Recovering Spectral Reflectance under Commonly Available Lighting Conditions

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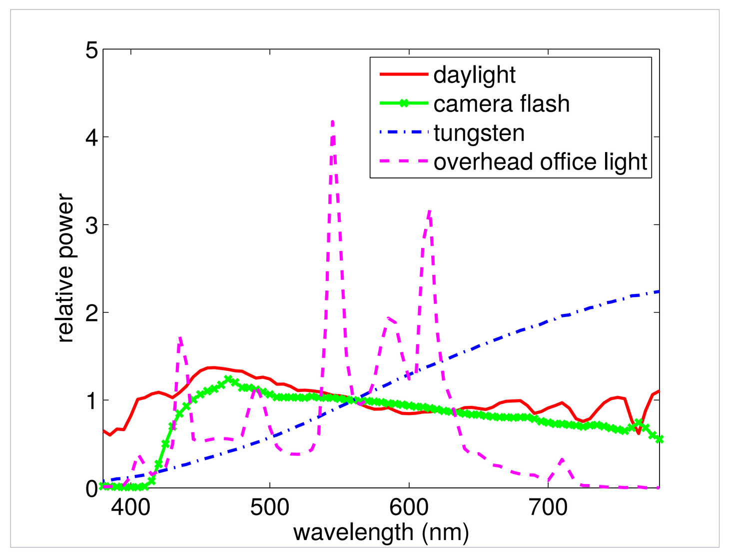
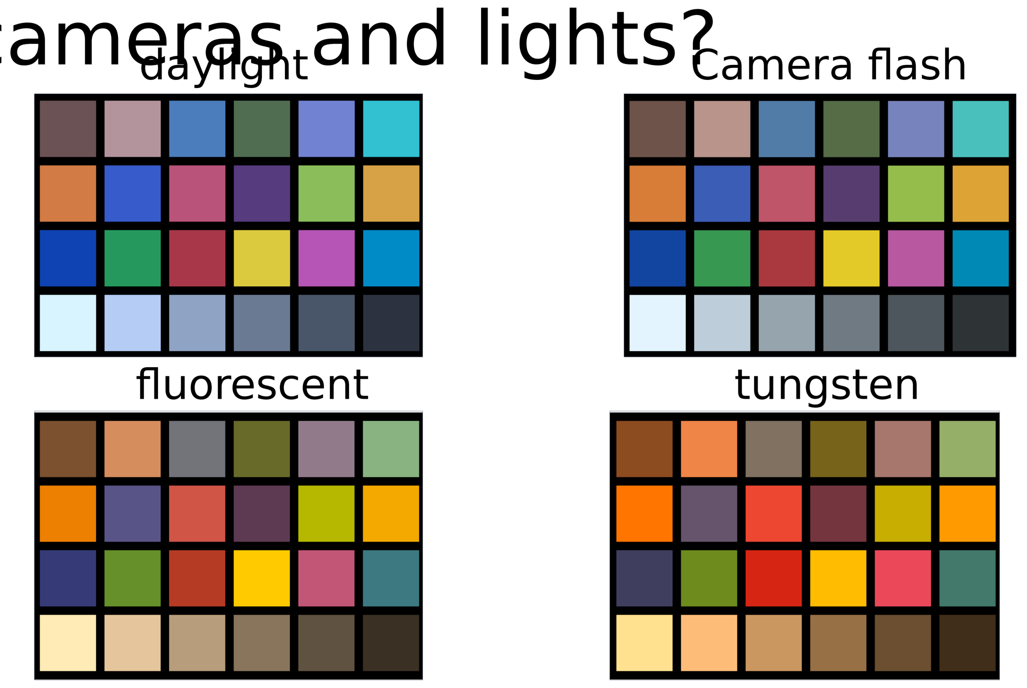
Commonly available light sources

daylight   Camera flash   fluorescent   tungsten



Can we capture spectral images with conventional cameras and lights?



Our Method

Radiance can be represented by

$$I = \int_{390nm}^{720nm} C(\lambda)P(\lambda)R(\lambda) \qquad I = CPR$$

Based on the PCA model, reflectance can be represented using less dimensions

$$R = B\sigma \qquad I = CPB\sigma = T\sigma$$

Two images are usually sufficient to recover the scene reflectance. Therefore, T becomes a 6x6 matrix.

