Image Decomposition Encoding and Localization (IDEL) a new proposal for hyperspectral imaging

M. Ahmad[1, 2], R. Vitale[2], C.S. Silva[3], C. Ruckebusch[2], M. Cocchi[1]

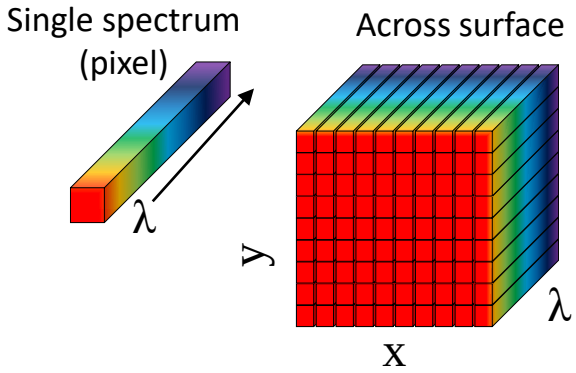
[1]*Università di Modena e Reggio Emilia, Dipartimento di Scienze Chimiche e Geologiche, Modena, Italy.*

[2] *Université de Lille, LASIRE CNRS, Lille, France.*

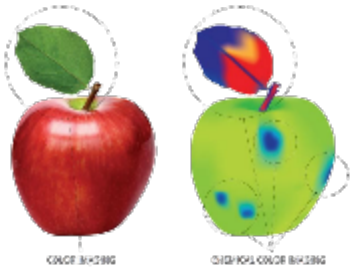
[3]*University of Malta, Department of Food Sciences and Nutrition, Msida 2080, Malta*

Contact: marina.cocchi@unimore.it

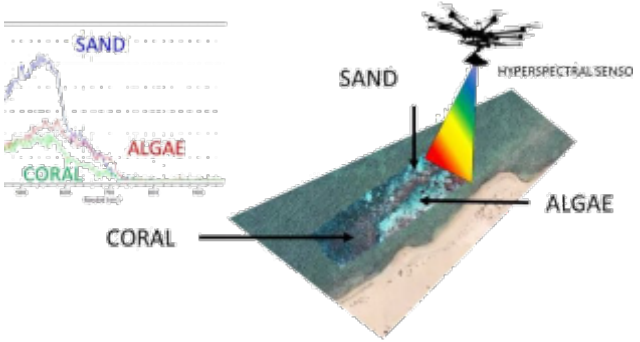
Spectral imaging



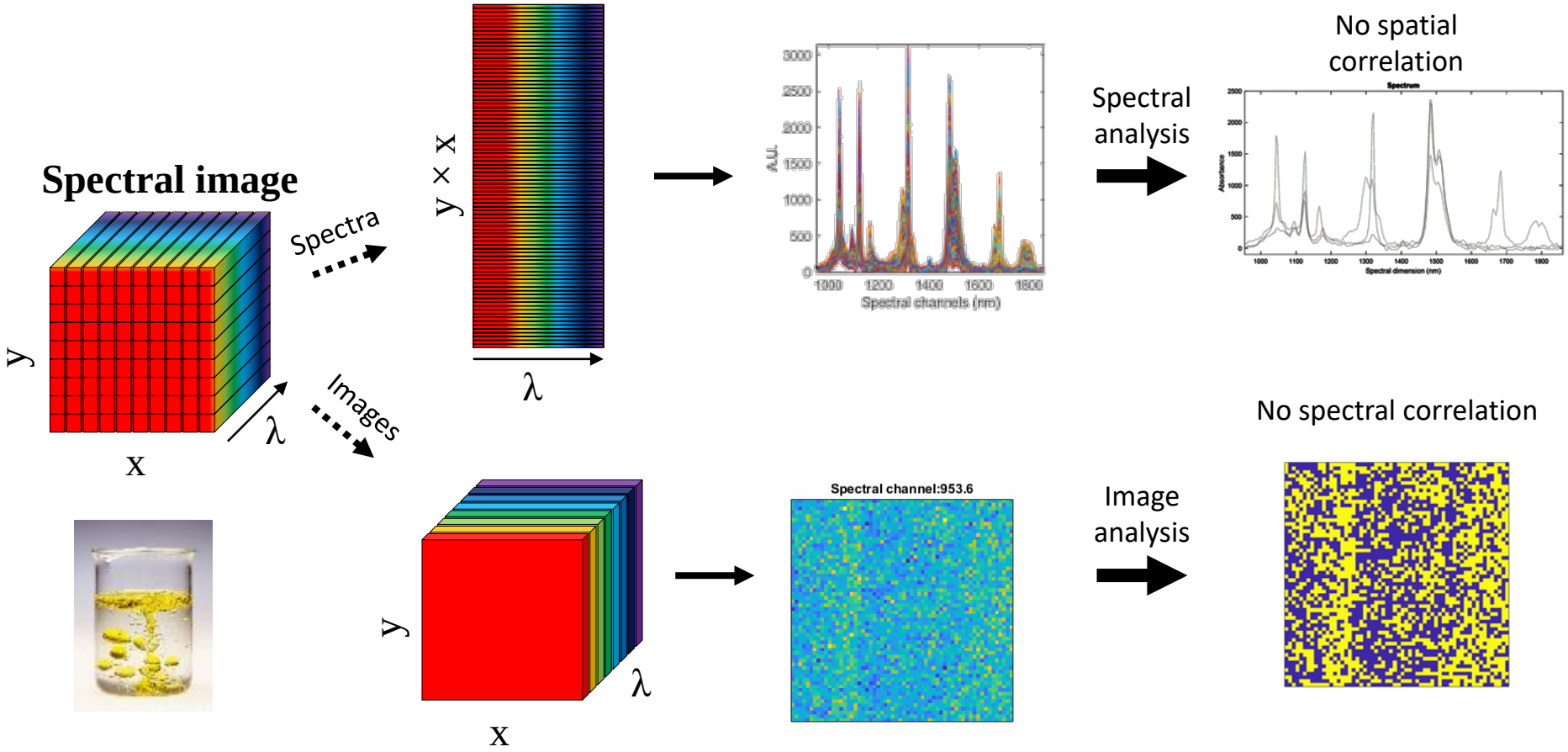
- Pixel: full spectrum for a point in space
- Crucial in many fields of analytical sciences



