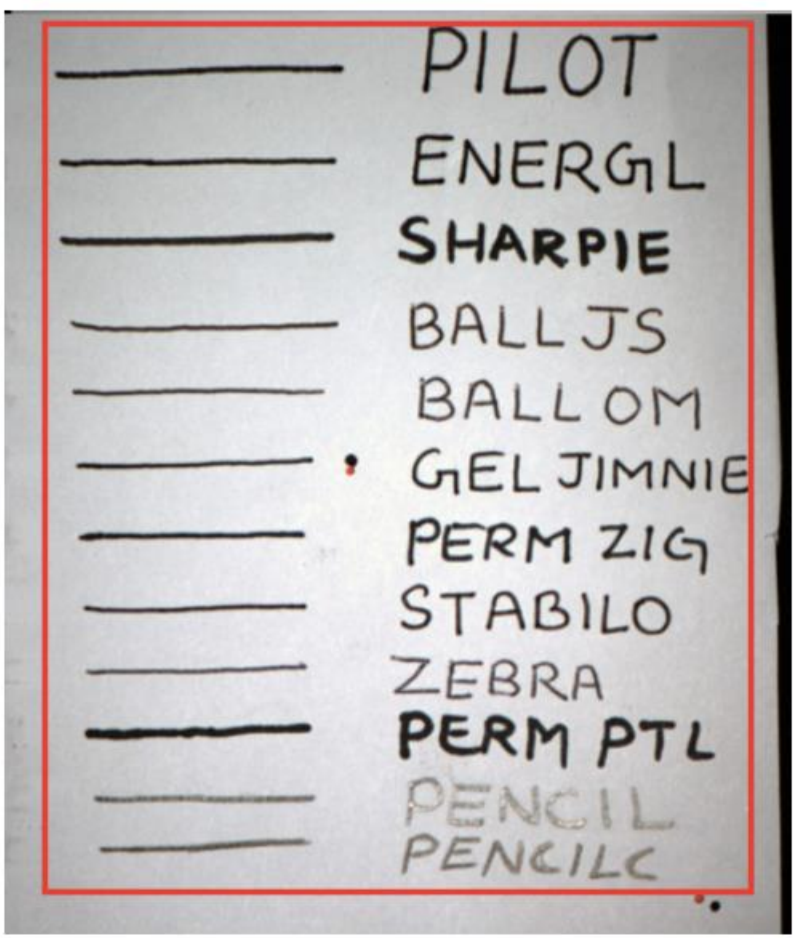
A New Perspective on Material Classification and Ink Identification

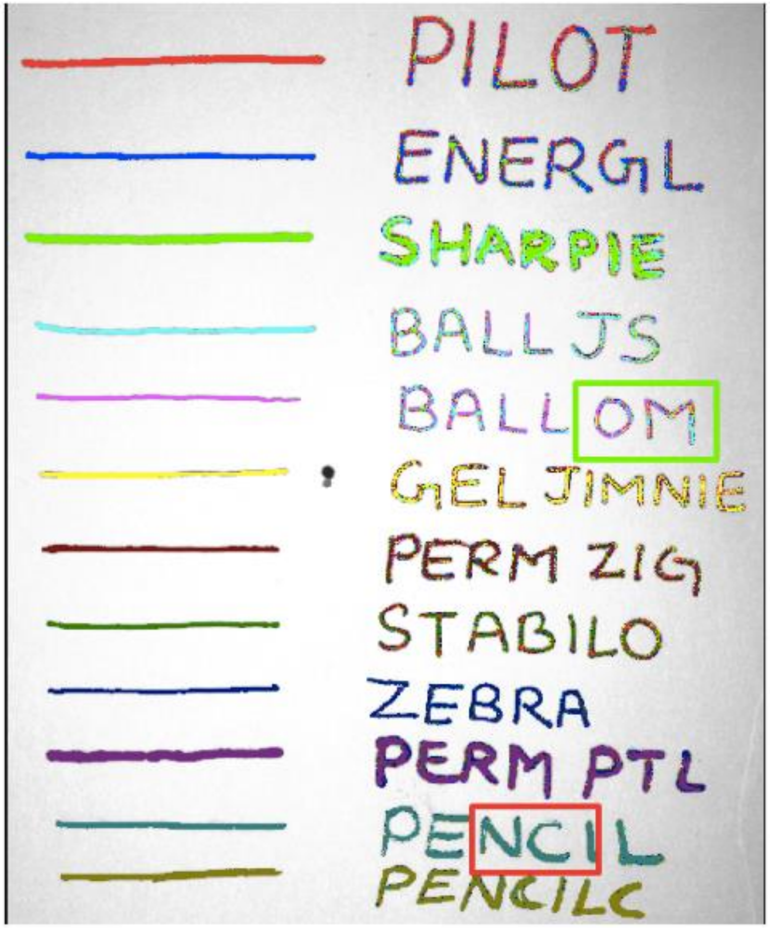
R. Shiradkar, L.Shen, G. Landon, S. Ong and P. Tan

Presented by Joe Bartels, Zhe Cao

Ink classification based on bi-directional ref



a) image of the ink strokes



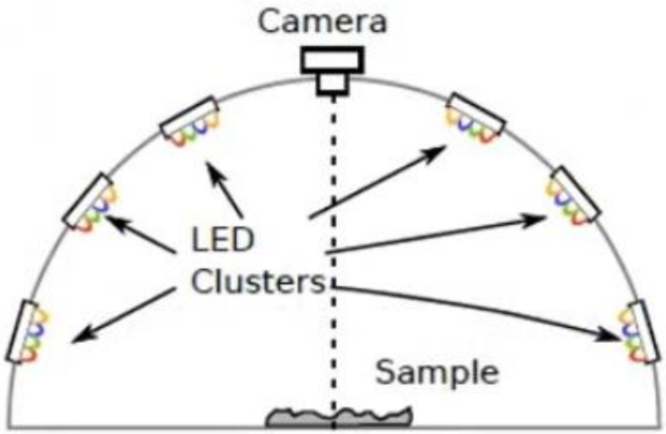
b) ink classification result

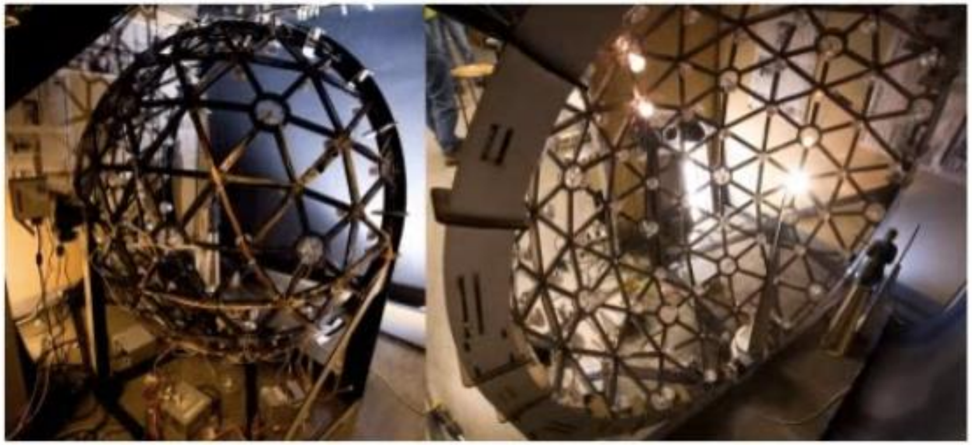
Related work on ink classification

- Disari [1] showed that statistical properties such as saturation histograms in HSV color space can differentiate ink.
- Berger [2] described an ink segmentation method based on based on intrinsic differences in the ink shades.

