Μέθοδοι ταξινόμησης δορυφορικών δεδομένων και αξιολόγησης της ακρίβειας

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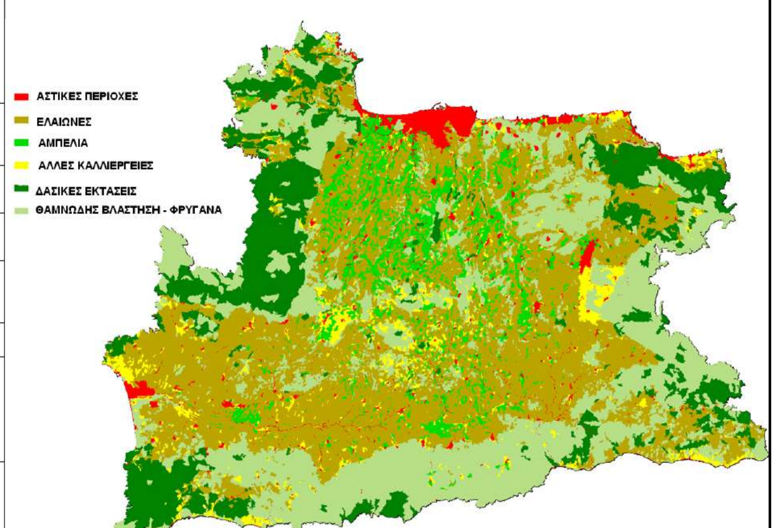
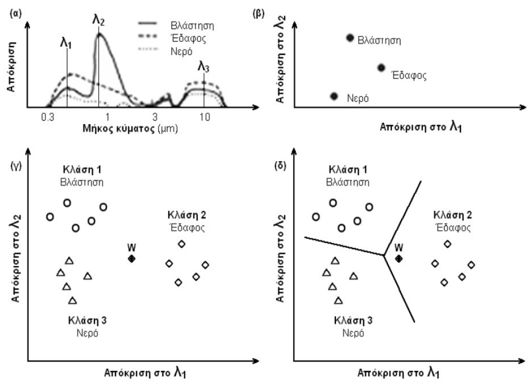
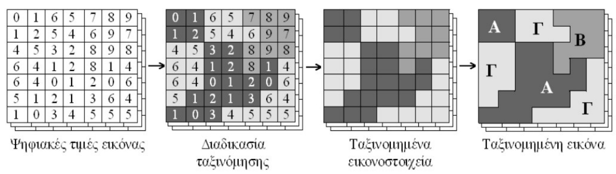
Εξαγωγή θεματικής πληροφορίας

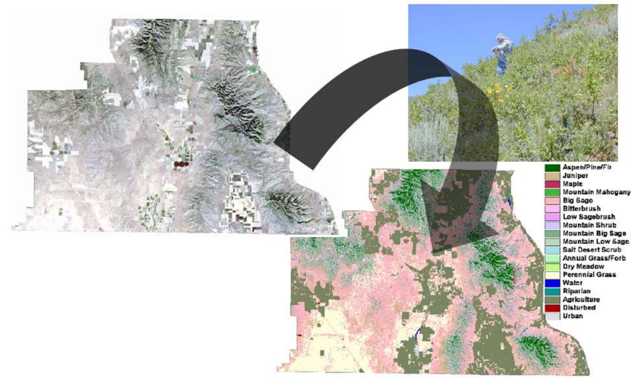
Level I	Level II
1 urban/built-up land	11 residential 12 commercial and services 13 industrial 14 transportation, communication, and utilities 15 industrial and commercial complexes 16 mixed urban/built-up land 17 other urban/built-up land
2 agricultural land	21 cropland and pasture 22 orchards, groves, vineyards, nurseries, and ornamental horticultural areas 23 confined feeding operations 24 other agricultural land
3 rangeland	31 herbaceous rangeland 32 shrub and brush rangeland 23 mixed rangeland
4 forest land	41 deciduous forest land 42 evergreen forest land 43 mixed forest land
5 water	51 streams and canals 52 lakes 53 reservoirs 54 bays and estuaries
6 wetland	61 forested wetland 62 non-forested wetland
7 barren land	71 dry salt flats 72 beaches 73 sandy areas other than beaches 74 bare exposed rock 75 strip mines, quarries, and gravel pits 76 transitional areas 77 mixed barren land
8 tundra	81 shrub and brush tundra 82 herbaceous tundra 83 bare ground tundra 84 wet tundra 85 mixed tundra
9 perennial snow or ice	91 perennial snowfields 92 glaciers