- Spectral fingerprint with spatial distribution



Two perspectives of analysis

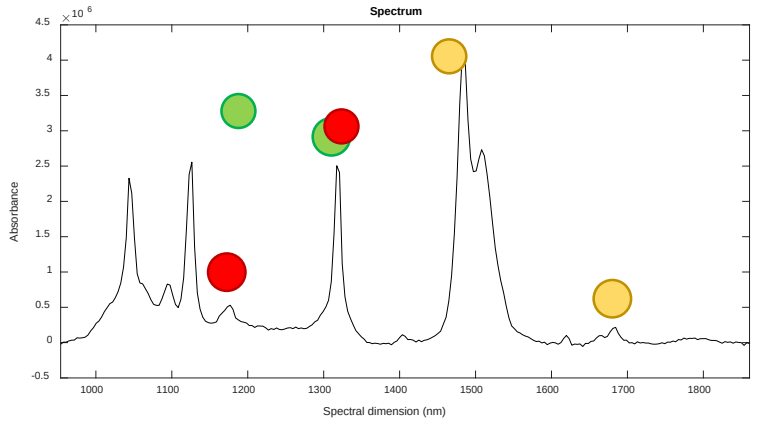


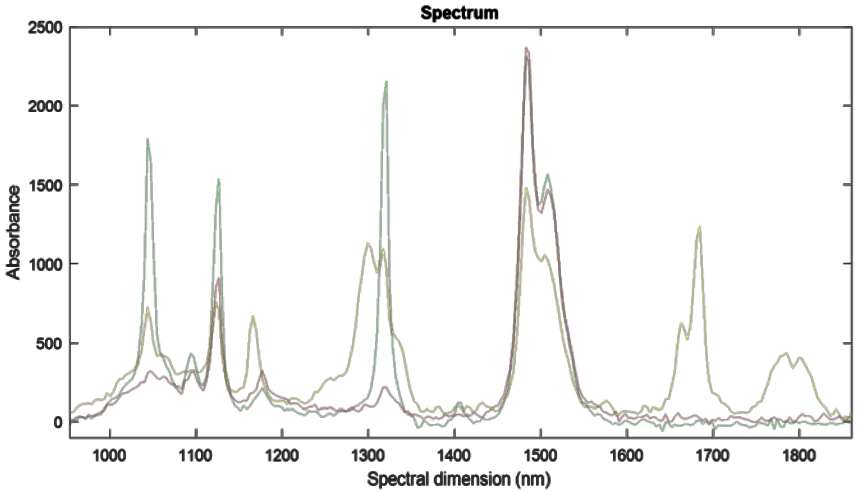
Simple example

- Oil in water emulsion
  - Clear spatial distribution
- Raman imaging
  - Spectral selectivity
- Clear chemical contributions
- Spatial **OR** Spectral analysis

are adequate

Mean spectrum





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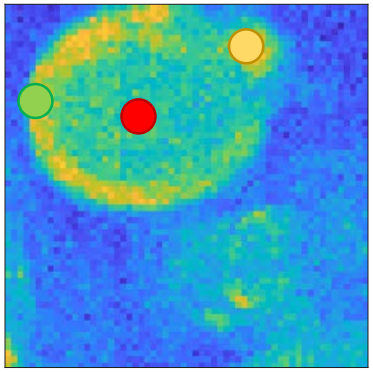
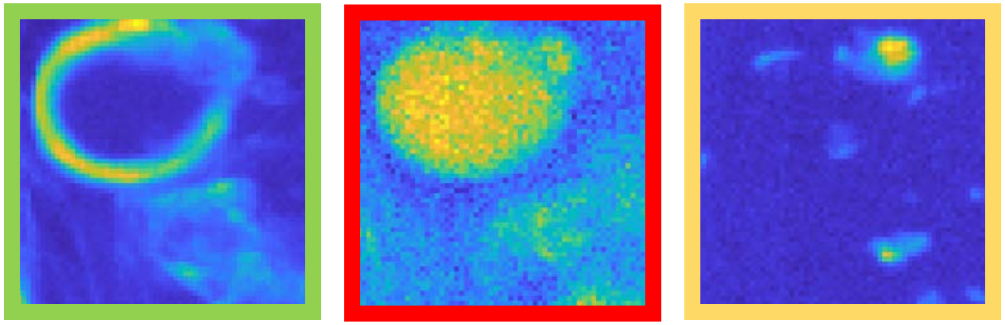
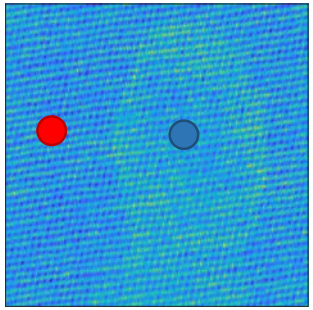