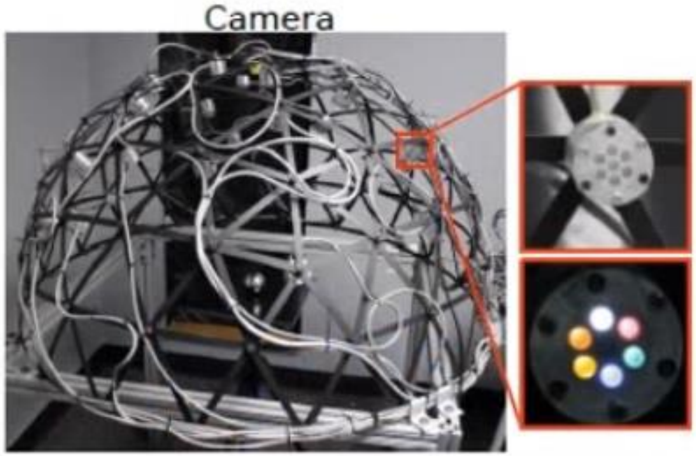
[1] B. Chakravarthy and H. Dasari. Classification of liquid and viscous inks using hsv colour space. Conf. on Doc. Analysis and Recognition, 2005.
[2]C. E. H. Berger. Objective ink color comparison through image processing and machine learning. Journal of the Forensic Science Society, 2013.

Related work on material classification





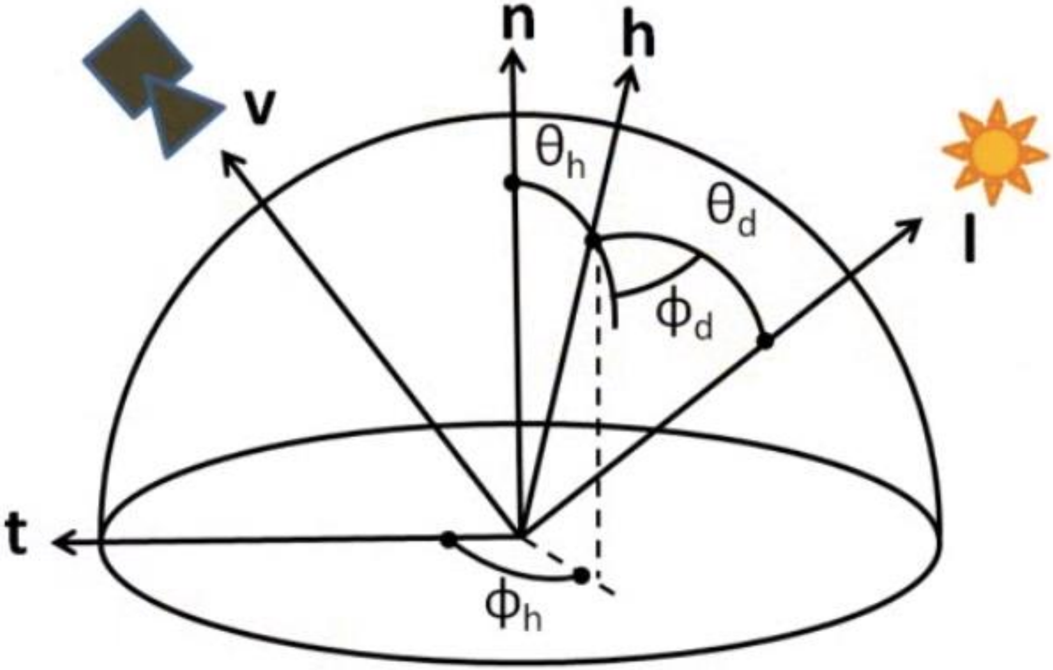
Wang et. al [5], CVPR'09



Jinwei and Chao [4], CVPR '12

Camera faces the surface head-on

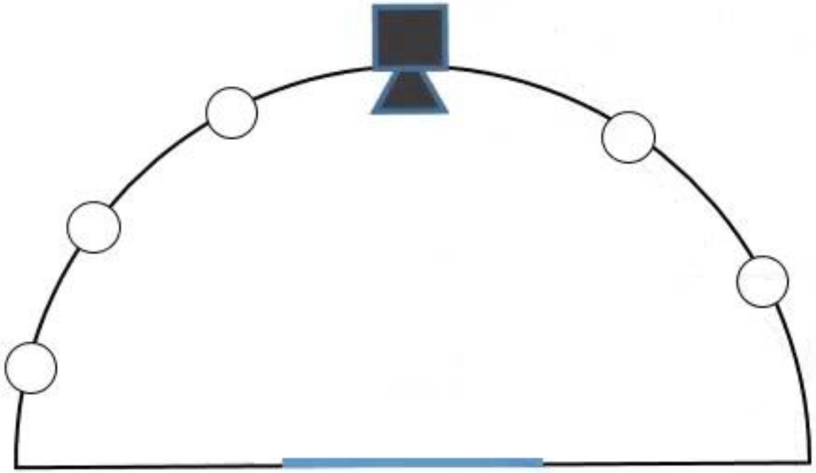
Rusinkiewicz's BRDF Parameterization



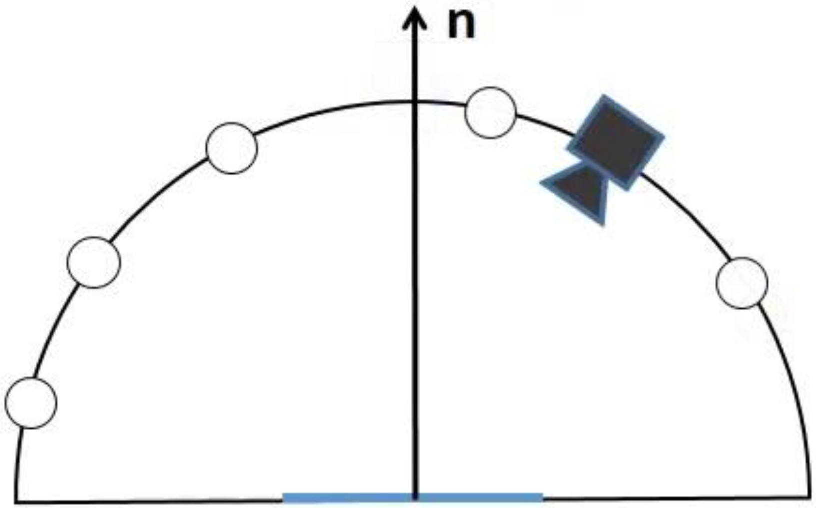
l – lighting direction
v – viewing direction
n – surface normal
h – bisector of **l**, **v**