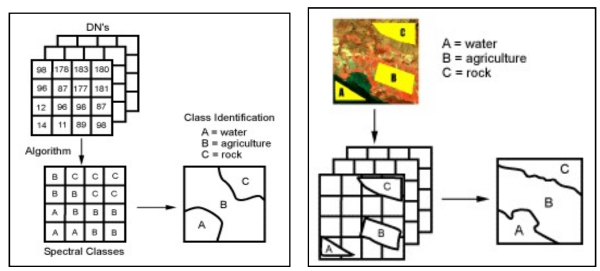


Διαδικασία ταξινόμησης



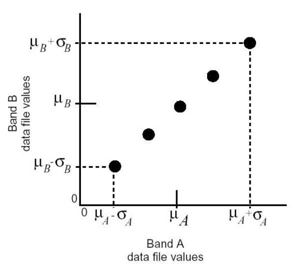


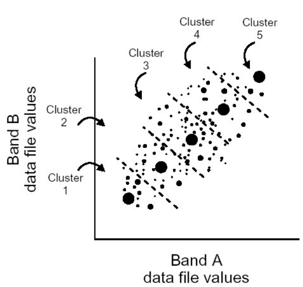


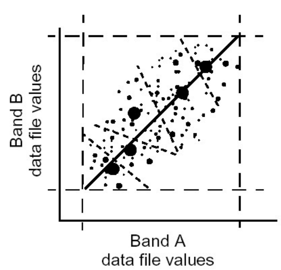


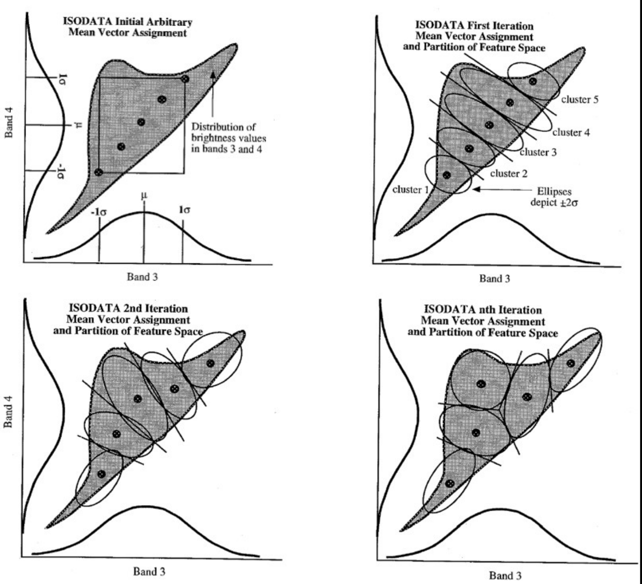
Μη επιβλεπόμενη ταξινόμηση

ISODATA Clustering

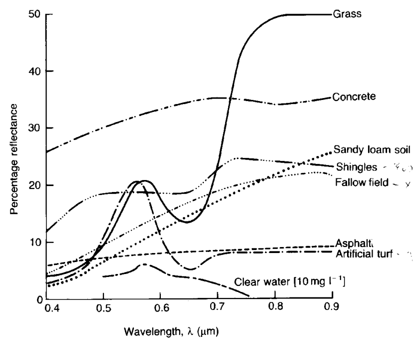


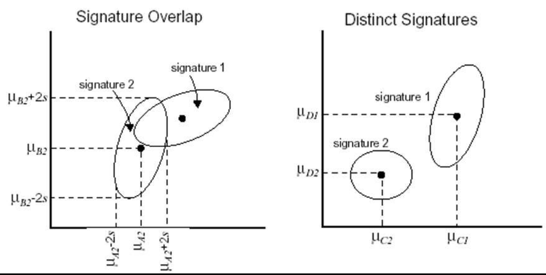


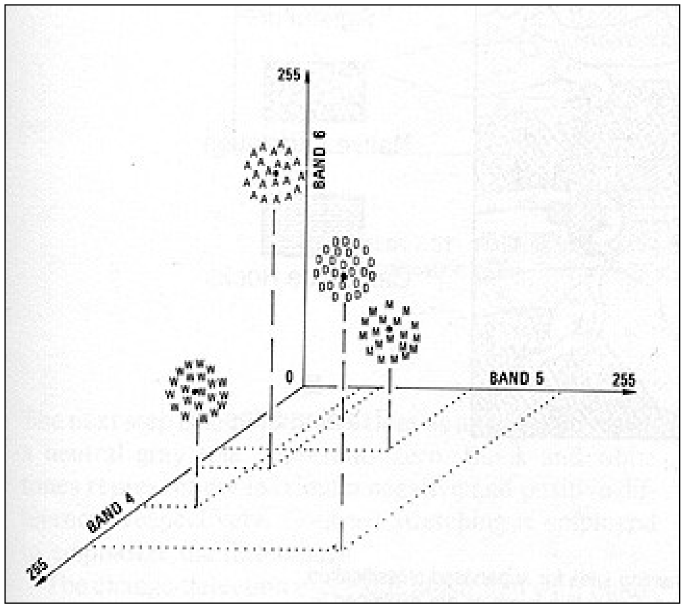




Επιβλεπόμενη ταξινόμηση

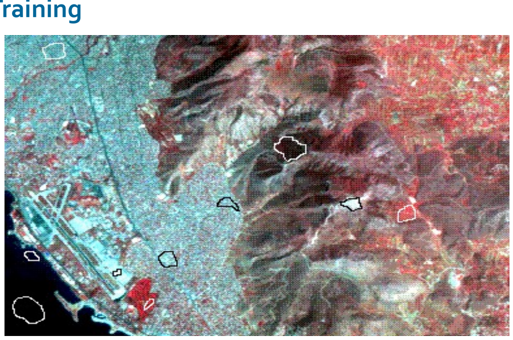






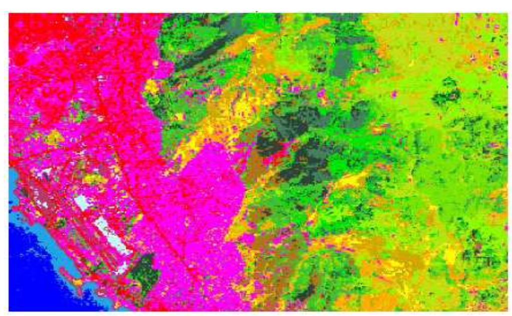
Επιβλεπόμενη ταξινόμηση

Training

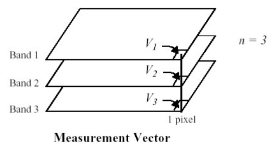


				Κανάλι		
	1	2	3	4	5	7
Τάξη	Κέντρο της τάξης ± τυπική απόκλιση					
Θάλασσα	81.0 ± 1.8	28.8 ± 1.0	25.8 ± 0.9	17.7 ± 0.8	16.7 ± 1.4	9.4 ± 0.9
Δασική βλάστηση	81.6 ± 3.3	36.3 ± 1.8	38.2 ± 3.0	58.7 ± 3.1	73.0 ± 11.4	31.7 ± 6.0
Αστική περιοχή	122.4 ± 11.4	60.9 ± 7.0	72.7 ± 9.7	71.7 ± 7.0	102.4 ± 13.7	58.2 ± 9.4
Γυμνό έδαφος	105.3 ± 5.5	53.8 ± 4.1	68.5 ± 5.7	76.1 ± 5.6	127.1 ± 12.2	64.5 ± 7.5

Classification

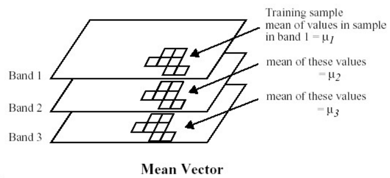


Πίνακας Συνδιακύμανσης



i = particular band
V_i = the data file value of the pixel in band i, then the measurement vector for this pixel is:

	band A	band B	band C	band D
band A	Var_A	Cov_{BA}	Cov_{CA}	Cov_{DA}
band B	Cov_{AB}	Var_B	Cov_{CB}	Cov_{DB}
band C	Cov_{AC}	Cov_{BC}	Var_C	Cov_{DC}
band D	Cov_{AD}	Cov_{BD}	Cov_{CD}	Var_D



$$\begin{bmatrix}\mu_1\\ \mu_2\\ \mu_3\end{bmatrix}$$

i = a particular band
μ_i = the mean of the data file values of the pixels being studied, in band i, then the mean vector for this training sample is:

$$C_{QR} \approx \frac{\sum_{i=1}^{k} (Q_i - \mu_Q)(R_i - \mu_R)}{k}$$

Where:

i = a particular pixel
k = the number of pixels

Διαχωρισιμότητα

Divergence

$$D_{ij} = \frac{1}{2}tr((C_i - C_j)(C_i^{-1} - C_j^{-1})) + \frac{1}{2}tr((C_i^{-1} - C_j^{-1})(\mu_i - \mu_j)(\mu_i - \mu_j)^T)$$

Where:

i and *j* = the two signatures (classes) being compared
C_i = the covariance matrix of signature i
μ_i = the mean vector of signature i
tr = the trace function (matrix algebra)
T = the transposition function

Transformed Divergence (< 2000)

$$D_{ij} = \frac{1}{2}tr((C_i - C_j)(C_i^{-1} - C_j^{-1})) + \frac{1}{2}tr((C_i^{-1} - C_j^{-1})(\mu_i - \mu_j)(\mu_i - \mu_j)^T)$$

$$TD_{ij} = 2000\left(1 - \exp\left(\frac{-D_{ij}}{8}\right)\right)$$

Where:

i and *j* = the two signatures (classes) being compared
C_i = the covariance matrix of signature i
μ_i = the mean vector of signature i
tr = the trace function (matrix algebra)
T = the transposition function

Jeffries–Matusita Distance (< 1414)

$$\alpha = \frac{1}{8}(\mu_i - \mu_j)^T\left(\frac{C_i + C_j}{2}\right)^{-1}(\mu_i - \mu_j) + \frac{1}{2}\ln\left(\frac{|(C_i + C_j)/2|}{\sqrt{|C_i| \times |C_j|}}\right)$$

$$JM_{ij} = \sqrt{2(1 - e^{-\alpha})}$$

Where:

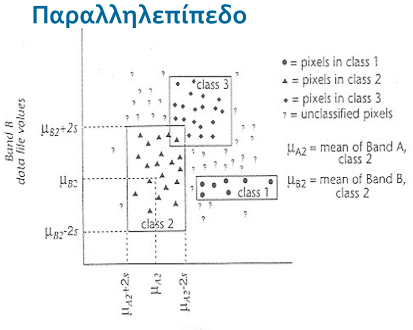
i and *j* = the two signatures (classes) being compared
C_i = the covariance matrix of signature i
μ_i = the mean vector of signature i
ln = the natural logarithm function
$|C_i|$ = the determinant of C_i

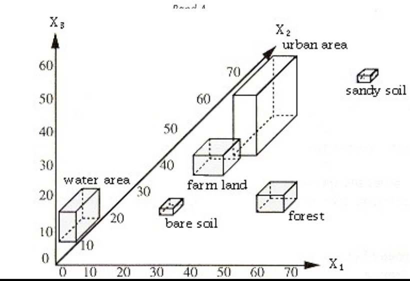
Contingency Matrix

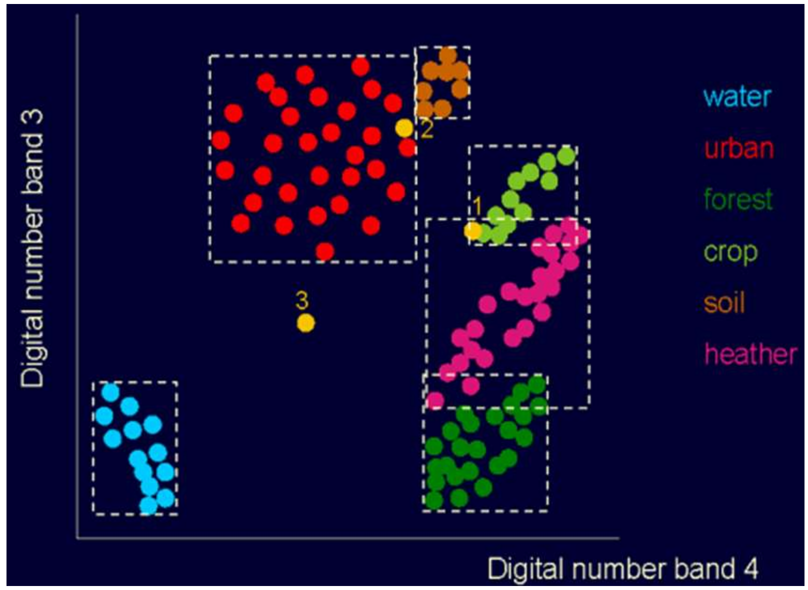
	Υπογραφή 1	Υπογραφή 2	Υπογραφή 3	Υπογραφή 4	Υπογραφή 5
Τάξη 1	100	0	0	0	0
Τάξη 2	0	56.3	22.3	6.6	0
Τάξη 3	0	35.9	67.3	7.1	0
Τάξη 4	0	7.8	10.4	86.3	0
Τάξη 5	0	0	0	0	100