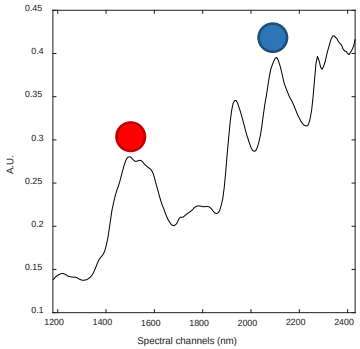
Complex example

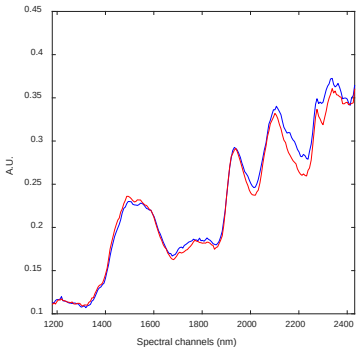
- Semen stain on cotton fabric
  - Textural pattern
  - Spatial overlap
- Near-infrared imaging
  - No spectral selectivity
- Non-linear scattering
- Spatial **AND** spectral analysis needed

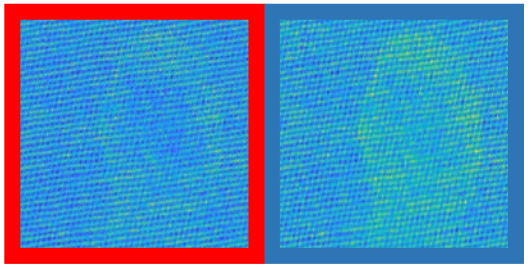
Mean image



Mean spectrum







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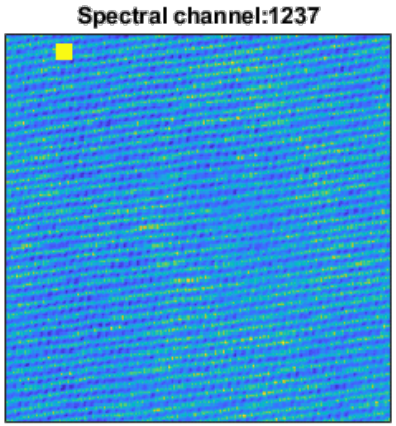


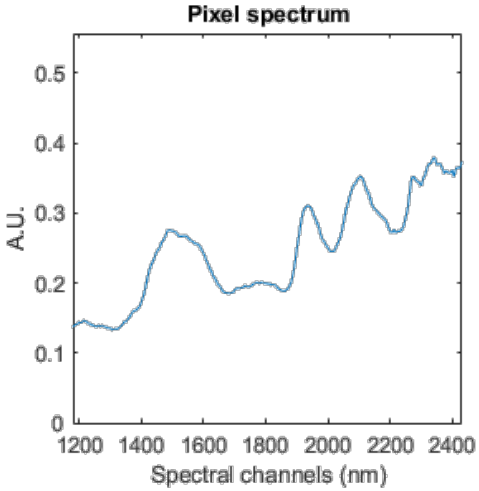
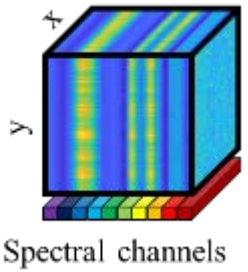
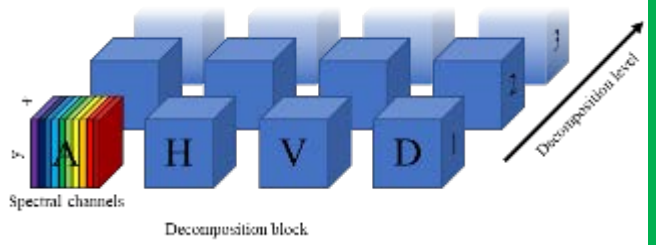


Image Decomposition, Encoding and Localisation (IDEL)

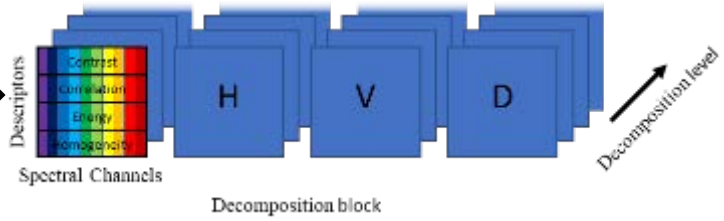
Spectral image



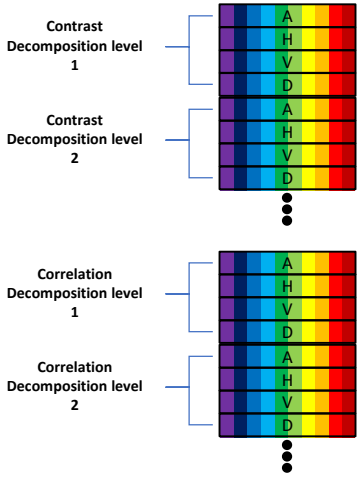
1. Wavelet decomposition



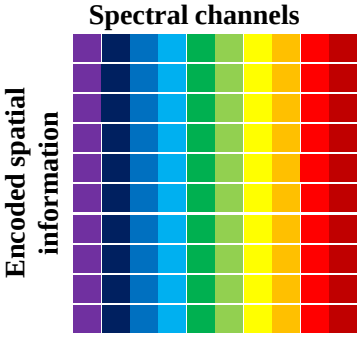
2. Encoding by **G**ray **L**evel **C**o-occurency **M**atrices **(GLCM)**



