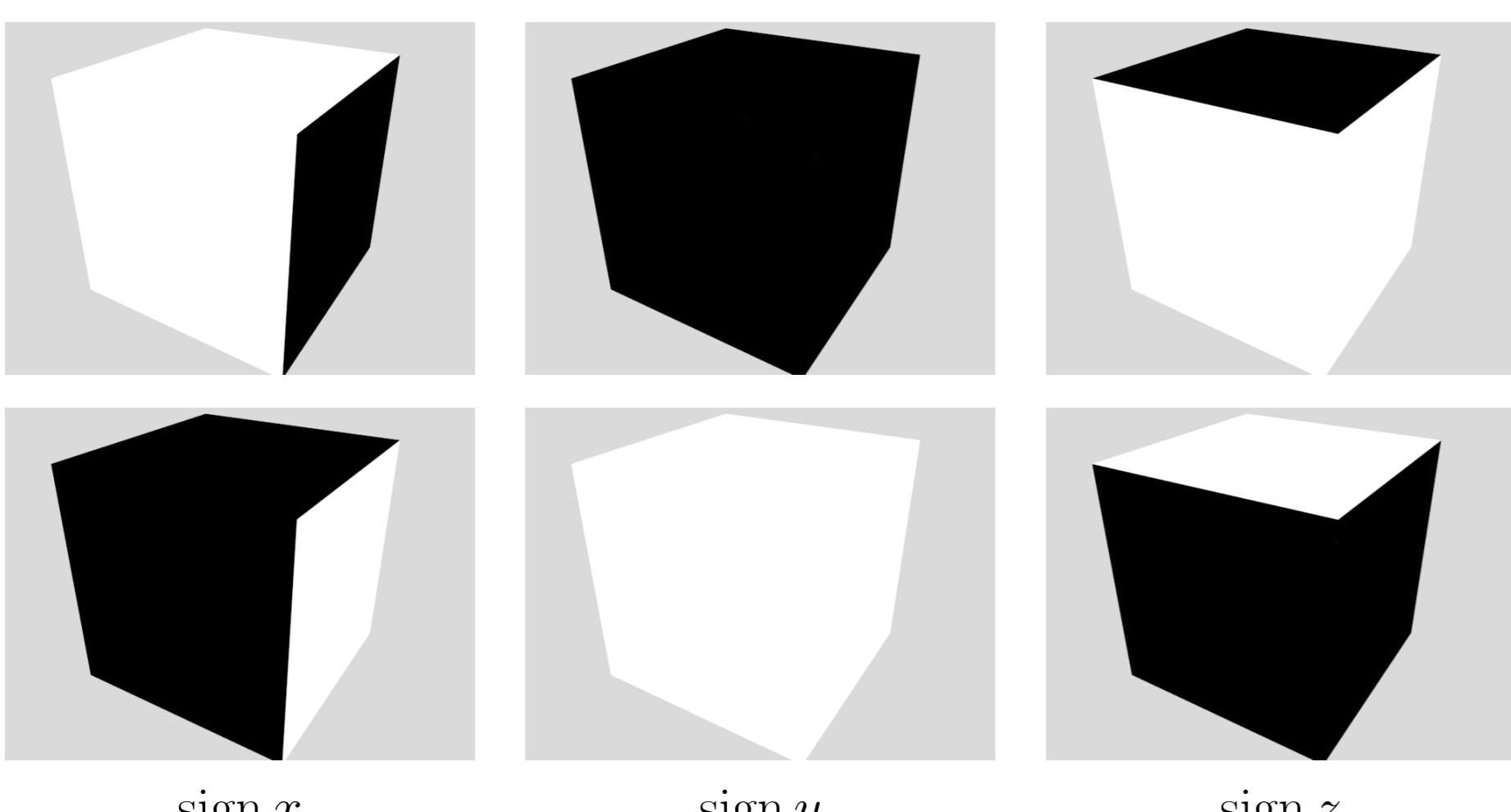
- leakage in naive approach to light map estimation:



