Image Data Analysis

I) Source & characteristics of "remote sensed" image data.

→ Remote sensing records the radiations of the Earth.

→ ACTIVE sensors : Energy source is provided by the platform & scattered back by the earth surface.

→ PASSIVE sensors : Energy source is provided by the sun ~~or~~ the Earth's own radiation.

or (the degree of reflection)

→ the scattering coeff. depends on the surface

- Smooth surfaces
- Rough "
- Manufactured "
- Volume "

Landsat 7 : a satellite 1999 - till now. observation sat.

→ Altitude : 705 km

→ Ranges used for earth resources sensing
Passive sensors

0.4 μm → 12 μm
[visible / IR range]

{ 30 mm → 300 mm
{ 1 GHz → 10 GHz
[Microwave range]

Satellites :

① Geostationary : 35 786 km
[weather & climate studies]

② LEO : Low Earth Orbit : 150 km → 2000 km
[Earth surface & oceanographic observation].

AVIRIS :

→ mechanical scanner [rotating mirrors]

→ record many spectral channels simultaneously.
[rectangular detectors]

Remote sensing in Microwave region

→ uses RADARs

→ SLAR : Side looking Airborne Radar

↳ Ground range resolution :

$$r_g = \frac{c\tau}{2 \sin \theta_i}$$

τ : length of the transmitted pulse.

↳ Azimuth size of a resolution element :

$$r_a = \frac{R_0 \lambda}{I}$$

R_0 : Range between Aircraft & target.

I : Azimuth direction.

→ SAR : Synthetic Aperture Radar

↳ uses the motion of the vehicle to give an effectively long antenna, "synthetic aperture".

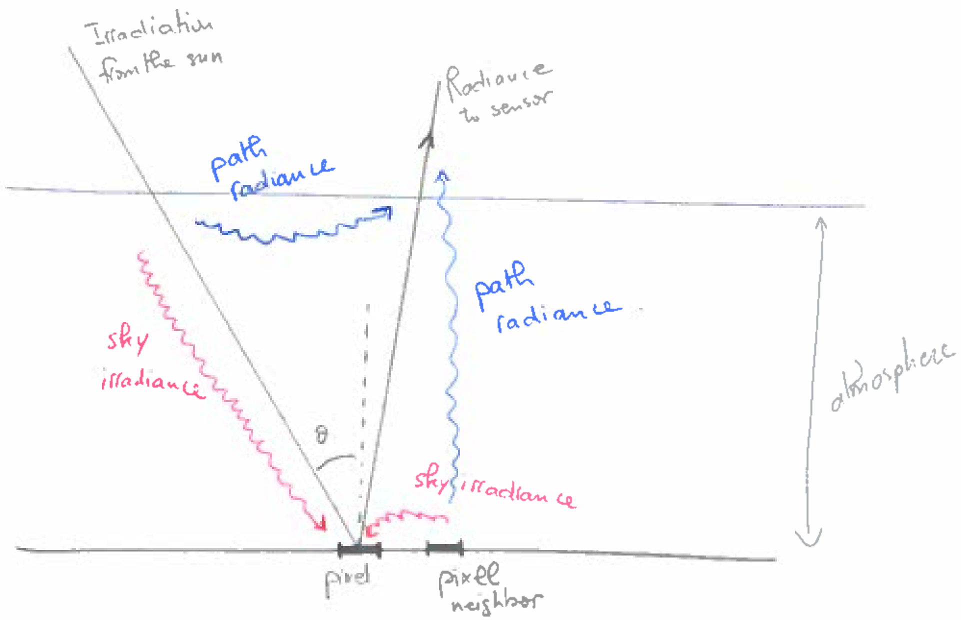
→ Side Looking Radar → in microwave region

↳ rotation distortion

$$\underset{\text{map}}{\begin{bmatrix} x \\ y \end{bmatrix}} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \underset{\text{image}}{\begin{bmatrix} u \\ v \end{bmatrix}}$$

↳ panoramic distortion

$$\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} \tan\theta/\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix}$$



II) Error correction and registration of image data

① Brightness errors = radiometric errors

- ↳ from the instrumentation used
- ↳ " the wavelength dependence of solar radiation
- ↳ " the effect of the atmosphere.

