Polarimetric Camera Calibration Using an LCD Monitor

Zhixiang Wang[1] Yinqiang Zheng[2](✉) Yung-Yu Chuang[1]

[1]National Taiwan University [2]National Institute of Informatics

wangzx1994@gmail.com, yqzheng@nii.ac.jp, cyy@ntu.edu.tw

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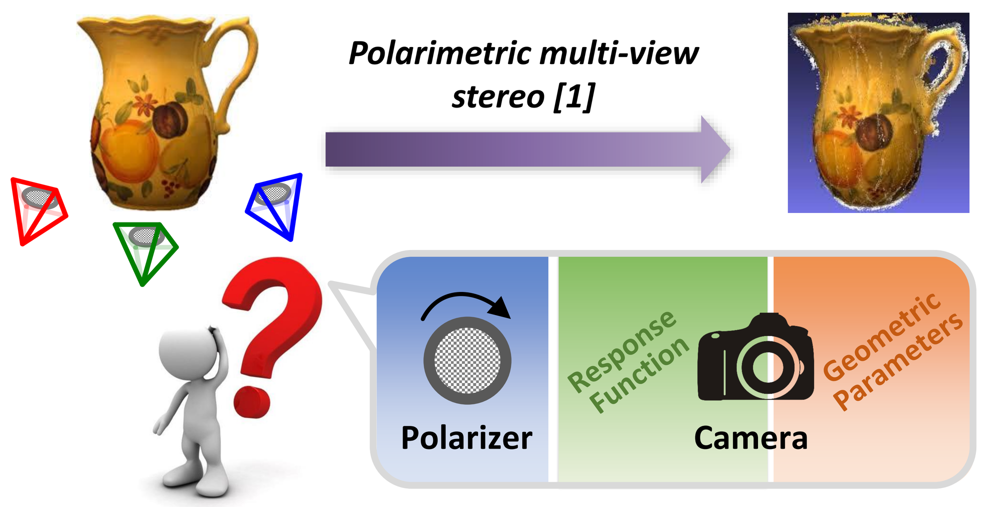
Problem Definition and Contribution

Goal: Jointly calibrating the polarizer angles $\{\phi_k\}_1^K$ and the inverse CRF $g(\cdot)$ with only the knowledge of measured intensity $\mathbf{M}$, s.t., $g(M_{k,p}) = t_p + a_p \cos 2(\phi_k - \psi_p)$.

Motivation:

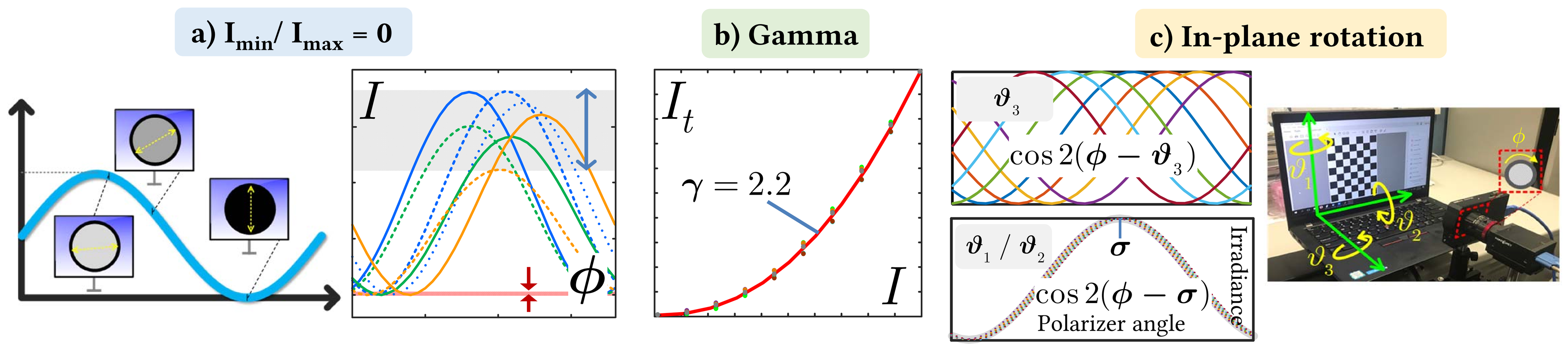


	Self-Calibrate?	Reliable?	Can work ≤3 polar. channels?	Robust to nonlinear CRF?	Can output CRF?	Can output geo. parameters?
[2]	✓	✗	✗	✗	✗	✗
[3]	✓	✗	✗	✗	✓	✗
Ours	✗	✓	✓	✓	✓	✓

