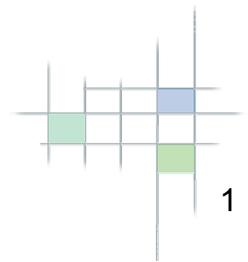


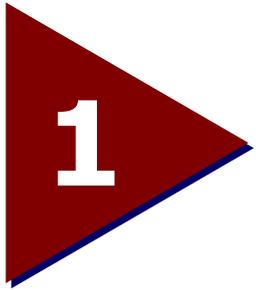
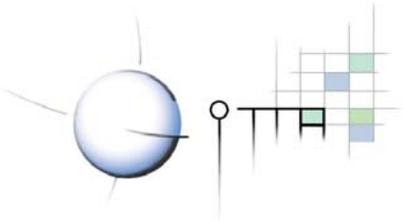
Unit 3: Pattern and neighborhood of spatial features

A: Introduction

B: Spatial pattern and neighborhood (relationships)

- for point features
- for linear features
- for areal features



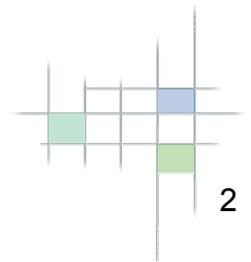


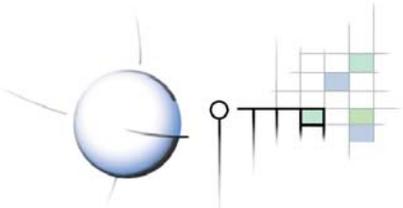
Introduction

B-AN / L2
Discrete spatial
variables

U3: Spatial pattern
of features

May 30 2003

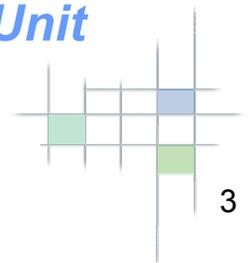


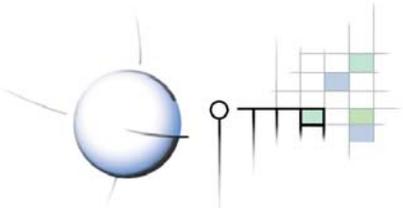


Spatial pattern and neighborhood

- Concepts of **pattern** and **neighborhood** are complex:
 - Only few properties will be considered: **central location**, **dispersion**, **contiguity**, **distance**, **proximity**
- Different models of space can be related with these concepts:
 - Plane isotropic space: **homogeneous** space, plane distance
 - Skew isotropic space: **heterogeneous** space, weighted distance
 - Skew anisotropic space: **heterogeneous** space with **variable properties**, weighted directionnal distance

Only the plane isotropic space will be considered in this Unit

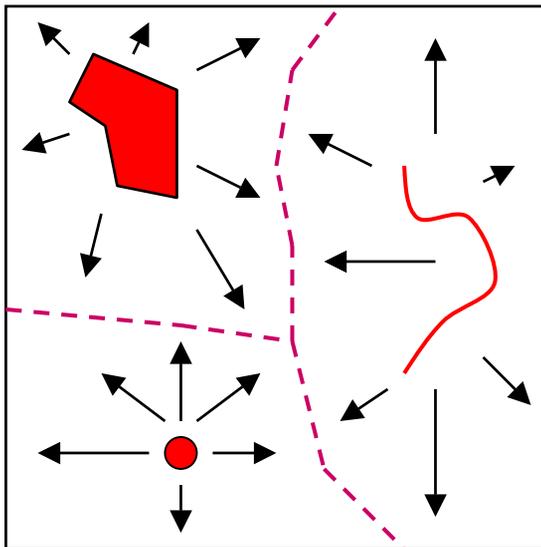




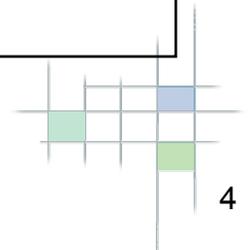
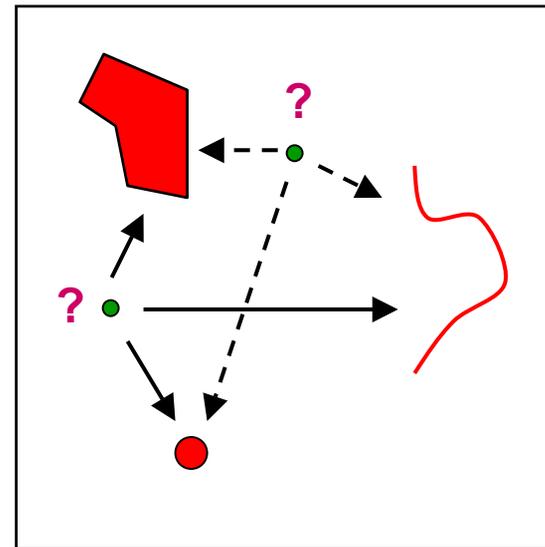
Proximity and distance

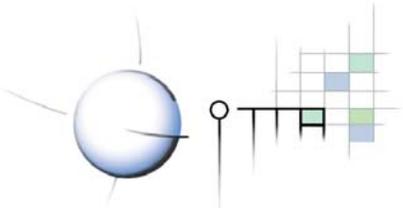
Concepts of largest proximity and minimum distance

Areas of largest proximity
« Field of influence of features »



Minimum distance
« Distance to the closest feature »

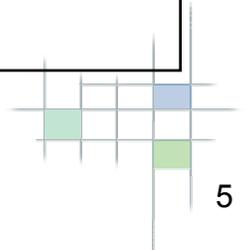
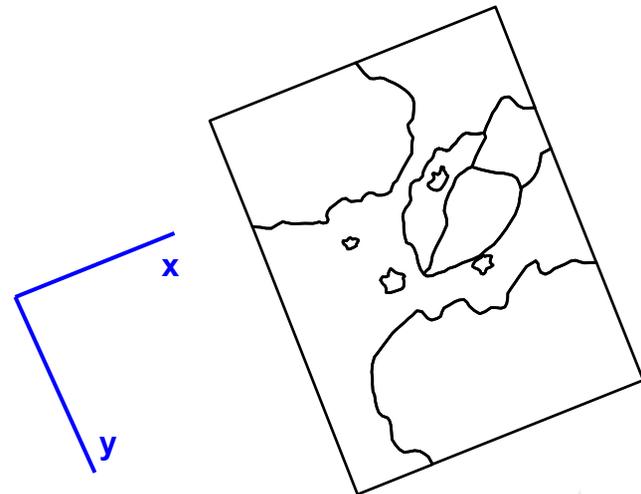


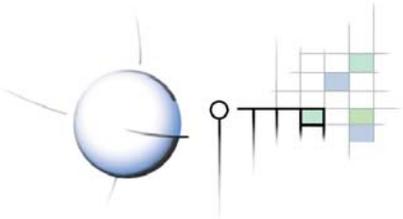


Model of space: Plane isotropic space

- Properties within the whole space are either **homogeneous** or **not considered**:
 - only the spatial dimension is taken into account
- Only concepts of **plane geometry** (euclidian) are used to describe the spatial pattern and neighborhood of features:
 - central location, dispersion
 - proximity: plane distance (horizontal, euclidian)

