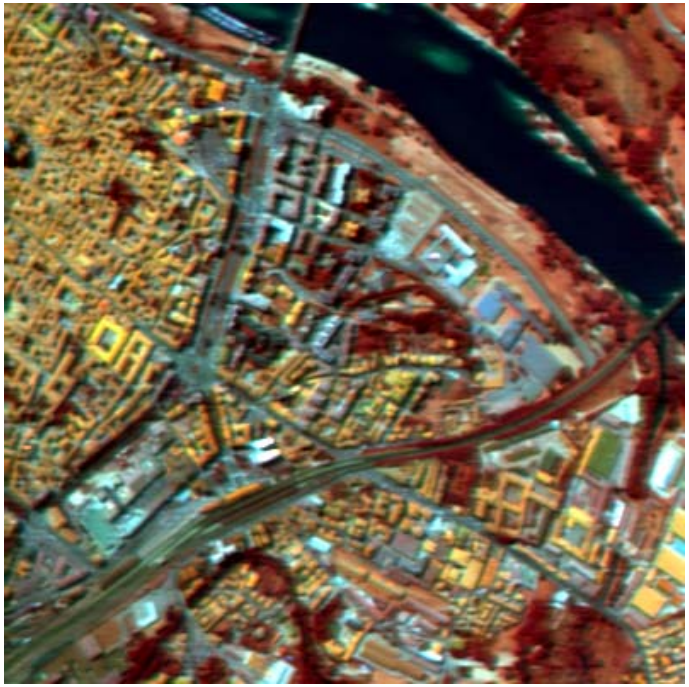
Remote sensing application 1:

Classification of hyperspectral images of an urban area using morphological profiles

Pavia data

- DAIS7915 airborne imaging spectrometer from DLR
- Pavia, ITALY
  - Date: 08/07/2002
- Spatial resolution 2.6 m
- 80 channels
  - 73 channels, 0.496 – 4.315 μm
    - Only use channels 1-40 (0.496 – 1.756 μm) due to noise in higher bands
  - 7 thermal infrared bands

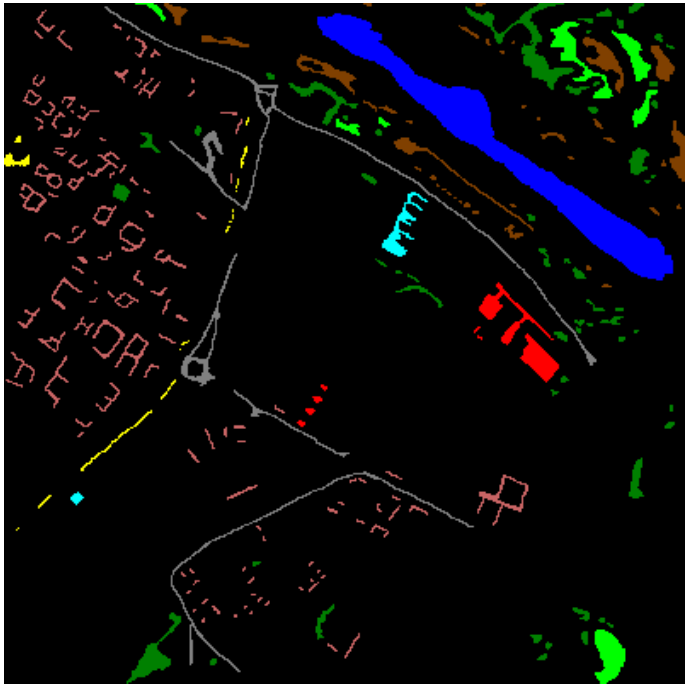


Channels 35(r), 8(g), and 1(b) (400 x 400 pixels)

Classification problem

- ***Task:*** Assign ***every*** pixel to ***one*** of the ***nine*** information classes:

Shadows
Roofs
Parking lots
Asphalt
Trees
Meadow
Soil
Bitumen
Water

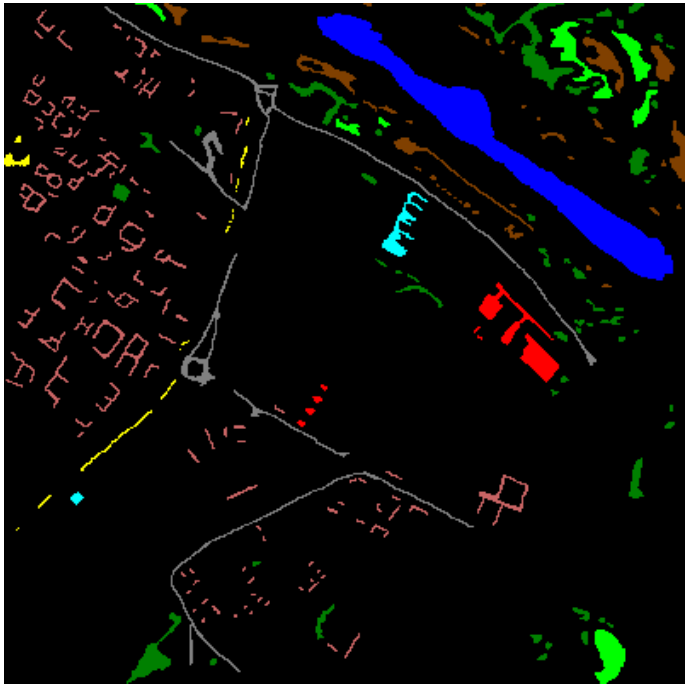


Ground truth reference

Classification problem

- ***Task:*** Assign ***every*** pixel to ***one*** of the ***nine*** information classes:

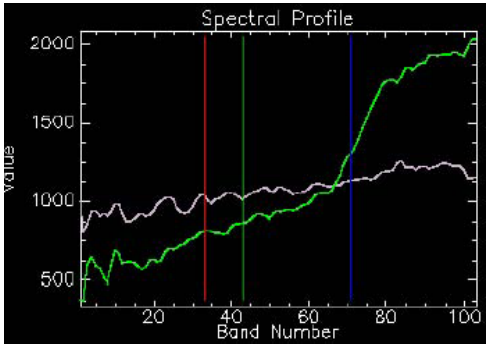
	Training samples	Test samples
Shadows	61	180
Roofs	500	1682
Parking lots	74	213
Asphalt	429	1275
Trees	500	1817
Meadow	311	940
Soil	366	1109
Bitumen	165	520
Water	500	3214



Ground truth reference

Classification approaches

- ***Only spectral*** information
  - ➢ Spectrum of each pixel is analysed
  - ➢ Directly accessible
  - ➢ Classification methods*:
    - Gaussian maximum likelihood
    - Neural networks
    - Kernel-based methods (e.g. SVM) → good performances



- ***Spectral + spatial*** information
  - ➢ Info about spatial structures included
  - ➢ How to define spatial structures?

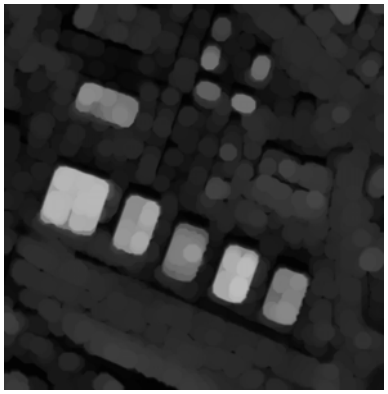
Mathematical morphology deals with the analysis of spatial structures

****To read: R. O. Duda et al., Pattern Classification, 2nd ed. Wiley, 2001.***

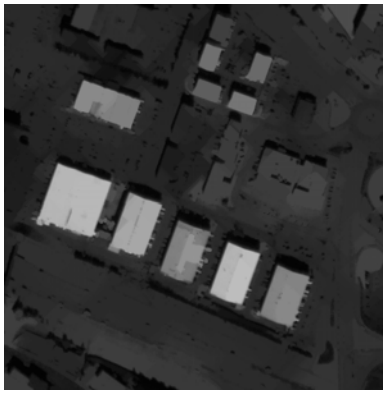
Morphological opening by reconstruction

- Consequence:
  - Features that are ***brighter*** than their immediate surroundings and ***smaller*** than the SE ***disappear***
  - Other features (dark, or bright and large) remain "unchanged"