T can be pre-computed if we know the reflectance of six points in the scene. In practice, we use a ColorChecker.

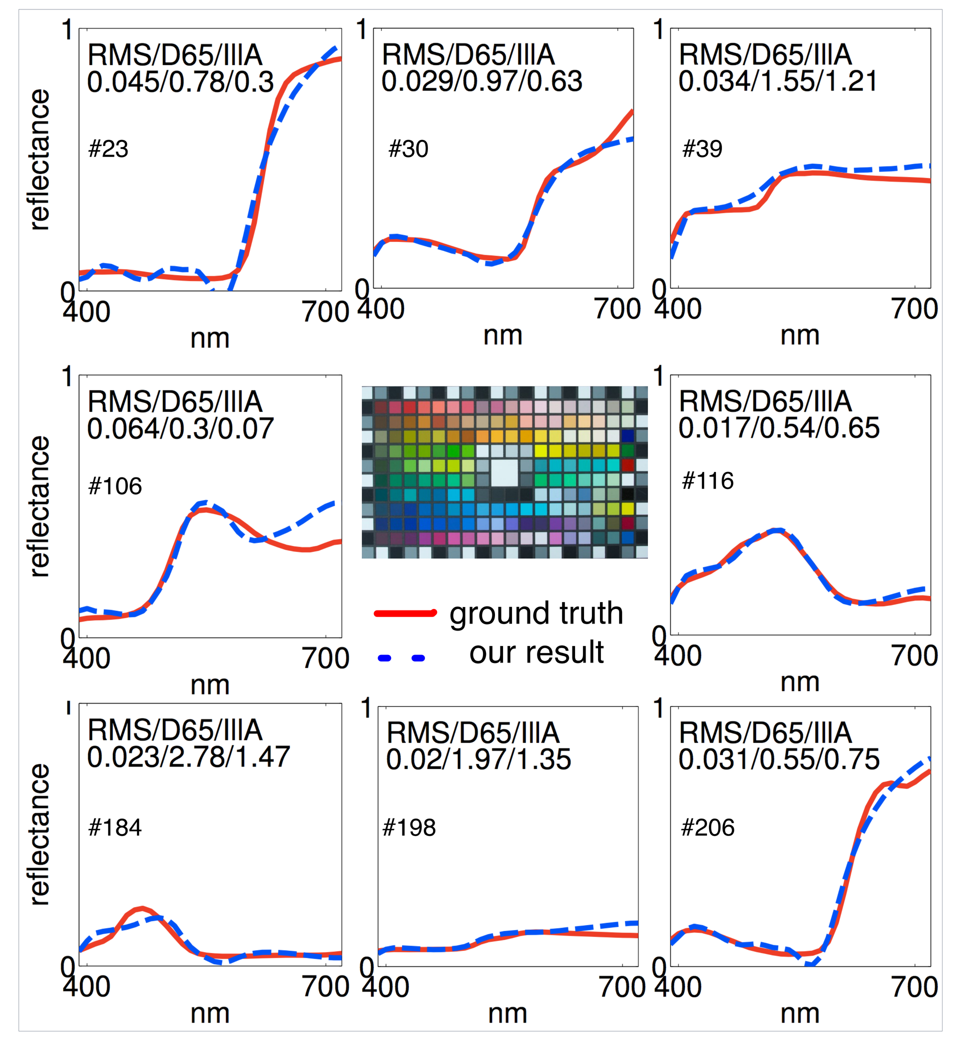
Once T is obtained, reflectance can be recovered as follows,

$$\hat{R} = BT^{-1}I$$

Reflectance can be recovered by optimizing difference in radiance, reflectance, or perceptual color

$$\min_{\hat{T}} \left\| \hat{T}\sigma - I \right\| \qquad \min_{\hat{T}^{-1}} \left\| \hat{R} - R \right\| \qquad \min_{\hat{T}^{-1}} \left\| \Delta E_{00}(\hat{R}, R) \right\|$$

Validation on CCDC



Noise analysis

Which light sources are overall the best for recovering spectral reflectance?

