MORPHOLOGICAL HYPERSPECTRAL IMAGE CLASSIFICATION – INTEGRATION OF SPECTRAL AND SPATIAL INFORMATION

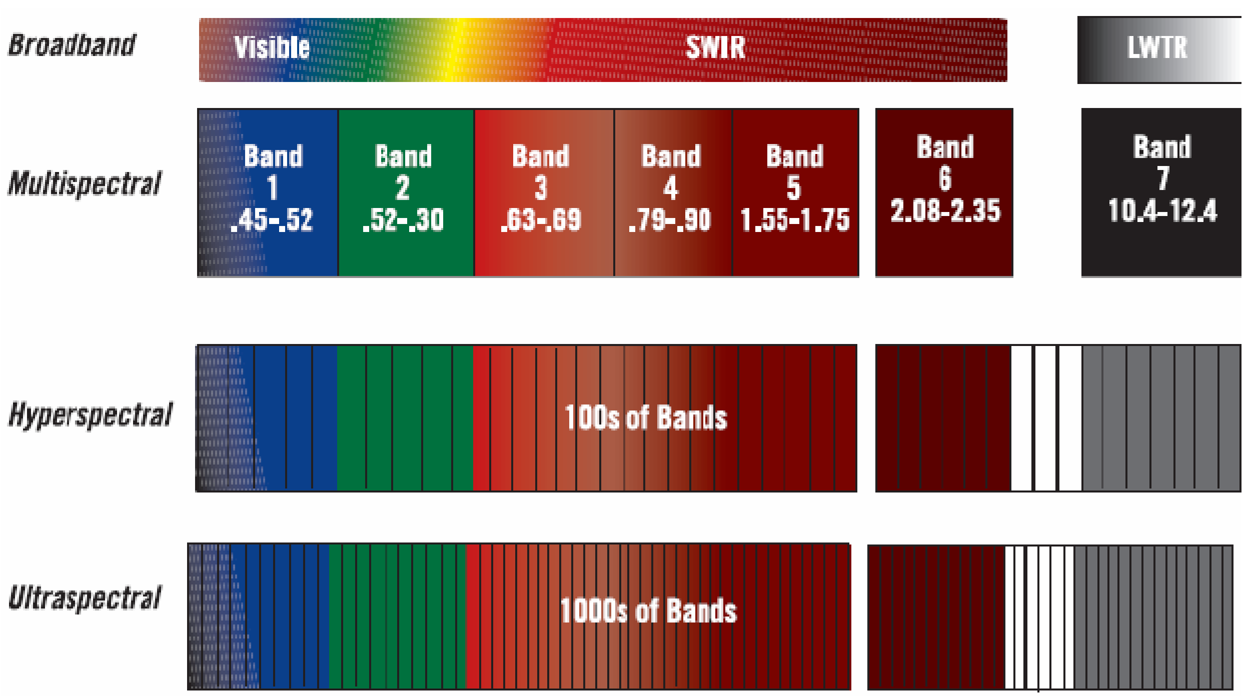
N. Rama Rao and R. Krishnan
Indian Institute of Space Science and Technology
Department of Space, Government of India
Thiruvananthapuram

(in honour of Prof. Jean Serra)