$\gamma_{15}(X)$



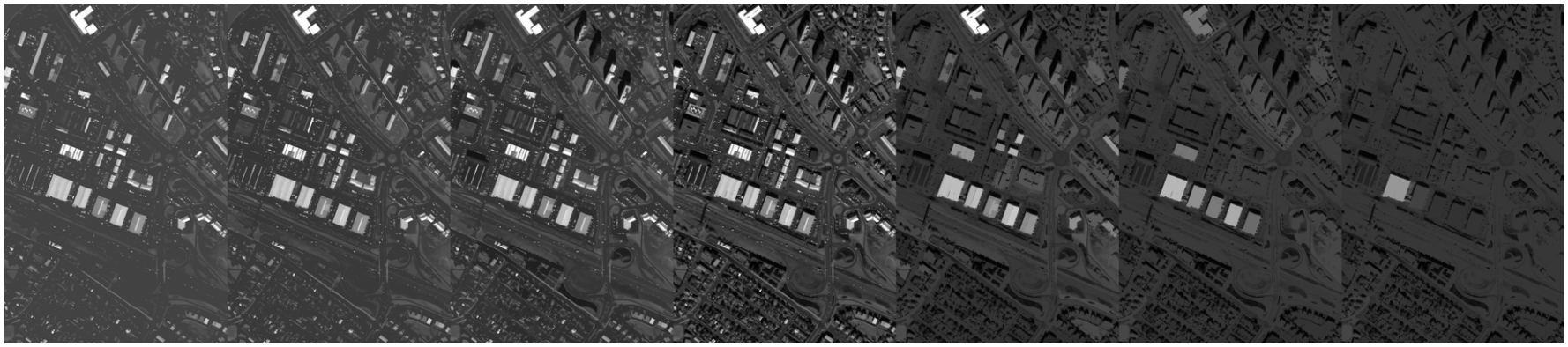
opening by reconstruction



Morphological profile

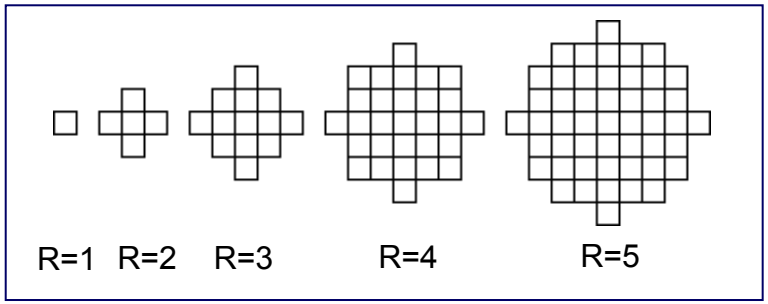
Closings (increasing SE)

Openings (increasing SE)



closing ES=21	closing ES=14	closing ES=7	original image	opening ES=7	opening ES=14	opening ES=21

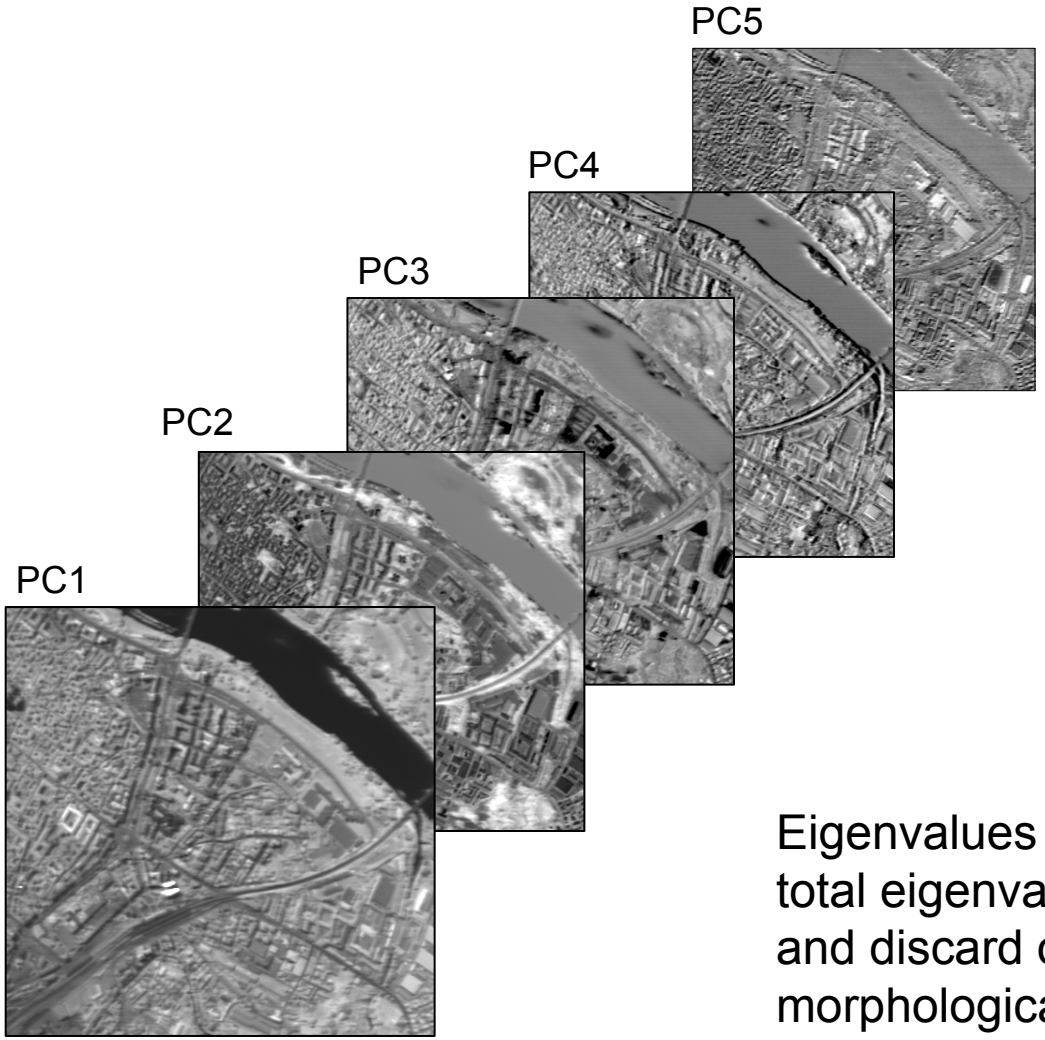
- Structuring Element: disc
- Segmentation Variables
  - Number of openings/closings
  - Radius increment (step size)