Αλγόριθμοι Ταξινόμησης

Παραλληλεπίπεδο







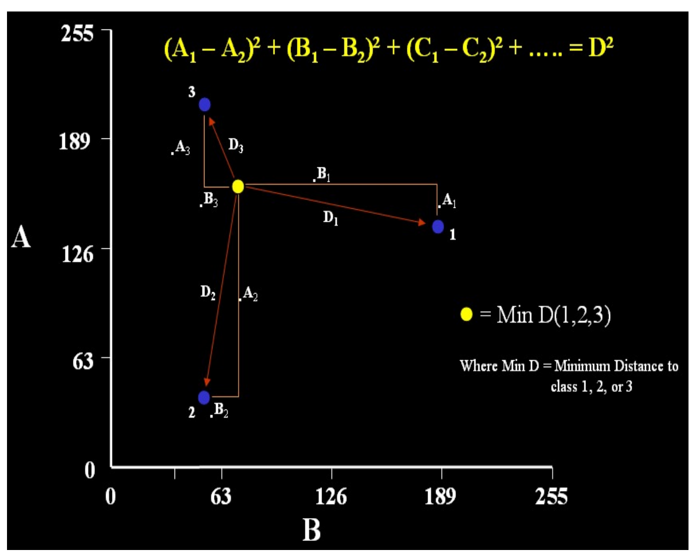
Αλγόριθμοι Ταξινόμησης

Ελάχιστη Απόσταση (Ευκλείδεια)

$$SD_{xyc} = \sqrt{\sum_{i=1}^{n} (\mu_{ci} - X_{xyi})^2}$$

Where:

n	=	number of bands (dimensions)
i	=	a particular band
c	=	a particular class
X_{xyi}	=	data file value of pixel *x,y* in band *i*
μ_{ci}	=	mean of data file values in band *i* for the sample for class *c*
SD_{xyc}	=	spectral distance from pixel *x,y* to the mean of class *c*



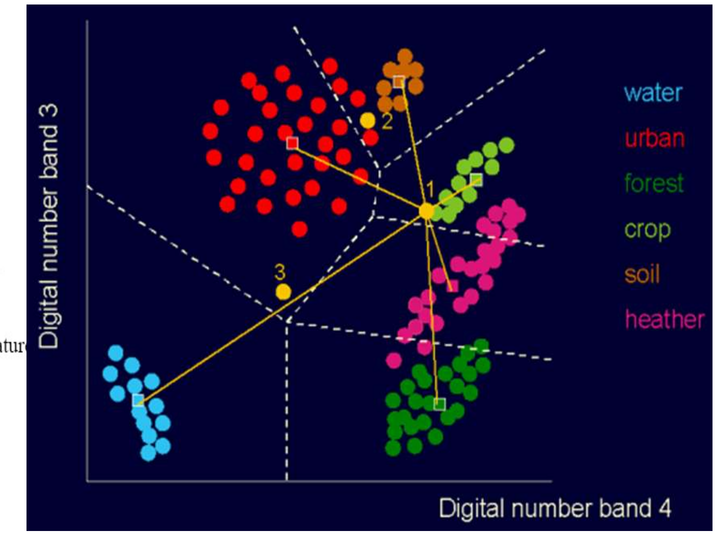
Αλγόριθμοι Ταξινόμησης

Ελάχιστη Απόσταση (Mahalobonis)

$D = (X-M_c)^T (Cov_c^{-1}) (X-M_c)$

Where:

D	=	Mahalanobis distance
c	=	a particular class
X	=	the measurement vector of the candidate pixel
M_c	=	the mean vector of the signature of class c
Cov_c	=	the covariance matrix of the pixels in the signatur
Cov_c^{-1}	=	inverse of Cov_c
T	=	transposition function



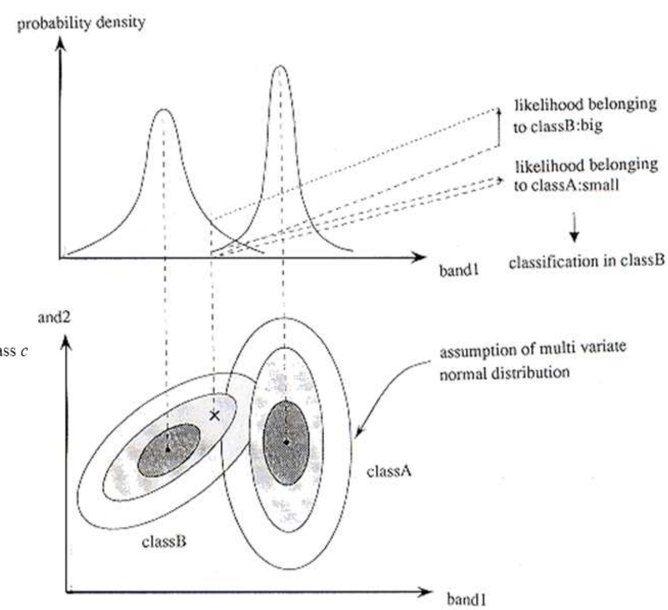
Αλγόριθμοι Ταξινόμησης

Μέγιστη Πιθανοφάνεια

$D = \ln(a_c) - [0.5 \ln(|Cov_c|)] - [0.5 (X-M_c)T (Cov_c^{-1}) (X-M_c)]$

Where:

D	=	weighted distance (likelihood)
c	=	a particular class
X	=	the measurement vector of the candidate pixel
M_c	=	the mean vector of the sample of class c
a_c	=	percent probability that any candidate pixel is a member of class c (defaults to 1.0, or is entered from *a priori* knowledge)
Cov_c	=	the covariance matrix of the pixels in the sample of class c
$\|Cov_c\|$	=	determinant of Cov_c (matrix algebra)
Cov_c^{-1}	=	inverse of Cov_c (matrix algebra)
ln	=	natural logarithm function
T	=	transposition function (matrix algebra)



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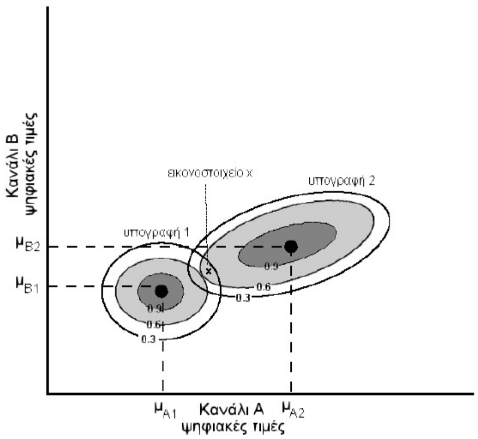
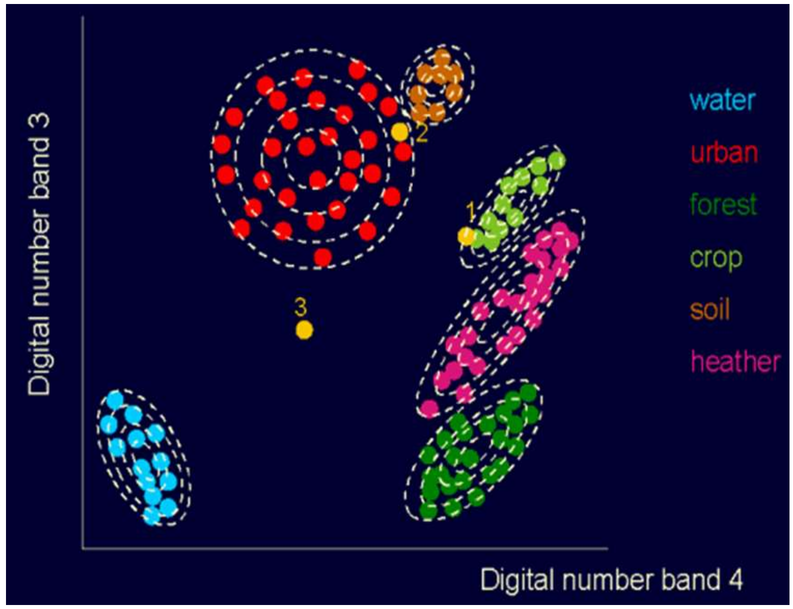
Αλγόριθμοι Ταξινόμησης