Most of the BRDFs are 2D functions of θ_d and θ_h

Limitation of Conventional Setup



Our New Perspective



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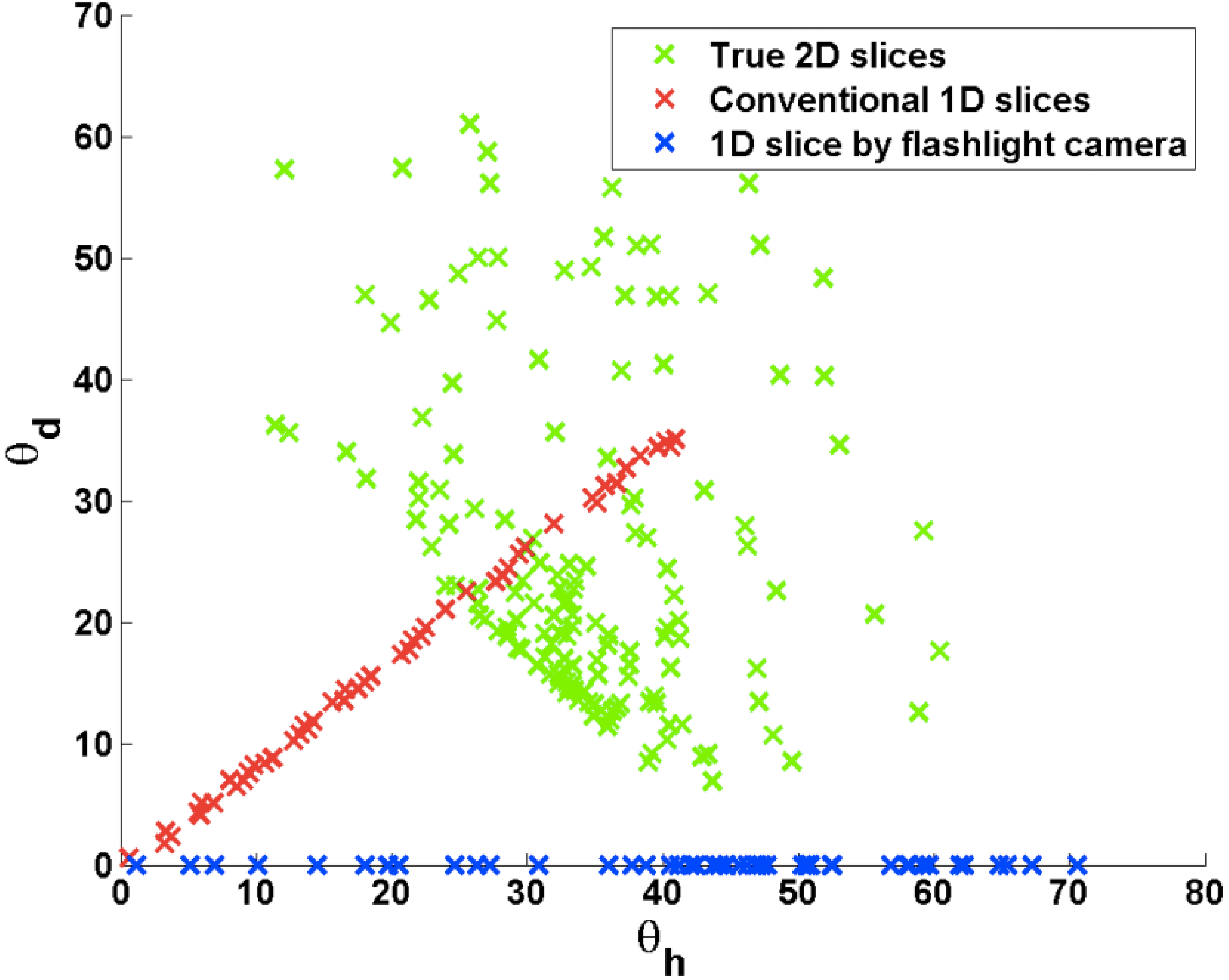
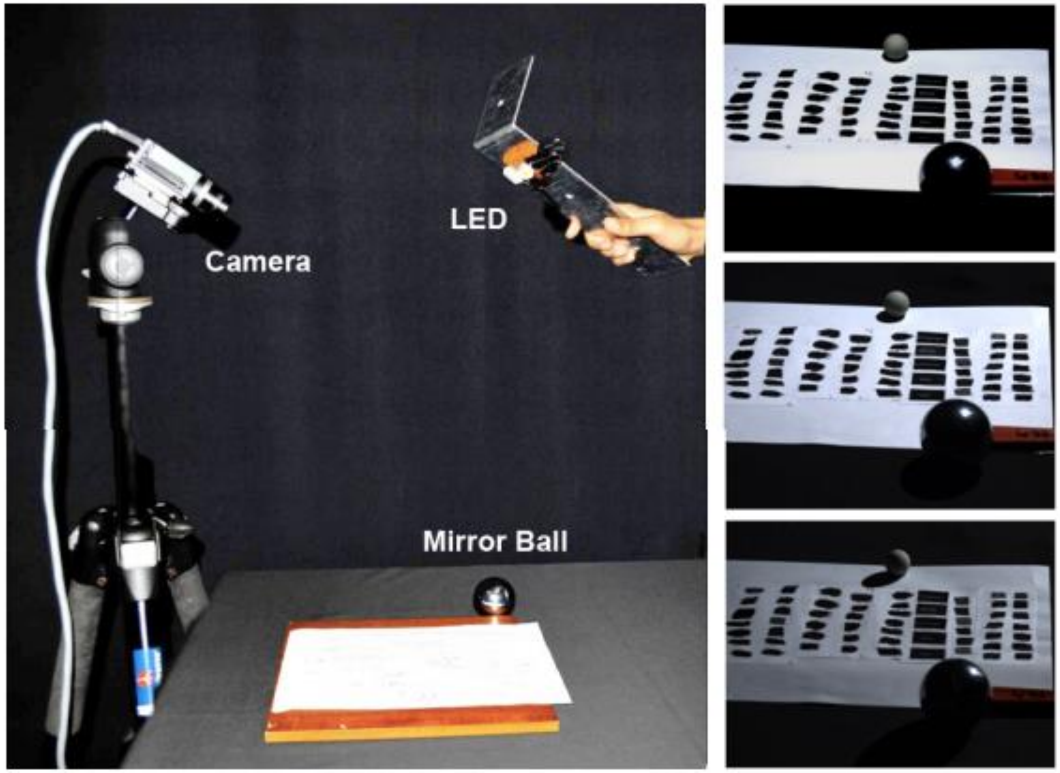