- proposed scheme:



- differential gray coding of sign:



Calibration

1. Coarse segmentation by thresholding

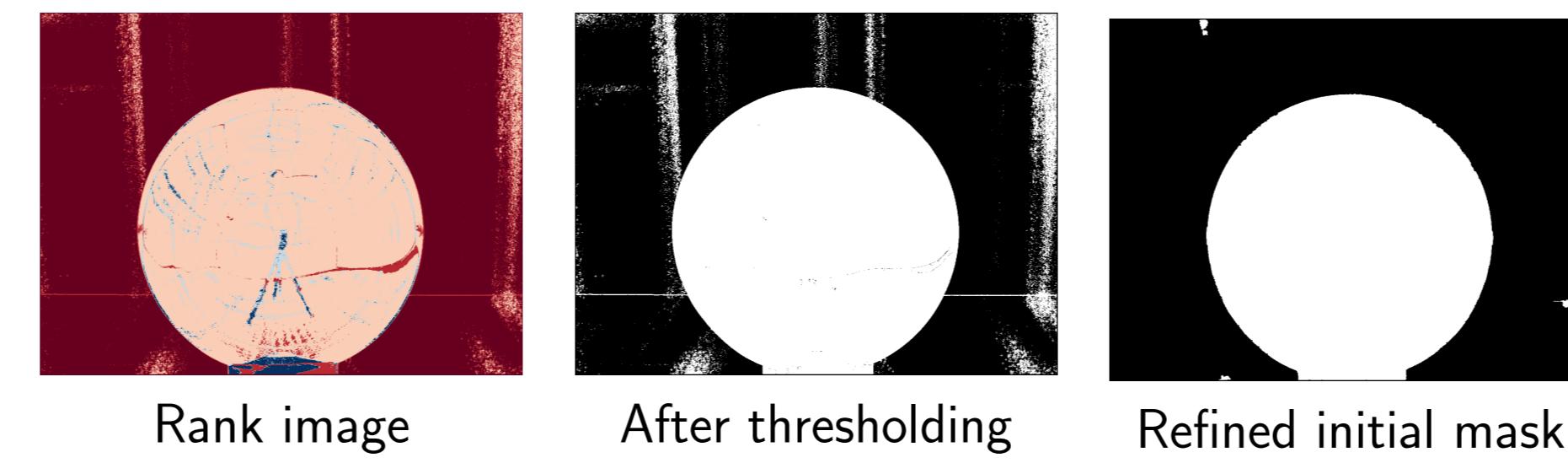
$$s(\mathbf{p}_{ij}) := |1 - r_{ij}^x r_{ij}^y|,$$

where

$$r_{ij}^x := \text{rank}(\mathbf{l}_{i-1,j}, \mathbf{l}_{i,j}, \mathbf{l}_{i+1,j})$$

and $r_{ij}^y := \text{rank}(\mathbf{l}_{i,j-1}, \mathbf{l}_{i,j}, \mathbf{l}_{i,j+1})$,

and \mathbf{p}_{ij} denotes the pixel in row i and column j .