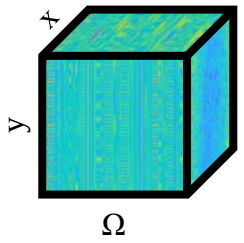
Descriptors matrix



3. Localisation



Ω-data cube



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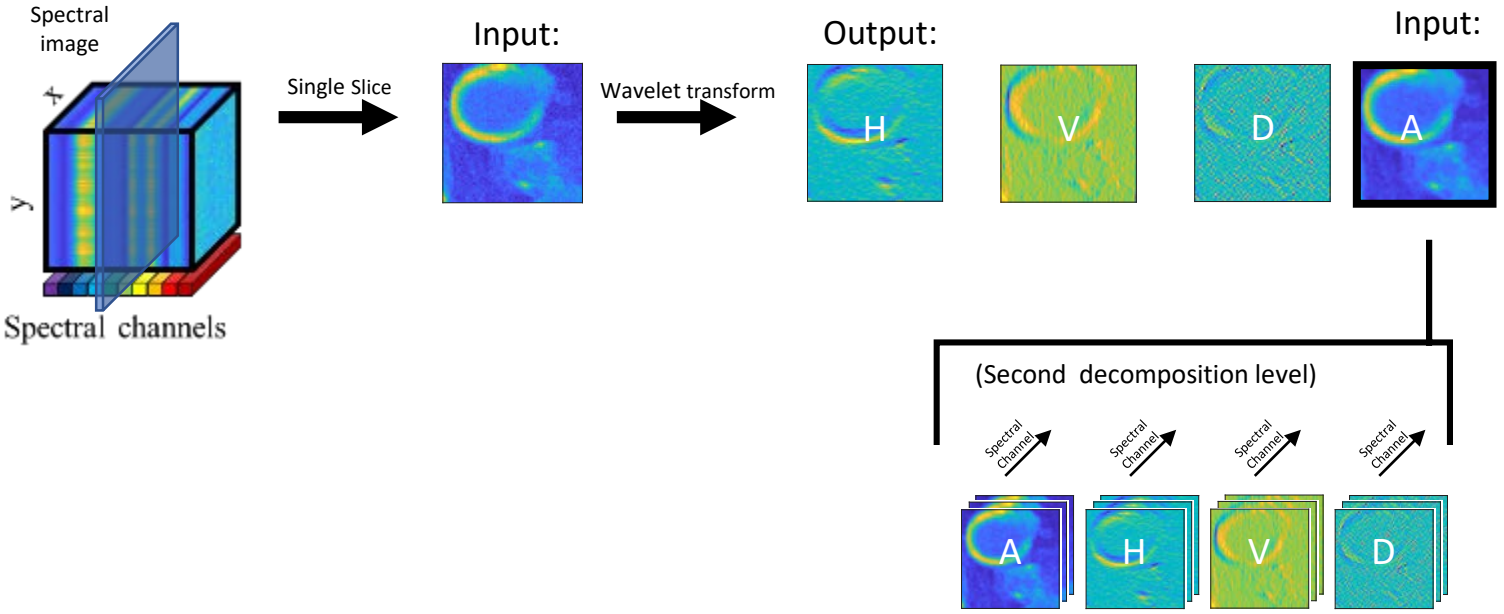
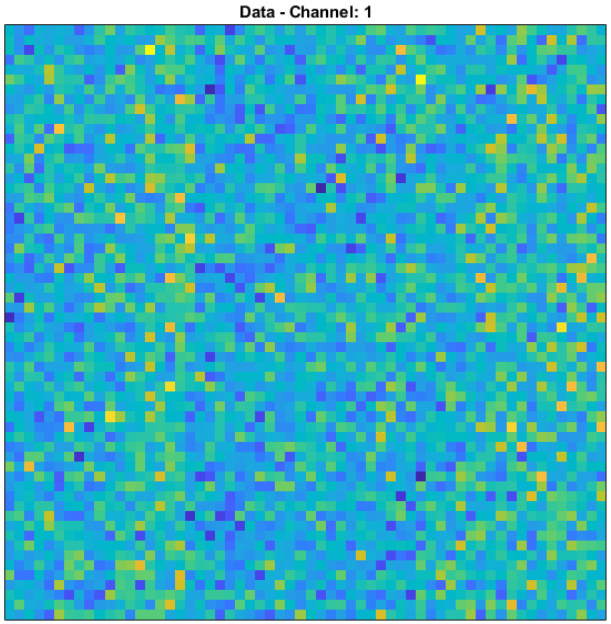
2D Stationary Wavelet Transform