Comparison with other methods

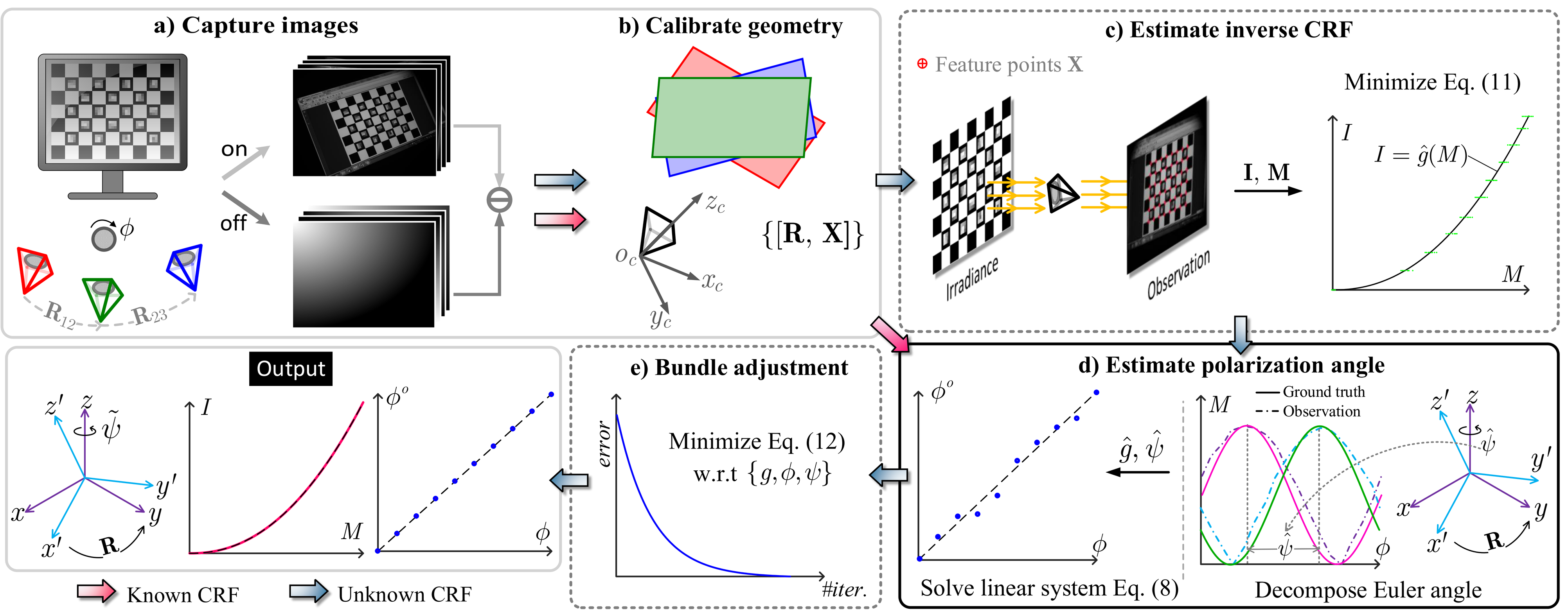
Main Idea

Characteristics of LCD Monitors:



Method

Flowchart:



Known CRF: a) → b) → d)