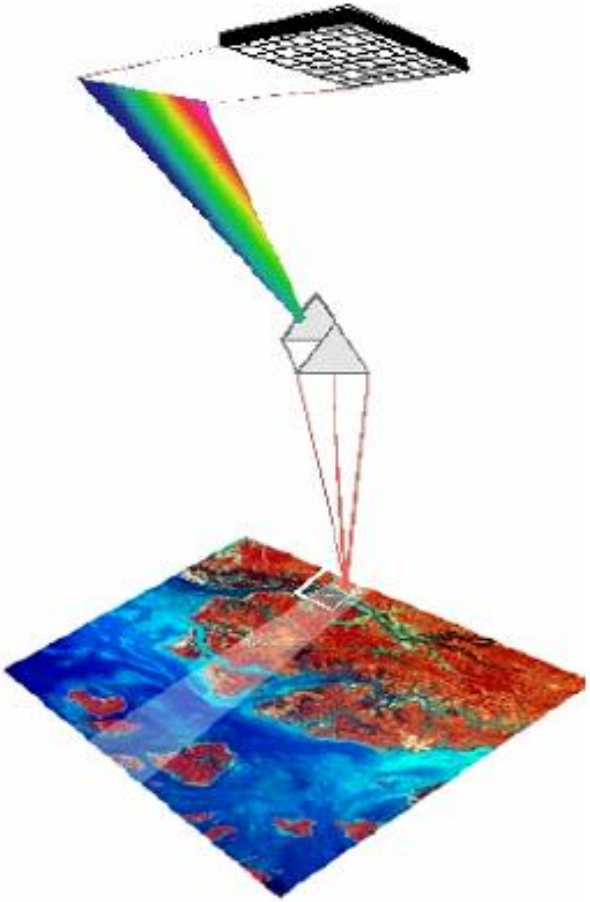
Outline

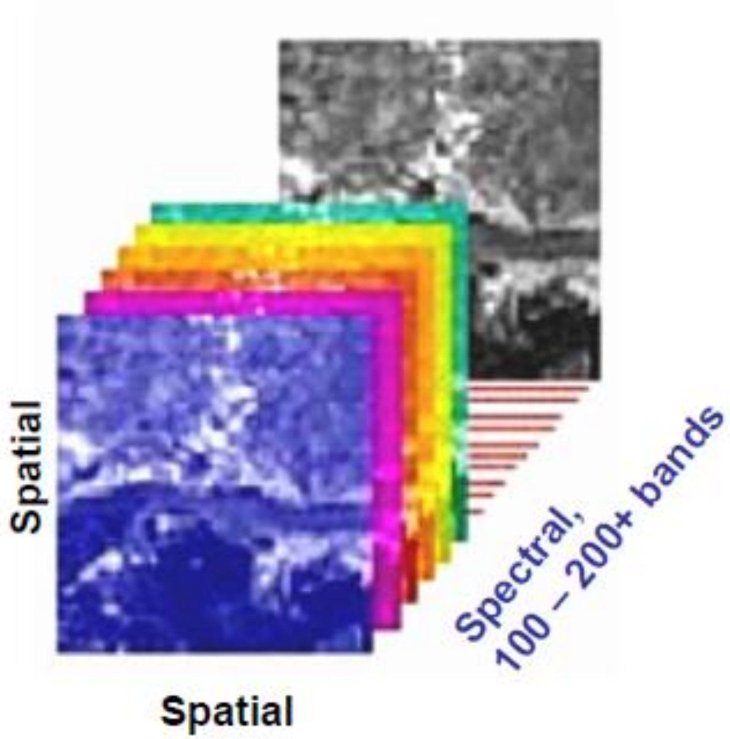
- Concepts of Hyperspectral Sensing
- Extension of Mathematical Morphology to Multichannel Images
- Vector Ordering Methods
- Emerging Techniques
- Summary

What is Hyperspectral Remote Sensing?



