Color visualization for spectral imaging: A segmented PCA approach

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under the supervision of

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Outline

- Generalities
- Principal Components Analysis
- Spectrum segmentation
- Results
- Conclusions
Why does one need dimensionality reduction?

- To eliminate noise and redundancy
- To ease interpretation by a human operator: color display, highlighting of RoI and OoI
- To ease interpretation by a machine operator: the « curse of dimensionality »
- To alleviate memory and computational burden
Generalities

How?

- **Band transformation**: linearly or unlinearly combine spectral bands

\[ \{B_1, B_2, \ldots, B_N\} \rightarrow \{C_1, C_2, \ldots, C_M\} \]

With \( M < N \) and \( C_i = \alpha B_1 + \beta B_2 + \ldots + \nu B_N \) (or unlinear)

*Examples*: PCA, ICA, CCA, CMF, ...

- **Band selection**: select a subset of interesting bands

*Examples*: Entropy, MEMC, Mutual Information with ground truth, ...

Multispectral imaging and biometrics 11/23/2010
Generalities

- **Advantages of band transformation over band selection**
  - Takes into account the whole dataset
  - Generally allows for a better handling of noise and redundancy

- **Advantages of band selection over band transformation**
  - Keeps the physical meaning of a spectral channel
Principal Components Analysis

- a.k.a. PCA, PCT, or KLT

  - Band transformation method based on a maximization of the variance.

- Large computational burden due to the manipulation of an N-sized correlation matrix

CIELAB mapping
Spectrum segmentation

Band clustering based on a similarity criterion

- Equal subgroups
- RGB-based
- Maximum energy (Tsagaris et al., 2005)
- Correlation (Jia et al., 1999) or Mutual Information (Martínez-Uso et al., 2007)

Correlation matrix – “Jasper Ridge” 224 bands
Spectrum segmentation

- Visualization-oriented spectrum segmentation

![Graph showing CMF coefficients vs Wavelength (nm) for different colors within the visible range.](image)
Spectrum segmentation

- Visualization-oriented spectrum segmentation
Results

- « True color »: a reference for naturalness

- Inter-Class Perceptual Distance (ICPD)

\[ \Delta E^* = \sqrt{(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2} \]
Results

- Equal Subgroups, Maximum energy, Correlation
Results

- \( \tau = 0.1, 0.5, 0.8 \) and 1
## Results

### Results for the “Flowers” image (left) and NEO (down)

<table>
<thead>
<tr>
<th>Segmentation technique</th>
<th>NR</th>
<th>ICPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal subgroups</td>
<td>12.37</td>
<td>101.34</td>
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<tr>
<td>Correlation-based</td>
<td>13.34</td>
<td>109.71</td>
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<tr>
<td>Maximum energy</td>
<td>22.50</td>
<td>117.42</td>
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<tr>
<td>CMF-based, $\tau = 0.1$</td>
<td>4.24</td>
<td>94.48</td>
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<tr>
<td>CMF-based, $\tau = 0.5$</td>
<td>1.73</td>
<td>96.33</td>
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<td>CMF-based, $\tau = 0.8$</td>
<td>3.81</td>
<td>100.73</td>
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<tr>
<td>CMF-based, $\tau = 1$</td>
<td>5.70</td>
<td>112.30</td>
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<thead>
<tr>
<th>Segmentation technique</th>
<th>NR</th>
<th>ICPD</th>
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<tbody>
<tr>
<td>Equal subgroups</td>
<td>53.76</td>
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<tr>
<td>Correlation-based</td>
<td>90.87</td>
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<tr>
<td>Maximum energy</td>
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<td>243.21</td>
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<tr>
<td>CMF-based, $\tau = 0.1$</td>
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<td>CMF-based, $\tau = 0.5$</td>
<td>14.40</td>
<td>227.36</td>
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<td>CMF-based, $\tau = 0.8$</td>
<td>11.96</td>
<td>224.55</td>
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<tr>
<td>CMF-based, $\tau = 1$</td>
<td>19.62</td>
<td>242.45</td>
</tr>
</tbody>
</table>
Conclusions

- The visualization-oriented spectrum segmentation allows for:
  - Alleviation of the computational burden of PCA (and, by extension, any dimensionality reduction technique)
  - A fast clustering of spectral channels based on perception
  - Taking all the spectrum into account for each segment
  - An overall better natural rendering than other techniques
  - Balancing between naturalness and informative content
Thank you for your attention
Some references