Μέγιστη Πιθανοφάνεια





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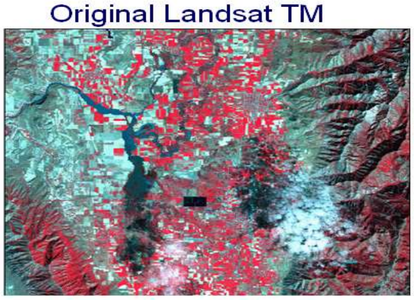
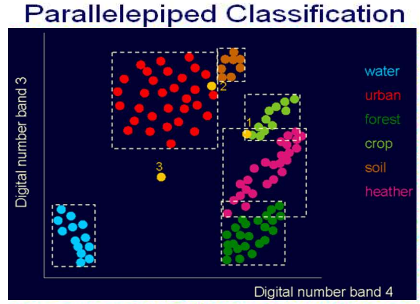
Επιβλεπόμενη ταξινόμηση

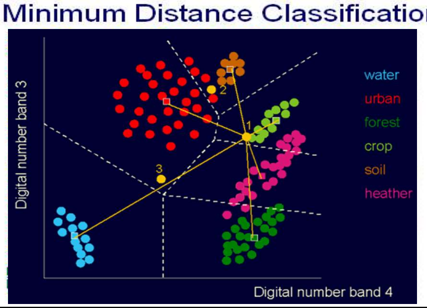
Original Landsat TM



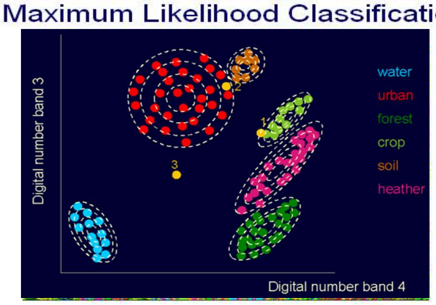
Parallelepiped Classification



Minimum Distance Classification



Maximum Likelihood Classification



Αξιολόγηση της ταξινόμησης

		Ground Reference Test Information Class 1 to *k* (*j* columns)					
		Residential	Commercial	Wetland	Forest	Water	Row total x_{i+}
Map Class 1 to *k* (*i* rows)	Residential	**70**	5	0	13	0	88
	Commercial	3	**55**	0	0	0	58
	Wetland	0	0	**99**	0	0	99
	Forest	0	0	4	**37**	0	41
	Water	0	0	0	0	**121**	121
	Column total x_{+j}	73	60	103	50	121	**407**

Overall Accuracy = 382/407 = 93.86%

Producer's Accuracy (omission error)

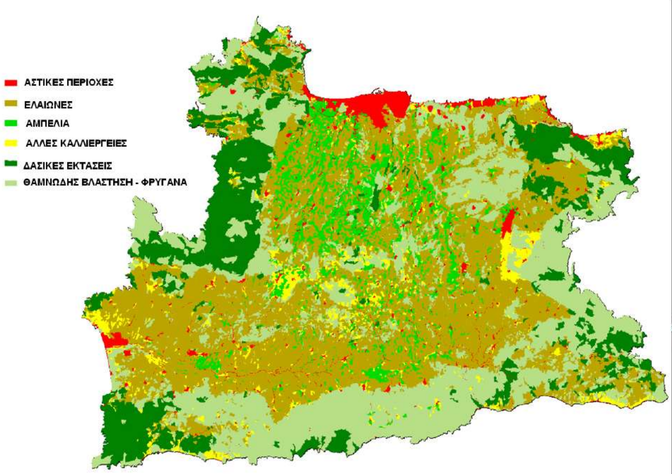
Residential = 70/73 =	96%	4% omission error
Commercial = 55/60 =	92%	8% omission error
Wetland = 99/103 =	96%	4% omission error
Forest = 37/50 =	74%	26% omission error
Water = 20/22 =	100%	0% omission error

User's Accuracy (commission error)

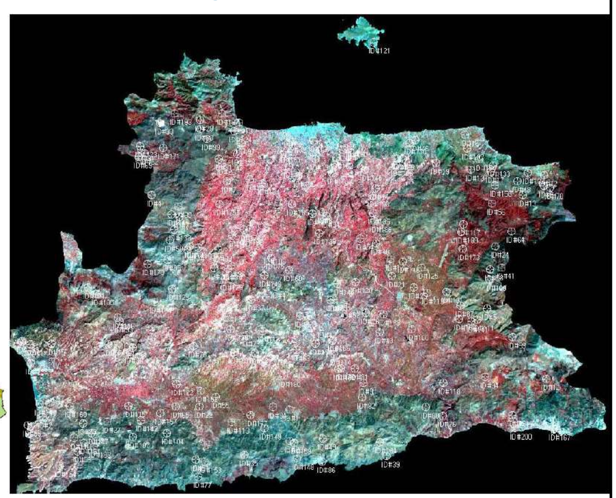
Residential = 70/88 =	80%	20% commission error
Commercial = 55/58 =	95%	5% commission error
Wetland = 99/99 =	100%	0% commission error
Forest = 37/41 =	90%	10% commission error
Water = 121/121 =	100%	0% commission error

Αξιολόγηση της ταξινόμησης

Θεματικός Χάρτης



Ground Truthing



Αξιολόγηση της ταξινόμησης

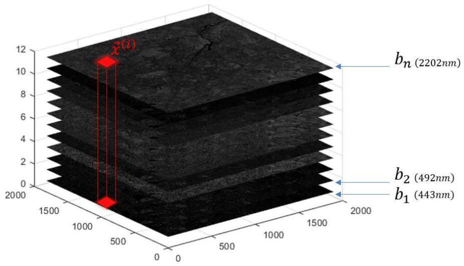
Σημείο	X	Y	Τάξη ως αποτέλεσμα της ταξινόμησης	Τάξη από δεδομένα αναφοράς
ID#1	601118.4595	3875238.862	3	3
ID#2	569903.4595	3874278.862	10	6
ID#3	615518.4595	3907113.862	9	9
ID#4	583778.4595	3902478.862	10	10
ID#5	626153.4595	3888078.862	10	10
ID#6	633443.4595	3903618.862	9	9
ID#7	593288.4595	3904278.862	3	3
ID#8	605378.4595	3900333.862	3	3
ID#9	610493.4595	3878583.862	3	10
ID#10	594728.4595	3911718.862	10	10
ID#11	568403.4595	3883488.862	5	5
ID#12	633743.4595	3879108.862	3	3
ID#13	630713.4595	3902463.862	3	3
ID#14	612053.4595	3903318.862	3	3
ID#15	571073.4595	3883563.862	3	3
ID#16	610793.4595	3887478.862	3	3
ID#17	626633.4595	3905493.862	3	3
ID#18	623393.4595	3910218.862	3	6
ID#19	619733.4595	3906603.862	3	3
ID#20	601118.4595	3871188.862	10	10
ID#21	614093.4595	3892218.862	3	3
ID#22	589838.4595	3875613.862	3	3
ID#23	595688.4595	3884643.862	3	3
ID#24	627278.4595	3895983.862	7	9
ID#25	616868.4595	3890763.862	3	4
ID#26	592673.4595	3906513.862	3	3
ID#27	578138.4595	3873648.862	7	7
ID#28	591698.4595	3893178.862	3	6