Third ……..and so on till max allowable by image size

2D Stationary Wavelet Transform

Allows exploitation of spatial information across spectral channels



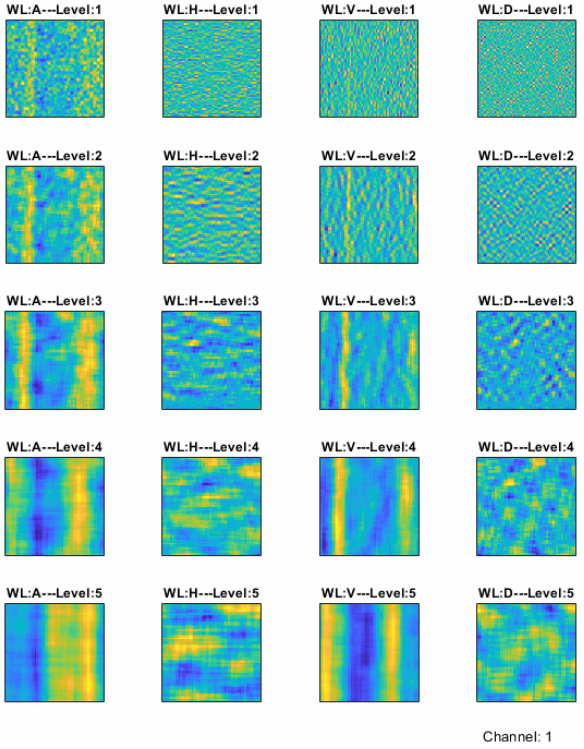
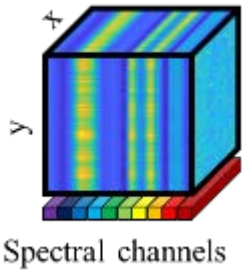
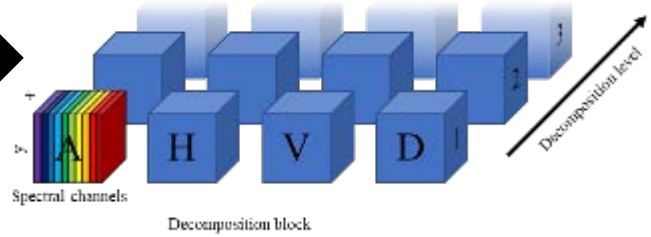


Image Decomposition, Encoding and Localisation (IDEL)

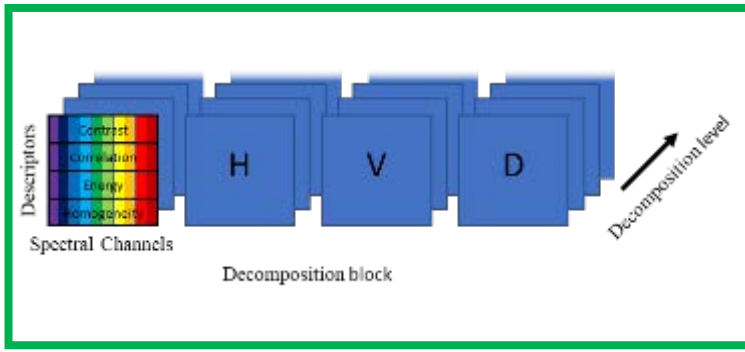
Spectral image



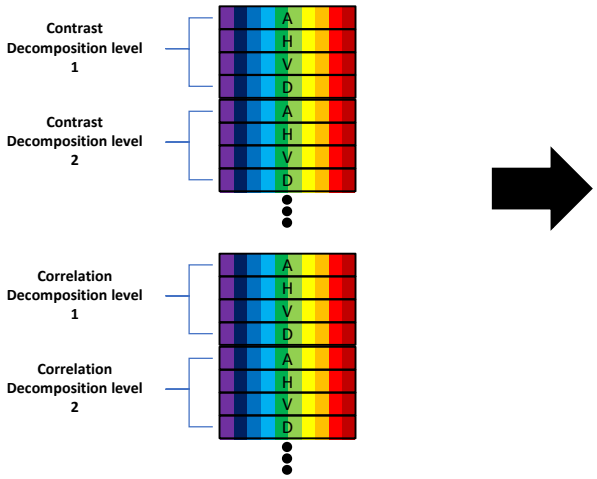
1. Wavelet decomposition



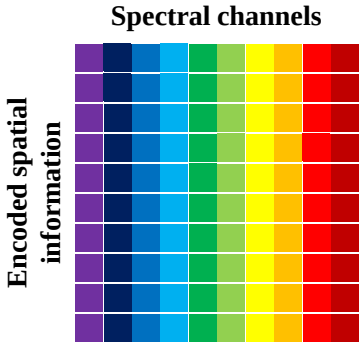
2. Encoding by Gray Level Co-occurency Matrices (GLCM)



