Neural Grey: Practical Vignetting Calibration from Casual Camera Rolls Supplementary Material

Yueze Wang and Spencer LaVere Smith

I. Additional Results

The 15-scenario representation study and the 12-case diagnostic benchmark address complementary questions under different protocols. The former tests physical/neural component removal; the latter tests selection, capture count, and local sensitivity. Synthetic-100, RayTraced-12, Real-21, and Enhanced-36 retain the benchmark definitions in the main text. The accompanying evidence archive contains the per-category and per-architecture tables and original result records.

TABLE S1
12-case diagnostic benchmark refits: mean PSNR (dB) before/after radial selection; 50 epochs, 256-pixel long edge, 20K coordinates, seed 42.

Variant	Joint fit	Complete
Default	24.0237	28.5523
Residual cap .12	24.0330	28.5809
Residual cap .24	24.0558	28.5782
Without fourth harmonic	24.0325	28.5701
Without explicit harmonics	24.0317	28.5737
Polynomial-only illumination	24.0168	28.5446
MLP-only illumination	24.0219	28.5505

Numerical sensitivity: 12-case diagnostic benchmark

Parameter	Tested values	Span (dB)
Eight loss weights	$0.5\times$ /$1\times$ /$2\times$	$\leq$ .4733
Envelope start; scale; power	.05/.10/.15; .80/.95/1.10; 1/1.6/2.2	$\leq$ .0218
Edge weight; SmoothL1; log-gain clamp	.75/1.25/1.75; .015/.03/.06; .15/.25/.35	$\leq$ .1860
Shading width	64/96/128	.0778
Shading depth	2/3/4	.0442
Illumination width	32/48/64	.0069
Illumination depth	1/2/3	.0301

The authors are with the Department of Electrical and Computer Engineering, University of California, Santa Barbara, Santa Barbara, CA, USA (e-mail: yueze@ucsb.edu; sls@ucsb.edu). Corresponding author: Spencer LaVere Smith.

Span is the maximum minus minimum mean PSNR; grouped rows report the largest span. Each sweep varies one factor under the Table S1 protocol.

Selector sensitivity: Enhanced-36

Parameter	Tested values	Span (dB)
Radial bins	32/48/64	.0044
Gaussian σ (px)	6/10/14	.1174
D_2 threshold	.010/.015/.022	.0326
Wide cosine power	6/7.5/9	.612
Standard blend	.15/.25/.35	.250

The 36 saved fits yield 1,332 scores across 18 factors and 37 settings; 14/18 spans are $<$ .15 dB. The default is 20.600 dB; the wide-power minimum is 19.988 dB. Gaussian widths refer to a 256-pixel long edge. The evidence archive contains all rows.

TABLE S2
Real-camera map errors, three-take means. Range: GT 95th–5th percentile. Gain: RMSE after GT-optimal scaling (diagnostic only).

Configuration	Range	RMSE	Gain	MAE
Canon FL 55 mm	.681	.092	.054	.081
Micro 60 mm	.681	.224	.211	.201
Sigma 20 mm	.788	.049	.035	.045

The ratio of squared mean error to MSE, averaged per take, is 77.3% for Canon 55 mm and 8.9% for Micro 60 mm. The diagnostic gain is $s^* = \langle \widehat{V}, V_{GT} \rangle / \|\widehat{V}\|^2$.

Controlled textured-image correction

Correction	PSNR (dB)	MAE
None	19.58	–
Joint fit	29.00	.03493
Complete estimator	31.40	.02438

Results average 21 measured shading maps applied to one common clean photograph in linear RGB and then corrected. A dash indicates an unreported value.

II. Real-Camera Comparisons

TABLE S3
REAL-21 PER-TAKE PSNR (DB), FULL-FRAME WITH NO PREDICTION-WISE SCALE FITTING. BOLD: BEST IN EACH ROW. COLUMN ABBREVIATIONS: NG, NEURAL GREY; KIM, KIM AND POLLEFEYS; CAO, CAO ET AL.; ZHENG, ZHENG ET AL.; ANALYTIC, ANALYTIC RADIAL (1F); DV4, DEVIGNET (4-SHOT); VCLUT, VCLUT-INSPIRED; CNN, CNN-4SHOT; UNET, UNET-4SHOT; ABDEL., ABDELHAMED ET AL. GOLDMAN RETAINS ITS FULL NAME. REFERENCES ARE AS IN THE MAIN COMPARISON TABLES.