Feature extraction

- Method previously applied to high resolution panchromatic data (grey-scale images)
- Here we consider the use of the method for high resolution hyperspectral data
- ***Need to create a morphological profile from the hyperspectral data***
- Use feature extraction: Principal Component Analysis (optimum for signal representation)

Pavia data: principal components

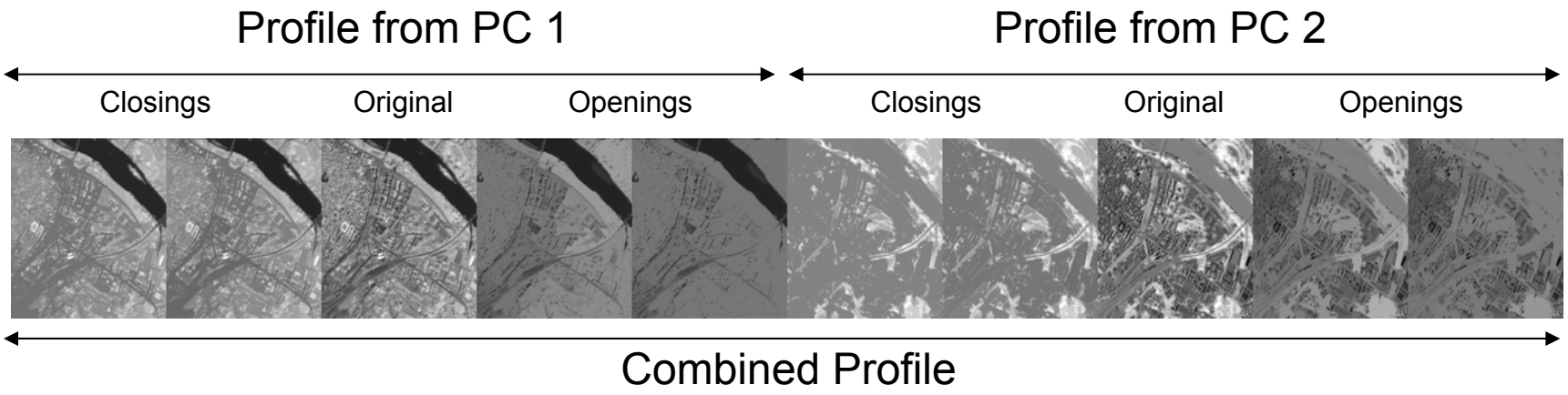


	Value	$\lambda_i / \sum\lambda$
λ_1	$2.27 \cdot 10^5$	78,2%
λ_2	$5.22 \cdot 10^4$	18.0%
λ_3	$8.39 \cdot 10^3$	2.9%
λ_4	$1.16 \cdot 10^3$	0.4%
$\lambda_5 + \ldots + \lambda_{40}$		<0.5%

Eigenvalues λ_1 and λ_2 make up >96% of the total eigenvalue sum. We keep PC1 and PC2 and discard other components for morphological processing.