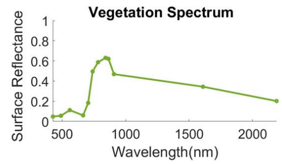
Α/Α	ΤΑΞΕΙΣ	Εικονοστοιχεία Αναφοράς	Ταξινομημένα Εικονοστοιχεία	Αριθμός Ταυτίσεων	Ακρίβεια Παραγωγού %	Ακρίβεια Χρήστη %
0	Υδάτινες Επιφάνειες	5	5	5	100.00%	100.00%
1	Αστικές Περιοχές	9	9	7	77.78%	77.78%
2	Γυμνό Έδαφος	5	5	4	80.00%	80.00%
3	Ελαιώνες	70	62	47	67.14%	75.81%
4	Αμπέλια	11	10	6	54.55%	60.00%
5	Θερμοκήπια	4	5	4	100.00%	80.00%
6	Άλλες Καλλιεργήσιμες Εκτάσεις	15	17	8	53.33%	47.06%
7	Κωνοφόρα	9	17	7	77.78%	41.18%
8	Πλατύφυλλα	5	7	3	60.00%	42.86%
9	Θαμνώδης Βλάστηση - Φρύγανα	48	41	36	75.00%	87.80%
10	Αραιή Φυσική Βλάστηση	24	27	17	70.83%	62.96%
	ΣΥΝΟΛΟ	205	205	144	70.83%	62.96%
	ΣΥΝΟΛΙΚΗ ΑΚΡΙΒΕΙΑ ΤΑΞΙΝΟΜΗΣΗΣ			70.25%		

Στάδια ταξινόμησης

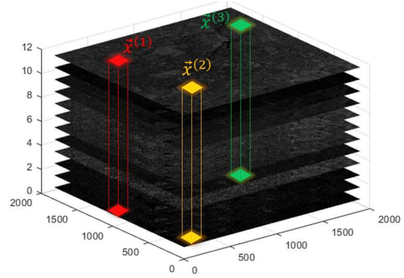
- Καθορισμός του σχήματος ταξινόμησης.
- Εκπαίδευση.
- Επιλογή του κανόνα ταξινόμησης.
- Αξιολόγηση των υπογραφών.
- Εφαρμογή του κανόνα ταξινόμησης.
- Αντιστοίχηση των φασματικών τάξεων σε τάξεις πληροφόρησης.
- Δημιουργία θεματικού χάρτη.
- Αξιολόγηση της ταξινόμησης.

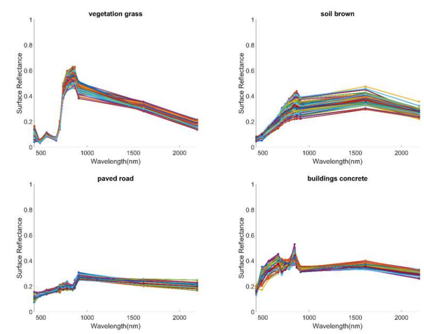
Machine Learning: SVM





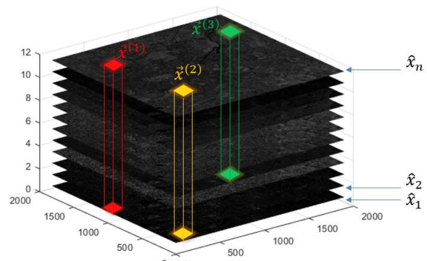
$$\vec{x}^{(i)} = \left[x_1^{(i)}, x_2^{(i)}, \dots, x_n^{(i)}\right]^T$$

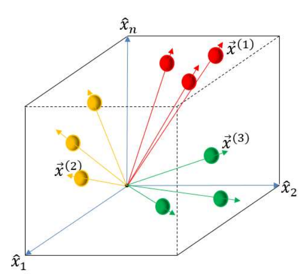


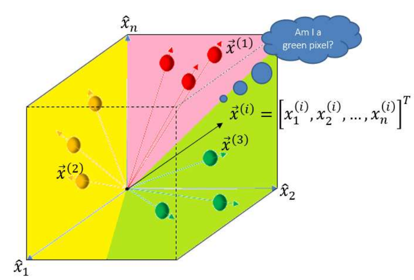


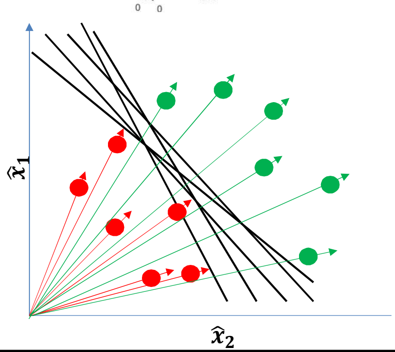
$$\vec{x}^{(i)} = \left[x_1^{(i)}, x_2^{(i)}, \dots, x_n^{(i)}\right]^T$$

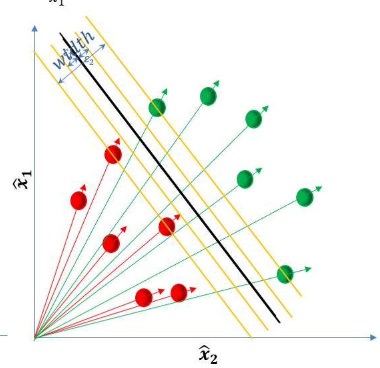
Machine Learning: SVM







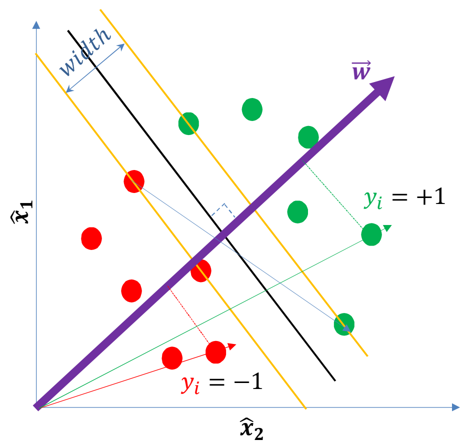




The optimal hyperplane:

- separates all the "red" training vectors from all the "green" training vectors
- has the same distance from both classes ($\varepsilon_1 = \varepsilon_2$)
- leaves the maximum possible empty space between two classes (width)

Machine Learning: SVM



cost function:

$$\max(\text{width}) = \frac{1}{2} min|\vec{w}|^2$$

constrains:

$$\vec{w} \cdot proj_{\vec{w}}\vec{x}_i + b \geq 1$$

$$\vec{w} \cdot proj_{\vec{w}}\vec{x}_i + b \leq -1$$

$y_i = +1$ $y_i = -1$

simplified constrains:

$$y_i(\vec{w} \cdot \vec{x}_i + b) - 1 \geq 0$$

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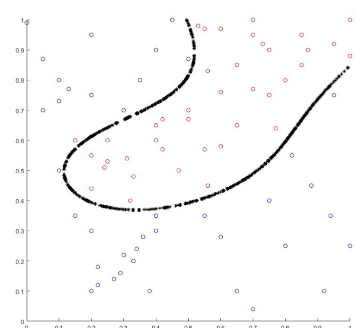
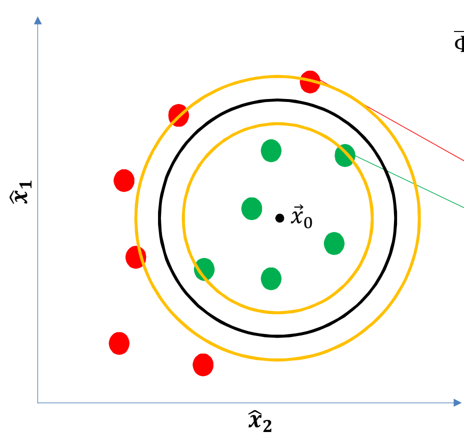
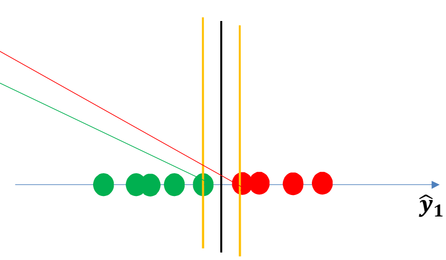
Machine Learning: SVM