True 2D slices
Conventional 1D slices
1D slice by flashlight camera
θ_d
θ_h
0
10
20
30
40
50
60
70
0
10
20
30
40
50
60
70
80

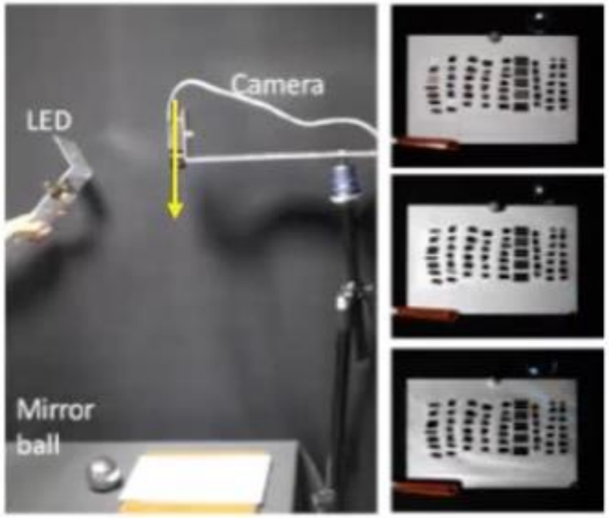
Experiments on ink classification

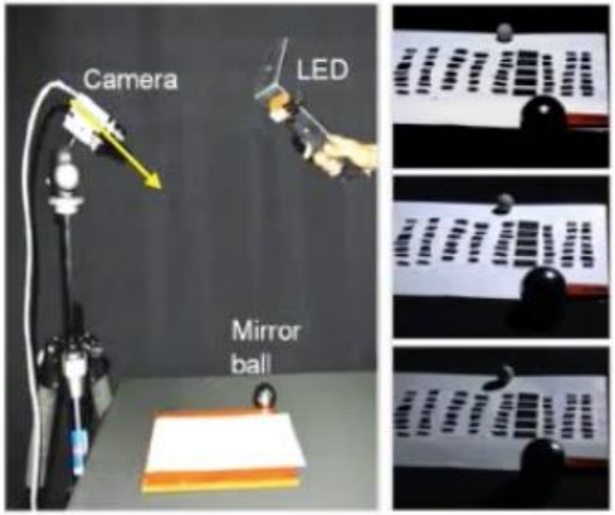


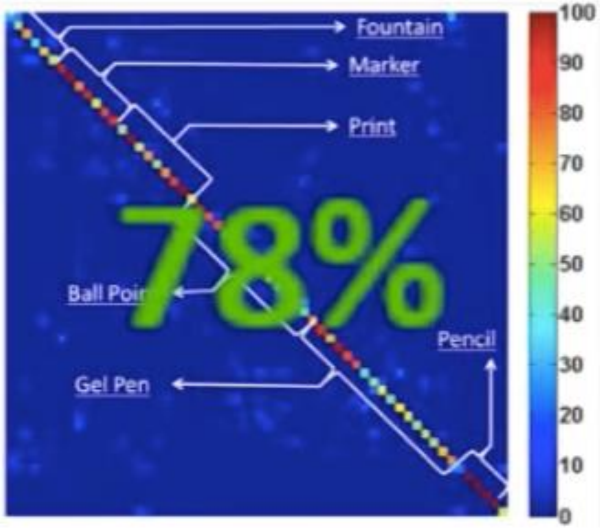
Reflectance info is recorded by

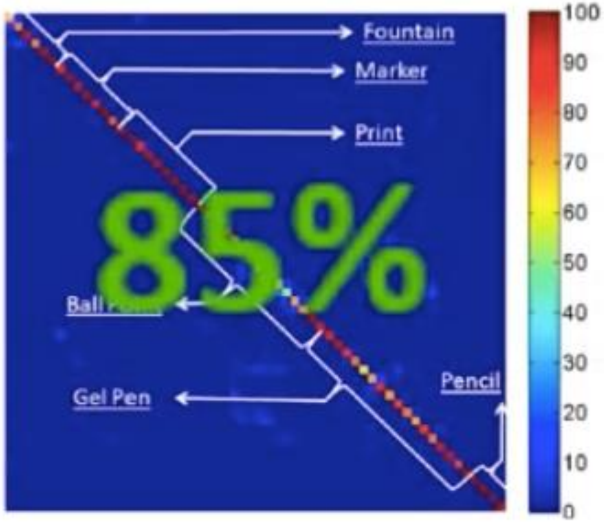
$$f\left(\theta_d, \theta_h\right) = I(\mathbf{x}) / \left(\mathbf{n} \cdot \mathbf{l}\right)$$