- **d)** Our linear method

$$\frac{\hat{g}(M_{k,p})}{\hat{g}(M_{1,p})} = \frac{1+\alpha_p \cos 2\phi_k + \beta_p \sin 2\phi_k}{1+\alpha_p \cos 2\phi_1 + \beta_p \sin 2\phi_1},$$

$$\Rightarrow \tilde{\mathbf{P}} = \left(\tilde{\mathbf{O}}^T\tilde{\mathbf{O}}\right)^{-1}\tilde{\mathbf{O}}^T\tilde{\mathbf{D}},$$

Unknown CRF: a) → b) → c) → d) → e)

- **c)** Estimate CRF

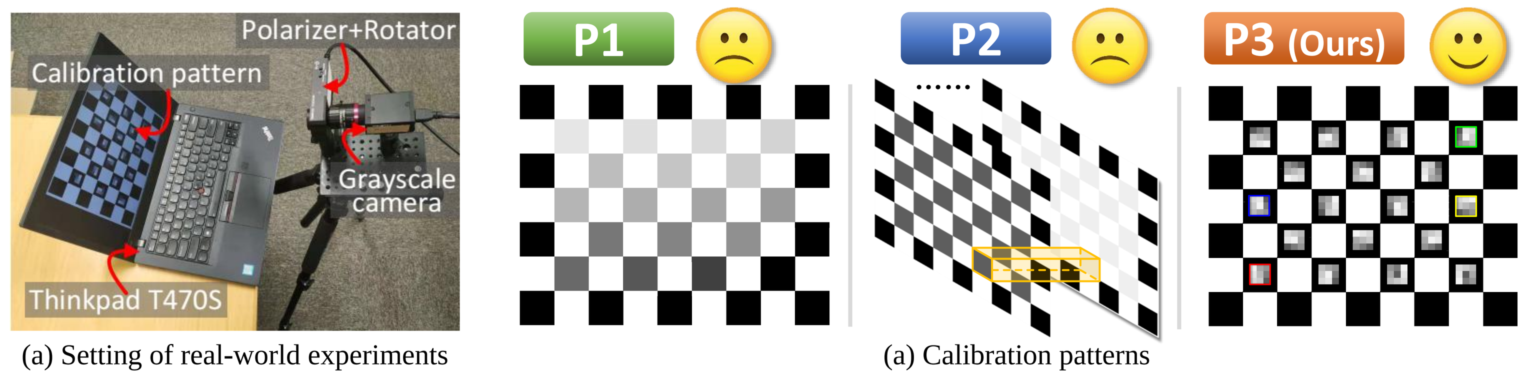
$$\hat{g} = \text{argmin}_{g\in\mathcal{W}} \|\mathbf{I} - g(\mathbf{M})\|^2 + \lambda \left|\frac{\partial^2 g}{\partial M^2}\right|,$$

- **e)** Bundle adjustment

$$\sum_{k=1}^{K}\sum_{p=1}^{P} \|t_p(\cos(2\phi_k)\cos(2\psi_p) + \sin(2\phi_k)\sin(2\psi_p)+1) - g(M_{k,p})\|^2,$$

Experiments & Results

Experiment setup:



(a) Setting of real-world experiments (a) Calibration patterns

Real-world Experiments:

(a) Results under different environment illumination settings.