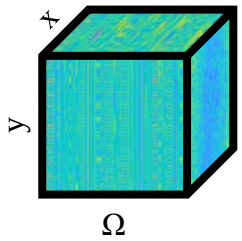
Descriptors matrix



3. Localisation

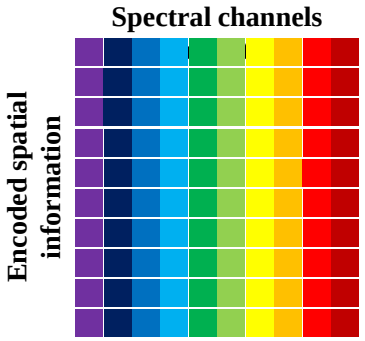


Ω-data cube

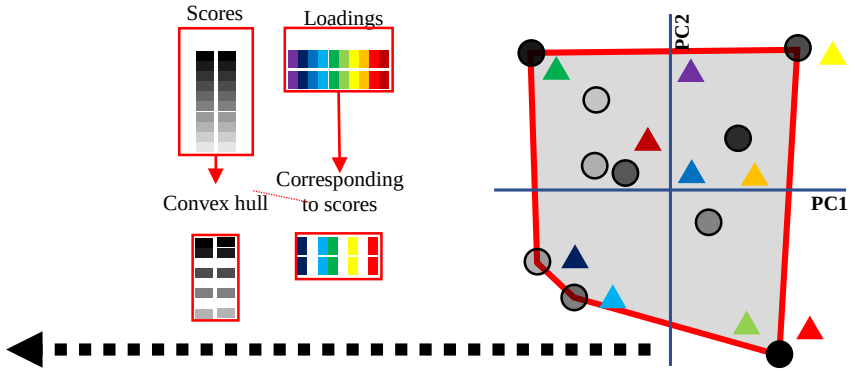


Localisation by PCA-Convex Hull

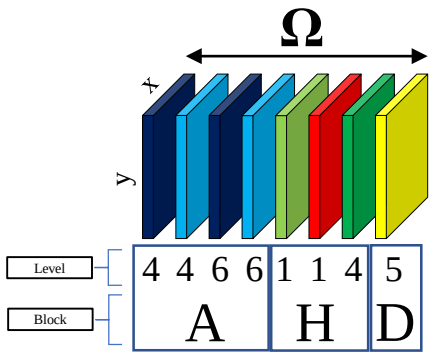
Descriptors matrix



Contributions with the highest variation e.g.



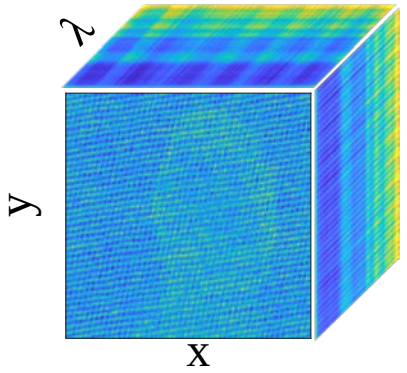
Extracted spatial features e.g.



Ω

GET the most significant spatial features at specific spectral channels

Semen benchmark*



- Samples:
  - Human semen on cotton substrate of different colours (white as calibration, red & green test)

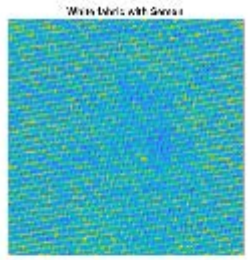
- Analysis:
  - SisuCHEMA – SWIR Chemical Imaging System
  - Spectral: 1000 - 2500 nm (6.3 nm interval)
  - Spatial: 50 × 50 mm (156 μm^2)

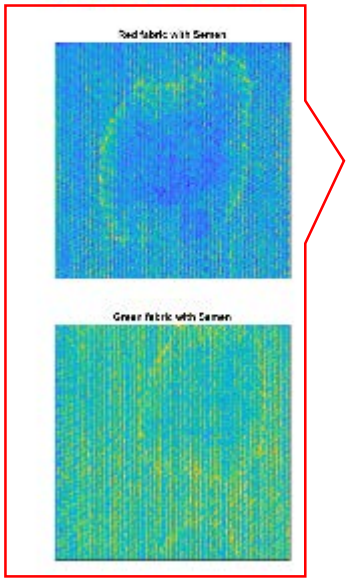
Pre-processing

Sav-Gol smoothing

WLS-baseline correction

Mean image

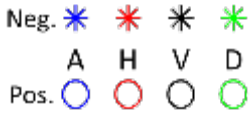




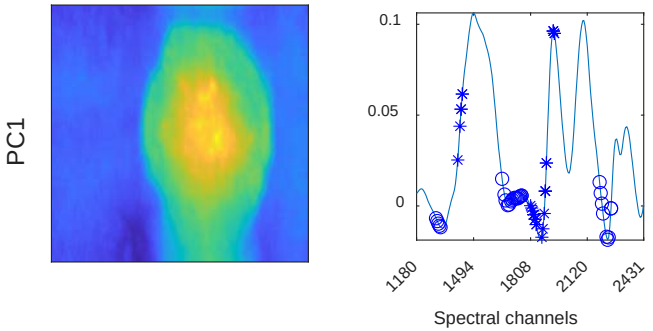
*C.S. Silva et al. Detecting semen stains on fabrics using near infrared hyperspectral images and multivariate models, Trends in Analytical Chemistry 95 (2017) 23e35