- Space is modeled as **homogeneous and plane**, expressing the homogeneity of its properties
- In fact properties are **ignored**:
 - the thematic dimension is not considered





Description of spatial pattern and neighborhood

Proposed indices of pattern and neighborhood

Indices	Plane space spatial dimension	Weighted space spatio-thematic dimension
Location	Mean, median centers	Weighted mean center
Dispersion	Standard deviations, interquartiles, standard distance, R index	Weighted standard deviation
Proximity	Plane distance, areas of largest proximity	Weighted distance, areas of largest weighted proximity

● **Indices and statistics of spatial pattern and neighborhood are presented according to the type of spatial features:**

● point

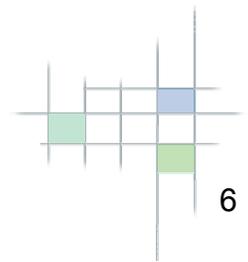
● linear

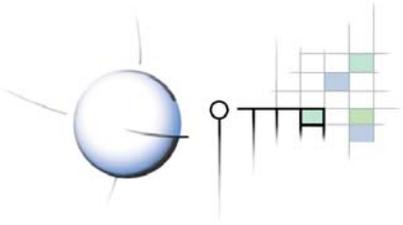
B-AN / L2

Discrete area variables

U3: Spatial pattern of features

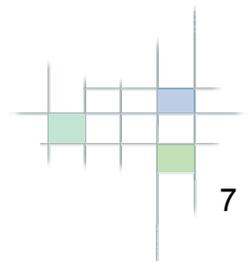
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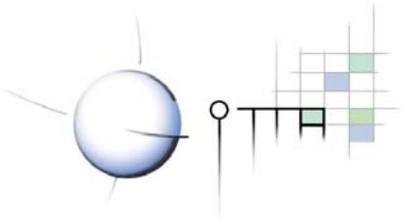




2

Spatial pattern and neighborhood of point features

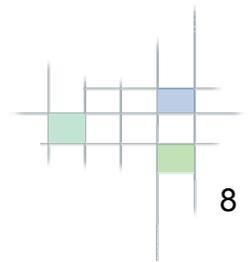


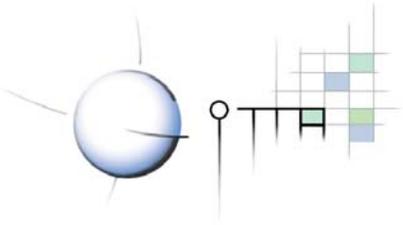


Point features: Pattern and neighborhood

Different indicators for the spatial distribution and relationships of point features

- **Spatial distribution description:**
 - statistical indices of location: central tendency
 - statistical indices of dispersion: variability
- **Spatial pattern description:**
 - index of spatial pattern
- **Neighborhood relationships description:**
 - distance to features, areas of largest proximity



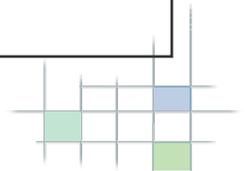
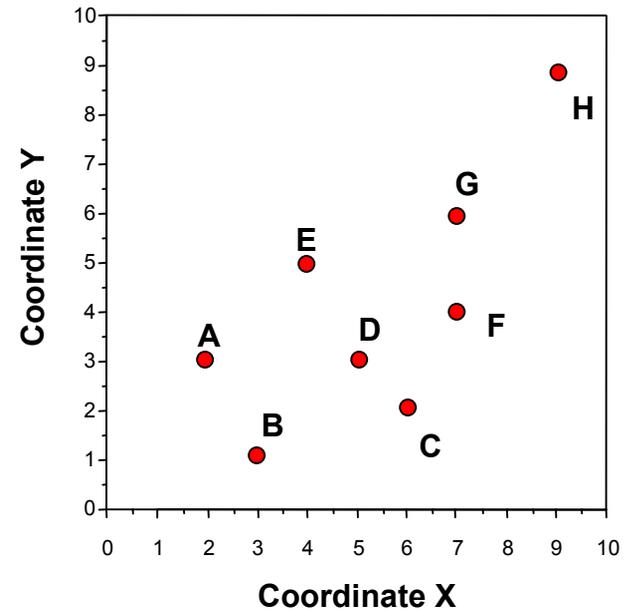


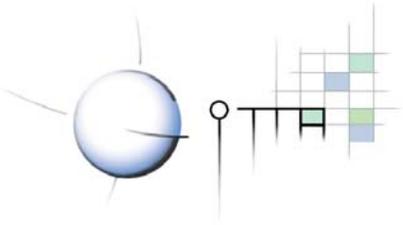
Point features : Example of a distribution

Location of 8 points

<u>Point</u>	<u>X (m)</u>	<u>Y(m)</u>
A	2.0	3.0
B	3.0	1.0
C	6.0	2.0
D	5.0	3.0
E	4.0	5.0
F	7.0	4.0
G	7.0	6.0
H	9.0	9.0

Spatial distribution of 8 points





Point features : Indices of central tendency

Based on the mean and median of X and Y coordinates

- Mean center **MC** (\bar{x} , \bar{y}) or (x_{mean} , y_{mean}) :

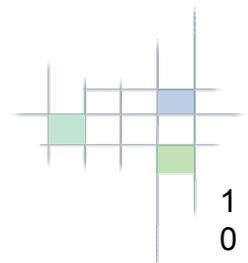
$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

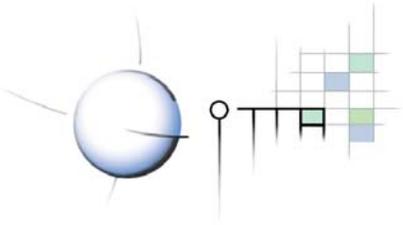
$$\bar{y} = \frac{1}{n} \sum_{i=1}^n y_i$$