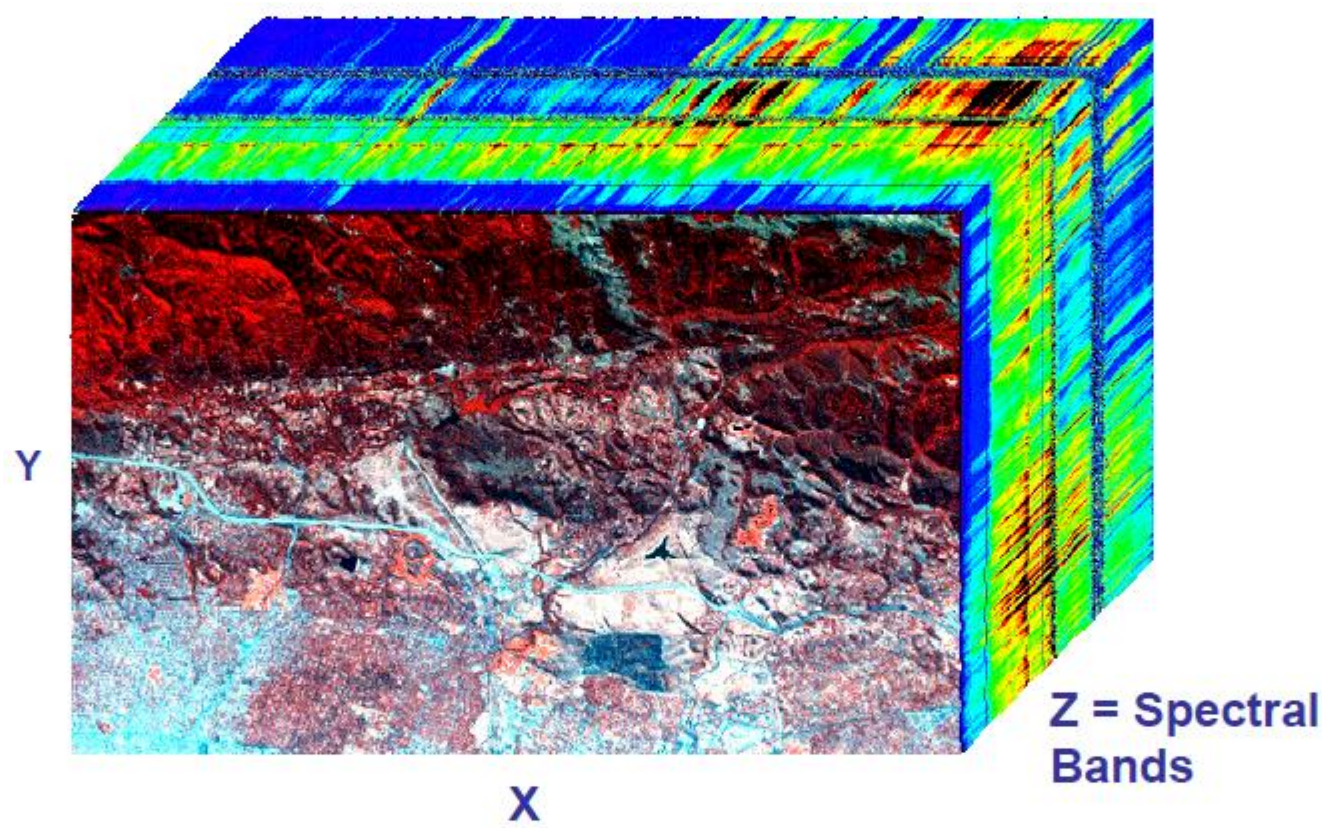
Hyperspectral Remote Sensing





Hyperspectral Remote Sensing

Data Cube – a way to visualize the data



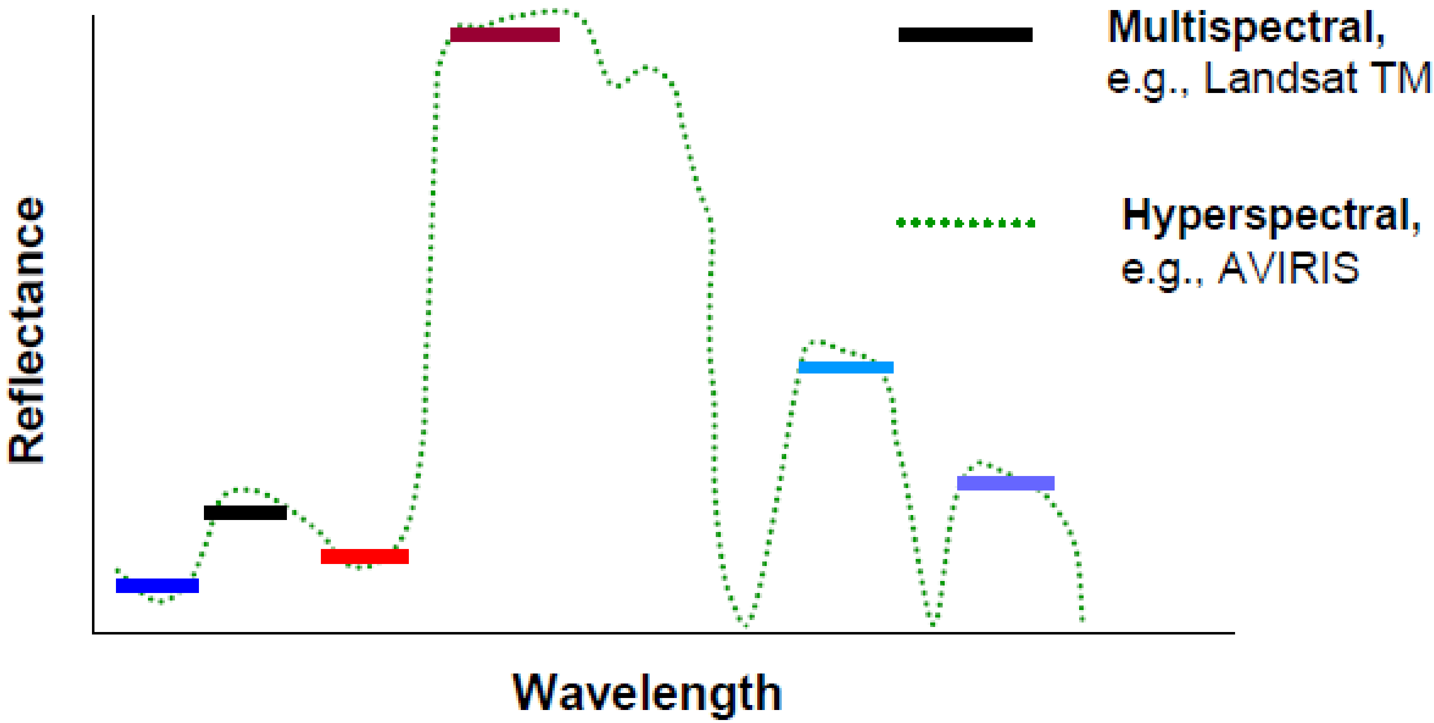
Hyperspectral Remote Sensing

Analogous to:

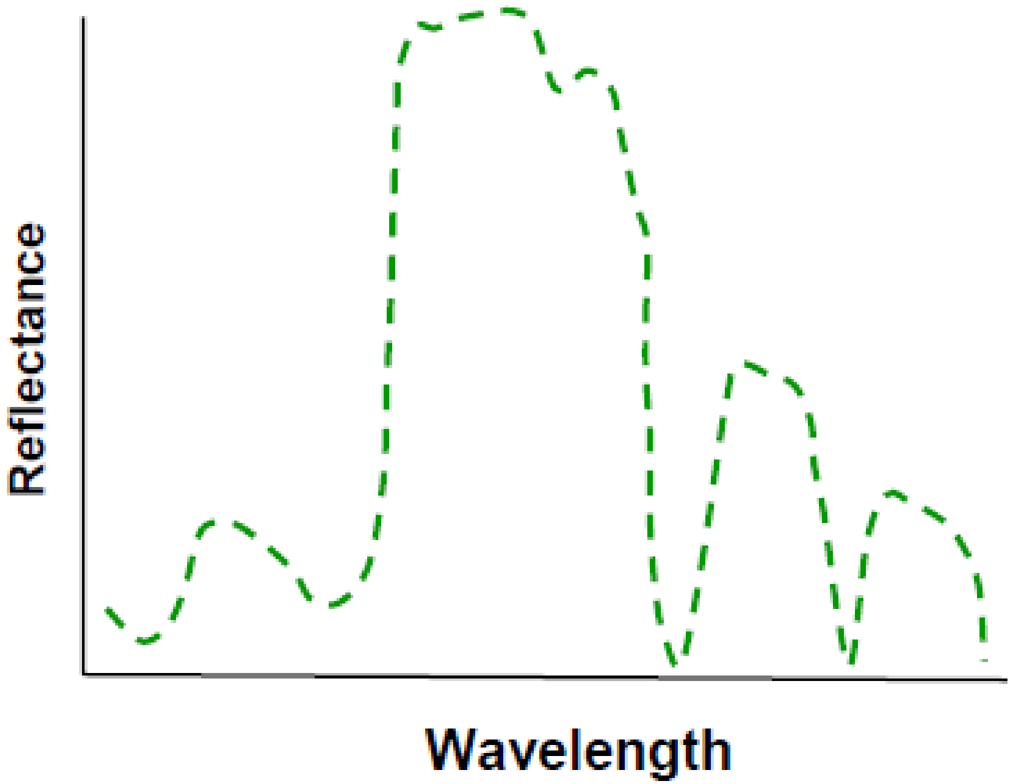
- Gas Chromatography
- Liquid Chromatography (HPLC)