$$\vec{x}^{(i)} \rightarrow \vec{\Phi}(\vec{x}^{(i)})$$

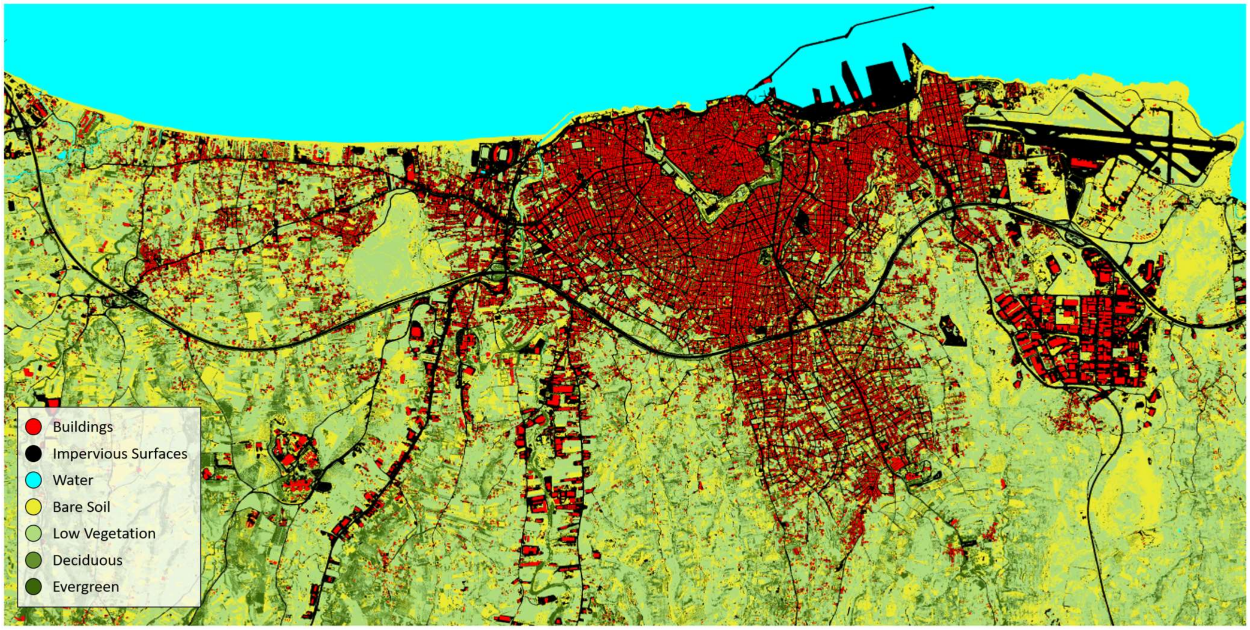
$$\vec{\Phi}(\vec{x}^{(i)}) = |\vec{x}^{(i)} - \vec{x}_0|$$



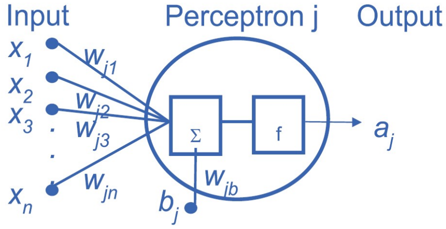


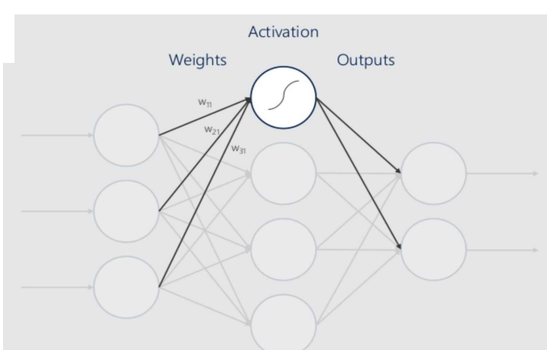


Machine Learning: SVM



Machine Learning: ANN

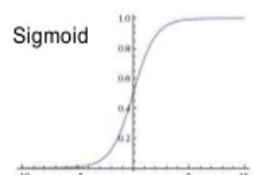




Activation functions

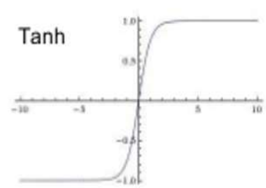
Sigmoid

$$f_1(x) = \frac{1}{1 + e^{-(1-a)x}}$$



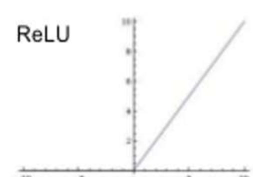
Tanh

$$f_2(x) = \frac{e^{(1-a)x} - e^{-(1-a)x}}{e^{(1-a)x} + e^{-(1-a)x}}$$



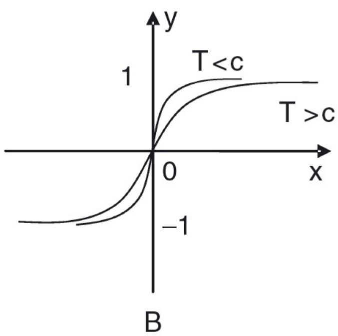
ReLU

ReLU = max (0; x)



Machine Learning: ANN

Training: learning process by which the connection weights are adjusted until the network is deemed to be optimal. Curves of activation functions as related to different threshold (T) values, given that c is any constant between 0 and 1.



Training a neural network: finding values for the weights w such that output y is close to a ground truth value $\hat{y}$.

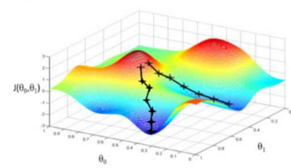
We define a loss function $\mathcal{L}(y(w), \hat{y})$ decreasing with the precision (for example: $||y - \hat{y}||^2$, cross-entropy).

$\mathcal{L}$ is usually an (almost) differentiable function but is generally nonconvex.

However, we can find good weights with Stochastic Gradient Descent.

Automatic differentiation: gradients are easily computed and propagated ("backprop").

Supervized learning, require a lot of high quality annotations.



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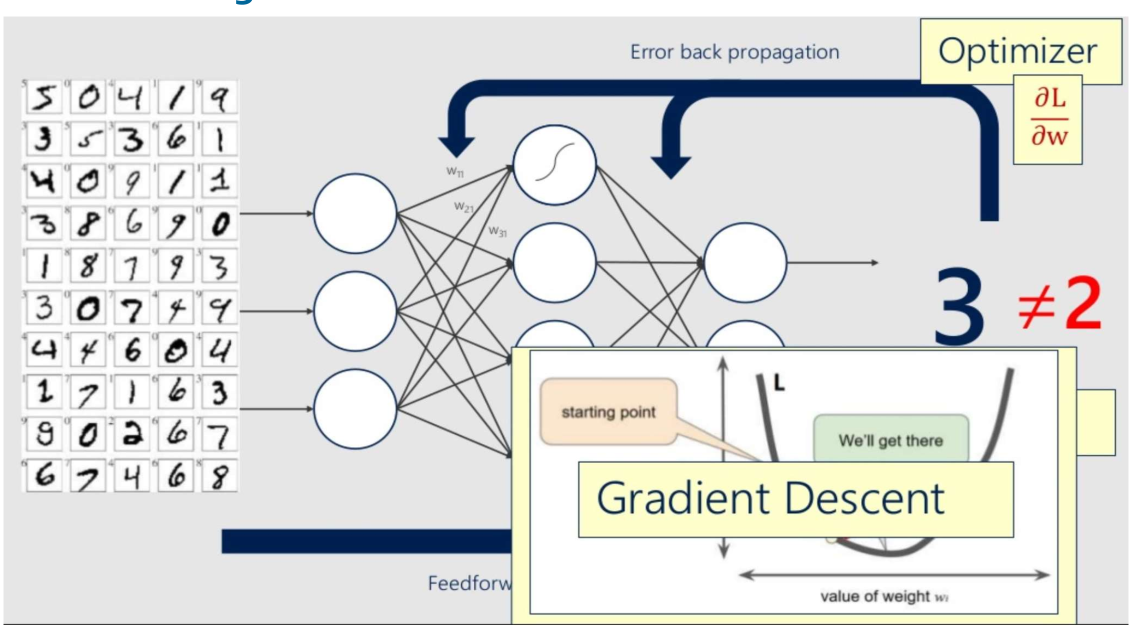
Machine Learning: ANN

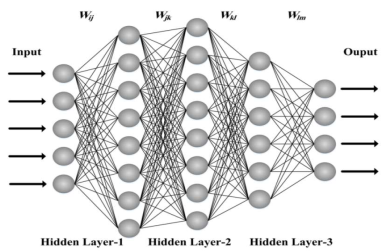


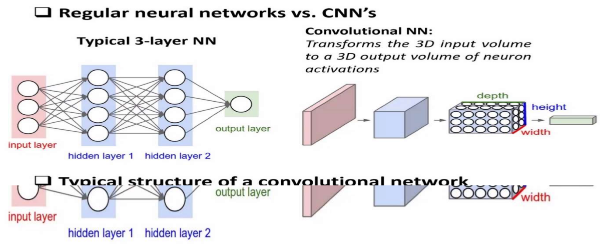
Machine Learning: DL

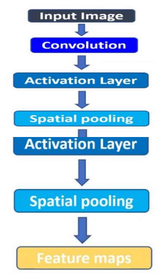
Problem: the size of W increase quadratically with the layers' size

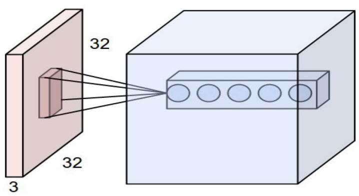
100×100 image : 10^8 parameters per layer! Unmanageable.