- it is the **center of gravity** or **barycenter** of the distribution

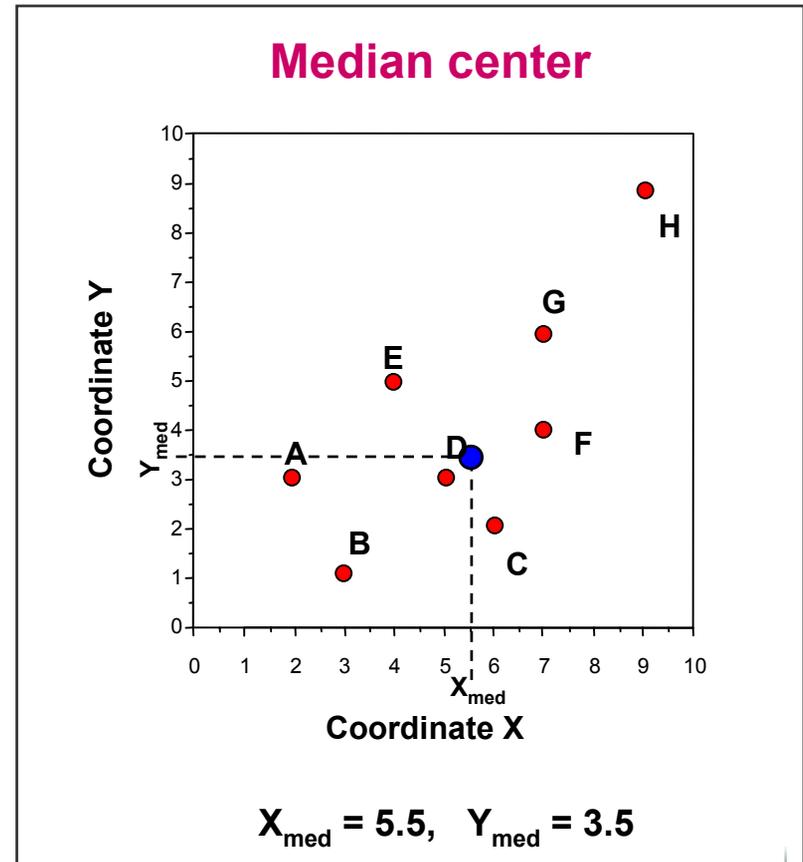
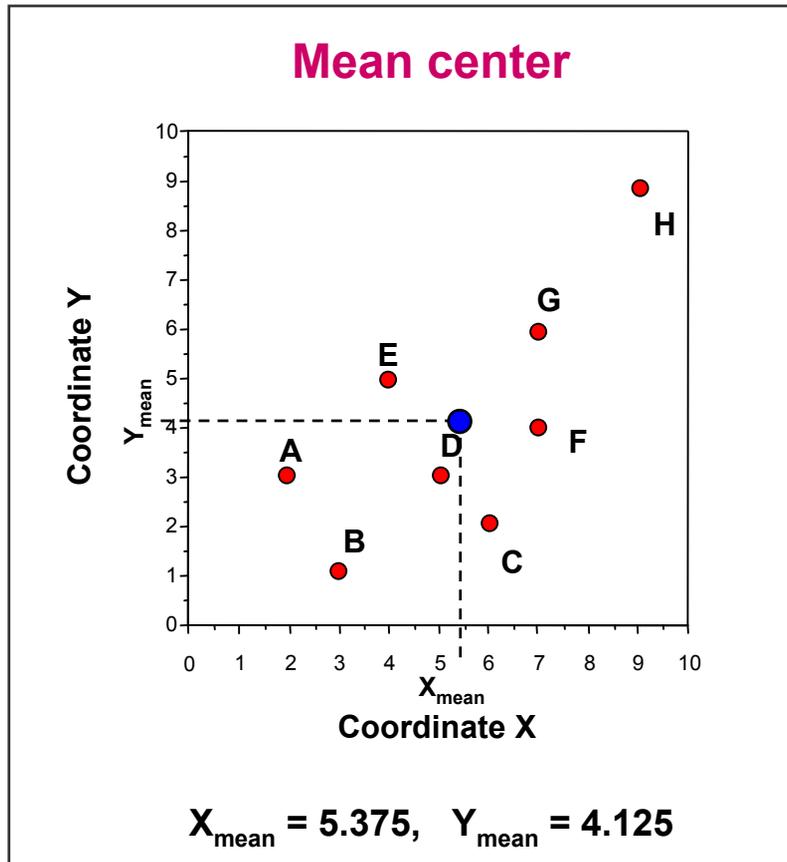
- Median center **C_{med}** :

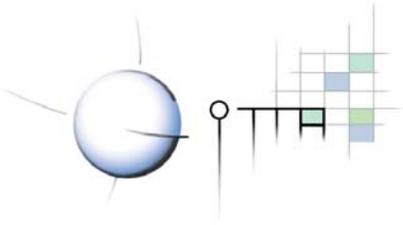
Location of coordinates ($X_{\text{méd}}$, $Y_{\text{méd}}$)





Point features : Indices of central tendency





Point features : Indices of dispersion

Based on standard deviations and quartiles of X and Y coordinates

- **Standard deviation of X s_x and Y s_y :**

$$S_x = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$$

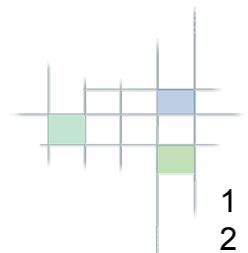
$$S_y = \sqrt{\frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n-1}}$$

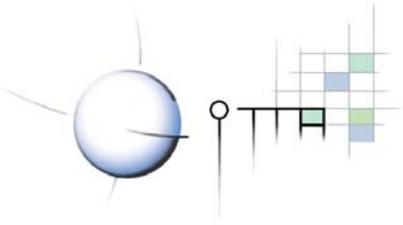
- **Interquartile of X x_{IQ} and Y y_{IQ} :**

$$X_{IQ} = Q_3 - Q_1$$

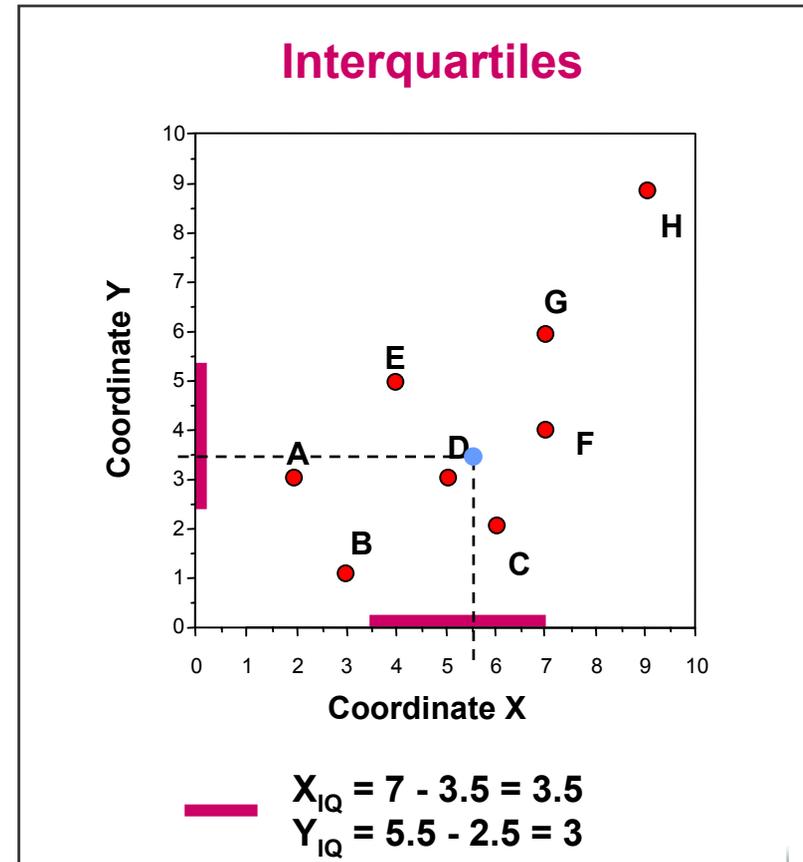
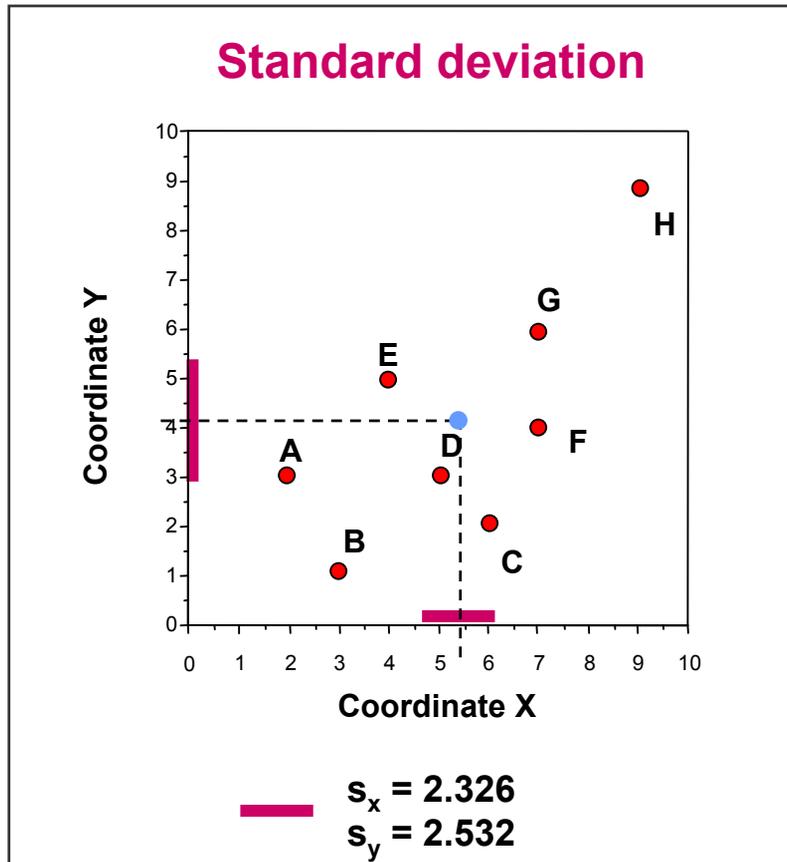
$$Y_{IQ} = Q_3 - Q_1$$