② Geometry errors :

- ↳ relative motion of the platform.
- ↳ non-ideal sensors
- ↳ curvature of the earth
- ↳ uncontrolled position & altitude variations.

Radiometric distortion

Intra-band

→ relative distribution of brightness in an image is different to the one in the ground scene.

Inter-band

→ relative brightness of one pixel is distorted from one band to another.

→ Irradiance : W/m^2

→ Radiance : $W/m^2 . sr$

→ Spectral irradiance $W/m^2 . \mu m$

↳ Irradiance :

$$E_{os} = E_{\Delta\lambda} . \cos\theta \; \Delta\lambda \qquad [W/m^2]$$

irradiance of the sun

solar zenith angle

↳ Radiance :

no atmosphere (ideal case)

$$L = E_{\Delta\lambda} . \cos\theta . \Delta\lambda \; \frac{R}{\pi} \qquad [W/m^2 . sr]$$

$$L = CK + L_{min}$$

$$K = \frac{L_{max} - L_{min}}{C_{max}} \qquad C \in [0, 255]$$

$$L_{min} < L < L_{max}$$

→ Problems caused by the atmosphere :

① Absorption

② Scattering → Rayleigh scattering.

→ Aerosol or Mie scattering

↳ Correction of atmospheric effect :

→ identify by how much the histogram is shifted from the origin.

→ shift back the histogram.

→ "Haze removal" to shift back the blue color histogram.

↳ Correction of instrumentation errors:

→ mean & standard variation produced by the sensor for different bands should be similar.

→ the difference in mean & S.V is attributed to gain & offset mismatches.

→ Adopt one sensor as a reference standard. [destriping].

↳ Correction of geometric distortion :

→ model the nature and magnitude of the source of distortion and use it to establish a correction formula.

→ Establish a mathematical relationship between the position of the pixels in an image and the corresponding coordinates on the ground.

III) Multispectral transformations of image data

PCA: preserves the essential information content of the image, with a reduced number of transformed dimensions.

↳ most of data in PC 1 ~ 95%

→ correlation matrix R :

$$R = \underbrace{\begin{bmatrix} 1 & \cdot & \cdot & \cdot \\ \cdot & 1 & \cdot & \cdot \\ \cdot & \cdot & 1 & \cdot \\ \cdot & \cdot & \cdot & 1 \end{bmatrix}}_{\text{nbr of dimensions} \rightsquigarrow 4 \text{ dim.}}$$

→ PCA is usefull :

↳ reduce data dimentionality.

↳ condense topographic and spectral information.

↳ improve image colour presentation.

↳ enhance some spectral features.

→ Taylor method of contrast enhancement (decorellation stretch)

① Apply PCT to transform original data to PCs.

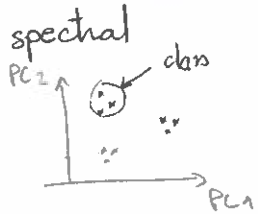
② Apply contrast enhancement to the PCs.

③ Apply inverse PCT to convert back to original images. "Bandwidth compression"

4) The intrepretation of digital image data

→ **Pattern recognition:**

↳ each pixel is plotted as a point with coordinates given by the brightnen value in each spectral component.



→ **Data set**

① Training set : to learn the modal

② Validation set : to select the best modal or parameters of a modal.

③ Test set : to evaluate the performance.

★ **Unsupervised classification**

↳ pixels assigned to spectral classes without knowing the name of the classes.

↳ clustering methods.

★ **Supervised classification:**

↳ Gaussian distribution

① Select training data

② Learn

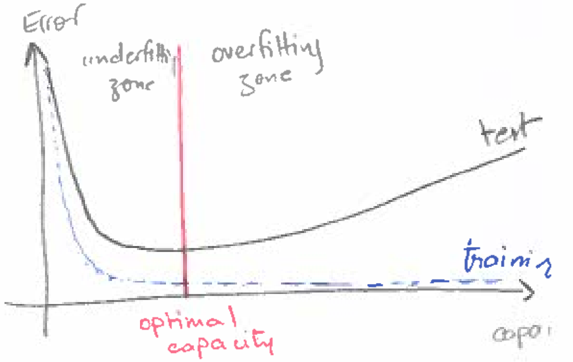
③ Classify.

