SPLINE-Net: Sparse Photometric Stereo Through Lighting Interpolation and Normal Estimation Networks

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PROBLEM AND CONTRIBUTIONS

Sparse Photometric Stereo

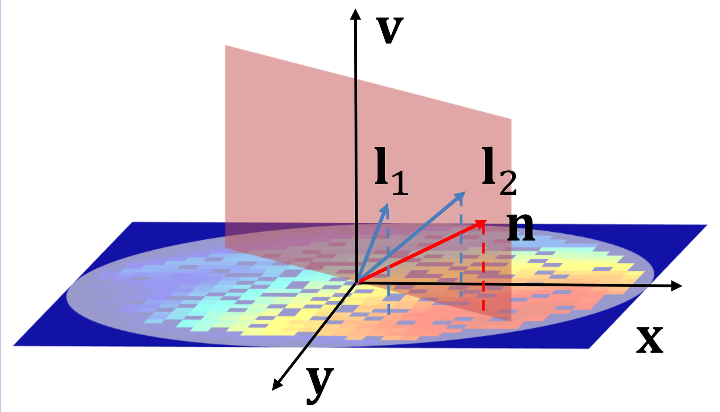
- Estimation of surface normal for static objects with general BRDFs given multiples images captured under a sparse set of arbitrary lights (≤ 10).

Key Contributions

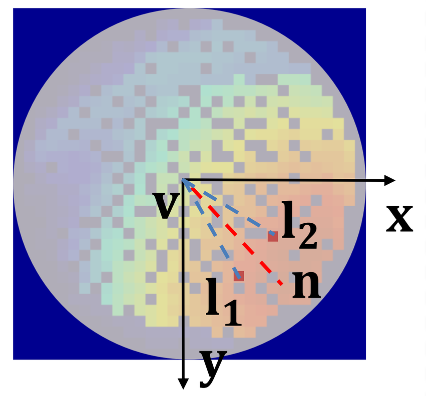
- Address the problem of sparse photometric stereo through an integrated learning procedure of lighting interpolation and normal estimation.
- Show how the proposed symmetric and asymmetric loss functions can be formulated to facilitate the learning of lighting interpolation and normal estimation with isotropy constraint and outlier rejection considered.