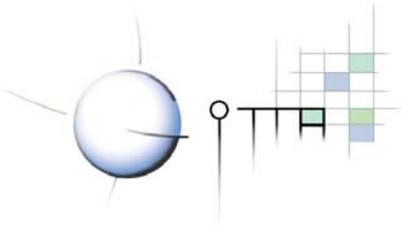
with: Q_1 the first quartile and Q_3 the third one





Point features : Indices of dispersion





Point features : Global index of dispersion

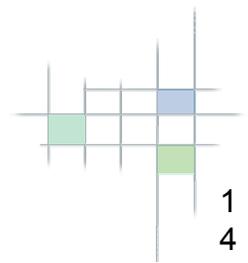
Based on the combined dispersion of X and Y coordinates

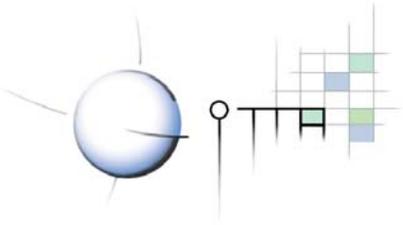
- **Standard Distance SD (Bachi distance) :**

$$DS = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2 + \sum_{i=1}^n (y_i - \bar{y})^2}{n}}$$

- It is a measure of the the combined dispersion in X and Y directions, with reference to the mean center

Corriger DS dans équation !





Point features : Standard distance

Computation

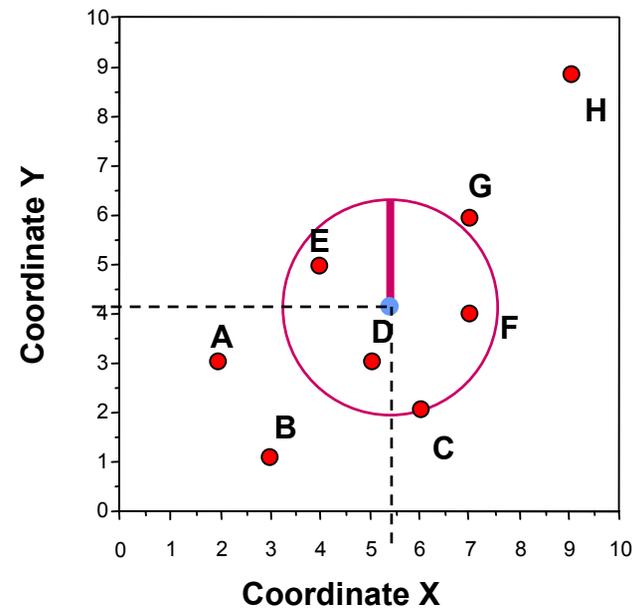
$$\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n} = 4.73$$

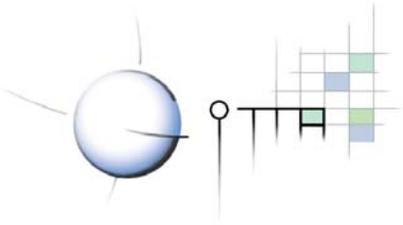
$$\frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n} = 5.61$$

$$SD = \sqrt{4.73 + 5.61}$$

$$SD = 2.37$$

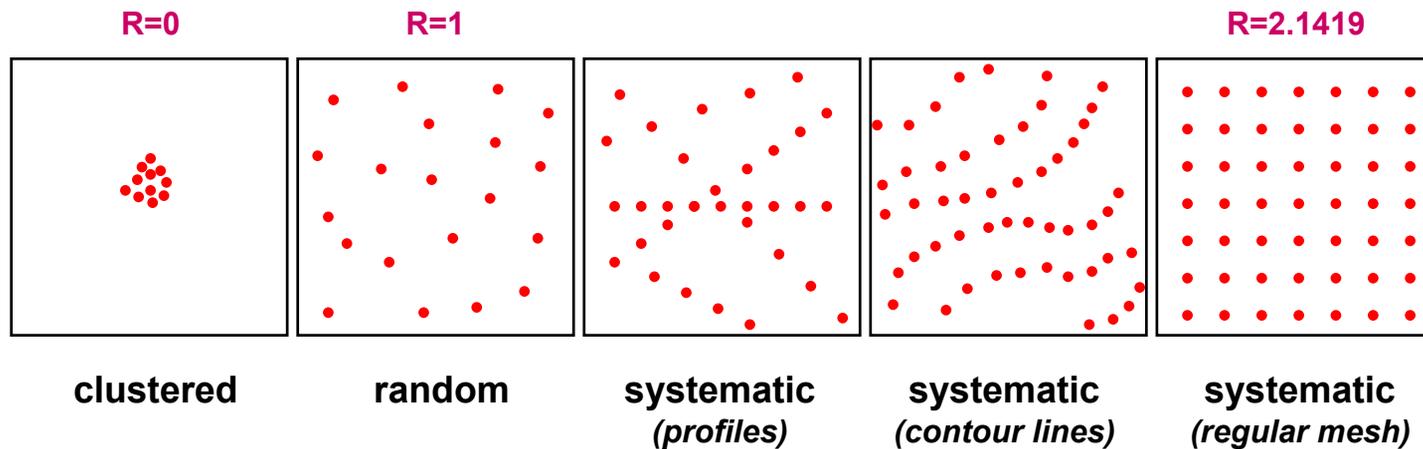
Standard distance



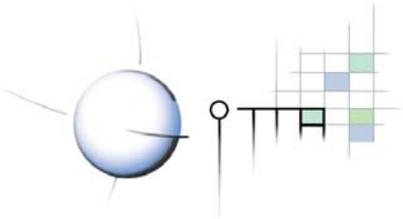


Point features : Spatial pattern index

Typology of point spatial distributions



Objective: Production of an index expressing these distribution differences



Point features : Nearest neighbor R index

The nearest neighbor R index compares the observed distribution of points with a theoretically random one.