Absorption spectra are obtained

Multispectral vs. Hyperspectral Data

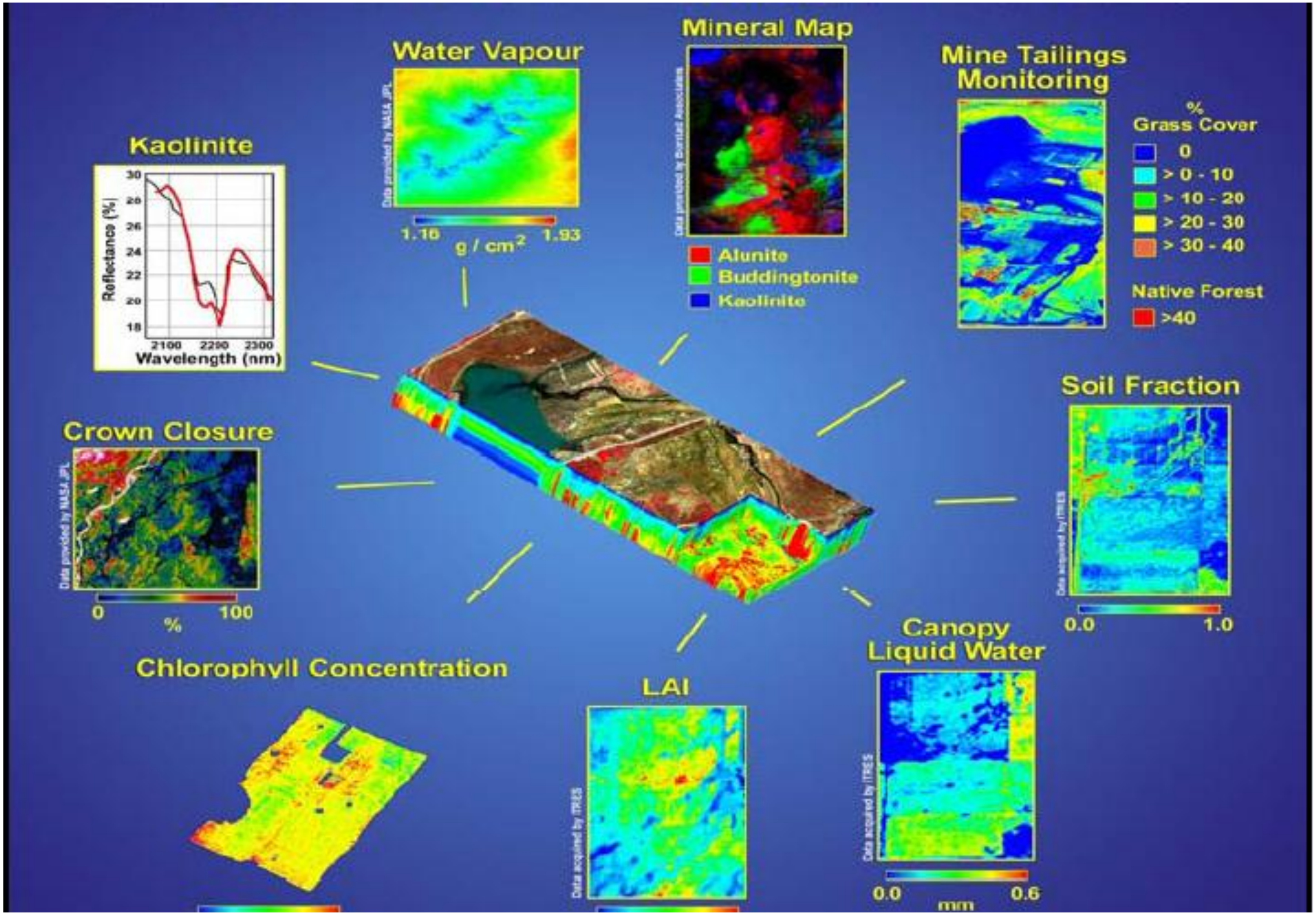


Analysis of Hyperspectral Data – Approaches



- Direct identification using diagnostic absorption and reflection features
- Comparison to laboratory and field measured spectra

Hyperspectral Applications Products



Hyperspectral Image Classification - Classical Approach

Need of incorporating spatial information in the classification of hyperspectral data

- Full Pixel classification
- Mixed pixel classification

- Most available techniques for hyperspectral data processing focus on spectral data

Mathematical Morphology

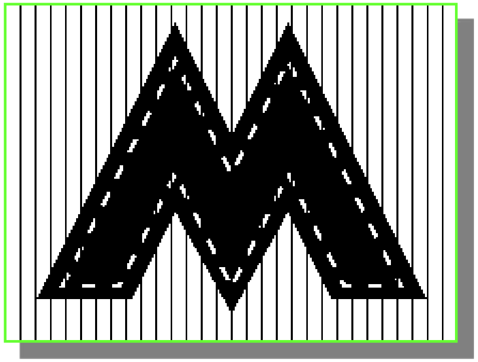
Mathematical morphology (MM) offers many theoretic and algorithmic tools to capture spatial information

⇒ **great potential for classification of man-made structures**

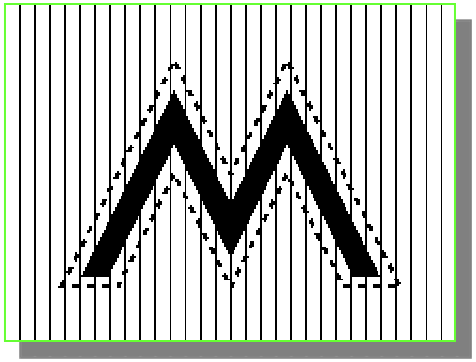
Generally speaking : spectro-spatial approaches to be developed

