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Hyperspectral Imaging for Ink Mismatch Detection

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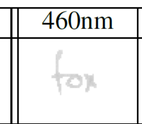
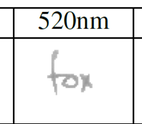
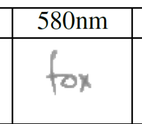
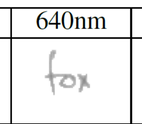
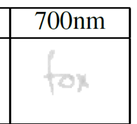
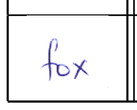
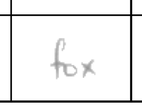
Overview

Ink mismatch detection provides important clues to forensic document examiners [1]

- identifying whether a particular handwritten note is written with a specific ink
- showing that some part (e.g. signature) is written with a different ink as compared to the rest of the note [2].

Hyperspectral images capture fine spectral detail

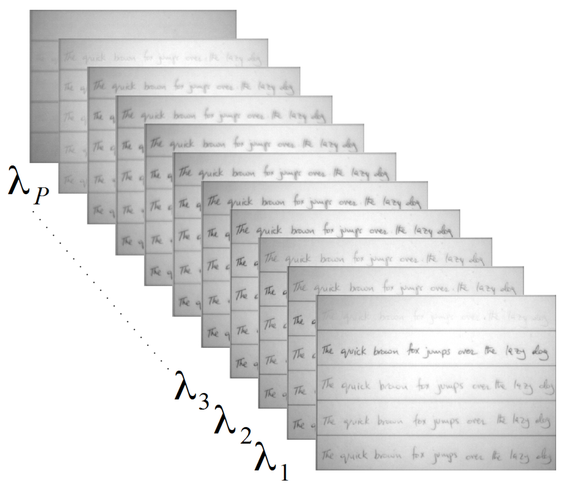
- non-destructive and efficient capture
- automated, accurate identification

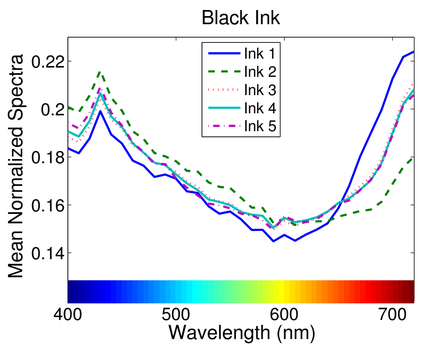
RGB	460nm	520nm	580nm	640nm	700nm
					
					

Ink Mismatch Detection

Inks are distinguishable in visible and near infrared range

- CCD camera with tunable filter captures hyperspectral images
- spectral responses vary in different portions of the EM spectrum
- non-uniform illumination modulates true spectral reflectances





Ink Segmentation and Clustering Algorithm

- segment ink pixles using *Sauvola's* algorithm [3]
- normalize spectral responses to unit magnitude
- *k-means* clustering of ink spectral responses (k=2)

$$\arg\min_{\mathcal{C}} \sum_{i=1}^{k} \sum_{\hat{x}_j \in \mathcal{C}_i} ||\hat{x}_j - \mu_i||^2$$

- forward feature (band) selection. leave-1-ink-out cross validation

Database

- Handwritten note: '*A quick brown fox jumps over the lazy dog*'
- 5 blue and 5 black inks by 7 subjects
- 33 band hyperspectral image in 400-720nm range (10nm steps)
- 3 channel RGB scan for comparison

UWA Writing Ink Hyperspectral Image Database:
http://www.csse.uwa.edu.au/~ajmal/databases.html