2. Find CAVE wall which appears most often in background.

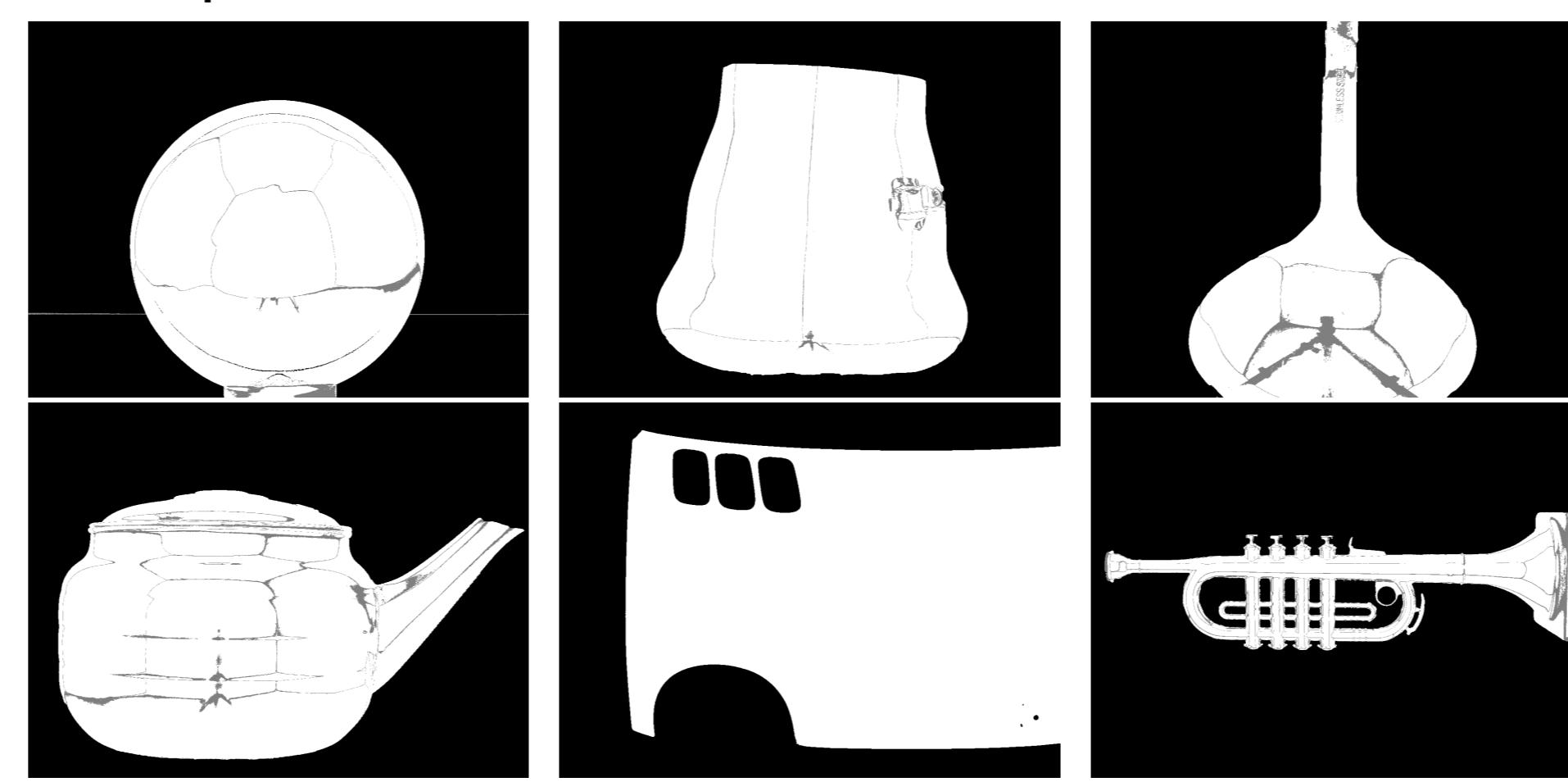
3. Estimate and factor homography to obtain initial estimate of extrinsic parameters $(\mathbf{R}, \mathbf{t}) \in \text{SE}(\mathbb{R}^3)$.

4. Threshold re-projection error:

$$\chi_b(\mathbf{p}_{ij}) := \begin{cases} 1 & \text{if } \|\pi(\mathbf{R}\mathbf{l}(\mathbf{p}_{ij}) + \mathbf{t}) - \mathbf{p}_{ij}\| < \theta, \\ 0 & \text{otherwise.} \end{cases}$$

5. Refine pose by bundle adjustment.

Examples:



Reconstruction

- light map \mathbf{l} equivalent to normal field $\hat{\mathbf{n}}_m : \mathbb{R}^3 \rightarrow \mathbb{S}^2$ with spatial support