Morphological Operations

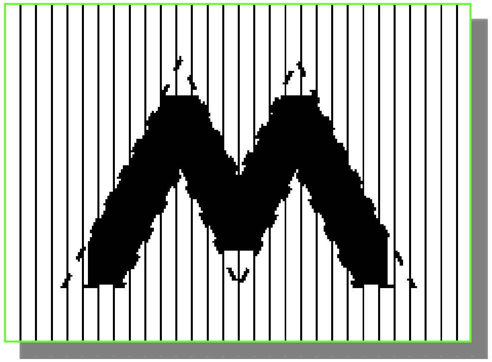
The four most basic operations in mathematical morphology are dilation, erosion, opening and Closing:



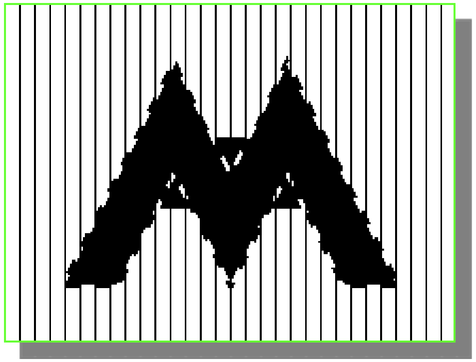
Dilation



Erosion



Opening



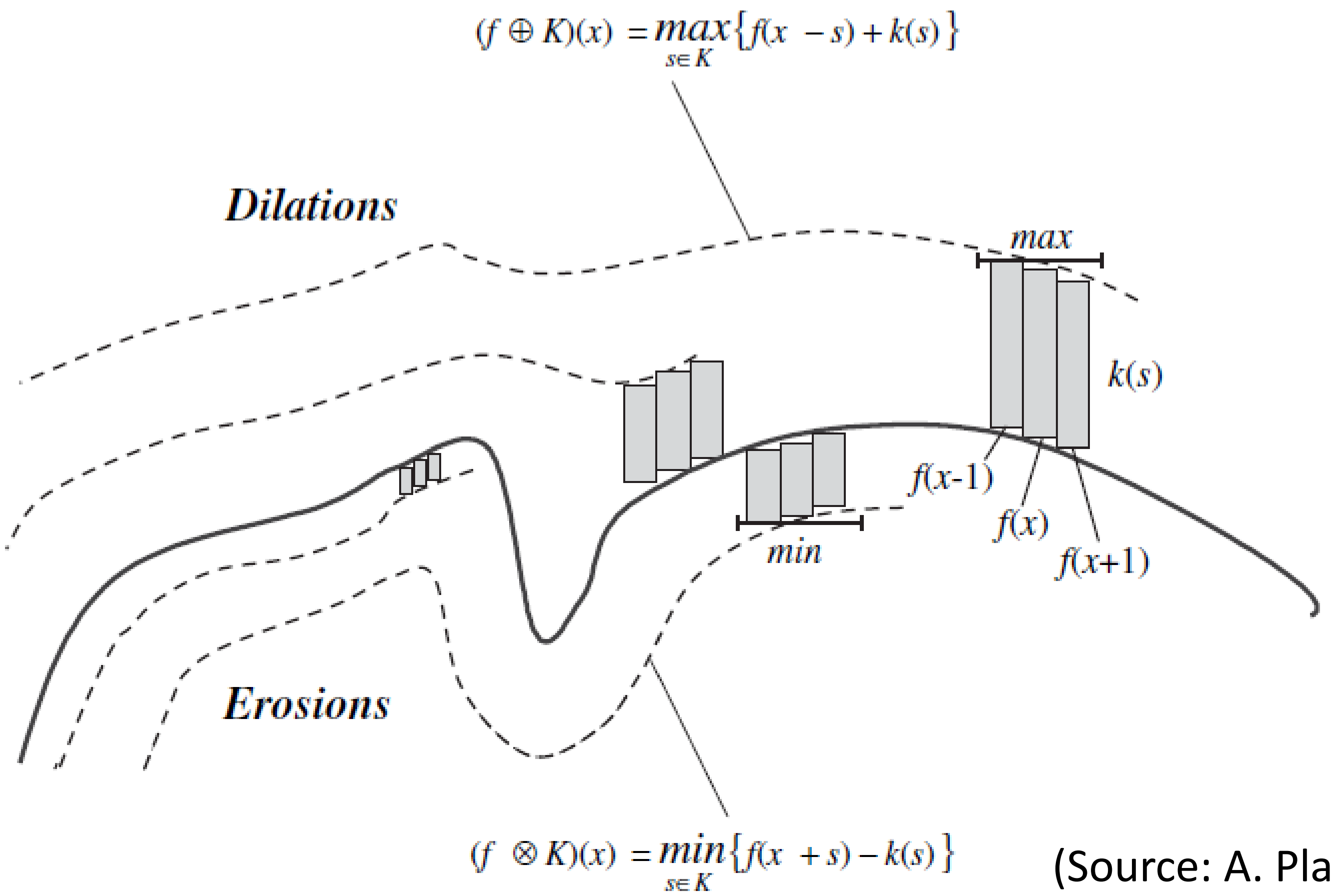
Closing

Extension of MM to Multichannel Image Processing

MM operators on gray-scale images

Binary MM . . . Soon extended to gray-tone (mono-channel) images

Gray scale morphological operations: erosion and dilation



(Source: A. Plaza, 2006)

MM Operators on Hyperspectral Imagery

Hyperspectral image

every pixel = spectrum = vector of very high dimension

Problem :
Mathematical morphology requires a **complete lattice structure**

Every set of pixels has one ***infimum*** and one ***supremum***

Shall one process hyperspectral data in a vector way ?
If yes : How can one order vectors ?
If no : how shall one proceed ?