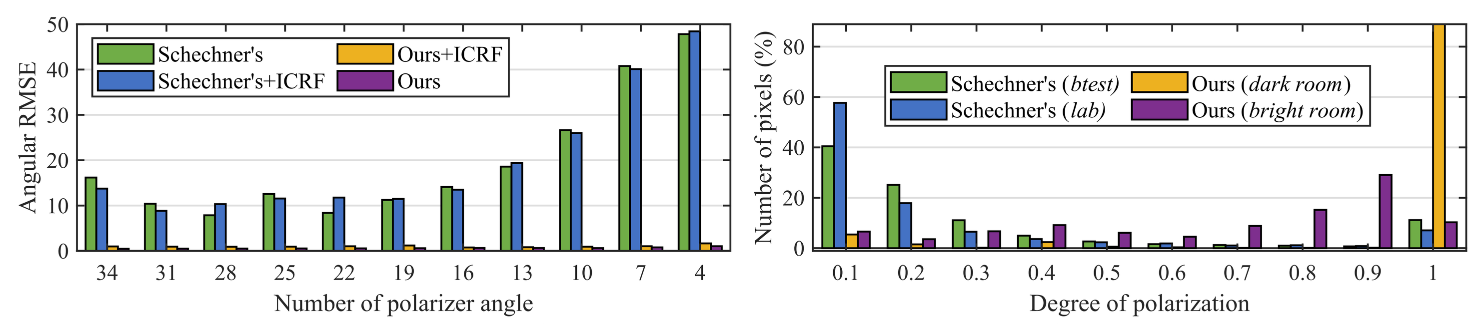
	Known ICRF		Unknown ICRF	
	CRF err.	Ang. err.	CRF err.	Ang. err.
Dark room	✗	0.76±0.20	0.01±0.01	**0.48±0.15**
Bright room	✗	0.80±0.28	0.05±0.01	**0.71±0.11**

(b) Comparison of different patterns (P0: *Checkerboard*).

	Known ICRF			Unknown ICRF		
	CRF err.	Ang. err.	#images	CRF err.	Ang. err.	#images
P0	✗	0.80±0.16	≥4	0.20±0.06	82.2±26.1	≥4
P1	✗	0.78±0.15	≥4	0.07±0.02	1.24±0.43	≥4
P2	✗	0.79±0.14	≥4	0.02±0.02	**0.38±0.32**	≥4+11
P3	✗	0.78±0.15	≥4	**0.01±0.01**	0.48±0.15	≥4

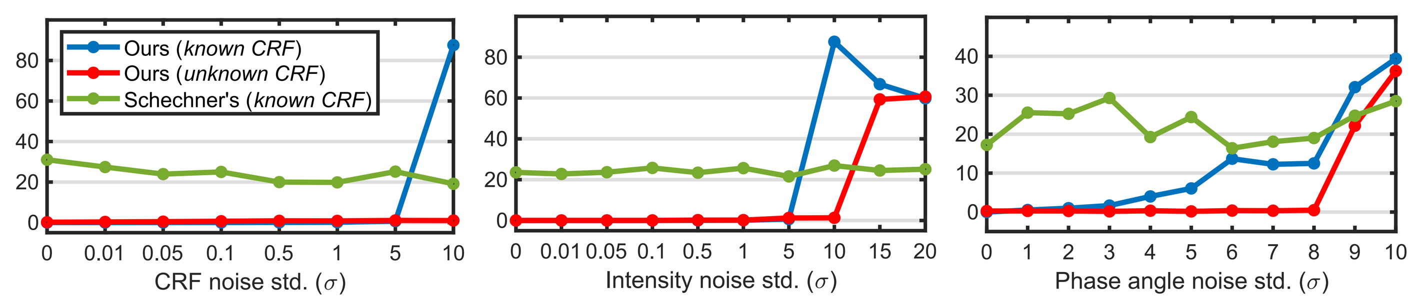
(c) Comparison of separate and joint processes.

	Known ICRF				Unknown ICRF			
	CRF err.	Ang. err.	ψ err.	#images	CRF err.	Ang. err.	ψ err.	#images
Separate	✗	0.45	3.08	≥4+2	0.02	0.83	3.10	≥4+2+11
Joint	0.02	**0.38**	**0.19**	≥4	**0.01**	**0.48**	**0.20**	≥4

