Multispectral image characterization by Partial generalized covariance

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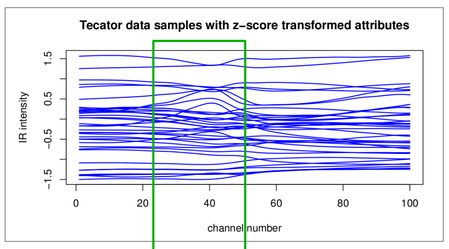
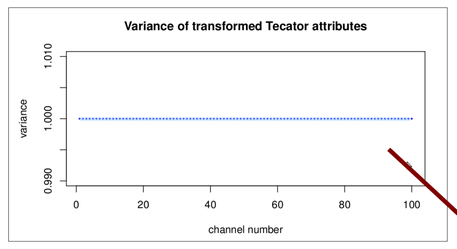
Goal

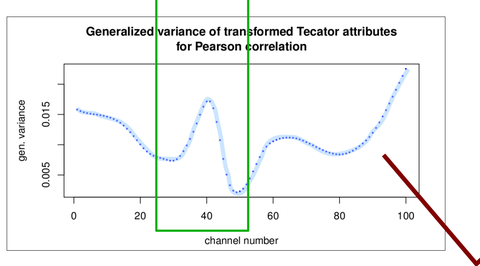
Assessment of attribute variability ('sensitivity')

for non-Euclidean distances ('similarity measures')

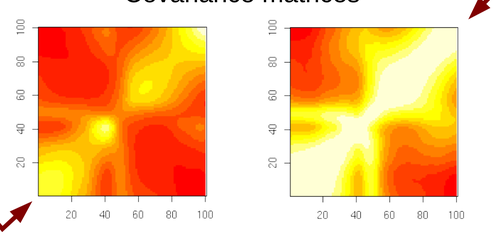


[http://lib.stat.cmu.edu/datasets/tecator]





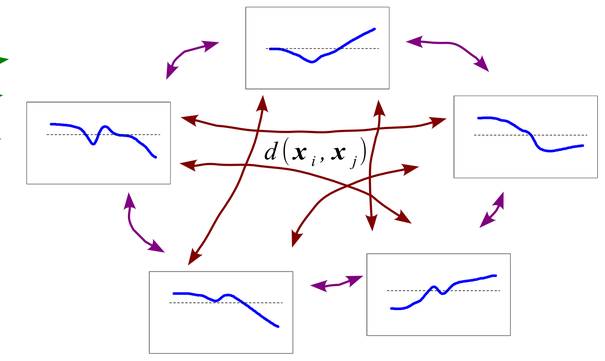
Covariance matrices



- principal component analysis (PCA)
- analysis of variance (ANOVA)
- redundancy analysis (by correlation)

Method

take 5 example spectra

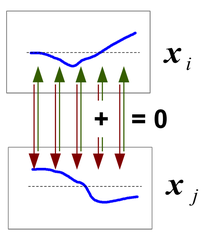


All distances pooled: $S = \sum_{i=1}^{5} \sum_{j=1}^{5} d(\boldsymbol{x}_i, \boldsymbol{x}_j)$

→ Channel contribution to pool: $\frac{\partial S}{\partial \boldsymbol{x}} = \frac{\partial S}{\partial d} \cdot \boxed{\frac{\partial d}{\partial \boldsymbol{x}}}$

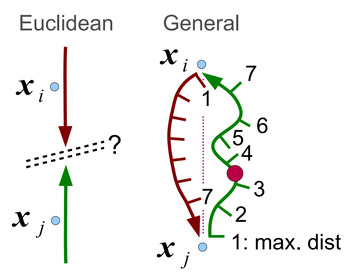
Two challenges

1. Cancellation by potential symmetry:



→ **magnitudes** of channel changes

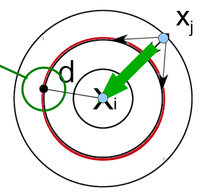
2. Point to point assumption:



→ variational path **integration**

Distance pursuit

distance is control parameter



$DP(x_j,x_i)$

(Euclidean illustration)

→ Global DP using Minkowski metrics leads to standard variance.

→ DP using Pearson correlation is similar to DP using γ-divergence.

Euclidean variance as double sum of derivatives:

$$\mathrm{var}(\mathbf{X}_{*,k}) = \frac{1}{d-1}\sum_{i=1}^{d}(\mathbf{X}_{i,k} - \mu_{\mathbf{X}_{*,k}})^2 = \frac{1}{2d(d-1)}\sum_{i=1}^{d}\sum_{j=1}^{d}(x_k^i - x_k^j)^2$$

Partial generalized covariance using Distance Pursuit:

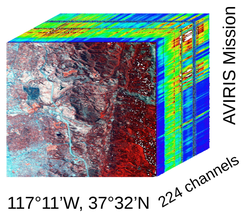
$$V_{kl} = \frac{1}{G}\cdot\sum_{i=1}^{d}\sum_{j=1}^{\boxed{|\mathcal{I}^i|}} \mathrm{DP}_{b_k}(\mathbf{x}^i, \mathbf{x}^{\mathcal{I}_j^i}, t)\cdot \mathrm{DP}_{b_l}(\mathbf{x}^i, \mathbf{x}^{\mathcal{I}_j^i}, t)$$