★ **overfitting** :

↳ performs well on training data but poorly on test da

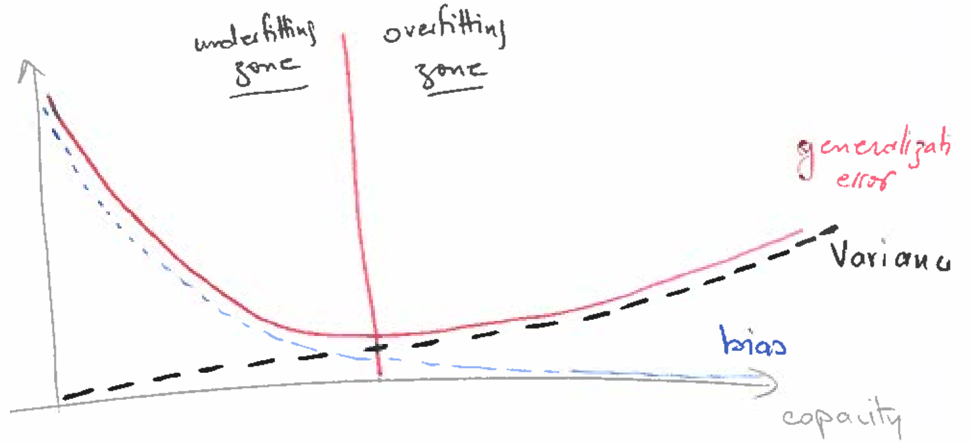
↳ solution : regularization , cross-validation.

★ **underfitting** : does not have enough dat to train or to test.



→ **Regularization** :

↳ modal selection to reduce generalization error but not training error.



→ Single pass algorithm :
↳ the first row of samples is used to obtain a starting set of cluster centers.
- Advantages :
  ↳ no user needed to specify nbr of clusters
  ↳ speed is higher than using k-means.
- Disadvantages :
  ↳ user needed to find some parameters.
  ↳ dependant upon the 1^{st} row line of samples.

→ Hierarchical clustering :
↳ fusion is displayed on a dendrogram
↳ all pixels assumed as individual clusters.
↳ merge neighbouring clusters.

→ Histogram peak selection :
↳ peaks of the histogram determines the cluster.
↳ useful when dimentionality of data is low.
↳ not applicable to hyperspectral imaging.

5) Supervised (statistical) classification techniques

common classifiers

→ Maximum likelihood decision rule : / classification time ↗ quadratically.

$x \in w_i$ if $g_i(x) > g_j(x)$ for all $j \neq i$

g_i : discriminant function.

→ Minimum distance classification : faster than ML decision — Max Likelihood.

→ Parallelpiped classification
↳ comparison of spectral components

[pixel - specific classifiers]
(do not take in consideration the neighbouring pixels)

→ Context classifiers : take into account the neighbor pixels. (context sensitive).

6) Supervised non-parametric classification : geometric approaches

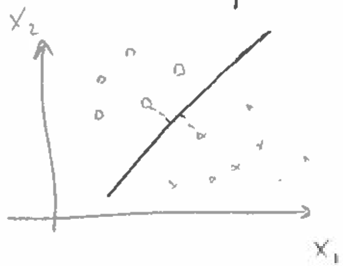
→ KNN : K Nearest Neighbour classifier.

↳ pixels close to each other in feature space are likely to belong to the same class.

↳ not well-suited for HSI dataset.

→ SVM : Support Vector Machine classifier

↳ finds a hyperplane that separates the data, based on the pixels ~~in the vacinity~~ that are the closest to it.



→ Slack variables : ξ_i

↳ Finding a maximum margin solution to overcome "class overlapping"

→ Kernel function:

↳ when a data is not linearly separable, it is mapped in a new dimension (N+1) ~~and the hyperplane becomes a~~ (feature space) then linearly separate it.

↳ RBF Kernel : Gaussian Radial Basis function kernel

↳ has one parameter : γ

7) Clustering and unsupervised classification :

→ Clustering : an image is segmented into unknown classes.

→ K-means algorithm (iterative optimization algorithm).

① select C points in multispectral space, to be cluster centers. $\hat{m}_i$ $i = 1, \dots c$.

↳ number of clusters C, has to be selected beforehand by the user.

② every location of pixel x is assigned to the cluster that is the closest to.