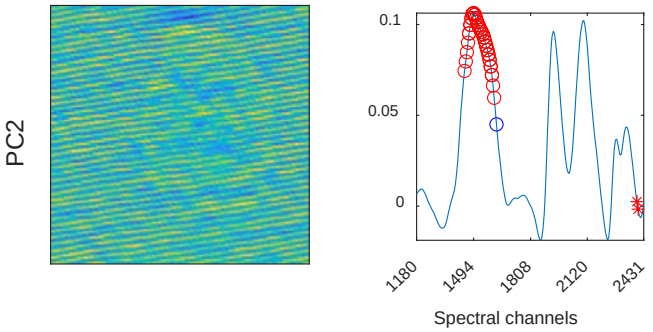
Exploratory PCA on Ω

Semen on White fabric



- PC1: Smooth pattern (without fabric pattern)
  - 1700, 1850 and 2200 nm
    - Protein bands [1]
  - 1300 nm
    - Not attributed to absorption (solely physical scattering)
  - 1450 and 1940 nm (negative contribution)
    - Water bands [2]
    - Linked to a subsequent PC
- PC2: Fabric pattern from cotton
  - Horizontal fibre texture (H sub-images)
  - Band at 1494 nm
    - First overtone of O-H stretching in cotton [1]

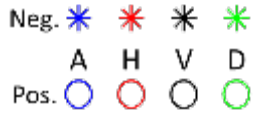




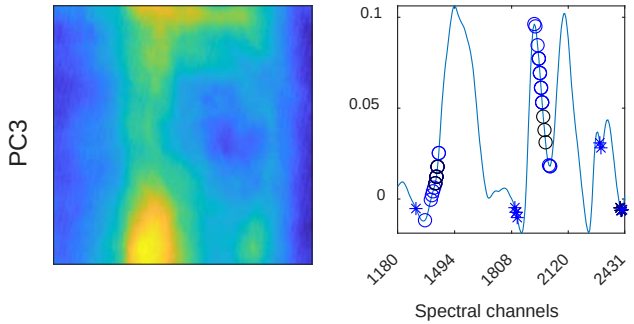
[1] E.W. Ciurczak, D.A. Burns, Handbook of near-infrared analysis
[2] Y. Ozaki, Applications in Chemistry, in: H.W. Siesler, Y. Ozaki, S. Kawata, H.M. Heise (Eds.), Near-Infrared Spectroscopy

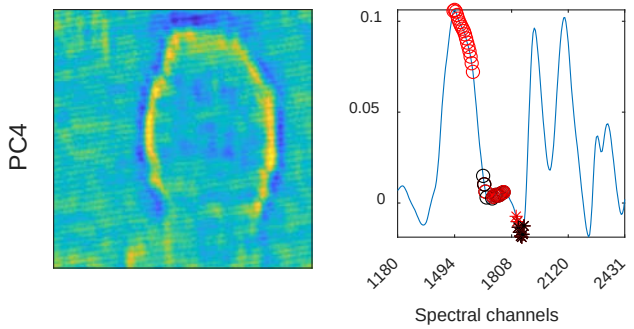
Exploratory PCA on Ω

Semen on White fabric



- PC3: Stain border effect (without fabric pattern)
  - 1300, 1450, 1850 and 1940 nm
    - Similar to PC1
  - 1450 and 1940 nm [2]
    - Drying effect
- PC4: Stain border effect (with fabric pattern)
  - 1500 and 1700 nm
    - Already attributed to Semen / Cotton
    - H/V sub-images
- Etc…

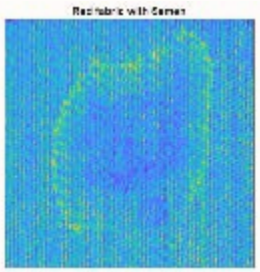


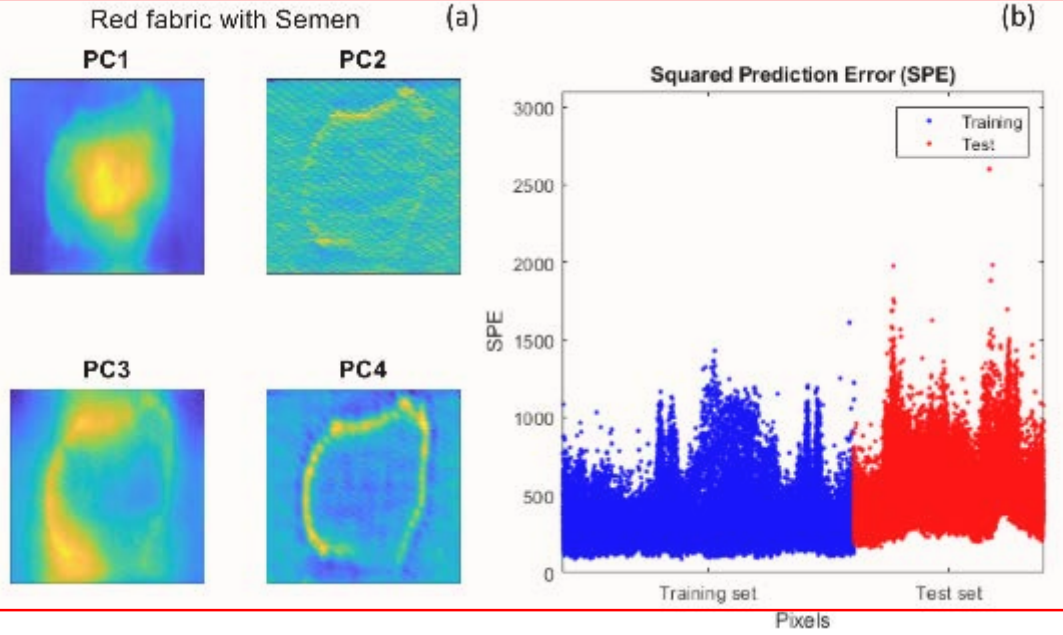


[1] H.W. Siesler, Y. Ozaki, S. Kawata, H.M. Heise (Eds.), Near-Infrared Spectroscopy
[2] Y. Ozaki, Applications in Chemistry, in: H.W. Siesler, Y. Ozaki, S. Kawata, H.M. Heise (Eds.), Near-Infrared Spectroscopy