It is a ratio

- **R Index :**

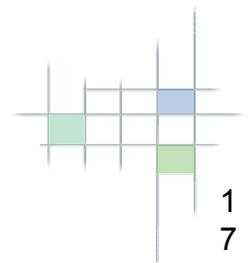
$$R = \frac{\text{Mean distance between pairs of points sample}}{\text{Mean distance for a random distribution}} = \frac{\bar{d}}{\bar{d}_{al}}$$

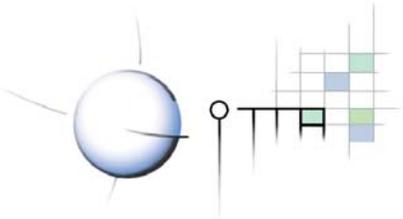
- **Mean distance in the observed distribution:**

$$\bar{d} = \frac{1}{n} \sum_i d_i \quad d_i = \text{distance from point } i \text{ to its nearest neighbor}$$

- **Mean distance in the random distribution :**

$$\bar{d}_{al} = 0.5 \sqrt{\frac{n}{s}} \quad \begin{array}{l} s : \text{area of the study region} \\ n : \text{number of points} \end{array}$$





Point features : R index - Example

Computation

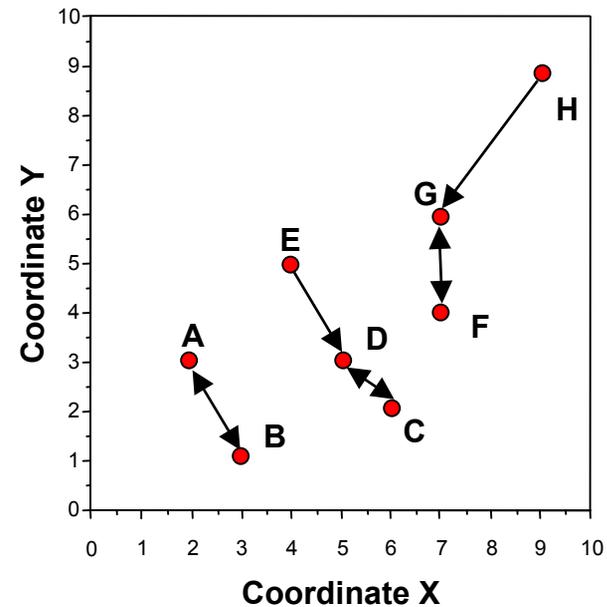
Point	Coord. X	Coord. Y	Nearest neighbor	Distance
A	2	3	B	2.23607
B	3	1	A	2.23607
C	6	2	D	1.41421
D	5	3	C	1.41421
E	4	5	D	2.23607
F	7	4	G	2
G	7	6	F	2
H	9	9	G	3.60555
Σ	43	33		17.1422
Mean	5.375	4.125		2.1428

$$\bar{d} = 17.1422 / 8 = 2.1428$$

$$\bar{d}_{al} = 0.5 / (\sqrt{8 / (10 * 10)}) = 1.768$$

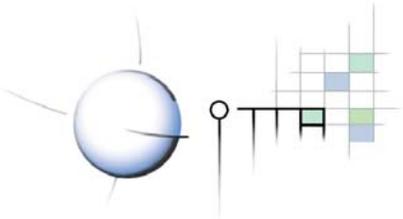
$$R = 2.1428 / 1.768 = 1.212$$

Nearest neighbors



$$R = 1.212$$

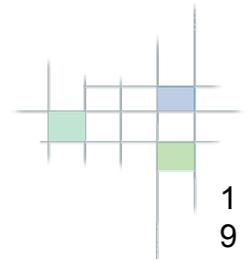
It is a near random distribution

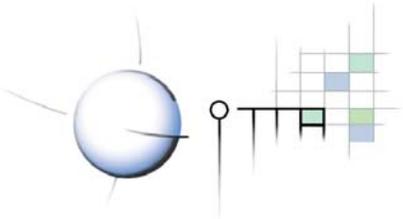


Point features : Neighborhood relationships

The most common neighborhood relationship is the measure of proximity to features

- **In object mode :**
 - **Areas of largest proximity**
 - delimited by equidistance line segments between points (**medians**)
 - they are called **Thiessen** or **Voronoi's polygons**
- **In image mode :**
 - **The distance to the nearest point region**
 - **Region of largest proximity**



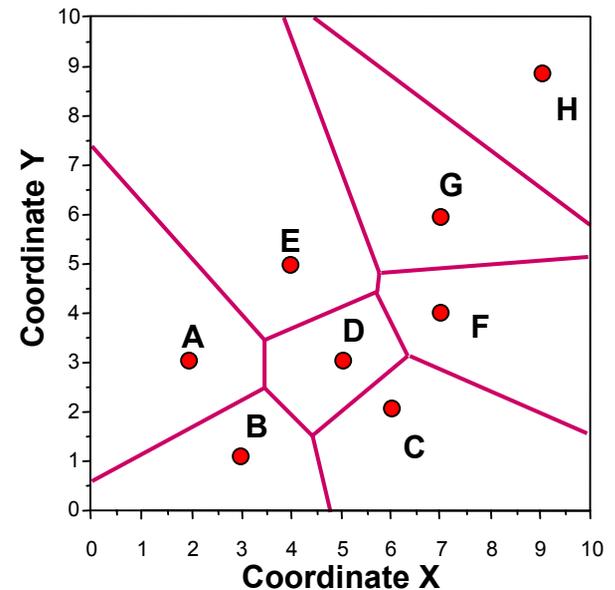


Point objects : Areas of largest proximity

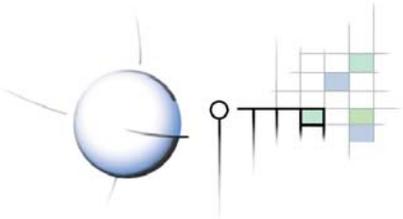
Properties

- The space is divided into areas delimited by the medians of segments connecting points
- Any location within each area is closer to its point center than any other
- These areas of largest proximity are called **Thiessen** or **Voronoi's polygons**