Combined morphological profile

- 2nd principal component contains too much information to be discarded
- Morphological profiles for 1st and 2nd principal components combined in one profile



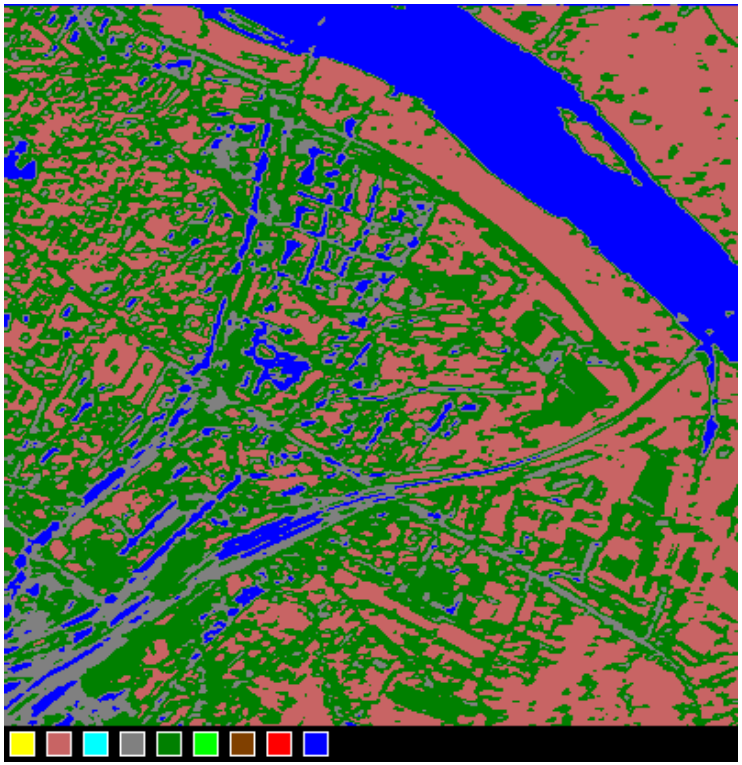
Classification of Pavia data

- Morphology settings
  - The use of 1st and 2nd Principal Components with four openings/closings and step size of 2 resulted in good classification accuracies

- Neural network (NN) classifier
  - Classification performed using a neural network with one hidden layer
  - Decision Boundary Feature Extraction (DBFE) for the NN was tested on the morphological profile

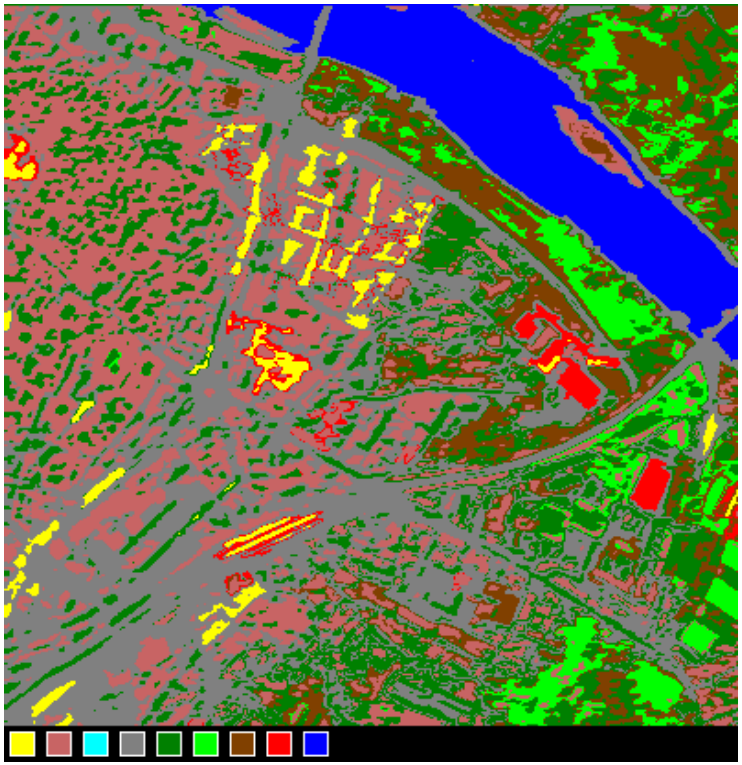
Pavia data: classification results

- Only the 1st principal component (1 input feature) is used for NN
- 3 hidden neurons
- Overall test accuracy: ***56.2%***