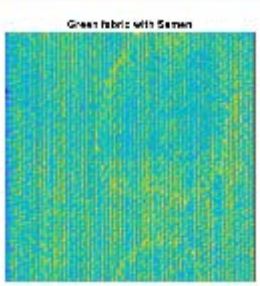
Exploratory PCA on Ω

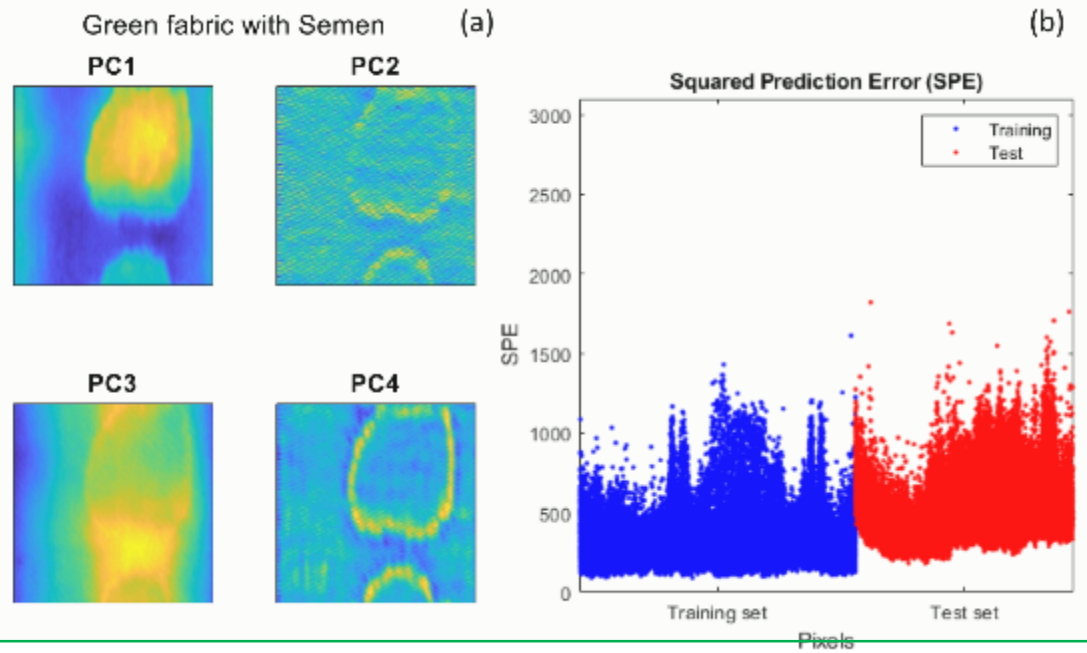
Projection Red fabric





Projection green fabric





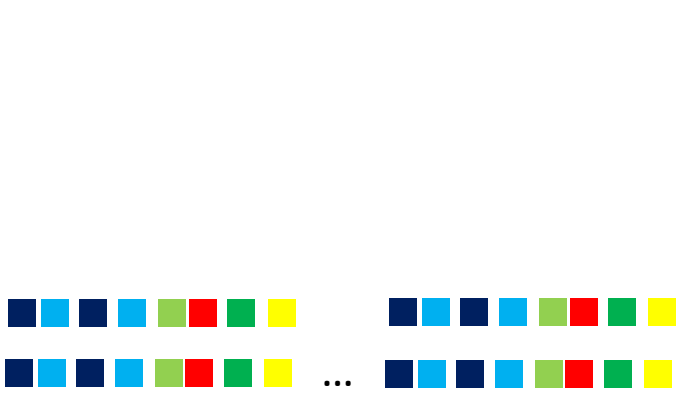
Conclusion

- Assuming no spatial-spectral interplay limits the information which can be extracted from spectral imaging
- Current methodology may encounter difficulties in complex cases (spatial and spectral overlap)

- IDEL seems able to isolate distinct but overlapping textures, that show similar spectral selectivity
  - utilises image processing while maintaining spectral correlation
  - based on image decomposition and encoding

- The spatial-spectral relationship is modelled and similar components can be extracted from new data

Perspectives



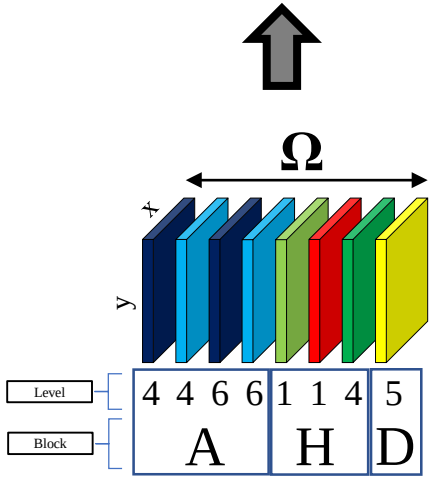
……

Sample2

Sample1

Regression, classification

Use Descriptors of selected sub-images



Use spatial features for other tasks….e.g. *segmentation, MCR*

Unfold pixel wise
+ Explorative analysis

Thanks for attention