Take	NG	Kim	Cao	Zheng	Analytic	Goldman	DV4	VCLUT	CNN	UNet	Abdel.
Canon 55–1	22.68	13.46	22.15	**23.08**	22.02	7.31	22.29	16.76	17.65	16.99	23.05
Canon 55–2	**19.49**	13.46	18.98	18.37	18.55	7.31	17.50	15.94	12.87	13.63	17.27
Canon 55–3	20.44	13.46	**22.82**	21.76	18.99	7.68	15.66	15.76	10.72	11.51	19.47
Micro 60–1	13.06	13.23	13.47	12.81	**13.60**	7.63	13.30	11.33	13.57	13.44	12.00
Micro 60–2	12.82	13.23	11.80	12.06	11.59	7.63	11.73	9.86	12.92	**13.89**	12.00
Micro 60–3	13.06	13.23	12.40	12.46	12.24	7.63	13.08	12.20	**13.27**	12.52	12.44
28–80 @28–1	**23.68**	14.16	12.73	12.32	12.49	6.97	10.89	10.49	16.32	18.11	13.22
28–80 @28–2	**24.36**	14.16	12.69	12.41	12.39	7.25	11.58	14.18	16.35	15.05	13.22
28–80 @28–3	**23.50**	14.16	11.83	12.98	15.20	7.32	8.67	14.13	16.50	16.12	9.59
28–80 @80–1	20.47	15.46	19.73	**21.35**	19.67	10.01	19.38	13.11	20.90	19.41	19.65
28–80 @80–2	**26.75**	15.38	23.56	19.79	21.52	11.15	25.16	15.95	21.72	15.58	24.53
28–80 @80–3	20.07	15.46	17.75	17.98	17.53	9.87	18.72	13.81	**21.83**	18.86	17.71
105–1	**31.55**	21.70	27.53	29.49	26.60	15.81	10.53	20.20	28.10	15.75	20.59
105–2	**37.68**	21.70	22.69	23.59	22.91	15.81	12.97	22.96	19.81	14.75	20.98
105–3	**36.99**	21.70	27.25	27.78	27.56	15.85	12.94	22.24	20.83	12.91	21.37
200–1	**35.40**	15.78	33.93	33.02	31.89	9.03	19.13	15.12	28.85	22.73	31.92
200–2	**33.65**	15.78	30.18	30.80	29.67	9.03	19.87	15.59	25.63	20.62	31.92
200–3	**38.80**	15.78	37.42	35.14	32.97	9.03	17.42	14.74	27.28	22.08	31.92
Sigma 20–1	**26.88**	12.15	12.41	12.56	11.55	3.46	9.57	7.85	12.74	14.12	14.09
Sigma 20–2	**26.03**	12.15	11.97	12.22	11.58	3.45	9.71	7.24	11.33	12.02	14.09
Sigma 20–3	**25.60**	12.15	11.75	12.05	11.28	3.64	9.66	6.90	11.44	12.86	10.38

Baseline protocols

Method	Inputs / fitting
Neural Grey; VCLUT-inspired	Joint four-capture fit
CNN-4Shot / UNet-4Shot	Joint four-capture fit; initialized per stack; 200 epochs
DeVigNet (4-Shot)	Fixed pretrained weights; mean of four single-image estimates
Classical single-frame	Canonical synthetic/ray image; mean of four estimates on Real-21/Enhanced-36
Joint radiometric	Four captures
Abdelhamed et al. adapter	Published Gaussian family selected from the captured radial profile; classifier weights unavailable

Lensfun comparison: PSNR (dB)

Record	Archived joint fit	Lensfun Oracle
Sigma 20 (exact)	13.12	12.02
Micro 60 (exact)	12.63	11.74
80–200 (optical equivalent)	34.56	24.62
105 (generation candidate)	31.33	30.62

Lensfun interpolation is selected using ground truth. Canon FL 55 mm has no matching profile.

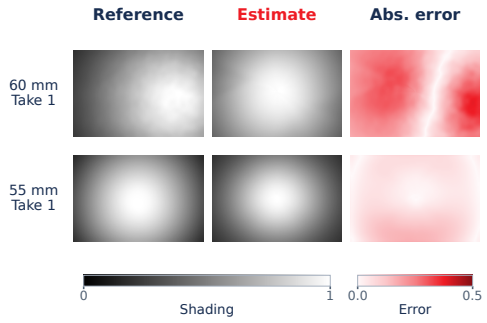


Fig. S1. First take per configuration. Shading: $[0, 1]$; absolute error: $[0, .5]$. Original estimates, without diagnostic scalar correction.

III. Data Sources and Fixed Settings

Real-21 reference and input preparation

Item	Setting
Acquisition	Seven optical configurations; three takes each; four quarter-turn captures per take
Apertures	Maximum aperture throughout: Sigma 20 mm $f/1.4$; Nikon AF-D 28–80 mm $f/3.5$ at 28 mm and $f/5.6$ at 80 mm; Canon FL 55 mm $f/1.2$; Nikon Micro 60 mm $f/2.8$; Nikon 105 mm $f/2.5$; Nikon 80–200 mm $f/2.8$ at 200 mm
Flat-field source	Separate ARRI LED panel + diffuser captures; matched camera, lens, aperture, focus
RAW conversion	Black-level subtraction; white-level normalization; averaged green sites; linear luminance
Reference filtering	Defective-pixel suppression; Gaussian smoothing at 1.2% long edge; central-peak normalization
Scoring	Full frame; intensity range 1; no prediction-wise scalar fitting
Capture preparation	95th-percentile intensity matching; blurred-image translation alignment
Internal anchor	Four-image trimmed mean; separate from the flat-field reference