PROPERTY OF OBSERVATION MAP

Isotropy of Observation Map

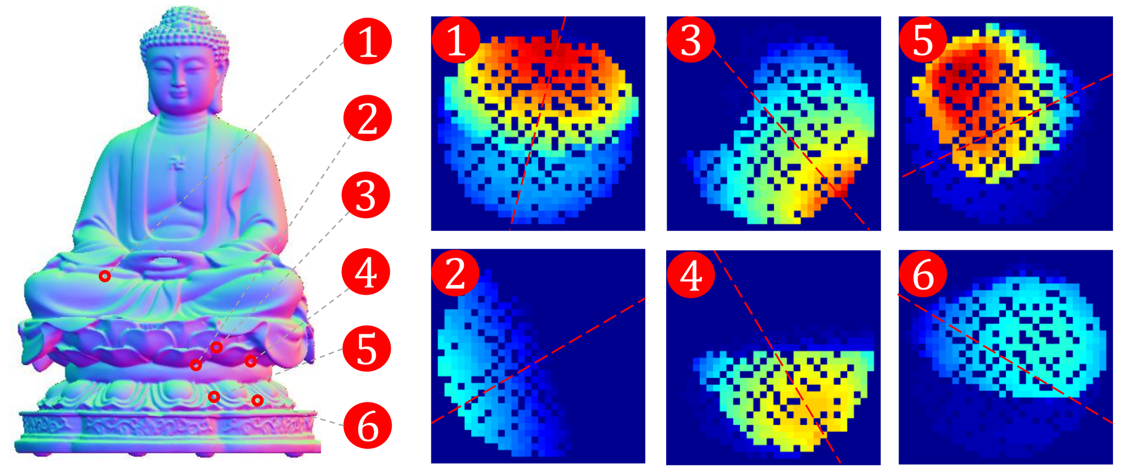


front view



top view

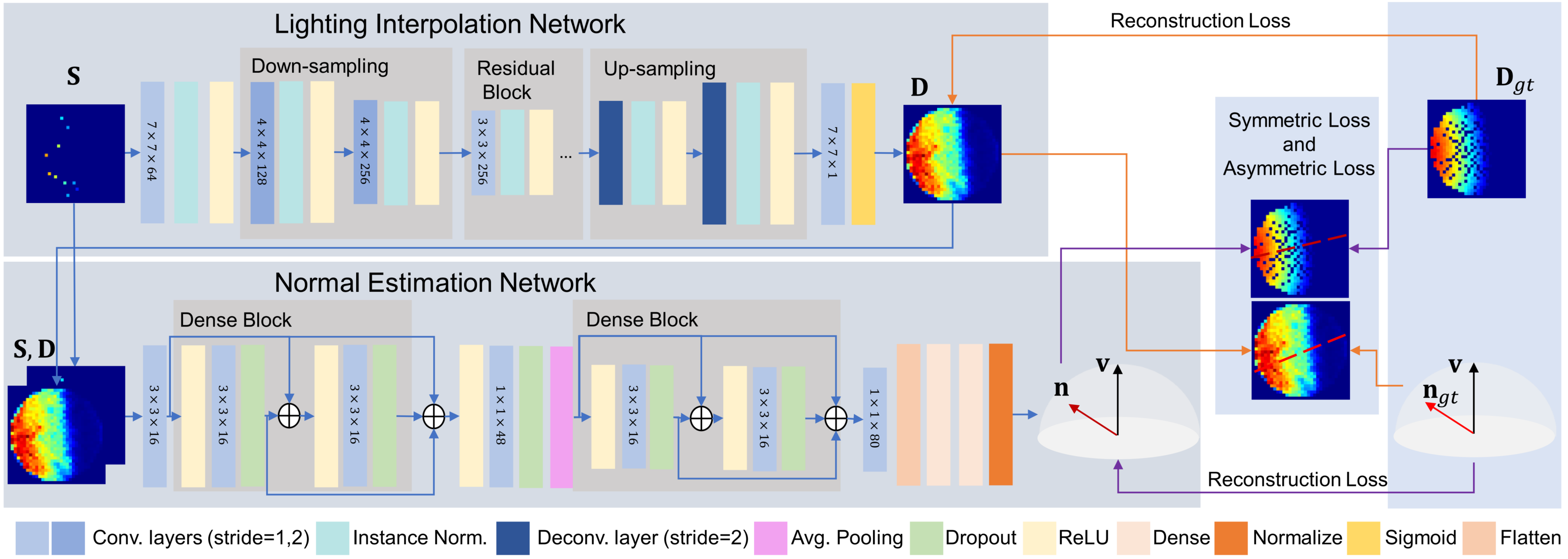
Illustrations of Observation Map



normal map isotropy global effects

METHOD

Framework



Key Idea

- Spatial continuity: image inpainting.
- Isotropic BRDFs: narrow down the solution space.

Loss Functions

- $\mathcal{L}_f = \mathcal{L}_f^{rec} + \lambda_s \mathcal{L}_f^s + \lambda_a \mathcal{L}_f^a$
- $\mathcal{L}_g = \mathcal{L}_g^{rec} + \lambda_s \mathcal{L}_g^s + \lambda_a \mathcal{L}_g^a$

Symmetric and Asymmetric Loss

- $\mathcal{L}_s = |\mathbf{D} - r(\mathbf{D}, \mathbf{n})|_1$
- $\mathcal{L}_a = \left| |\mathbf{D} - r(\mathbf{D}, \mathbf{n})|_1 - 1 \right|_1 +$

$$\lambda_c \left| |p(\mathbf{D}) - p(r(\mathbf{D}, \mathbf{n}))|_1 - 1 \right|_1$$