Thiessen Polygons



Areas of largest proximity to the 8 points

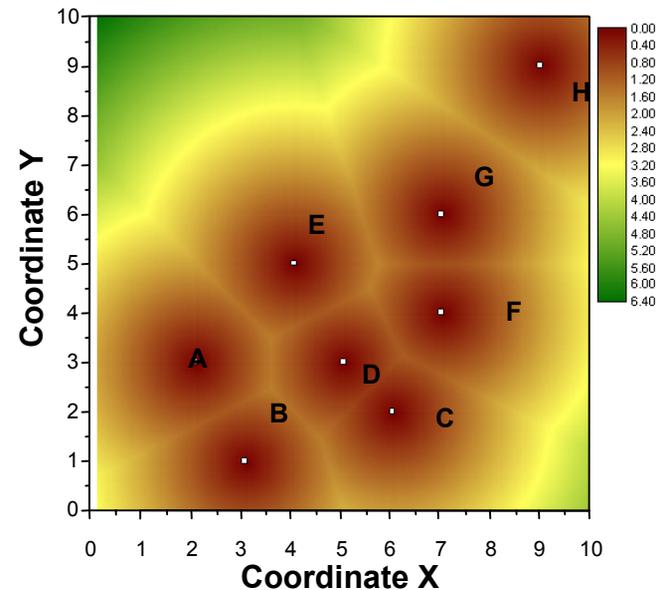


Point regions : Minimum distance

Properties

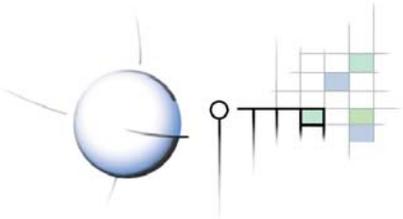
- Distance image from each cell to the nearest point region, the **minimum plane (horizontal, crow fly) distance**
- The graphical representation suggests limits of areas of largest proximity
- Image values express the **proximity (distance)** to the nearest point region, but without identifying it !

Minimum plane distance



Maximum of minimum distances: 6.40

Mean of minimum distances: 1.95

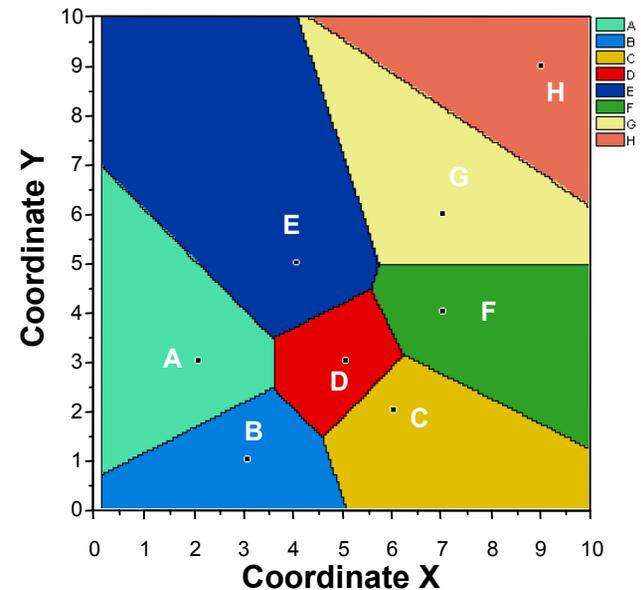


Point regions : Regions of largest proximity

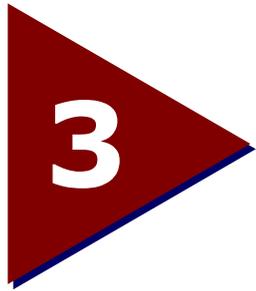
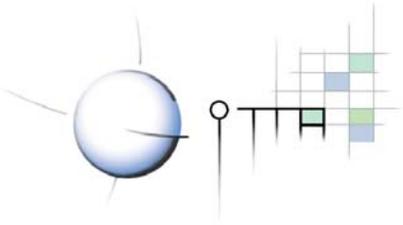
Properties

- Image cells are assigned to the point region with the largest proximity
- Space is divided into areal regions of **largest proximity** to their center
- Image values **identify the point region** having the largest proximity. This information adds to the distance value computed above

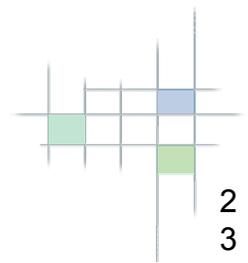
Regions of largest proximity

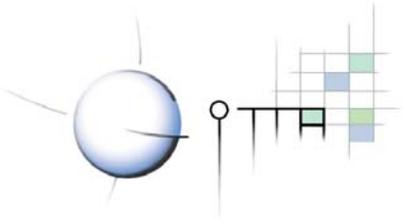


Attribution to the closest point region



Spatial pattern and neighborhood of linear features



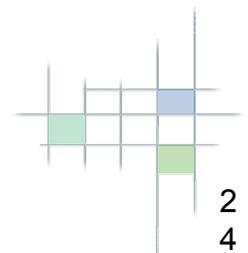


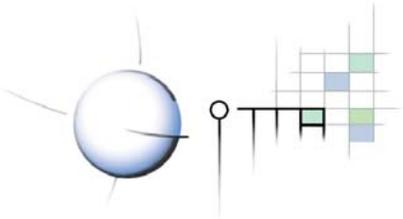
Linear features: Pattern and neighborhood

Different indicators for the spatial distribution and relationships of linear features

- **Spatial pattern description:**
 - mean size, index of spatial density
- **Neighborhood relationships description:**
 - connexity indices of linear features
 - distance to features, areas and regions of largest proximity

Connexity indices for linear features organised as a network will be discussed in the Lesson dedicated to accessibility



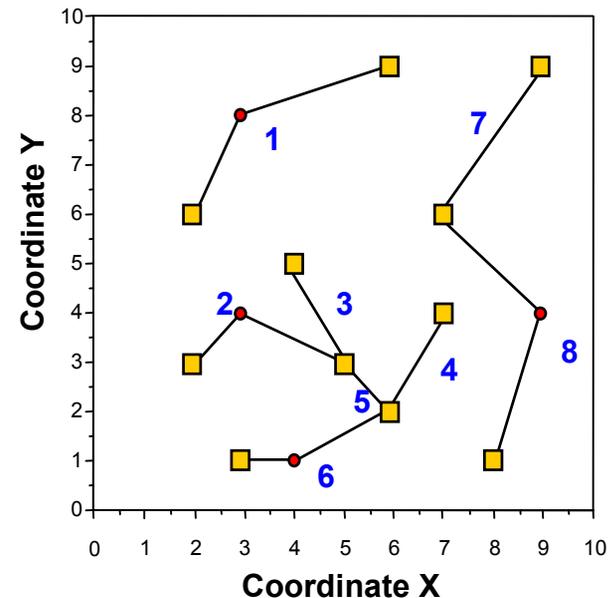


Linear features: Example of a distribution

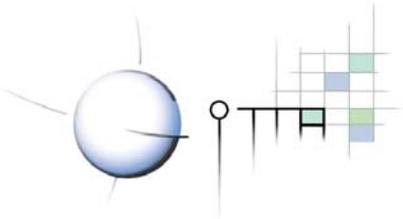
Global description of features

- 8 linear features (**id**)
- Most are **connected** and one is **isolated** :
 - 1 isolated feature: feature 1
 - 2 sets of connected features: {2,3,4,5,6}, {7,8}
- Each linear feature is **simple**, made of a single chain with or without vertices (inflexion points)