12-case diagnostic benchmark construction

Component	Source / value
Lensfun profiles	Three groups × three focal bins: 18–35, 40–80, 85–200 mm
Full-well levels	80K / 50K / 30K electrons across groups
Analytic profiles	Three pupil-overlap profiles: 24 / 50 / 135 mm
Optical target	Source profile + selector radial prior in log space; prior weight $0.90/[1+(f/(2.5d_s))^{20}]$; low-order angular residuals
Illumination	Radial/fourfold terms; shared sensor-fixed gradient; first-/third-view transients
Noise	Signal-dependent Gaussian shot, read, row noise
Real-21 inputs	None; simulated captures

Fitting and capture-error settings

Item	Setting
Default fit	1024-pixel long edge; 200 epochs; batch 8192; 240K coordinates; seed 42
Diagnostic selector/capture fits	256-pixel long edge; 20K coordinates; 200 epochs; seed 42
Diagnostic sensitivity fits	Same spatial sampling; 50 epochs; seed 42
Optimizer	Adam; cosine annealing
Learning rates	Shading 10^{-3}; physical 1.2×10^{-4}; illumination 6×10^{-5}; gain/bias/warp 10^{-4}
Capture-error sweep	Five levels; three scene seeds per case; 36 runs per level; 256 pixels, 50 epochs, 20K coordinates
Other perturbations	Roll $\sigma = .15°$; translation .5 px/axis; scale .2%; log-exposure .01
Pose/exposure reference	First view

Field parameters

Parameter	Fixed form / value
Elliptical radius	$r_{ell} = \sqrt{(x_{rot}/a_x)^2 + (y_{rot}/a_y)^2}$; learned center/rotation
Shading inputs	$[x, y, r_{ell}, \cos\phi, \sin\phi, \cos 2\phi, \sin 2\phi]$
Shading MLP	3×96, Tanh
Residual	$.18\tanh(f_\eta) + e(r_{ell})\mathcal{H}_\omega(\phi)$
Envelope	$e(r) = \mathrm{clip}((r-.10)/.95, 0, 1)^{1.6}$
Harmonics	Bounded second-/fourth-order sine and cosine terms
Illumination	Second-order polynomial + 2×48 Tanh MLP; log-residual cap .25; mean-centered
Physical exponent	$p \in [2, 6]$
Gains	$\exp(\mathrm{clamp}(g_k^{raw}, -.25, .25))$
I_0	Sigmoid; initialized near 1
Loss weights	$(\lambda_{phys}, \lambda_{light}, \lambda_{anchor}, \lambda_{res}, \lambda_{gb}, \lambda_{warp}, \lambda_f, \lambda_c) = (1, .10, .20, 3, .15, .20, .15, .05)$

Radial selection rule

$F = G_\sigma * \widehat{V}$; $\sigma = 10$ pixels per 256-pixel long edge. $\mathcal{P}_{D_2}$: mean of identity, horizontal, vertical, and two-axis flips. $E_D = \mathrm{mean}\,|\mathcal{P}_{D_2}F - F|$; $\mathcal{N}$: peak-one normalization.

$$\widetilde{V} = \mathcal{N}\left[\widehat{V} + \frac{E_D^6}{E_D^6 + .015^6}(\mathcal{P}_{D_2}F - F)\right]. \tag{S1}$$

p_b: 48-bin radial median of $\log\max(\widetilde{V}, 10^{-4})$, centered by the median at $r \le .2$; geometric image center, corner-normalized radius. $a = \log\max(\widetilde{V}, 10^{-4}) - p_b$. f: focal length; d_s: sensor diagonal.

$$\begin{aligned} f_w &= 2f/d_s, \quad p_w(r) = -\tfrac{7.5}{2}\log[1 + (r/f_w)^2], \\ f_s &= .9f/d_s, \quad p_s(r) = -3\log[1 + (r/f_s)^2]. \end{aligned} \tag{S2}$$

$\delta_j = \mathrm{mean}_b\,|p_b - p_j|$; σ_l: logistic function.

$$\begin{aligned} g_w &= \frac{\delta_w^8}{\delta_w^8 + .20^8}, \qquad g_s = \frac{\delta_s^4}{\delta_s^4 + .05^4}, \\ \beta_w &= \frac{.80 g_w}{1 + [f/(.808 d_s)]^8}, \\ \beta_s &= \frac{.25 g_s\, \sigma_l((f - .97d_s)/(.046d_s))}{1 + [f/(2.5d_s)]^{20}}. \end{aligned} \tag{S3}$$

$V_{out} = \mathcal{N}\{\exp[a + (1 - \beta_w - \beta_s)p_b + \beta_w p_w + \beta_s p_s]\}$.