Conventional Setup vs. Our New Perspective







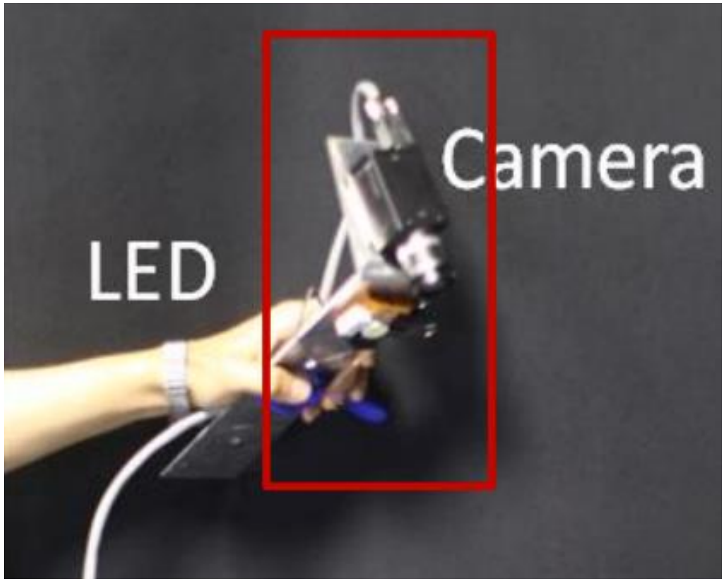


Handheld Capture Method

- BRDF slices over

$$\theta_h = \left[0, \frac{\pi}{2}\right]$$

$$\theta_d = 0$$



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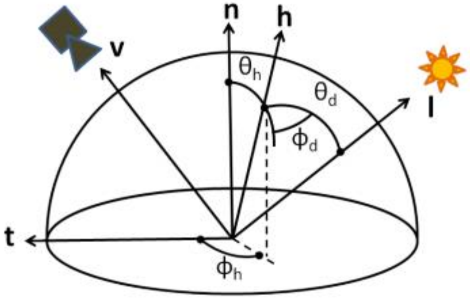
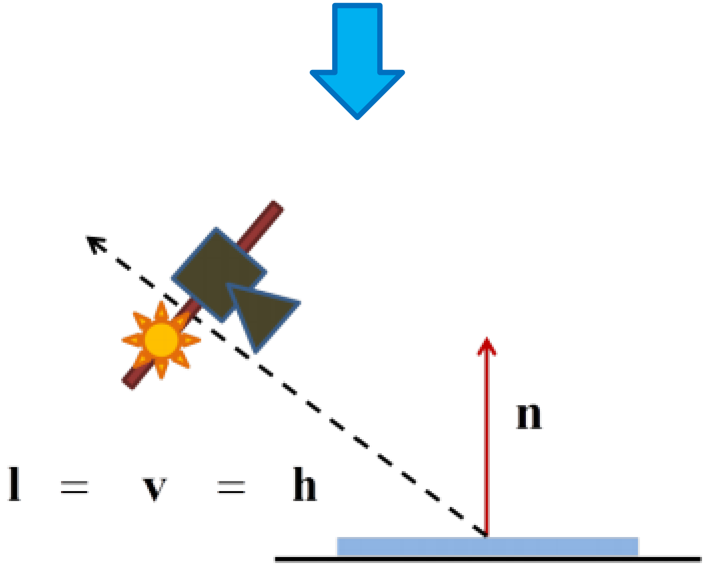




Reflectance Properties

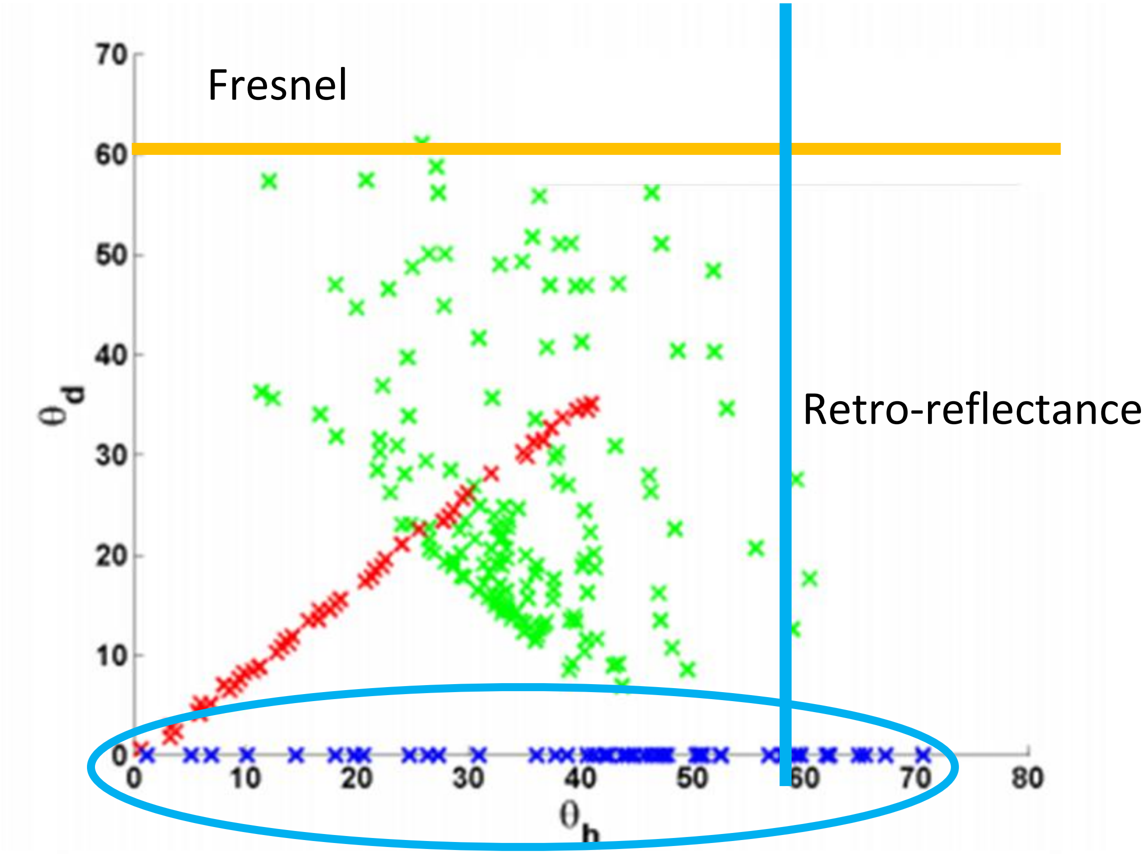
Captures retro-reflectance:

$$\theta_d = 0$$

$$\theta_h > \frac{\pi}{3}$$

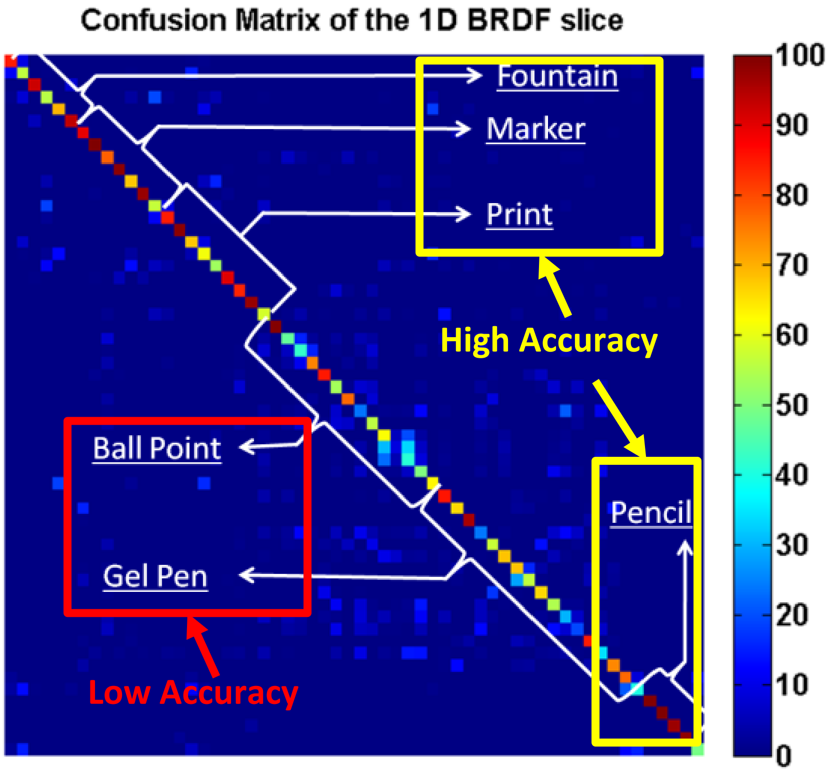
However does not capture Fresnel effects:

$$\theta_d > \frac{\pi}{3}$$



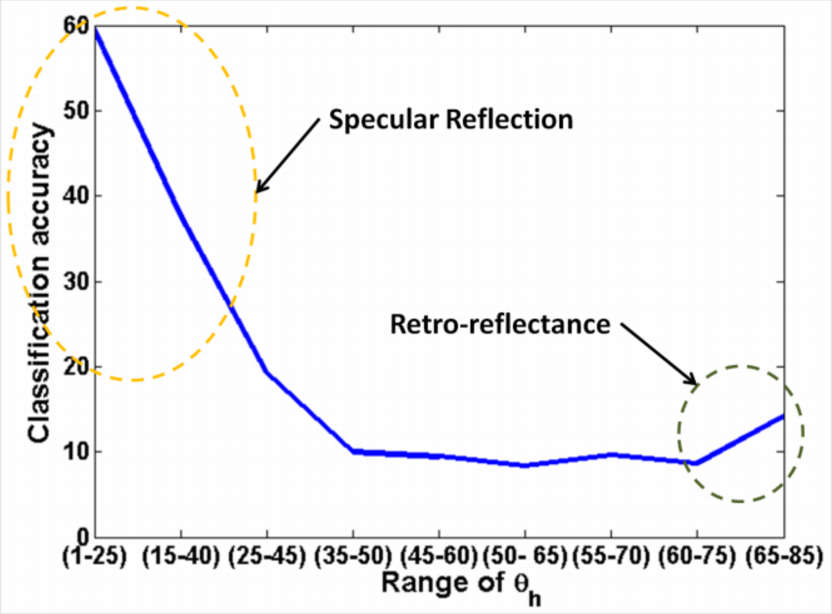
Handheld Capture Method Accuracy

- Classification accuracy of 71%
- Conventional 1D method had 78% accuracy
- True 2D BRDF 85%
- Error comes partly from imprecision in registration of handheld camera positions



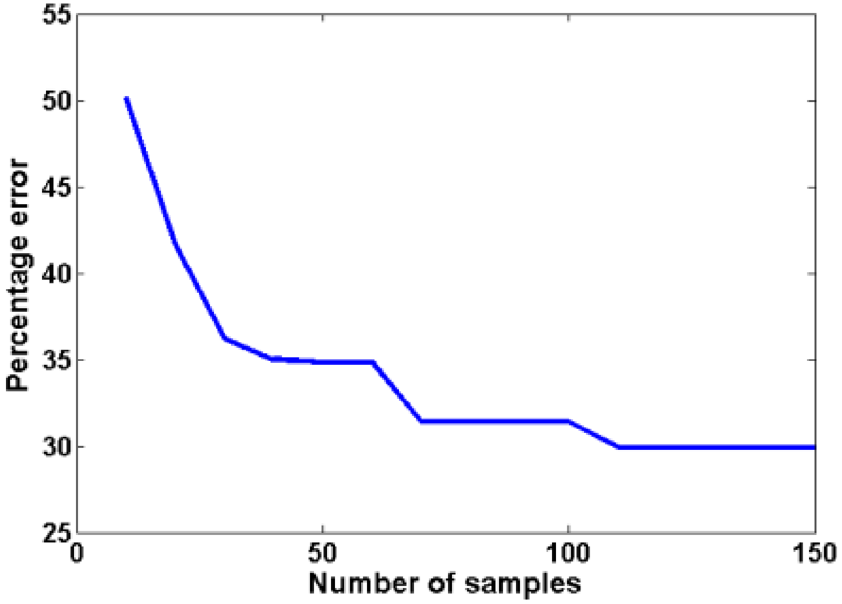
BRDF Slice Intervals

- Some slice intervals may be more informative than others
- Train new SVM classifier on overlapping regions of BRDF slice
- Accuracy is highest in the specular reflection and retro-reflection intervals
- Accuracy of using full slice is better than any single interval