Spatial distribution of features



n : identifier



Linear features: Spatial density

Definition

- **Mean size**

- $T_m = L_t / n$

- with: L_t : total length

- n : number of features

this index expresses the **average length** of overall features

- **Density**

- $D = L_t / A$

- with: L_t : total length

- A : area of the region

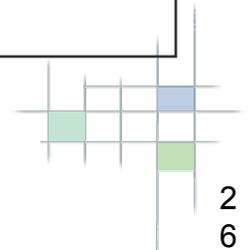
this index can be used to **compare** density of several regions

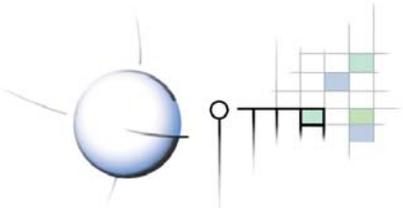
Example

Feature	Size (length)
1	5.3
2	3.5
3	2.2
4	2.2
5	1.4
6	3.2
7	3.6
8	5.9
Σ	27.3
Mean	3.413

$$T_m = 27.3 / 8 = 3.413\text{m}$$

$$D = 27.3 / 100 = 0.273$$





Linear features: Connexity index

Definition

- **C Index of connexity**

- $C = c / 0.5 n (n-1)$

with: c : number of chains

n : number of nodes

The denominator expresses the number of 2 by 2 combinations of connections

Comments

Therefore: $0 \geq C \leq 1$

For a planar network with $n > 3$, C could not be equal to 1

Example

In the above example, the set of 8 features contain 11 nodes and 8 chains, C index value is:

$$C = 8 / 0.5 (11 * 10) = 0.15$$

Comments

The connexity of the whole set is low

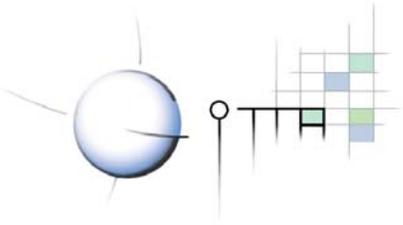
Each one of the 3 subsets has a different level of connexity:

$$C_1 = 1 / 0.5 (2 * 1) = 1$$

$$C_{2-6} = 5 / 0.5 (6 * 5) = 0.33$$

$$C_{7,8} = 2 / 0.5 (3 * 2) = 0.67$$

See also Kansky's beta and gamma indices

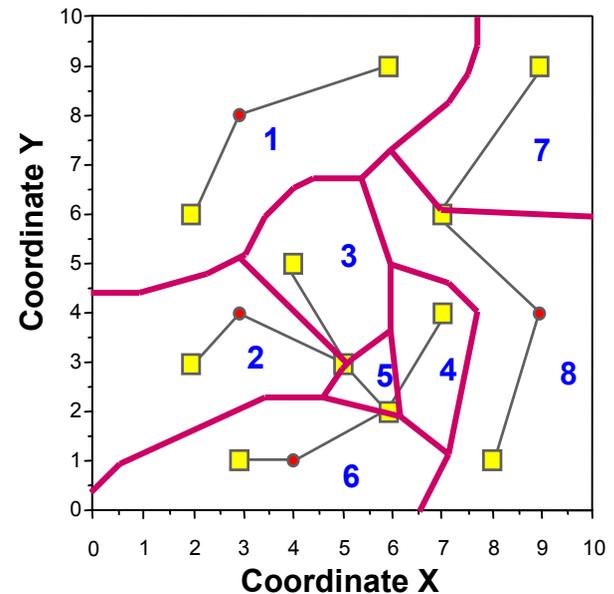


Linear objects: Areas of largest proximity

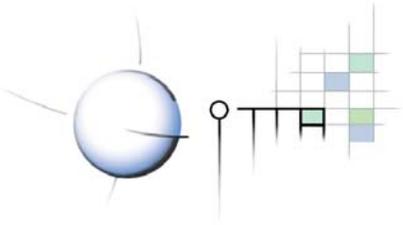
Properties

- The space is divided into areas with the largest proximity to each linear feature
- Any location within each area is closer to its linear feature than any other
- These areas of largest proximity can be associated to the previously presented **Thiessen** or **Voronoi's polygons**

Areas of largest proximity



Areas of largest proximity to the 8 linear features

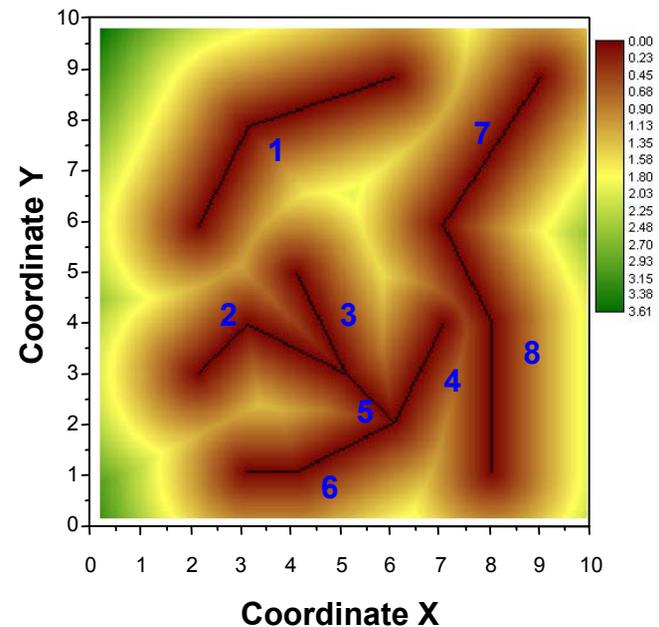


Linear regions: Minimum distance

Properties

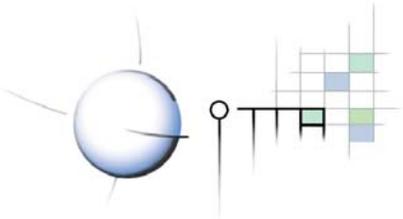
- Distance image from each cell to the nearest linear region, the **minimum plane (horizontal, crow fly) distance**
- The graphical representation suggests limits of areas of largest proximity
- Image values express the **proximity (distance)** to the nearest linear region, but without identifying it !