$r(\cdot)$ mirrors $\mathbf{D}$ with respect to $\mathbf{n}$

$p(\cdot)$ is average pooling operation to ensure spatial continuity

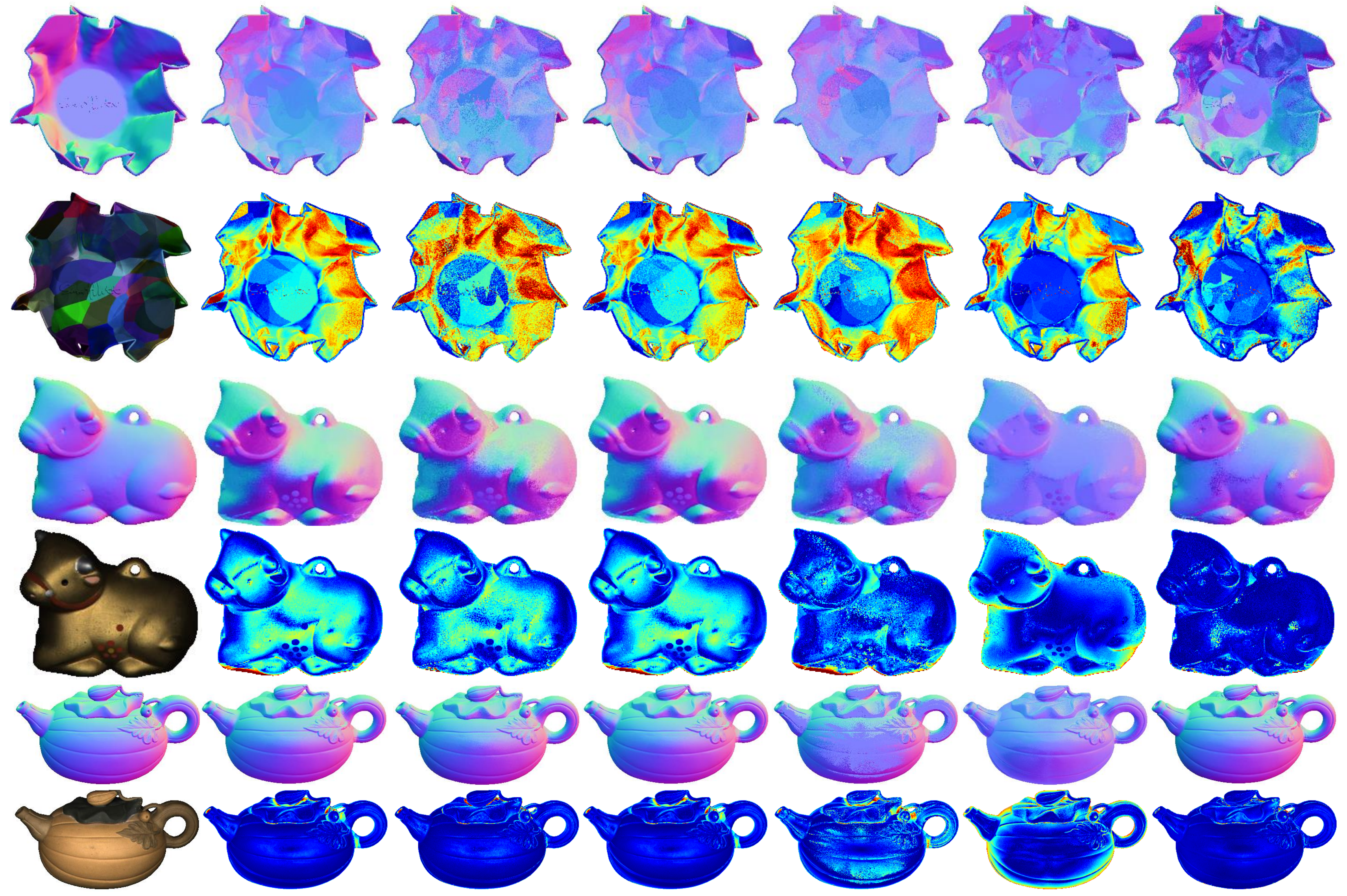
Overall Performance (CyclesPS-Test, DiLiGenT)

	PAPERBOWL		SPHERE		TURTLE		Avg.	PAPERBOWL		SPHERE		TURTLE		Avg.
	M	S	M	S	M	S		M	S	M	S	M	S	
LS	41.47	35.09	18.85	10.76	27.74	19.89	25.63	43.09	37.36	20.19	12.79	28.51	21.76	27.28
IW12	46.68	33.86	16.77	**2.23**	31.83	12.65	24.00	48.01	37.10	21.93	**3.19**	34.91	16.32	26.91
ST14	42.94	35.13	22.58	4.18	34.30	17.01	26.02	44.44	37.35	25.41	4.89	36.01	19.06	27.86
IA14	48.25	43.51	18.62	11.71	30.59	23.55	29.37	49.01	45.37	21.52	13.63	32.82	26.27	31.44
CNN-PS	37.14	23.40	17.44	6.99	22.86	10.74	19.76	38.45	26.90	18.25	9.04	23.91	14.36	21.82
SPLINE-Net	**29.87**	**18.65**	**6.59**	3.82	**15.07**	**7.85**	**13.64**	**33.99**	**23.15**	**9.21**	6.69	**17.35**	**12.01**	**17.07**