MM Operators on Hyperspectral Imagery

To move on MM operations with hyper bands…..

Divide and Rule ….???

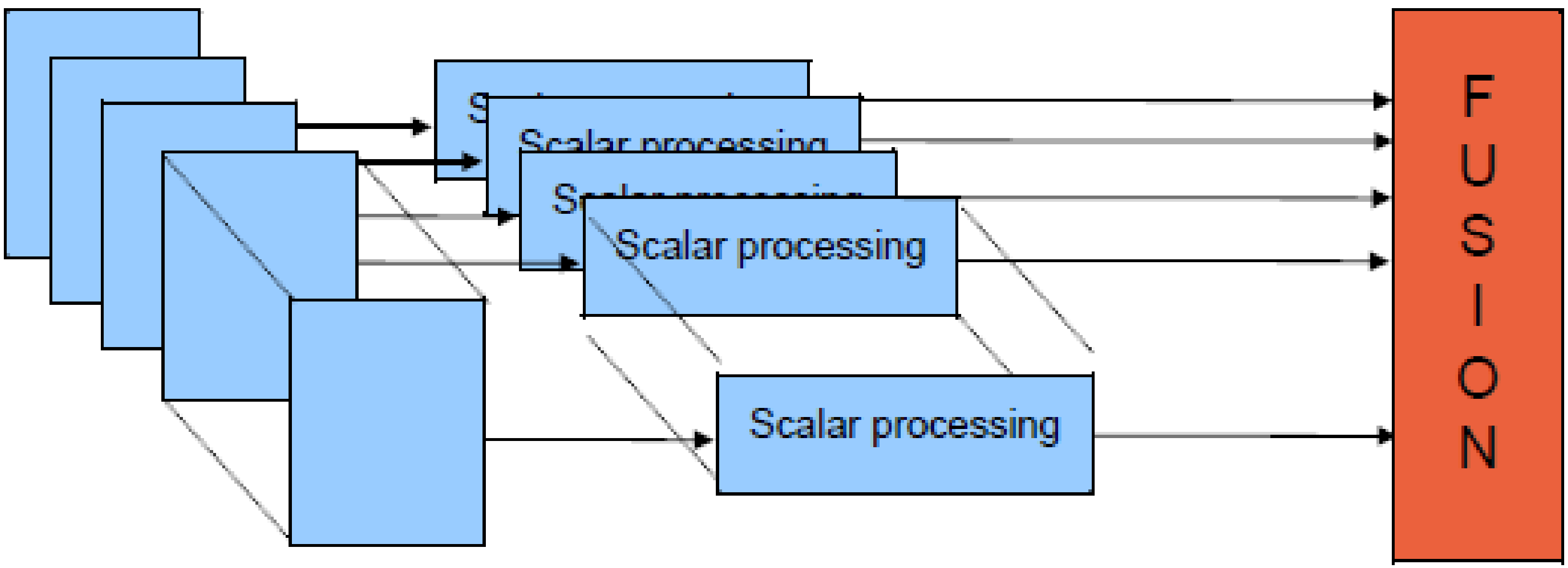
One approach consists in applying gray scale MM techniques to each channel separately

(Pitas and Kotropoulos, 1994)

MM Operators on Hyperspectral Imagery

Marginal approach

hyperspectral image = set of grey level images that are processed separately

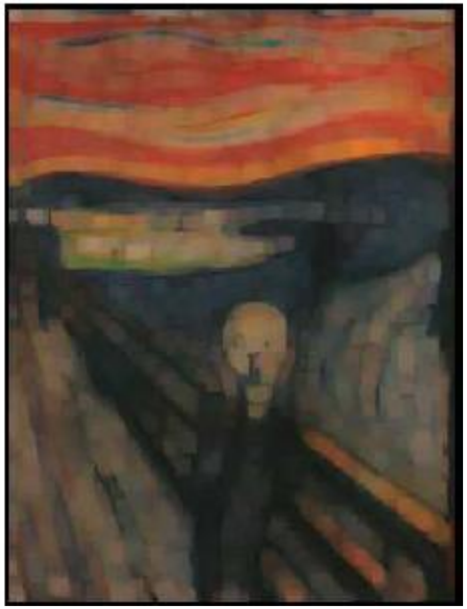


MM Operators on Hyperspectral Imagery

Marginal approach

hyperspectral image = set of grey level images that are processed separately

Original image



Marginal opening

MM Operators on Hyperspectral Imagery

Limitation for use in remote sensing: marginal approach is often unacceptable in RS because of "false colours"