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Experiments

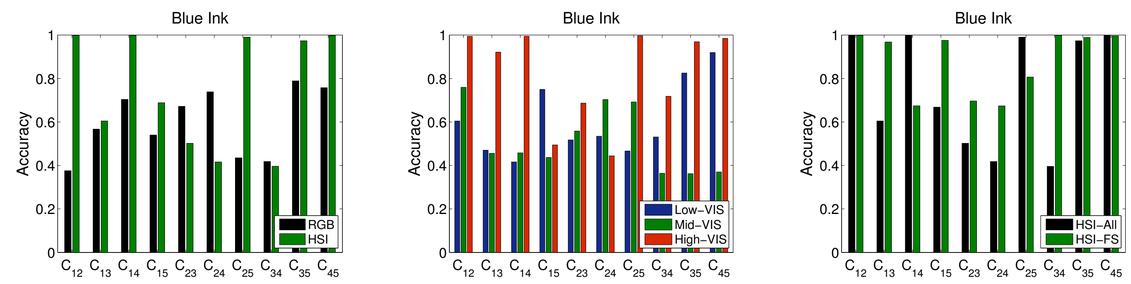
Evaluation Setup

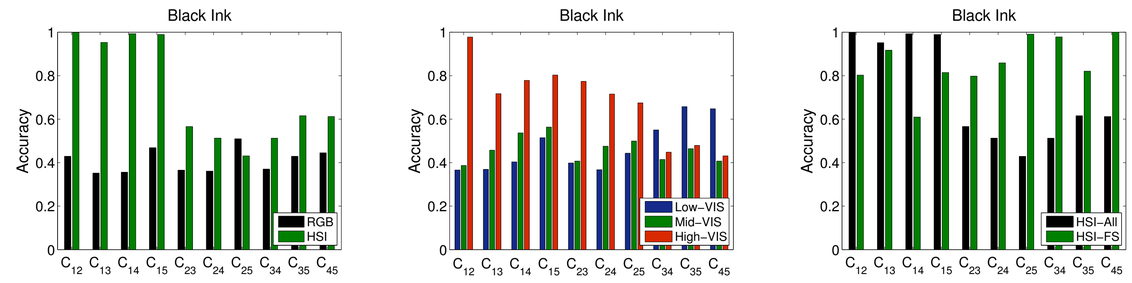
- mix 2 different ink images in equal proportions
- 5 inks, taken 2 at a time, results in 10 different mixed ink images

$$\text{Accuracy} = \frac{\text{True Positives}}{\text{True Positives} + \text{False Positives} + \text{False Negatives}}$$

Segmentation Results

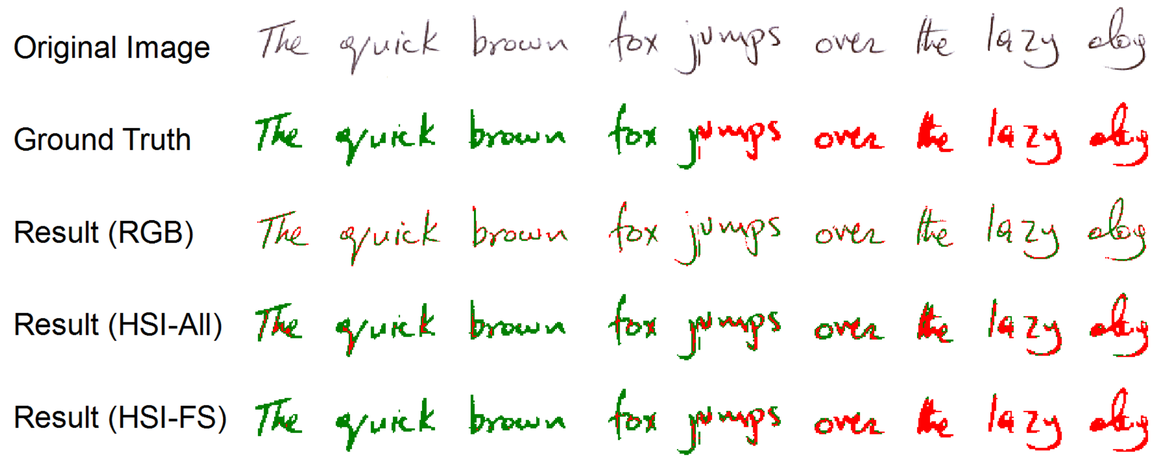
- RGB versus HSI segmentation comparison
- Sub-visual range comparative analysis
- Segmentation with and without feature selection





Example: Discriminating Black Inks

- mix black ink 4 and black ink 5



Conclusion

Hyperspectral imaging is of critical value in supporting ink examination.

- 1st database collected and made publicly available
- overcome hardware limitations in future

References

[1] G. Edelman, E. Gaston, T. van Leeuwen, P. Cullen, and M. Aalders, "Hyperspectral imaging for non-contact analysis of forensic traces," Forensic Science International, vol. 223, pp. 28–39, 2012

[2] E. B. Brauns and R. B. Dyer, "Fourier transform hyperspectral visible imaging and the nondestructive analysis of potentially fraudulent documents," Applied spectroscopy, vol. 60, no. 8, pp. 833–840, 2006.

[3] F. Shafait, D. Keysers, and T. M. Breuel, "Efficient implementation of local adaptive thresholding techniques using integral images," Document Recog. and Retrieval XV, pp. 681510–681510–6, 2008