Solution: local convolutions: values of a layer only depend on a small number of points in the previous layer (the *receptive field*).









❑ Typical structure of a convolutional network

- ✓ **Convolution blocks**
- ✓ **Training** → multi-layer neural nets (stacked blocks)
- ✓ **Final layer** → fully connected layer
- ✓ **Output size: number of classes!**

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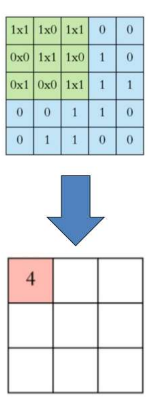
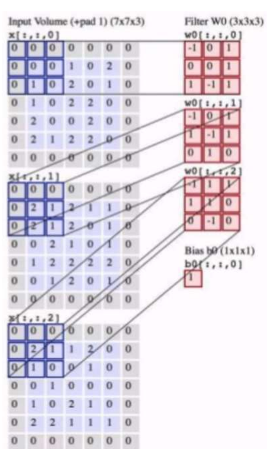
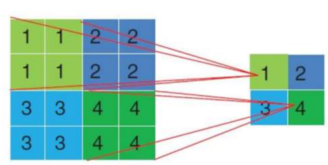
Machine Learning: DL

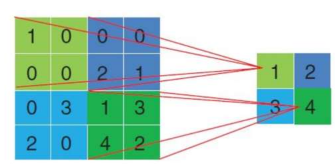
Convolution

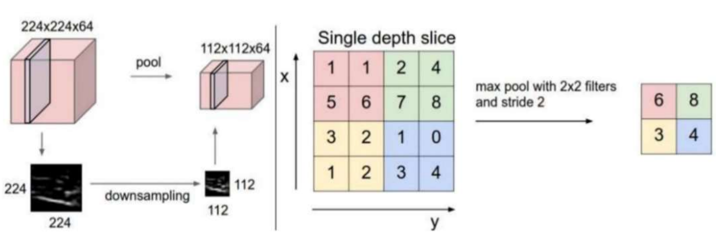




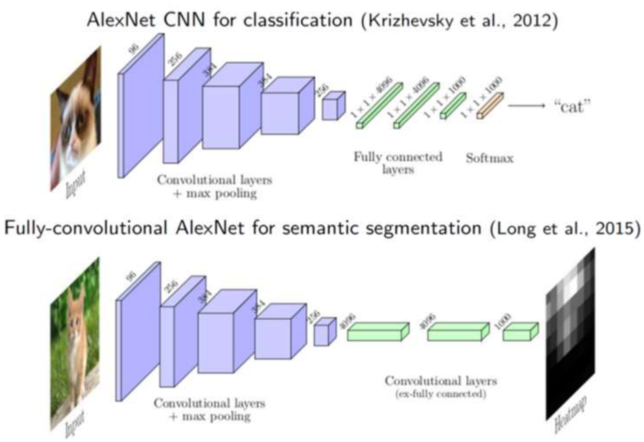
Pooling

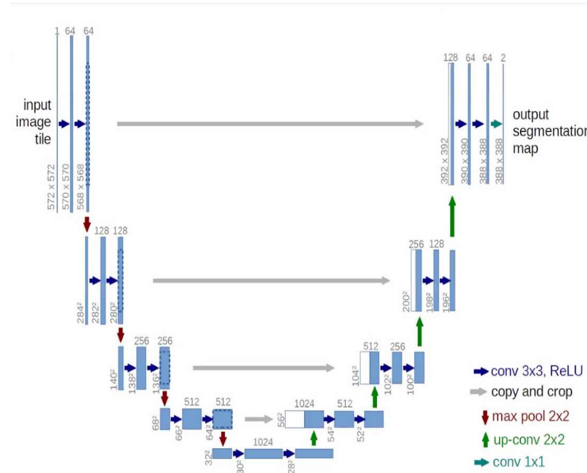




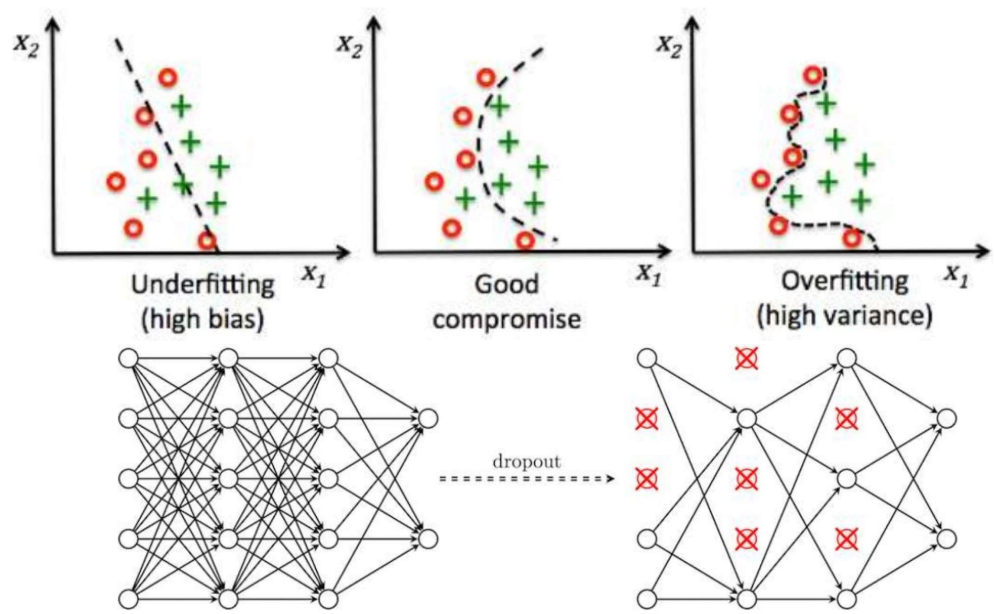


Machine Learning: DL

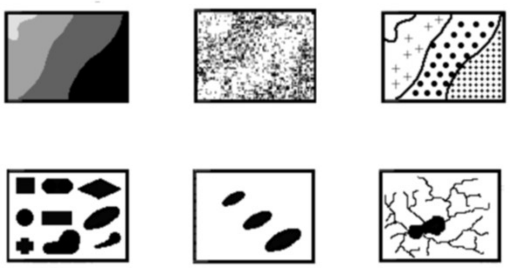




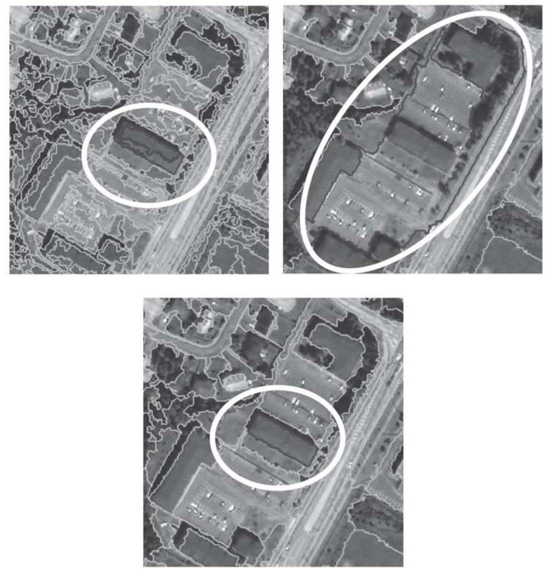
Machine Learning: DL



Αντικειμενοστραφής ταξινόμηση



Segmentation



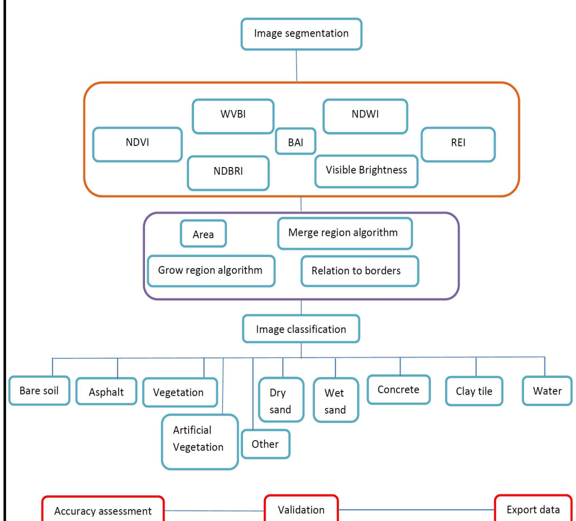
Geographic OBject-based Image Analysis (GEOBIA):