→ Then, the cluster is examined to :

↳ merge it

↳ divide it

↳ separate ;

\+ Kmeans = ISODATA algorithm

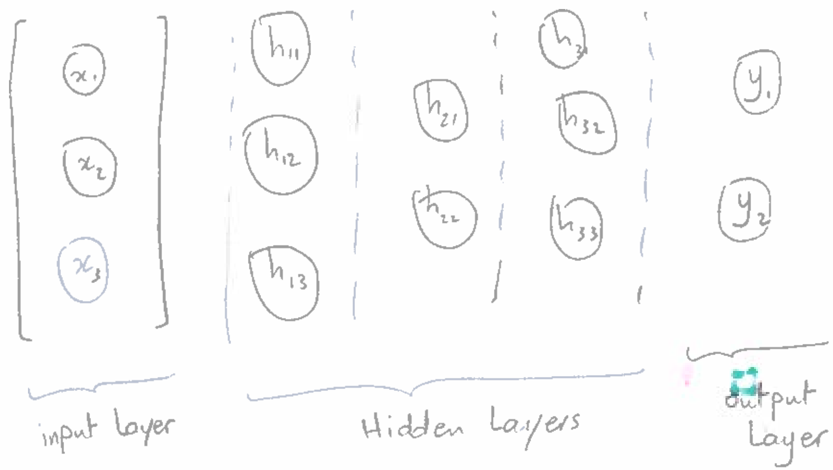
[Iterative Self Organizing DATA Analysis]

- **Downsampling: pooling**
  - → Pooling has no parameters.
  - → it is applied to each channel separately (keeps nbr of channels).
  - → Max pooling provide invariance to small translations of the input.

- **Fully connected layer**
  - → are most memory intensive part of VGG architecture.

8) From shallow to Deep Neural Networks

MLP: (Multilayer perception) NN with no feedback connection.



→ Hidden Layer: $h_i = g(A_i h_{i-1} + b_i)$

→ Backpropagation is used for learning.

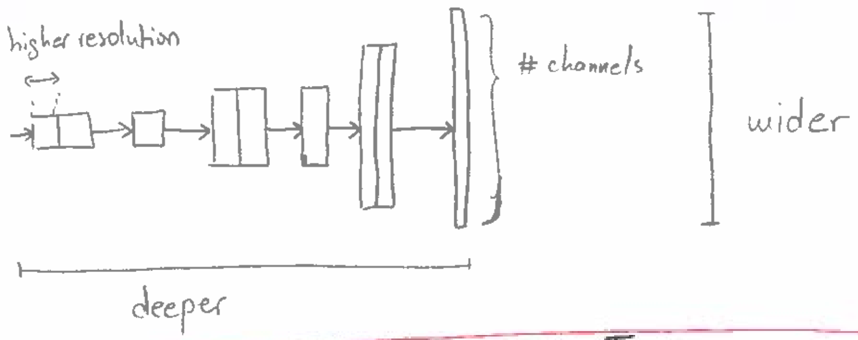
→ $g(\cdot)$: non-linear function (activation fct)