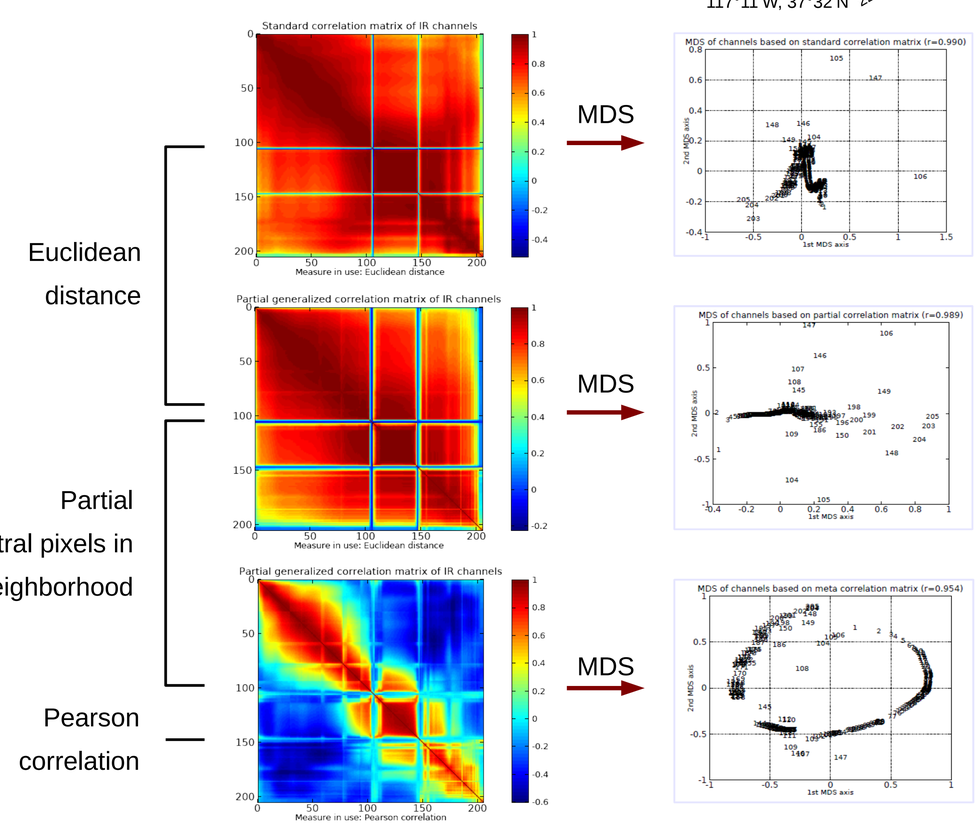
Partial generalized correlation:

$$R_{kl} = V_{kl}/\sqrt{V_{kk}\cdot V_{ll}}$$

Applications

Remote Sensing

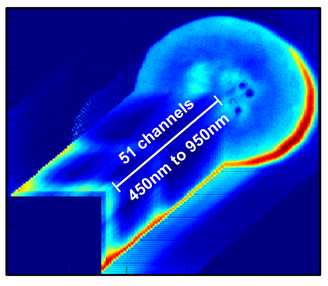




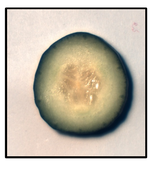
Spectral channel variance / eigen structure

Standard correlation	80%	9%	5%	∑=94%
Partial correlation	78%	8%	3%	∑=89%
Partial meta-correlation	36%	20%	9%	∑=65%

Food analysis

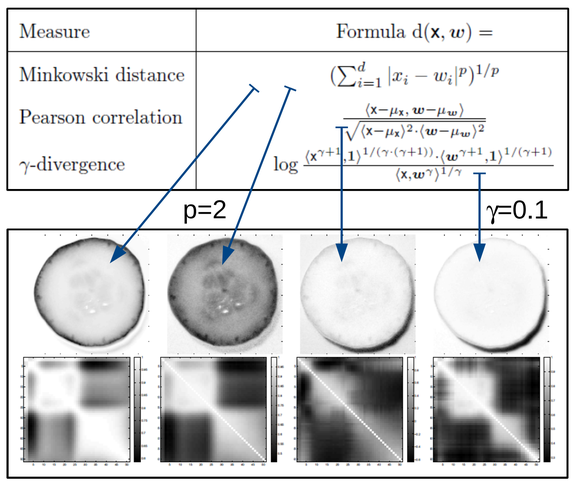


derived RGB image



Pixel and channel variability

Measure	Formula $d(\mathbf{x}, w) =$
Minkowski distance	$(\sum_{i=1}^{d} \lvert x_i - w_i\rvert^p)^{1/p}$
Pearson correlation	$\frac{\langle \mathbf{x}-\mu_{\mathbf{x}}, \boldsymbol{w}-\mu_{\boldsymbol{w}}\rangle}{\sqrt{\langle \mathbf{x}-\mu_{\mathbf{x}}\rangle^2 \cdot \langle \boldsymbol{w}-\mu_{\boldsymbol{w}}\rangle^2}}$
γ-divergence	$\log \frac{\langle \mathbf{x}^{\gamma+1}, \mathbf{1}\rangle^{1/(\gamma\cdot(\gamma+1))} \cdot \langle \boldsymbol{w}^{\gamma+1}, \mathbf{1}\rangle^{1/(\gamma+1)}}{\langle \mathbf{x}, \boldsymbol{w}^{\gamma}\rangle^{1/\gamma}}$



Conclusions

→ Measure-specific attribute assessment by path integral of its derivatives.

→ Attribute redundancies are a matter of distance measure.

→ Partially connected data →local contrast enhancement.

→ Generalized covariance time complexity: **$O(t \cdot n^2 \cdot d^2)$**.

References

R-Program code: http://mi.informatik.uni-siegen.de/projects_data/dp.zip

T. Villmann and S. Haase, "Divergence-Based Vector Quantization", Neural Computation, vol 23, pp. 1343–1392, 2011.

M. Strickert, B. Labitzke, and V. Blanz, "Partial Generalized Correlation for Hyperspectral Data", Proceedings CIDM IEEE-SSCI, pp. 365–372, 2011.

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