Methods	BALL	BEAR	BUDDHA	CAT	COW	GOBLET	HARVEST	POT1	POT2	READING	Avg.
LS	4.41	9.05	15.62	9.03	26.42	19.59	31.31	9.46	15.37	20.16	16.04
IW12	**3.33**	7.62	13.36	8.13	25.01	18.01	29.37	8.73	14.60	16.63	14.48
ST14	5.24	9.39	15.79	9.34	26.08	19.71	30.85	9.76	15.57	20.08	16.18
IA14	12.94	16.40	20.63	15.53	18.08	18.73	32.50	**6.28**	14.31	24.99	19.04
CNN-PS	17.86	13.08	19.25	15.67	19.28	21.56	21.52	16.95	18.52	21.30	18.50
Nets *w/o* loss	6.06	7.01	10.69	8.38	10.39	11.37	**19.02**	9.42	12.34	16.18	11.09
Nets with $\mathcal{L}^s$	5.04	**5.89**	10.11	7.79	9.38	10.84	19.03	8.91	**11.47**	**15.87**	10.43
SPLINE-Net	4.96	5.99	**10.07**	**7.52**	**8.80**	**10.43**	19.05	8.77	11.79	16.13	**10.35**

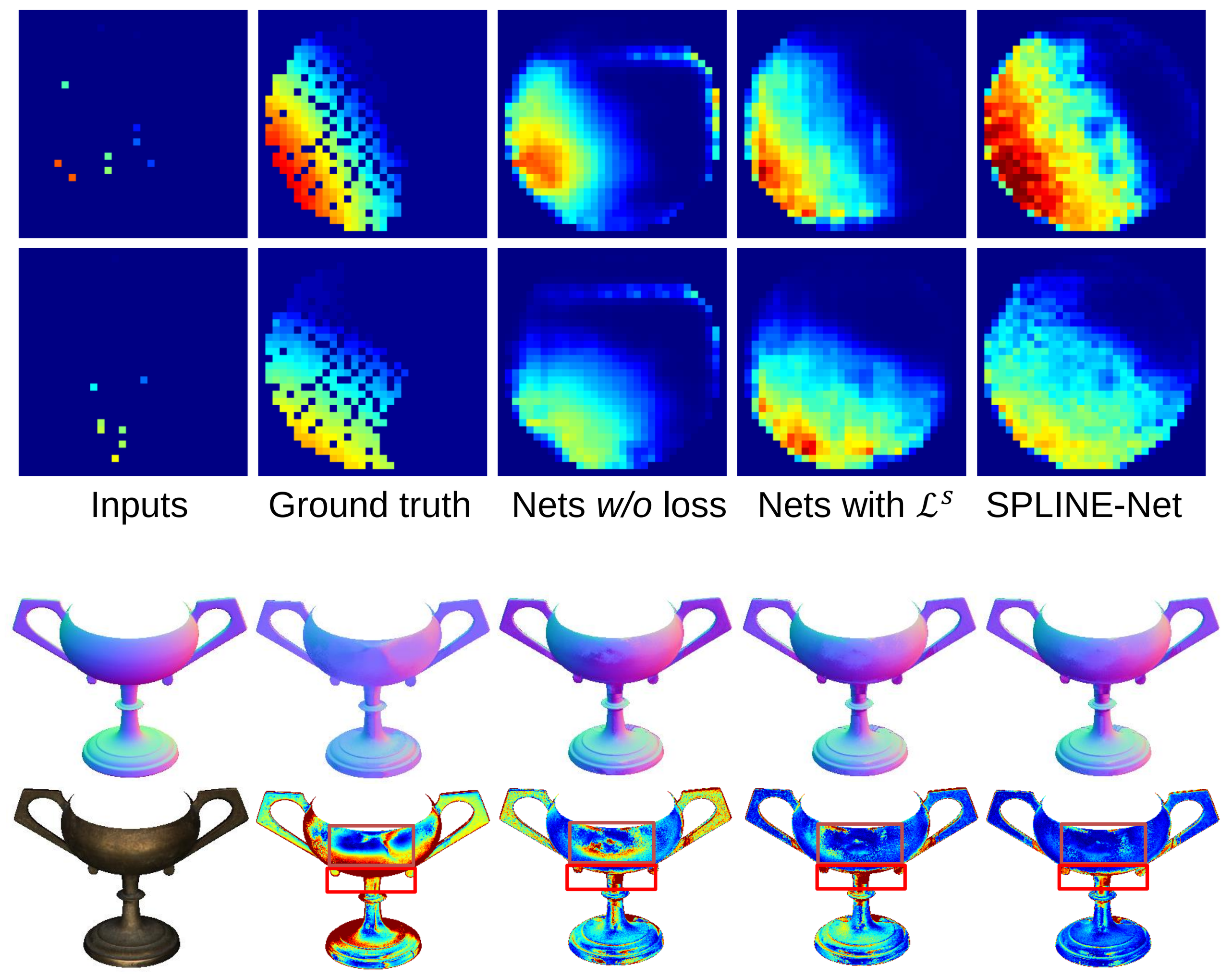
EXPERIMENTAL RESULTS

Visual Quality Comparison



Ground truth LS IW12 ST14 IA14 CNN-PS SPLINE-Net

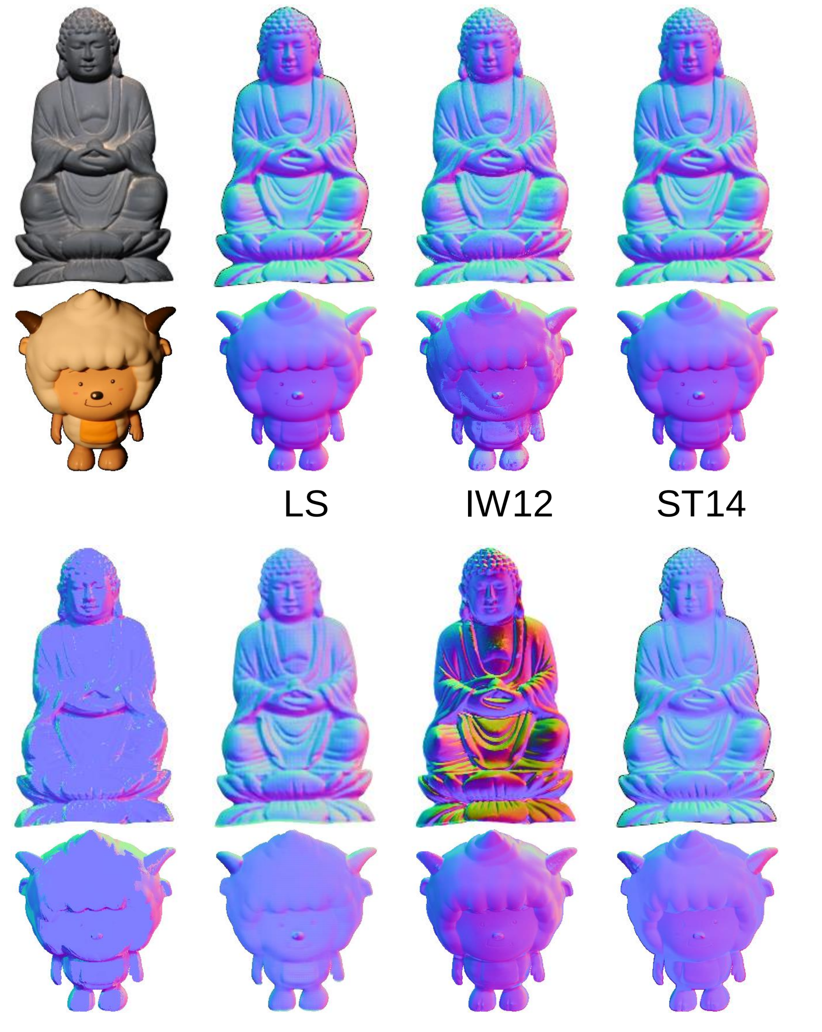
Ablation Study



Inputs Ground truth Nets *w/o* loss Nets with $\mathcal{L}^s$ SPLINE-Net

Ground truth CNN-PS Nets *w/o* loss Nets with $\mathcal{L}^s$ SPLINE-Net

Limitations



LS IW12 ST14

IA14 PS-FCN CNN-PS SPLINE-Net