Discriminative Illumination for Classifying Raw Materials

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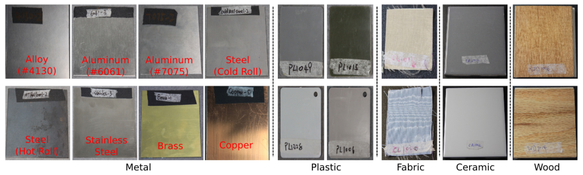
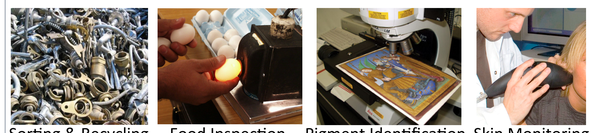
Raw Material Classification: What & Why?

Classify materials based on appearance-related features:
* color, BRDF, transmittance, translucency, polarization, texture, etc.



Raw material classification is needed in a variety of applications:



Sorting & Recycling | Food Inspection | Pigment Identification | Skin Monitoring

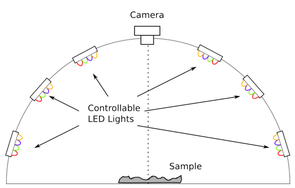
Per-Pixel Raw Material Classification based on Spectral BRDF

Main challenge: appearance is high dimensional.

Prior work: (1) measure slices of high-dimensional appearance function, and (2) use slices for classification [1], or select a subset for classification [2].

$$\mathbf{w}^T\mathbf{x}+b=\begin{cases}\geq 0 & y\in \text{Class 1}\\ <0 & y\in \text{Class 2}\end{cases}$$

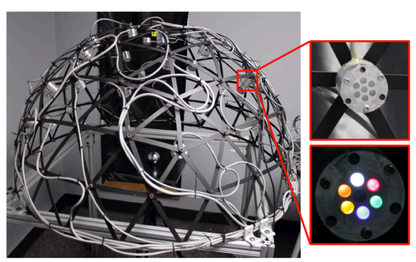
Question: Can we ***directly*** measure discriminative features?



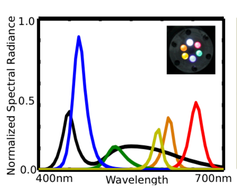
$$I=\mathbf{w}^T\mathbf{x}$$

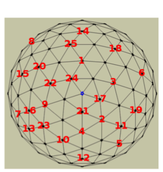
Measured radiance | Incident light field | BRDF vector

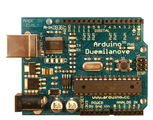
LED-based Multispectral Light Dome:



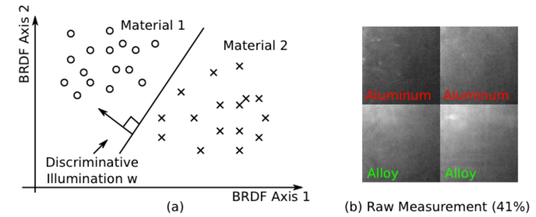
* 25 LED clusters, 6+1 LEDs/cluster
* PWM controlled with 25 Arduino
* Lumenera camera with HDR
* 10 classes, 100 sample plates

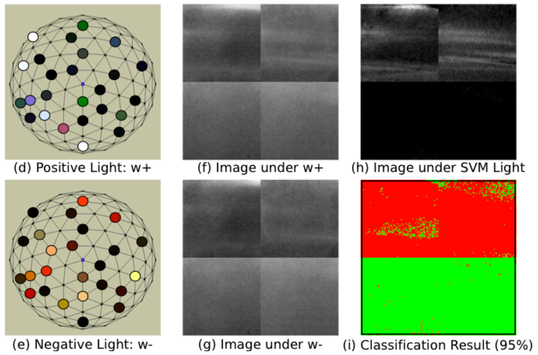






Key Idea: Use Coded Illumination as Classifiers





Learn coded illumination ***w*** that maximizes discriminative ability:

* Fisher (LDA) Light
* Support Vector Machine (SVM) Light (linear kernel)

SNR Benefit due to Illumination Multiplexing

$$y=\mathbf{w}^T(\mathbf{x}+\mathbf{n})+b \qquad SNR=\frac{|\mathbf{w}^T\mathbf{x}|}{|\mathbf{w}|_2\sigma}$$

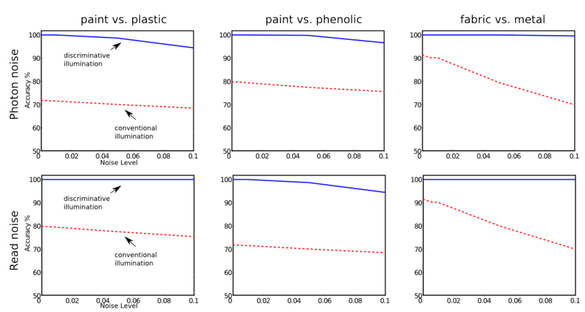
SNR gain when read noise dominates (M - # of raw measurements)