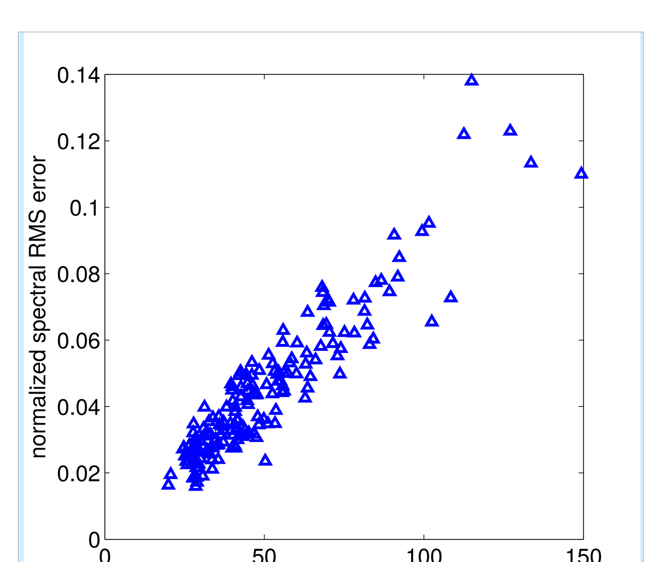
$$Z = 1^T \times W^2 \times T \times B^T \times 1 \qquad W = BT^{-1}$$

Given two light sources, which reflectance can be best recovered?

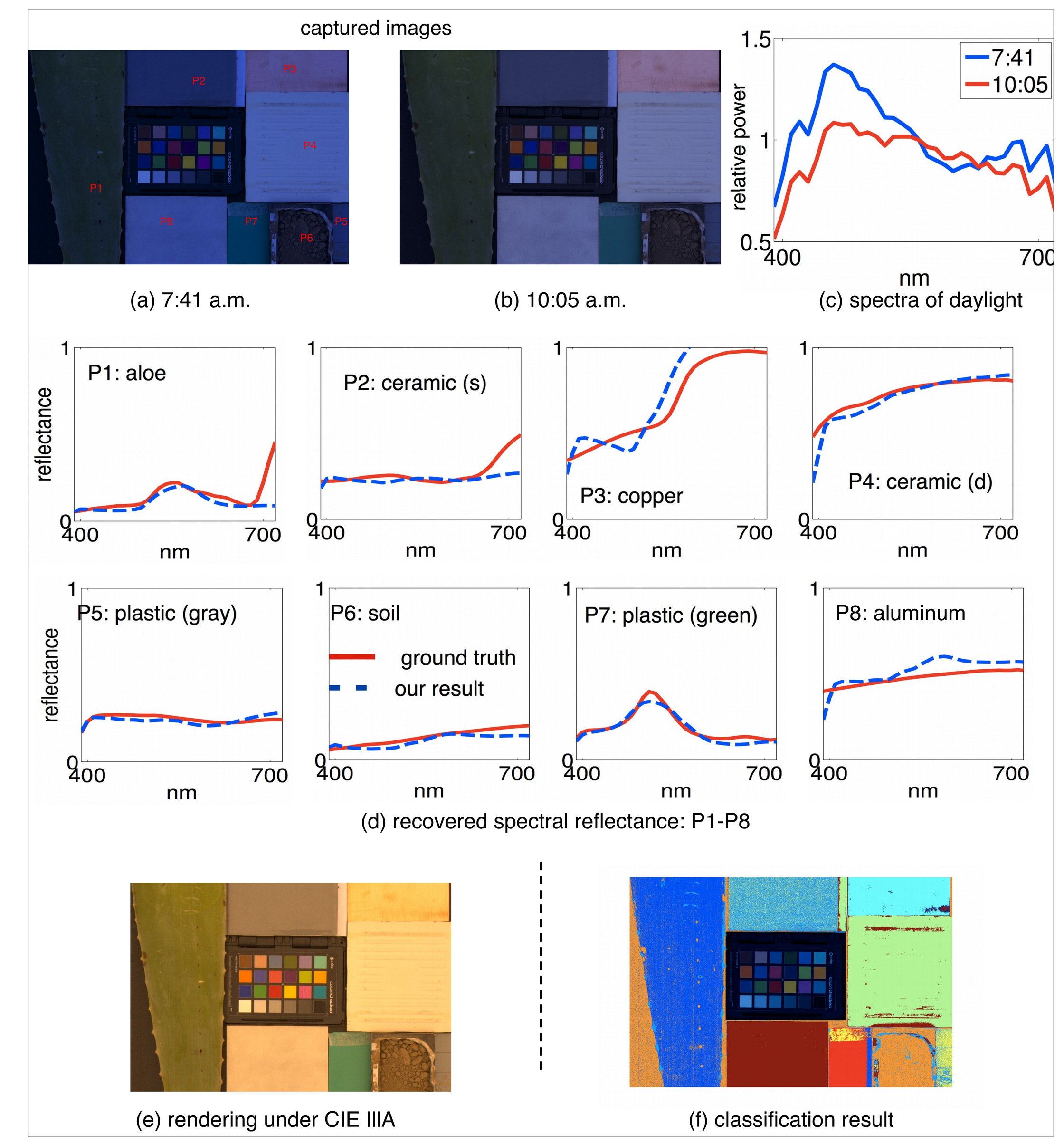
$$\rho = \frac{\|\Delta R\|}{\|R\|} = \sqrt{\frac{1^T \times W^2 \times T \times B^T \times R}{R^T R}}$$