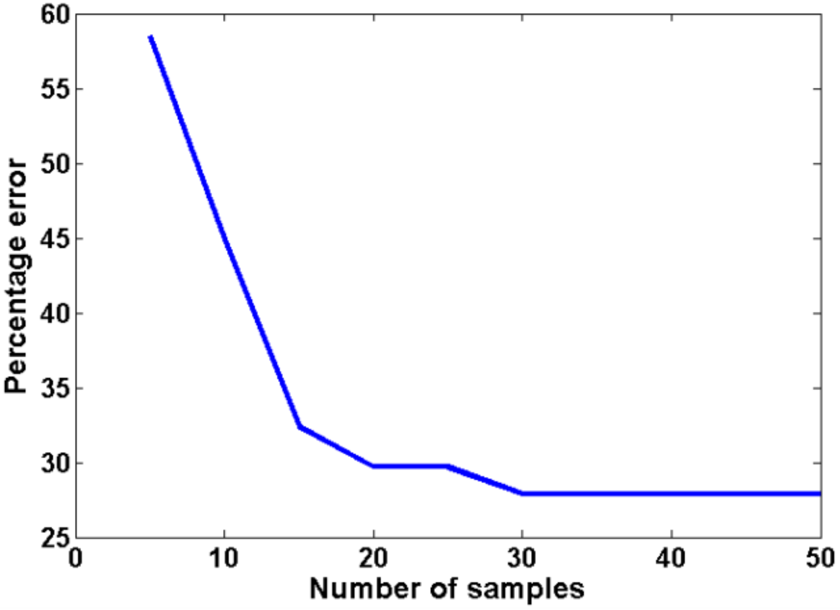


Number of Images

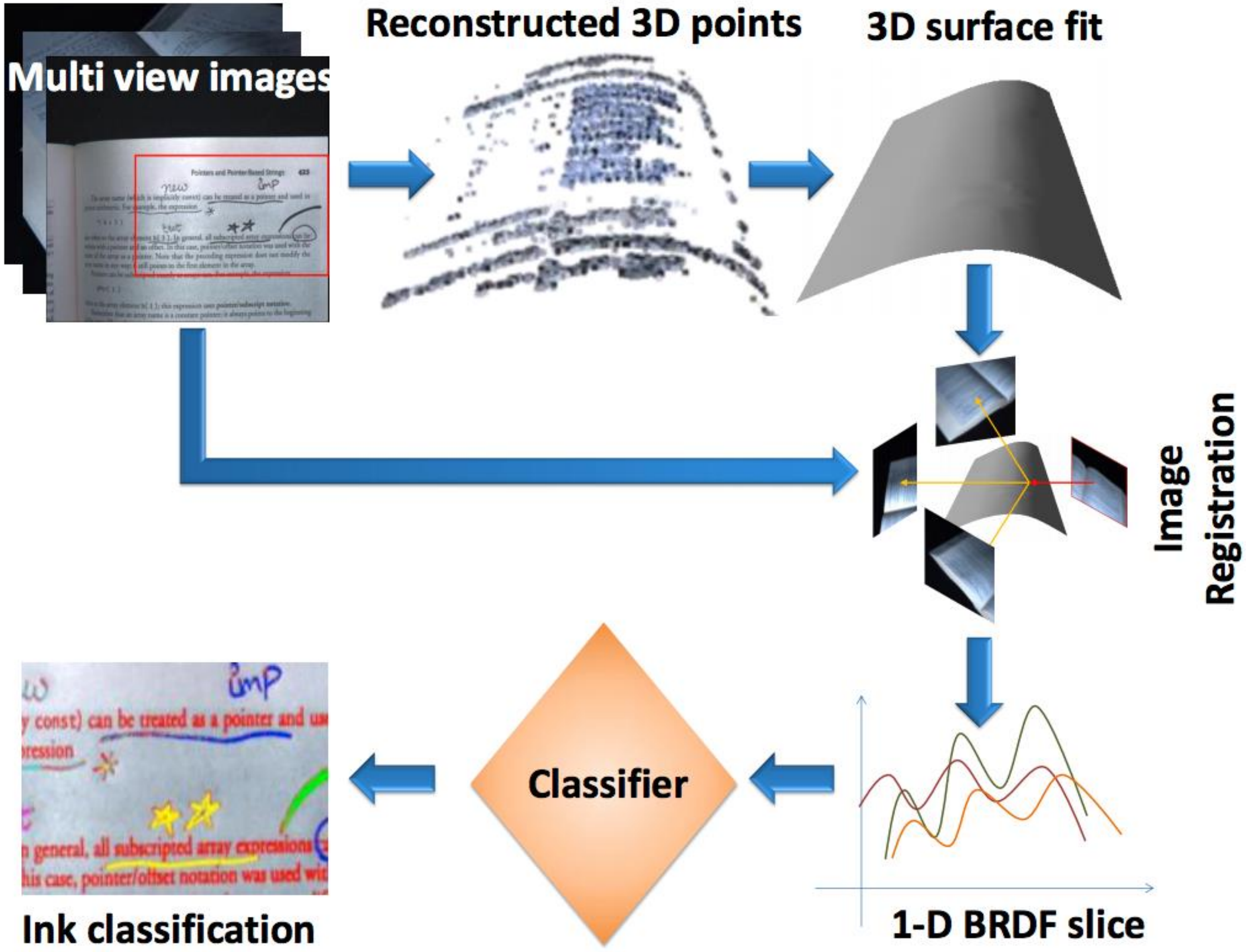
Convention 1D Data Capture



Handheld Capture Method



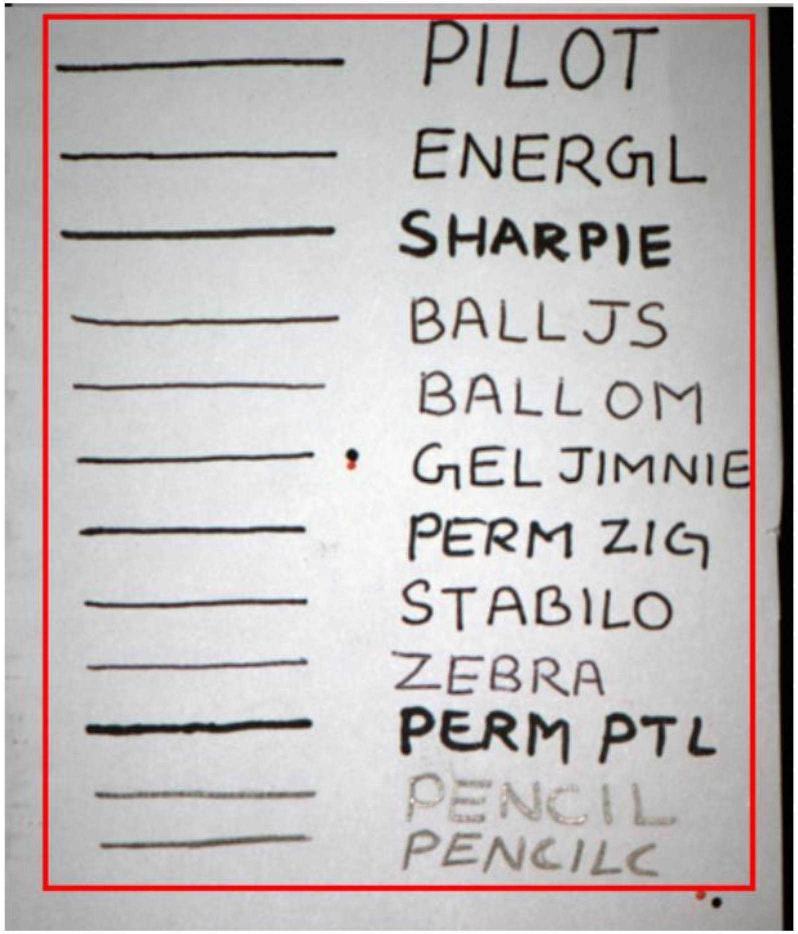
Ink Segmentation on Curved Documents



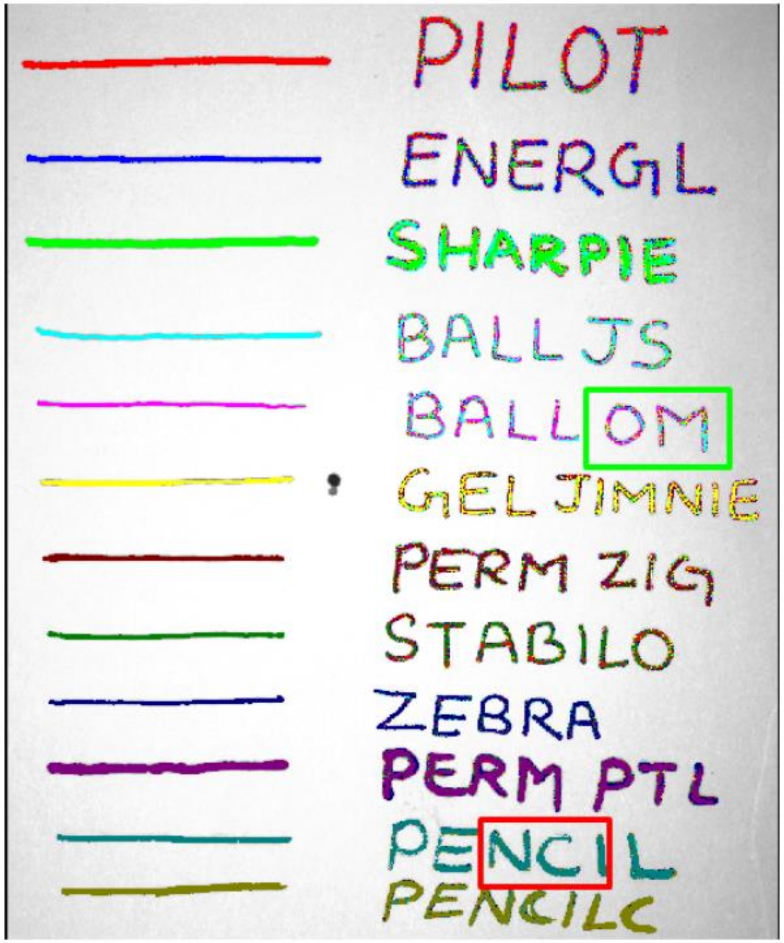
$$f\left(\theta_d, \theta_h\right) = I(\mathbf{x}) / \left(\mathbf{n} \cdot \mathbf{l}\right)$$