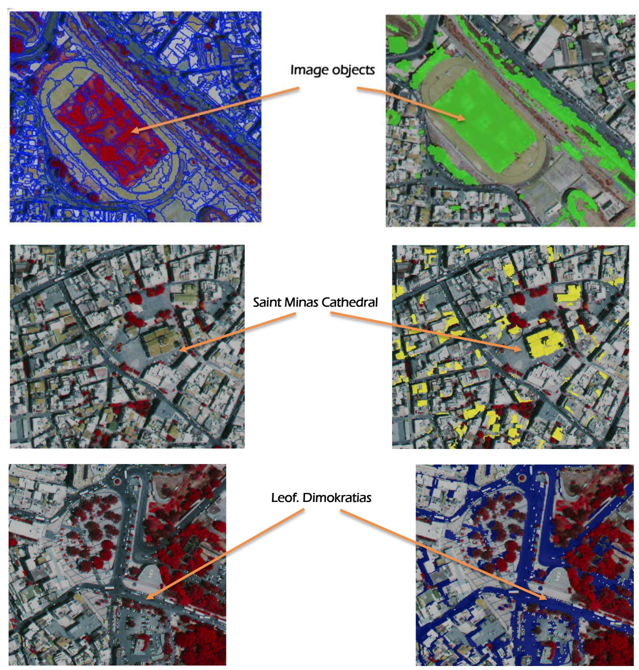
The first step is to segment an image, representing a scene or the ground area into image objects.

An image object is defined as a group of pixels sharing similar spectral and/or textural properties.

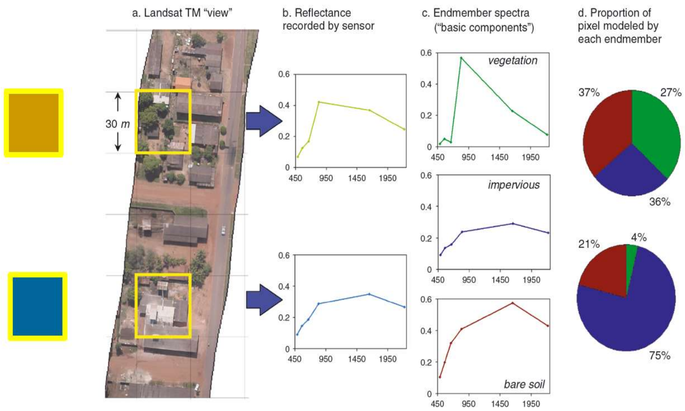
The segmentation function is based on three parameters: shape, compactness and scale.

Αντικειμενοστραφής ταξινόμηση





Φασματική ανάμειξη



$$R_i = \sum_{k=1}^{n} a_k R_{ik} + \mathrm{ER}$$

$i = 1, \dots, p$ spectral band

p the number of bands

n The number of end-membrs

R_{ik} the spectral response of the end-member k in channels n

ER the error of the model

$$\begin{bmatrix} R_1 \\ \vdots \\ R_p \end{bmatrix} = \begin{bmatrix} R_{11} & \cdots & R_{1n} \\ \vdots & \ddots & \vdots \\ R_{p1} & \cdots & R_{pn} \end{bmatrix} \begin{bmatrix} a_1 \\ \vdots \\ a_k \end{bmatrix} + ER$$

Observation spectra

Spectral response of end-member 1

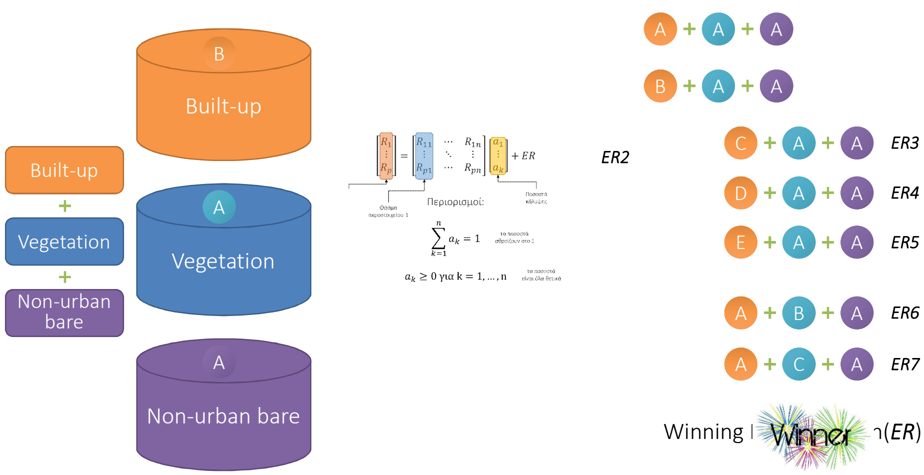
abundances

Constraints:

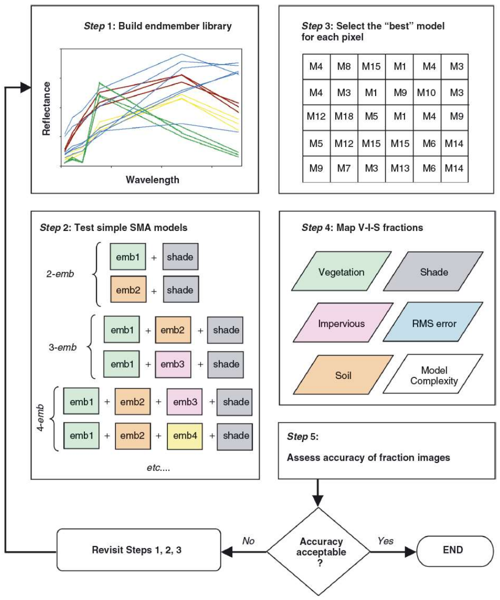
$$\sum_{k=1}^{n} a_k = 1$$

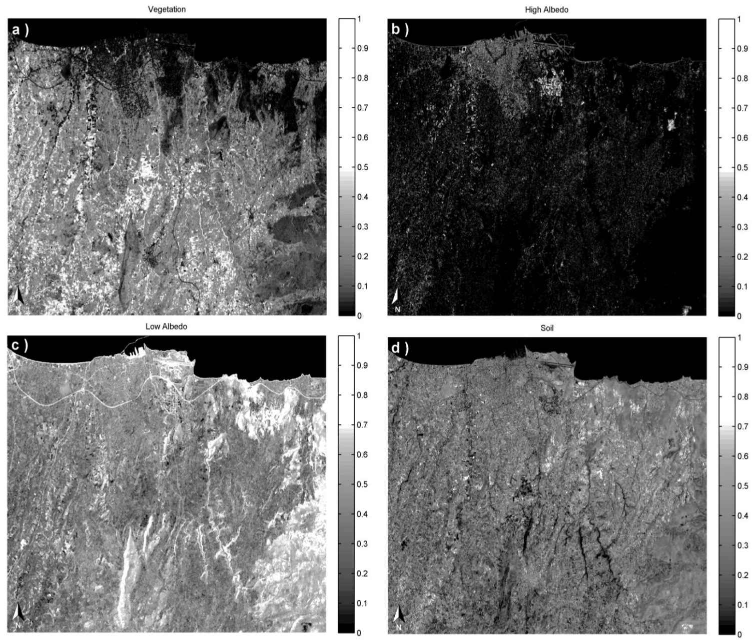
$a_k \geq 0$ για k = 1, …, n

Φασματική ανάμειξη



Φασματική ανάμειξη





Φασματική ανάμειξη