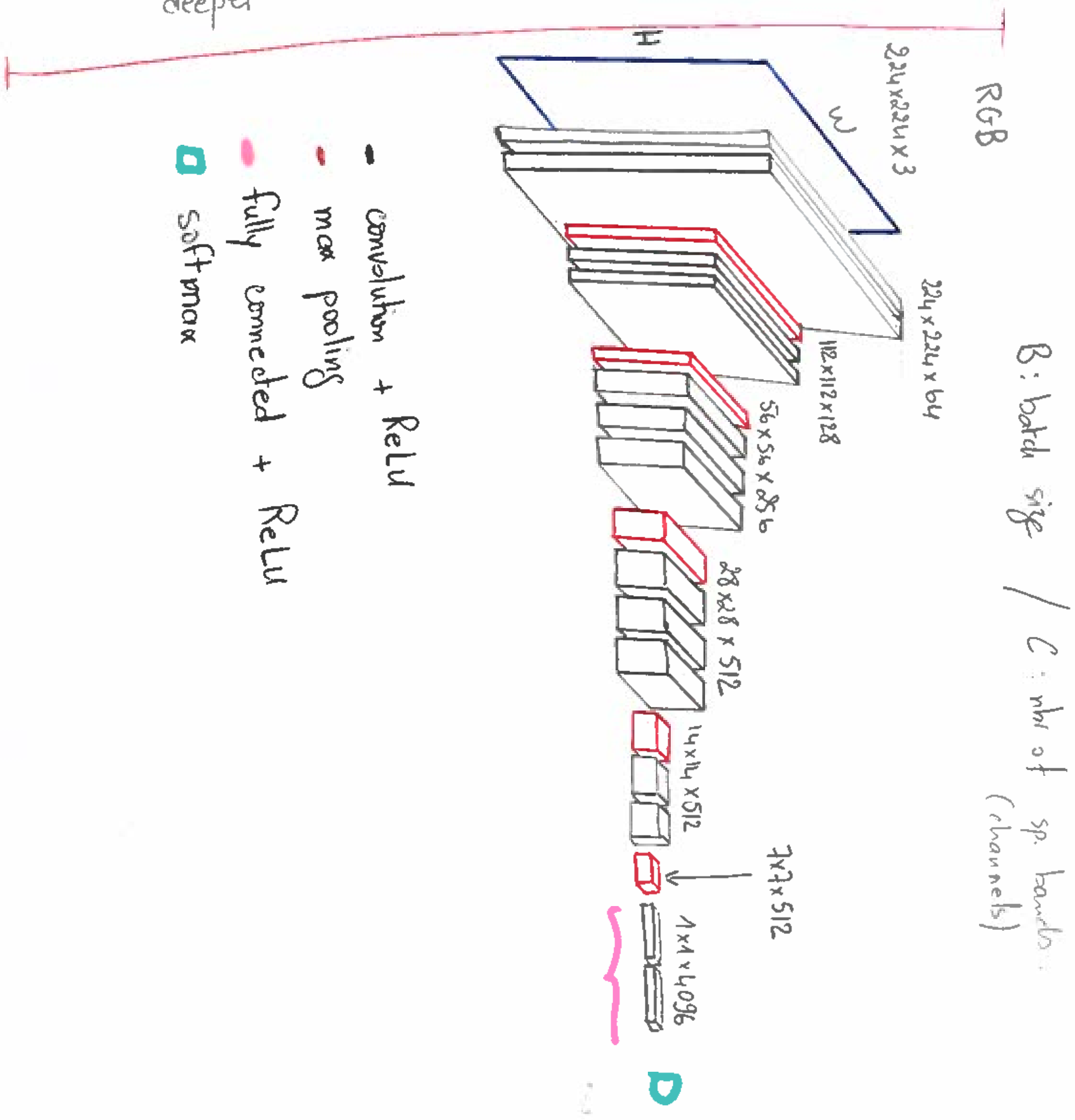
→ Non-linearities are crutial in terms of expressiveness of the network.

↳ more neurons ⇒ expressiveness increases.

→ 2 Layers network (one hidden layer) requires exponential width.
↳ more memory and computational time.

9) Convolutional Neural Networks





- **Fully connected Layer**

→ nbr of weights for layer $i = W_{out} \times H_{out} \times C_{out} \times (W_{in} \times H_{in} \times C_{in} +$

- **Convolutional layer:**

→ nbr of weights for layer $i = C_{out} \times (K \times K \times C_{in} + 1)$

→ "weight sharing" (C_{out}) : same weight in all image / feature map.

→ Localized focus $(K \times K)$.

→ convolution are translation equivalent

↳ $[A \star H](x) = \sum_{\Delta \in \mathbb{Z}^2} A(\Delta x) \cdot H(x + \Delta x)$

A : the Kernel $K \times K$

H : feature map

→ Padding : add boundary with appropriate size with zeros.

→ **Downsampling:**

↳ reduces the spatial resolution

↳ increases the receptive field.

~~10) AI and Deep Learning for medical image analysis~~

→ **Convolutional layer** : we want to preserve spatial structure

↳ we use a small filter and slide it through the image spatially, computing dot products . $\underbrace{w^T x}$ + b

→ **Pooling Layer** :

↳ make the representations smaller and more manageable .

↳ operates over each activation map independently .

[downsampling] . (spatially) .

Max pooling : slide the filter along the image (input volume) and we take the maximum value each time .

stride ???

↳ Max pooling commonly used,

[each value is "how much the neuron fired in this location"].