Summary

• Vision
• Hyperspectral hardware
• Hyperspectral software
• Applications & Examples
Vision

Source → Sample → Sensor
Color

Visible Light

400 nm  500 nm  600 nm  700 nm
Perception
Machine Vision
Camera types

- B/W
- UV, IR, SWIR, ...
- RGB
- Hyperspectral VisNIR
- Hyperspectral SWIR
# Camera types

<table>
<thead>
<tr>
<th></th>
<th>B/W</th>
<th>RGB</th>
<th>SWIR</th>
<th>Hyperspectral VisNIR</th>
<th>Hyperspectral SWIR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Monochromatic</td>
<td>• RGB</td>
<td>• Monochromatic</td>
<td>• Camera B/W</td>
<td>• Camera SWIR</td>
</tr>
<tr>
<td></td>
<td>• Si, 400–1000 nm</td>
<td>• Si, 400–1000 nm</td>
<td>• InGaAs, 950–1700 nm</td>
<td>• VisNIR spectrograph</td>
<td>• SWIR spectrograph</td>
</tr>
<tr>
<td></td>
<td>• Eventual spectral filter</td>
<td>• Bayer filter</td>
<td>• Eventual spectral filter</td>
<td></td>
<td>• Temperature control</td>
</tr>
</tbody>
</table>
Hyperspectral imaging
Hyperspectral hardware

• Spatial scanning configuration (push-broom)
• Hyperspectral camera
  • Objective lens
  • Hyperspectral optics
  • Camera
Hyperspectral data
Hyperspectral cube

- 3D dataset \((x, y, \lambda)\)
  - \(x\): Spatial dimension (across-track)
  - \(\lambda\): Spectral dimension
  - \(y\): Spatial dimension (along-track)
Slicing the cube

500  600  700  800  900  1000

1100  1200  1300  1400  1500  1600
Slicing the cube
Chemometrics

- Spectral reflectance (color) as a fingerprint
- Training set to develop a mathematical model capable of classifying future samples
Model fitting and data classification

**TRAIN**
- Image labelling (supervised method)
- Preprocessing
  - Spectral bands selection
  - Binning/Smoothing
- Train/test random sampling
- Cross-validation (k-fold)

**PREDICT**
- Classification of unknown samples
Two Kinds of Application

- Regression
- Classification
HSI Classification Model

- Spectral features (color) only
- Precise and conservative labelling
- Relatively small and exemplary training set
- Bigger test set to evaluate performance

- PRO: Lightweight & fast computation
- CON: Spatial features are ignored!

Training Dataset Size
Halogen lamps

Visible light

X-rays  UV  280  400  780  1000  1700  λ [nm]

NIR

VisNIR

SWIR

Halogen Lamp

microtec.eu
Matteo Caffini, PhD
**LEDS**

<table>
<thead>
<tr>
<th>280</th>
<th>400</th>
<th>780</th>
<th>1000</th>
<th>1700</th>
<th>( \lambda ) [nm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-rays</td>
<td>UV</td>
<td>Visible light</td>
<td>NIR</td>
<td>SWIR</td>
<td></td>
</tr>
</tbody>
</table>

- **Visible light**: 400-780 nm
- **NIR**: 780-1000 nm
- **SWIR**: 1000-1700 nm

**White LED**

**Non standard hardware**
application & sample dependent
Development protocol

- Problem definition
  - What feature needs to be seen?
  - How can we measure it?
- Sample collection
  - Multiple samples per class
  - Good distribution of features
- Lab testing & validation
- Wavelength range analysis
- Design & production
Thank You

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