$$\sqrt{M/2}\leq G_r\leq M/\sqrt{2}$$

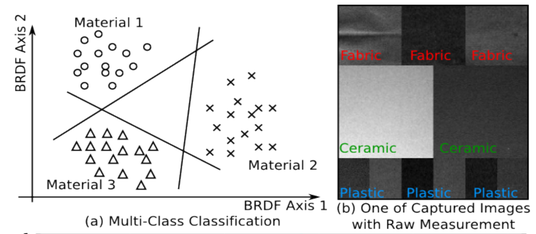
SNR gain when photon noise dominates

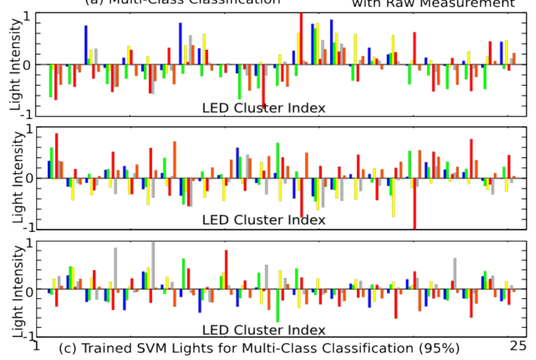
$$1\leq G_p\leq\sqrt{M}$$

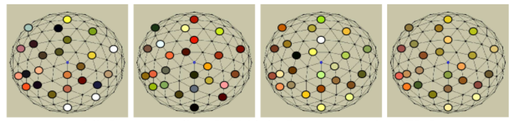
Simulation results on MERL 100-BRDF database [3]



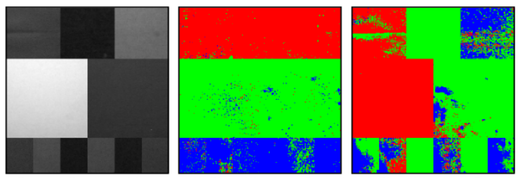
Extension 1: Multi-Class Classification





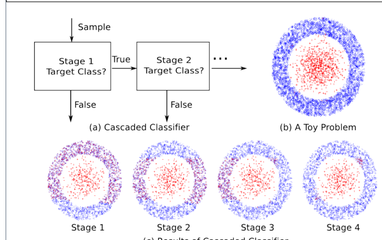


(d) Corresponding SVM Light Patterns on the LED Dome

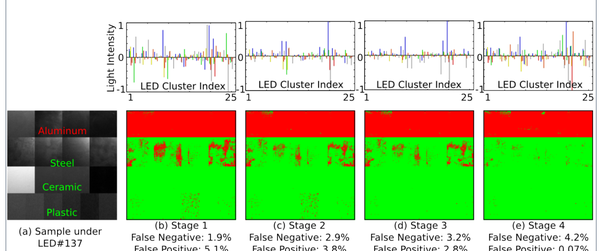


(e) One of Captured Images under SVM Light | (f) Classification Result SVM Light (94%) | (g) Classification Result Raw Measurement (62%)

Extension 2: From Linear to Nonlinear

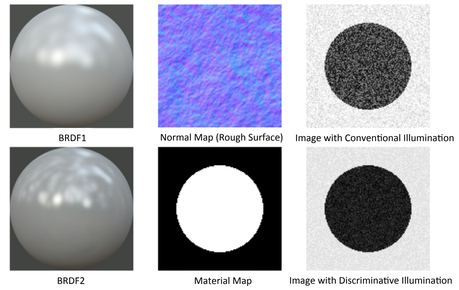


In addition to cascade classifier, other ensemble classifiers can also be applied for nonlinear classification (e.g., boosting).



Dealing with Surface Normal Variations

Solution: Augment training sets with normal-variant "BRDFs".



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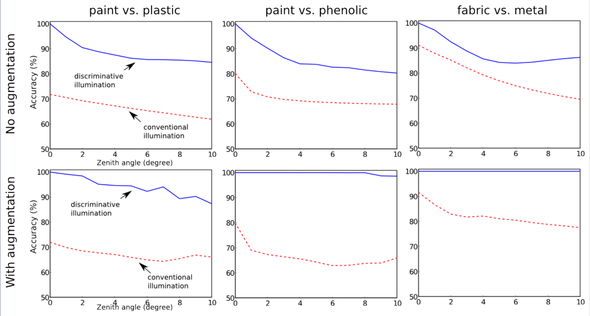
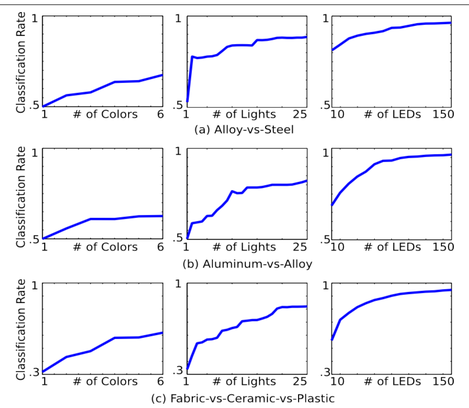


Both color and BRDF are useful for classification



References

[1]. O. Wang, et al. Material classification using BRDF slices. CVPR 2009.

[2]. M. Jehle, et al. Learning of optimal illumination for material classification. Pattern Recognition, vol. 6376, 2010.

[3]. W. Matusik, et al. A data-driven BRDF model. SIGGRAPH 2003.

Acknowledgement & Database

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Database, code, & paper are available at

http://www.cis.rit.edu/jwgu