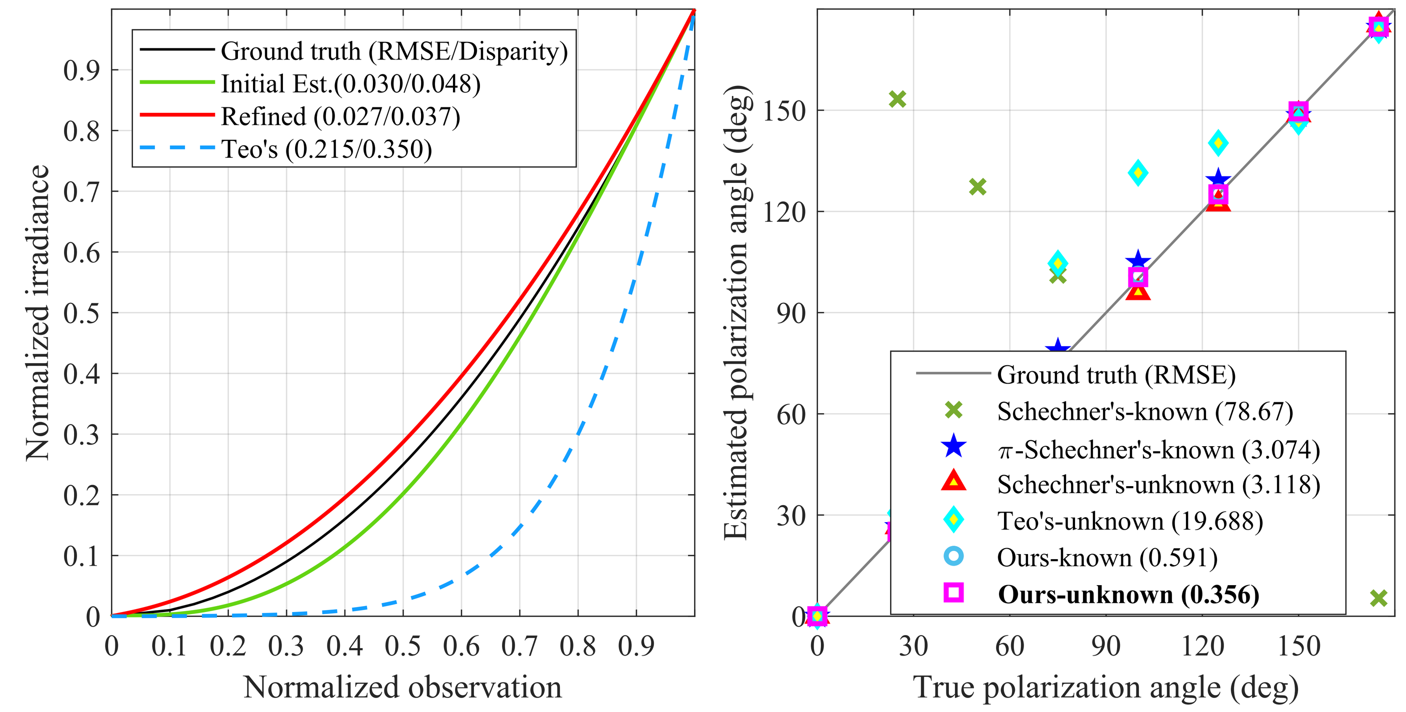


(d) Ang. RMSE *vs.* # polarizer ang. (e) # pixels *vs.* DoP

Simulation (sensitivity analysis)