The noise is assumed to be photon noise

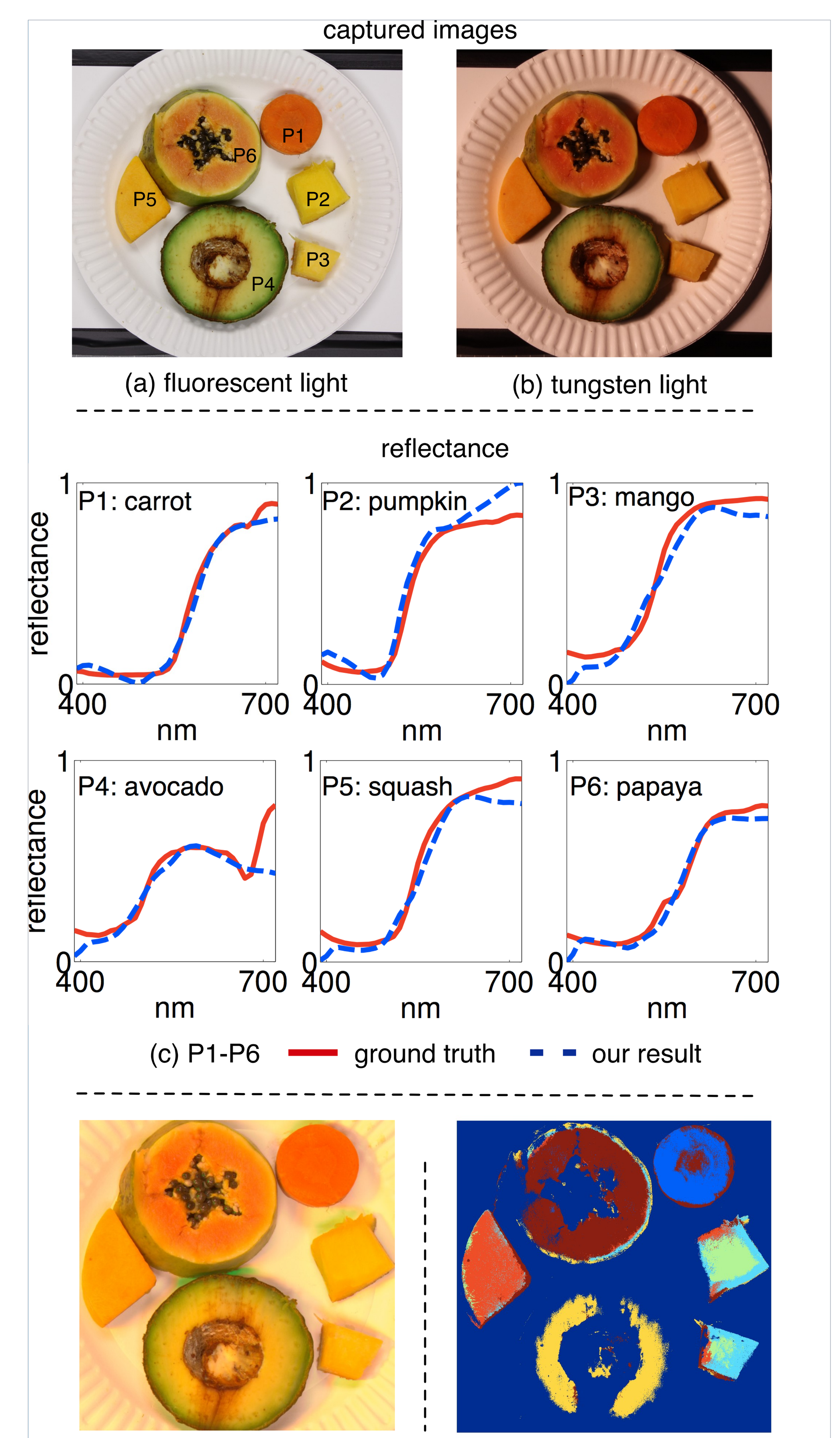
Lighting Combinations	Z (Gaussian noise)	Z (Photon noise)	Validation Performance RMS/ΔE_{D65} /ΔE_{IllA}
Horizon/ Illuminant A	5.11e+6	3.31e+5	0.09/4.3/4.2
Studio flash light/ Tungsten	3.52e+6	1.25e+5	0.07/2.5/2.1
Cool white/ Horizon	6.11e+5	4.22e+4	0.05/1.7/1.6
Fluorescent/ Tungsten	3.34e+5	2.28e+4	0.03/1.9/1.0
PCA model			0.01/0.5/0.4