Original image

Marginal opening

MM Operators on Hyperspectral Imagery

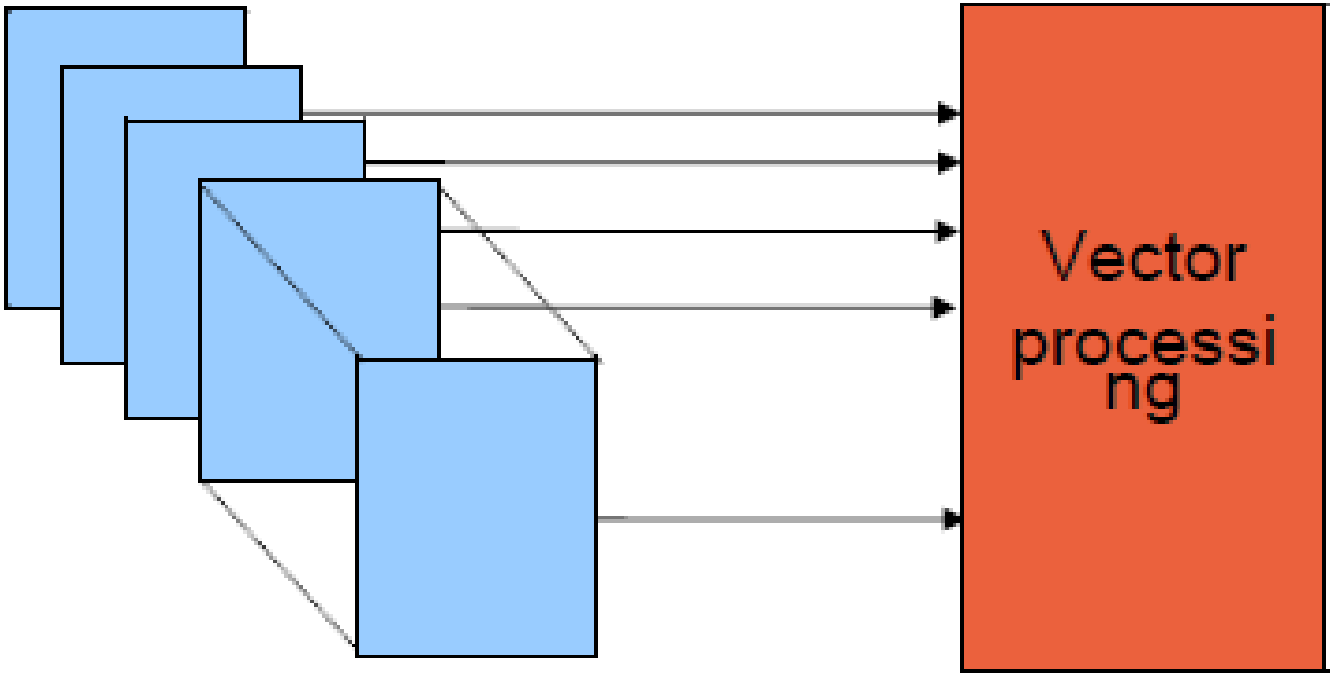
An alternative to marginal Approach:

treat the data at each pixel as a vector

MM Operators on Hyperspectral Imagery

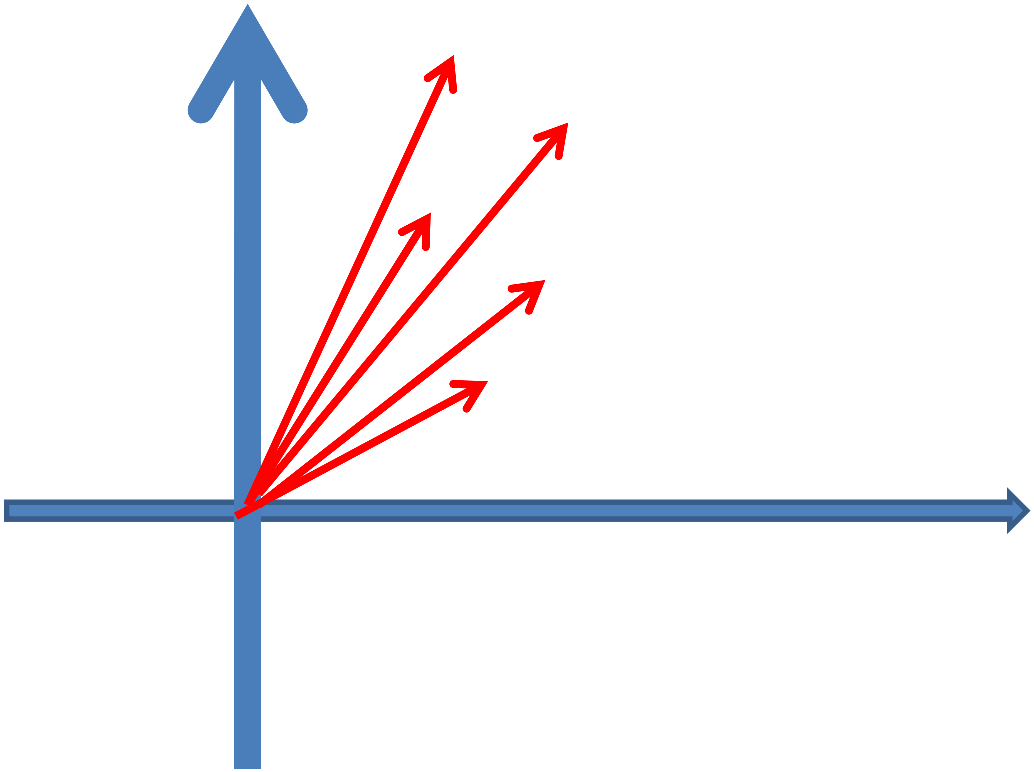
Vector approach

hyperspectral image = one single image, every pixel is one (very long) vector



MM Operators on Hyperspectral Image – Identifying Minimum and Maximum

N-Dimensional Vector:
Which is Minimum and which one is a maximum vector….?



MM Operators on Hyperspectral Image – Identifying Minimum and Maximum

How to compare vectors ….?

It is all that easy as of 1’s or 0’s to compare…..?

defining the minimum and maximum values between two vectors of more than one dimension

MM Operators on Hyperspectral Image – Identifying Minimum and Maximum

defining the minimum and maximum values between two vectors of more than one dimension

- Appropriate arrangement of vectors in the selected vector space
- Depends on the application requirements of hyperspectral image analysis
- The special characteristics of hyperspectral images pose different processing problems, which must be necessarily tackled under specific mathematical formalisms, such as classification, segmentation, spectral unmixing, and so on.