Pavia data: classification results

- Morphological profile of the 1st PC (9 input features)
  - ➢ 4 openings/closings, radius increment: 2
- 9 hidden neurons
- Overall test accuracy: ***77.0%***

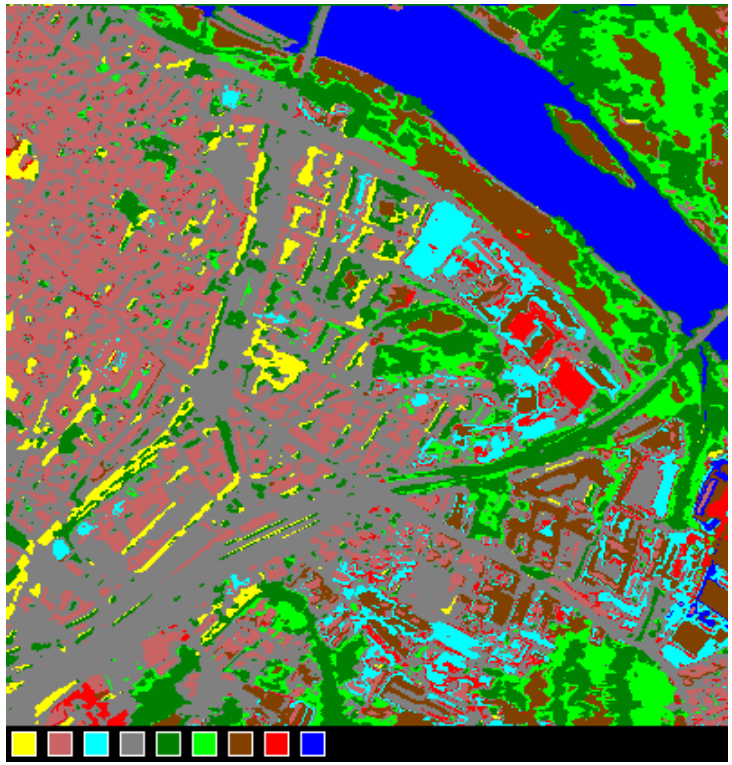


Pavia data: classification results

- Morphological profile of the 1st and 2nd PCs (18 input features)
  - PC1: 4 openings/closings, radius increment: 2
  - PC2: 4 openings/closings, radius increment: 2
- 13 hidden neurons
- Overall test accuracy: ***91.5%***

Pavia data: classification results

- Morphological profile of the 1st and 2nd PCs (18 input features)
  - PC1: 4 openings/closings, radius increment: 2
  - PC2: 4 openings/closings, radius increment: 2
- DBFE
  - Reduced to 8 features (99%)
- Overall test accuracy: ***95.0%***



Pavia data: overall test accuracies for NN (%)

Index		PC1	PC1 Morph. profile	PC1+PC 2 Morph. profiles	PC1+PC 2 Morph. profiles with DBFE
1	Shadows	0.0	73.3	40.0	**83.9**
2	Roofs	89.1	91.6	84.8	**89.8**
3	Parking lots	0.0	0.0	87.3	**97.2**
4	Asphalt	39.6	88.5	95.5	**96.4**
5	Trees	51.3	46.2	94.1	**94.2**
6	Meadow	0.0	53.5	**94.3**	94.1
7	Soil	0.0	57.4	79.0	**95.3**
8	Bitumen	0.0	83.7	82.5	**84.4**
9	Water	**100.0**	**100.0**	**100.0**	**100.0**
	Overall Acc.	56.2	77.0	91.5	**95.0**

Summary: classification using MM profiles

- Spatial information captured by morphological profiles
  ➔ Great potential for classification of images of urban areas

- The use of morphological profiles for hyperspectral data
  ➔ Use feature extraction: Principal Component Analysis

- Spectral-spatial approaches for image analysis to be developed