Ink Classification Results

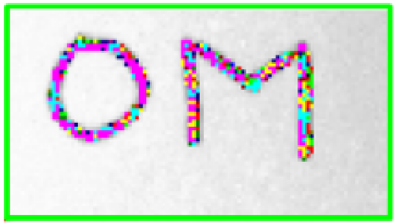
Training Data **Test Data**

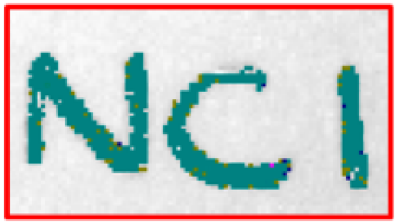


Training Results **Test Results**



Ink Classification Results





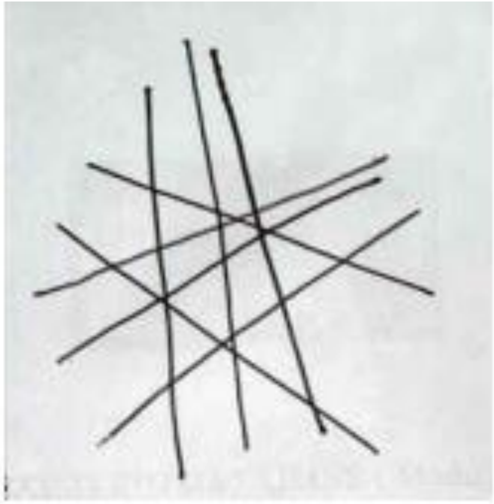
Classified as

Actual Label

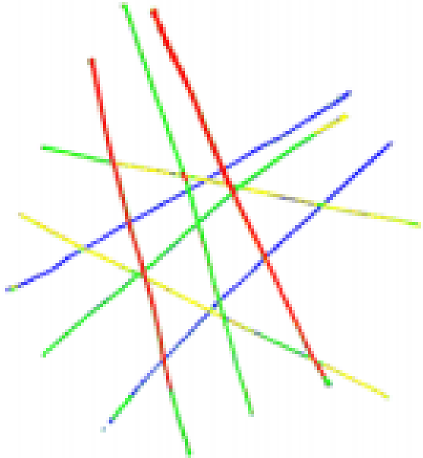
	Pilot	Stabilo	EnerGel	Jimnie	Ball JS	Ball OM	Zebra	Sharpie	PermPtl	PermZig	Pencil 1	Pencil 2
Pilot	**71.5**	8.2	15.1	0.8	1.3	1.9	0	0.9	0	0.3	0	0
Stabilo	11.5	**65.2**	3.3	4.1	0.4	1.5	0.8	0	1.8	10.4	1	0
EnerGel	9.2	1.9	**73.2**	7.1	3	4.2	0.1	1.3	0	0	0	0
Jimnie	2.4	6.6	1.5	**64**	0.8	9.4	0.1	0.4	0	14.6	0.2	0
Ball JS	1.9	0.9	1.9	0.2	**64.9**	16.3	9.6	2.6	1.4	0.3	0	0
Ball OM	4.2	5.6	1.4	1.1	18.1	**55.9**	8.5	4.3	0.1	0.8	0	0
Zebra	0	0.4	0.3	0.1	2.3	1	**83.9**	0.1	7.5	0	3.1	1.3
Sharpie	3.5	0.2	4.1	0.4	15.6	5	0.7	**70.5**	0	0	0	0
PermPtl	0.2	3.9	0	0	0.6	0	10.3	3.6	**76.7**	3	2.7	0
PermZig	0.6	14.8	0.5	12.9	1.3	3	0.5	0	0.2	**65.9**	0.2	0.1
Pencil 1	0	0.3	0	0	0	0.2	1.4	0	0.1	0.8	**94.4**	2.8
Pencil 2	0	0	0	0	0	0	0.4	0	0	0	1.3	**98.3**

Line Results

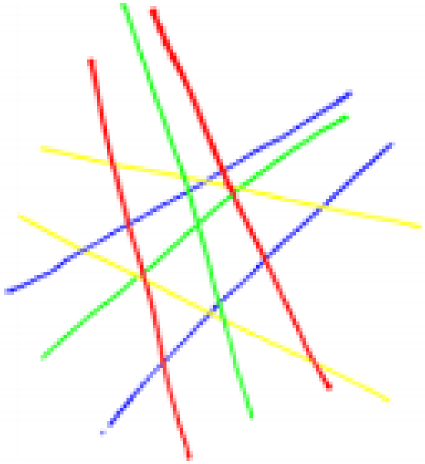
Input



Results



Ground Truth



Legend

Fountain
Ball OM
Zebra
Stabilo

Check Forgery Detection

Input

UNITED OVERSEAS BANK LIMITED

CAMPUS

2 4 0 6 1 4

AACVPR 2014

Five hundred

dollars only

S$ 5,00.00

Results

CAMPUS

2 4 0 6 1 4

AACVPR 2014

Five hundred

dollars only

S$ 5,00.00

Ground Truth

CAMPUS

2 4 0 6 1 4

AACVPR 2014

Five hundred

dollars only

S$ 5,00.00

Positive Contributions

- First work that applies material classification to document analysis
- First use of reflectance properties to identify ink
- Developed method to capture a larger portion of 2D BRDF domain than the conventional near 1D BRDF slices.
- Method increased ink classification accuracy from 78% to 85%.
- Handheld flashlight camera for ink identification
  - Captures specular reflection and retro-reflectance
  - Requires fewer input images than previous methods and allows for more flexible data capturing

Paper Shortcomings

- Assumes prior knowledge of BRDF slices, maybe that is okay. A short description or image of how the prior work did it would have been nice
- A more detailed description of training the SVM classifier(e.g. whether to sample the lighting direction, how to adjust pixel difference) will be helpful for readers to replicate the results
- Several typos

Technical Correctness

- Method shortcomings:
  - Authors said that some error in handheld camera system was caused by registration error
  - Handheld system registration error could be caused from multiple sources including estimating normals from the interpolated surface shape
    - Maybe improve by directly finding normals and depth with handheld photometric stereo methods by Higo, Matsushita, Joshi and Ikeuchi, ICCV 2009
  - Handheld flashlight camera doesn’t capture Fresnel effects for increased performance

Summary

- Improvement in classification performance can be achieved by simply setting the camera at a slanted view to capture a larger portion of the 2D BRDF domain.
- Handheld flashlight camera can capture important reflectance properties such as specular reflection and retro-reflectance for material classification.

- Rating: 2- Accept