- shape optimization problem:

$$S^* = \arg \min_S \int_S \frac{1}{2} \|\hat{\mathbf{n}}(\mathbf{x}) - \hat{\mathbf{n}}_m(\mathbf{x})\|^2 d\mathbf{x}.$$

- gauge freedom necessitates *regularization*

- here: point $\mathbf{x}_0 \in S^*$ assumed known

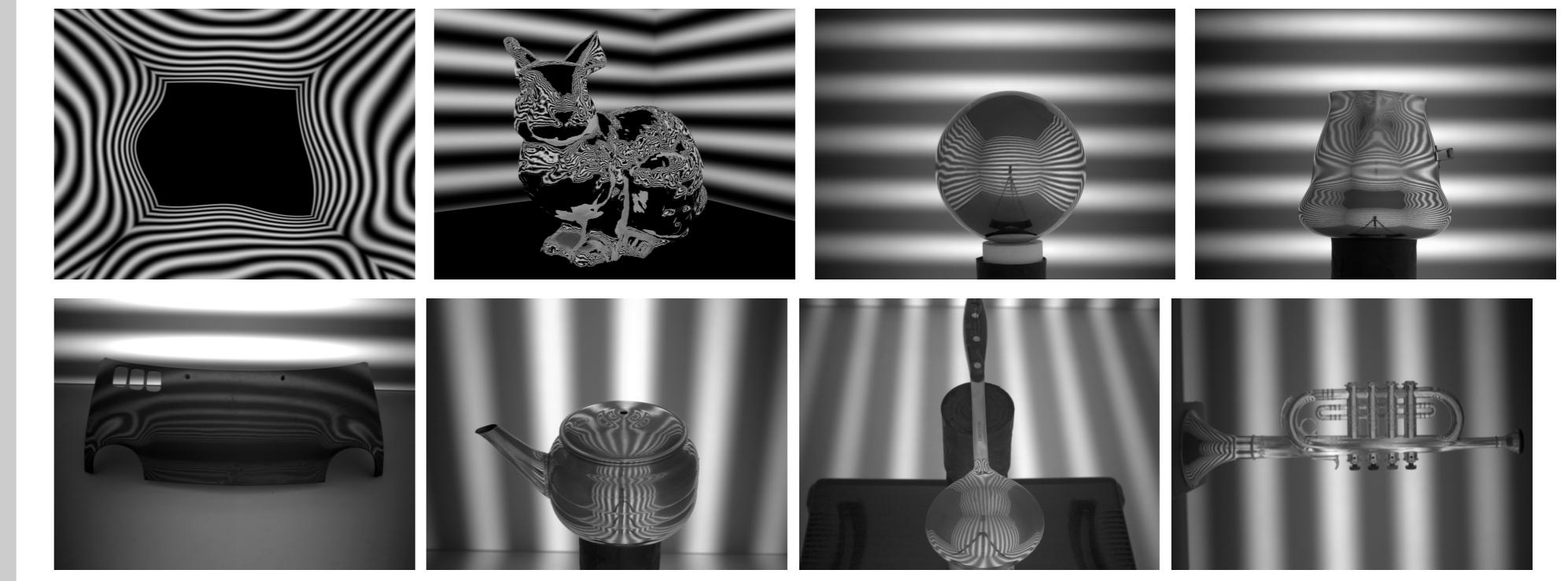
Implementation

- OpenScenGraph plug-in for camera-display synchronization
- patterns as OBJ models with varying texture maps
- standard phase decoding technique [GP98]
- C++ library for normal integration with QT front-end

Download: <http://bitbucket.org/jbalzer/>

Data set

- 4 rendered scenes
- ground truth geometry
- 6 real scenes
- VTK legacy format
- I/O routines for Python/MATLAB provided