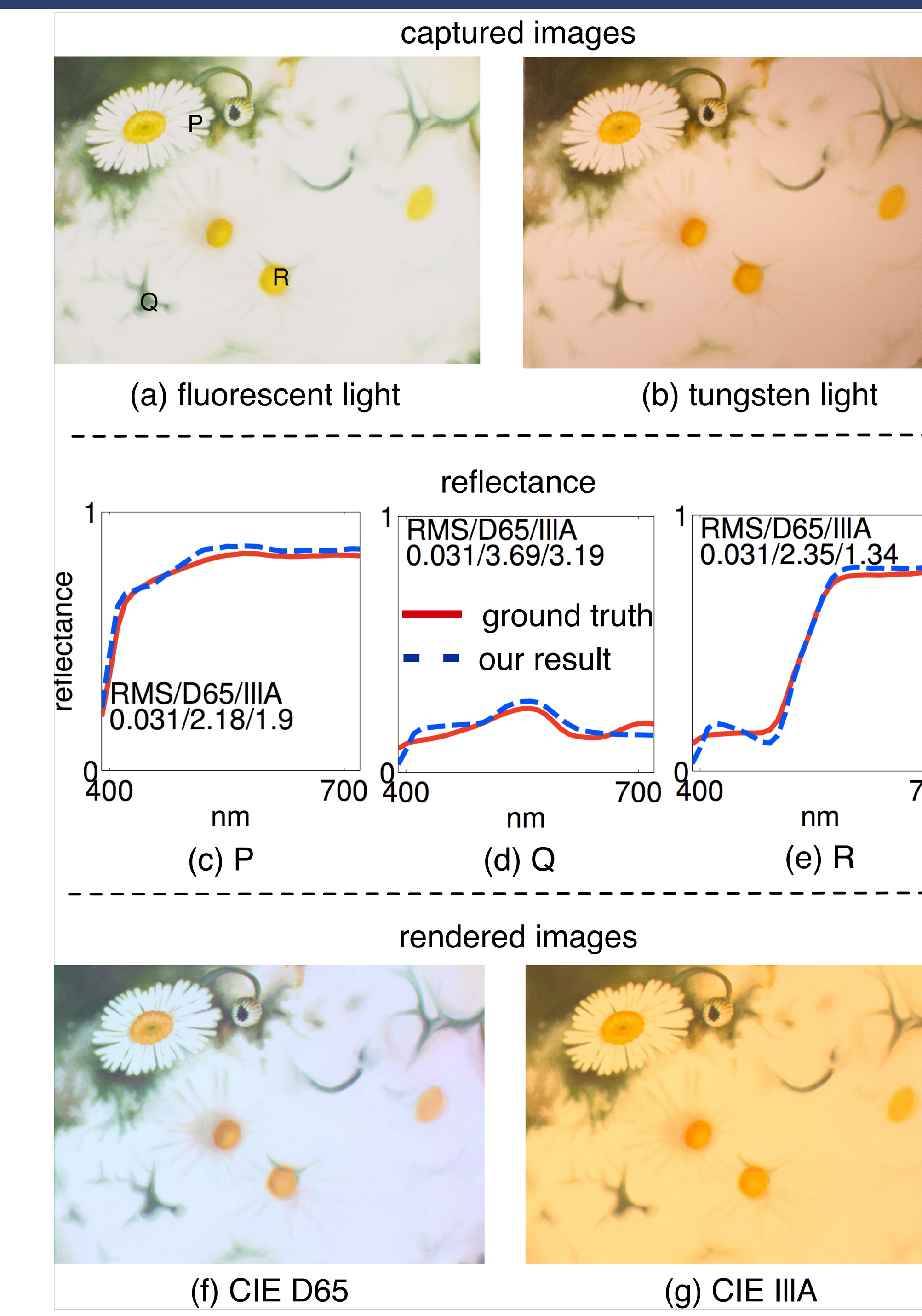
App1: Material Classification under Daylight