Vector Ordering Strategies for Multidimensional Morphological Operations

Can be categorized into four methods:

Marginal ordering (M-ordering): Each pair of observations would be ordered independently along each of the N channels

Reduced ordering (R-ordering), ordering by computing a scalar parameter

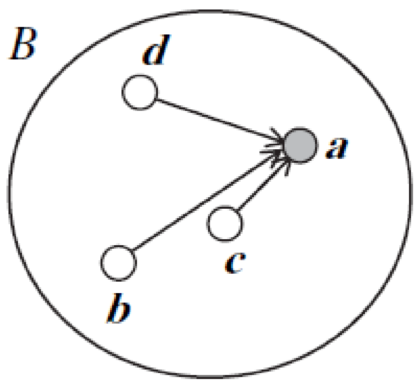
Partial ordering (P-ordering), ordering by partitioning channels into smaller groups

Conditional ordering (C-ordering), the pixel vectors would be initially ordered according to the ordered values of one of their components

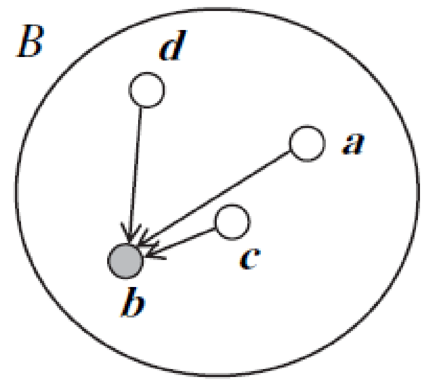
Vector Ordering Technique – Based on a Spectral Purity Criterion

- each pixel vector is ordered according to its spectral distance to other neighbouring pixel vectors in the data
- Spectral distance measures – e.g., Mahalanobis Distance
- Angle measures - Spectral Angle Mapper

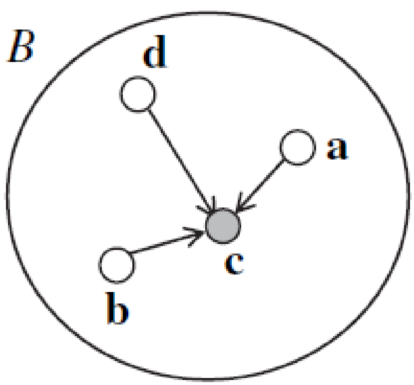
Vector Ordering Technique – Based on a Spectral Purity Criterion



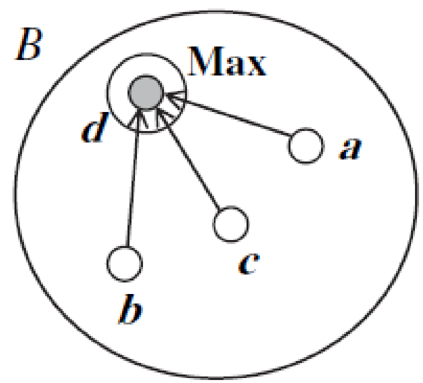
$D_B(\boldsymbol{a})=\mathrm{Dist}(\boldsymbol{b},\boldsymbol{a})+\mathrm{Dist}(\boldsymbol{c},\boldsymbol{a})+\mathrm{Dist}(\boldsymbol{d},\boldsymbol{a})$



$D_B(\boldsymbol{b})=\mathrm{Dist}(\boldsymbol{a},\boldsymbol{a})+\mathrm{Dist}(\boldsymbol{c},\boldsymbol{b})+\mathrm{Dist}(\boldsymbol{d},\boldsymbol{b})$



$D_B(\boldsymbol{c})=\mathrm{Dist}(\boldsymbol{a},\boldsymbol{c})+\mathrm{Dist}(\boldsymbol{b},\boldsymbol{c})+\mathrm{Dist}(\mathrm{d},\mathrm{c})$



$D_B(\boldsymbol{c})=\mathrm{Dist}(\boldsymbol{a},\boldsymbol{d})+\mathrm{Dist}(\boldsymbol{b},\boldsymbol{d})+\mathrm{Dist}(\boldsymbol{c},\boldsymbol{d})$

Vector Ordering Technique – Based on a Spectral Purity Criterion

each pixel vector is ordered according to its spectral distance to other neighbouring pixel vectors in the data.

$$D_B[f(x,y)] = \sum_s \sum_t \mathrm{Dist}[f(x,y), f(s,t)], \qquad \forall (s,t) \in Z^2(B)$$

supremum and an infimum are defined, given an arbitrary set of vectors $S = \{ S_1, S_2, \ldots S_n \}$ where n is the number of vectors in the set, by computing $D_B(S)$ and selecting s_p such that $D_B(s_p)$ is the minimum of that set, with $1 \leq p \leq n$

select s_k such that $D_B(s_k)$ is the maximum of that set, with $1 \leq k \leq n$

Emerging Techniques – Parallel Processing Algorithms for MM

Huge demands for processing power

- Ability to handle spectral-spatial processing operations on real-time basis
- Parallel processing is expected to become a requirement in most ongoing and planned remote sensing missions
- Need for integrated software/hardware solutions in hyperspectral imaging
- Development of processing algorithms on several types of parallel platforms, including commodity (Beowulf-type) clusters of computers, large-scale distributed systems , and specialized hardware architectures

Recent example: NASA’s Beobulf Cluster computing facility

SUMMARY

- Mathematical morphology offers a framework to achieve the integration of spatial and spectral information in hyperspectral data analysis

- New processing challenges posed by high dimensionality of data

- Need of generalized and automated pixel vector ordering methods

Thank you