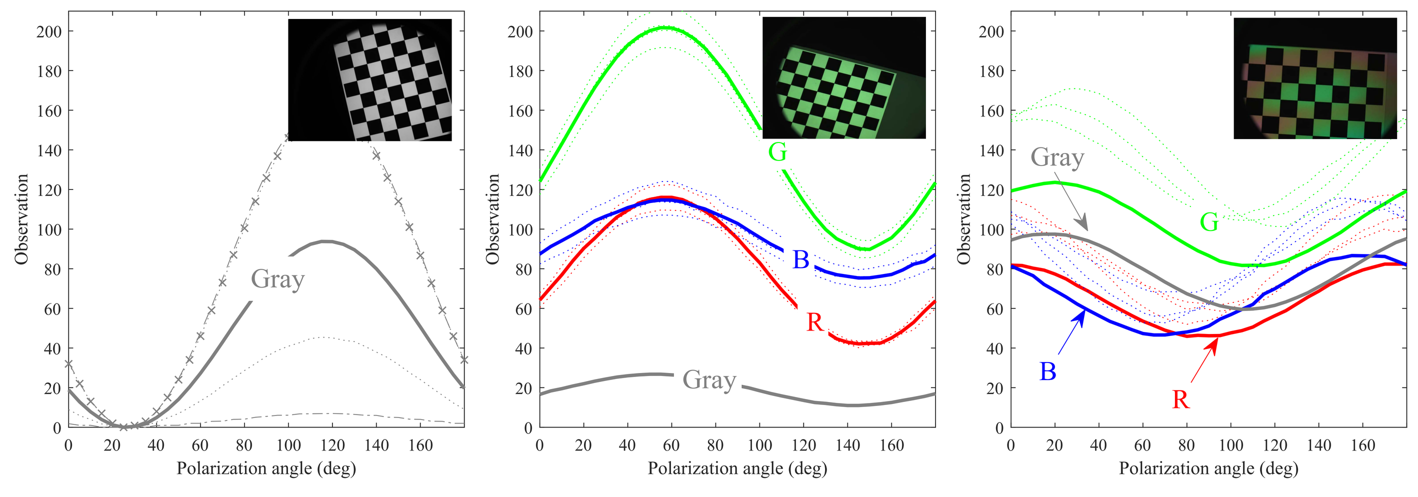
Real-world Experiments (Comparison):



(a) Light source (b) BUNNY

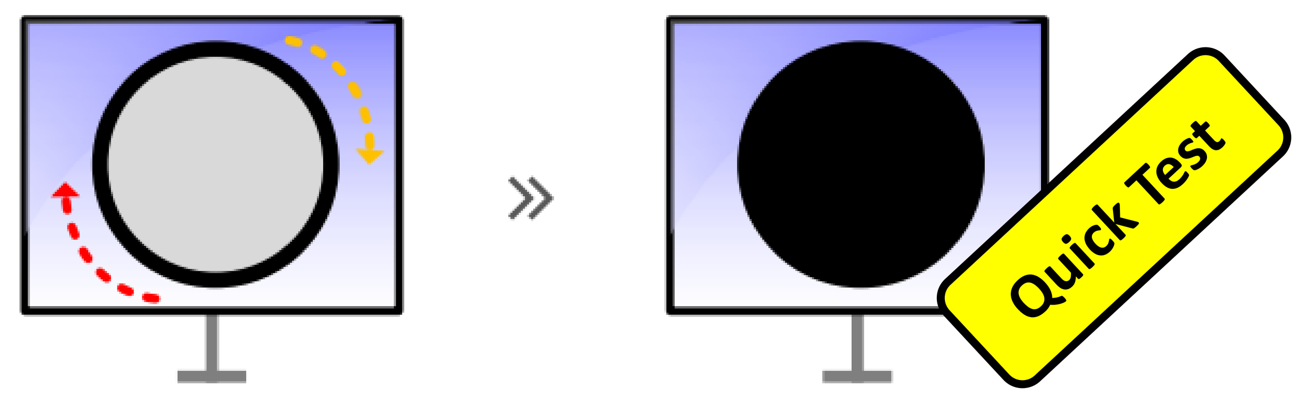
CRF	Method	CRF err.	Ang. err.	#polar. ang.	#images
known	[2]	✗	8.85±15.39	≥4	≥4
	Ours	✗	**0.62±0.28**	**≥2**	≥4
unknown	[2] + ICRF	✗	15.84±29.59	≥4	≥4+11
	[3]	0.13±0.09	12.56±7.31	≥4	≥4
	Ours	**0.04±0.02**	**0.63±0.18**	≥2	≥4

LCD screens with a touch panel:



(a) HUAWEI MATE 10 LITE (b) IPHONE 6S (c) IPHONE 7 PLUS

LCDs' suitability:



References:

[1] Cui *et al.*, Polarimetric multi-view stereo. CVPR17

[2] Schechner, Self-calibrating imaging polarimetry. ICCP15

[3] Teo *et al.*. Self-calibrating polarising radiometric calibration. CVPR18

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