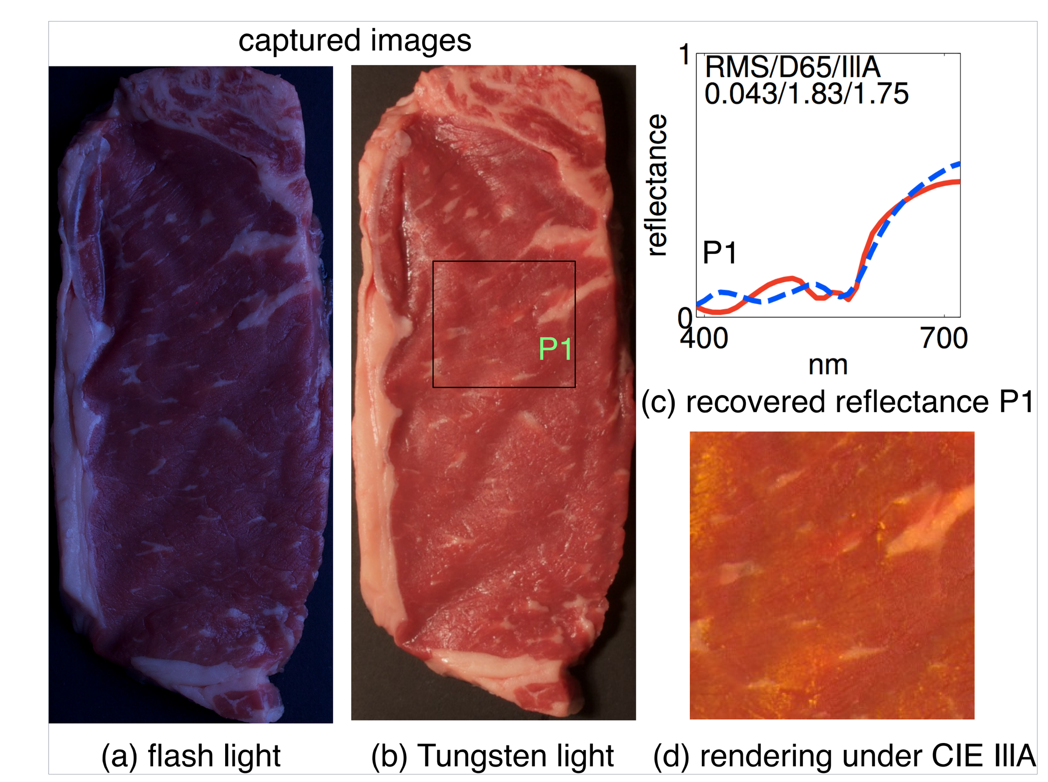
App2: Fruit Identification



App3: Spectral Imaging of Fine Art



App4: Food Inspection



Summary

A simple spectral imaging method to recover the scene reflectance

Two predictors based on noise analysis

Several applications using spectral imaging

More experimental results are:
https://www.cis.rit.edu/~jxj1770/spectralImaging/index.html