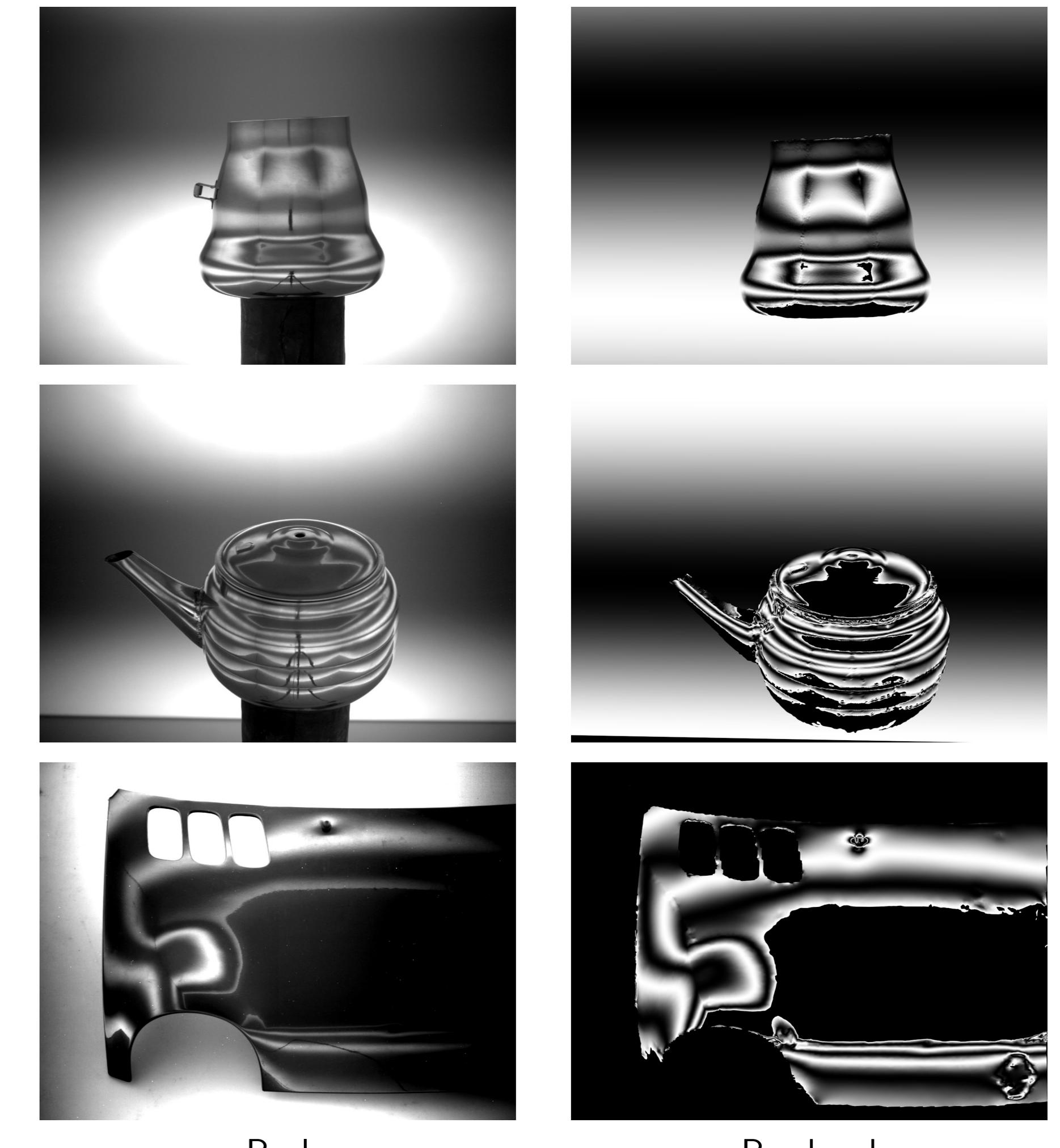
Download: <http://vision.ucla.edu/~jbalzer/cavlectometry/>

Results

Reconstruction error in mm:



“Closing the loop”:



References

- [GP98] Dennis C. Ghiglia and Mark D. Pritt. *Two-dimensional phase unwrapping: theory, algorithms, and software*. Wiley, 1998.