Minimum plane distance



Maximum of minimum distances: 3.61

Mean of minimum distances: 0.95

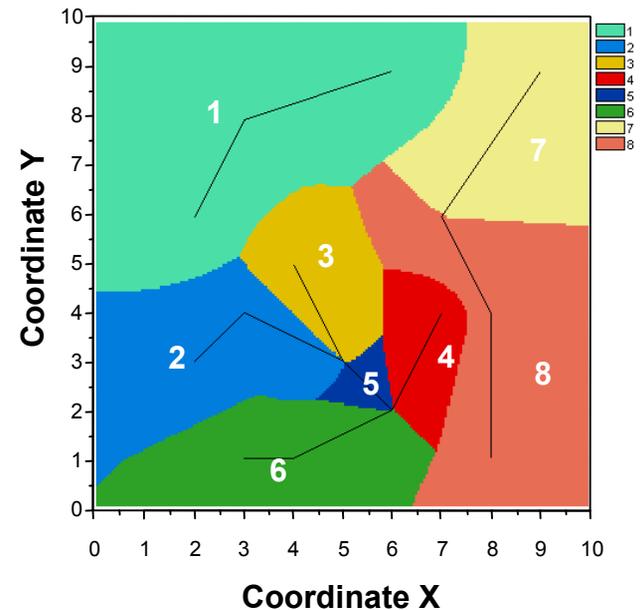


Linear regions: Regions of largest proximity

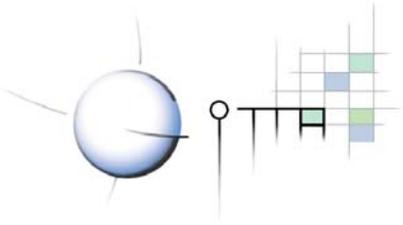
Properties

- Image cells are assigned to the linear region with the largest proximity
- Space is divided into areal regions of **largest proximity** to their linear feature
- Image values **identify the linear region** having the largest proximity. This information adds to the distance value computed above

Regions of largest proximity

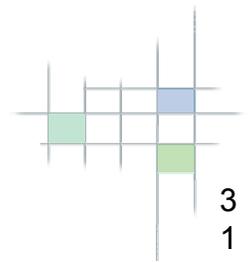


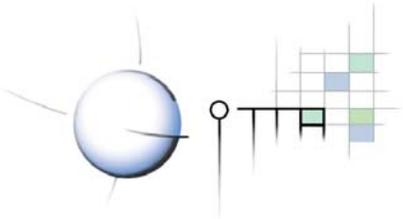
Attribution to the closest linear region



4

Spatial pattern and neighborhood of areal features



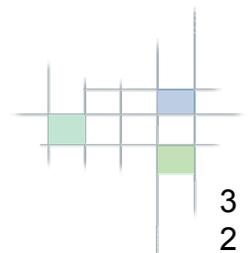


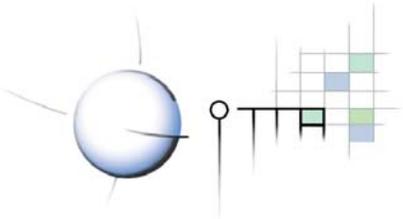
Areal features: Pattern and neighborhood

Different indicators for the spatial distribution and relationships of areal features

- **Spatial pattern description:**
 - indices of size, index of spatial density
- **Neighborhood relationships description:**
 - areas of largest proximity
 - distance to features, regions of largest proximity

Proposed density indices are just a selection of indices used in landscape analysis (see Fragstats)



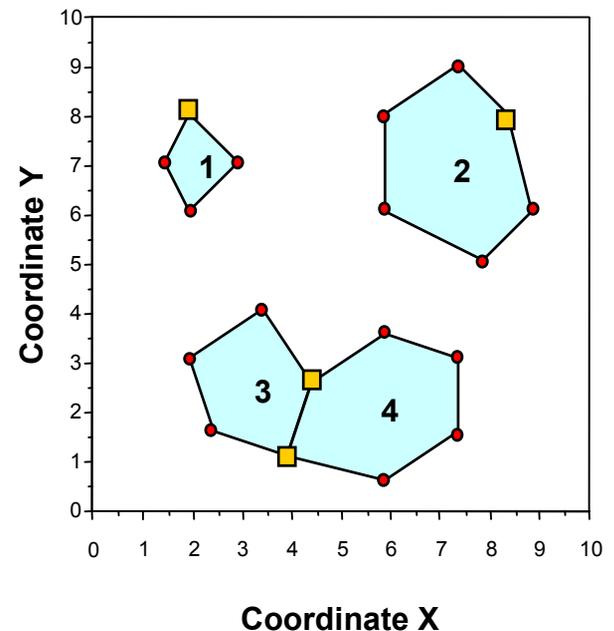


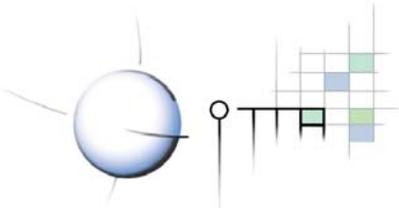
Areal features: Example of a distribution

Global description of features

- 4 areal features (id)
- Some are **contiguous** and some other **isolated** :
 - 2 isolated features: 1 and 2
 - 2 contiguous features: 3 and 4
- Each areal feature is **simple**, made of a single chain (no inner or outer islands)

Spatial distribution of features





Areal features: Pattern indices (1)

Context

- **Landscape analysis**

Concepts attached to Landscape analysis are used in this Unit as follow :

- **patch** : each of the 4 areal features
- **class** : the set of the 4 areal features
- **landscape** : the study area

Example

- **Geometrical properties**

- **areal features**

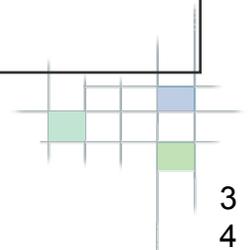
<u>Feature</u>	<u>Perimeter</u>	<u>Area</u>
1	5.065	1.5
2	10.929	8.25
3	8.349	4.63
4	10.329	7.25
Class	31.512 *	21.63

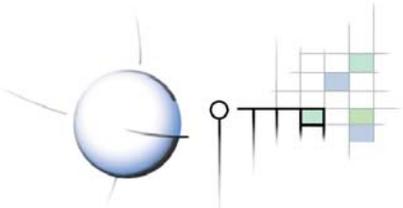
* The perimeter value takes into account the contiguity of areas 3 and 4

- **study area**

Perimeter = $4 \times 10 = 40\text{m}$

Area = $10 \times 10 = 100\text{m}^2$





Areal features: Pattern indices (2)

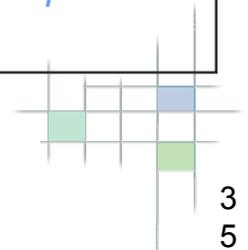
Definition

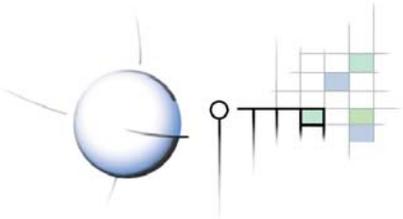
- **Number of areas (NP)**
 $NP = \text{number of features}$
- **Density (PD)**
 $PD = NP / A_R$
with: A_R : area of the region
- **Extensivity (%Land)**
 $\%Land = 100 (A_C / A_R)$
with: A_C : area of the class
- **Mean size (MPS)**
 $MPS = A_C / NP$
- **Size variability (PSSD)**
 $PSSD = \text{standard deviation of the area (acreage)}$

Example

- **Number of areas (NP)**
 $NP = 4$
- **Density (PD)**
 $PD = 4 / 100 = 0.04$
- **Extensivity (%Land)**
 $\%Land = 100(21.63/100) = 21.63\%$
- **Mean size (MPS)**
 $MPS = 21.63 / 4 = 5.41m^2$
- **Size variability (PSSD)**
 $PSSD = 27.12/3 = 3.01$

The derived coefficient of variation (PSSD / MPS) allows to compare different pattern distributions



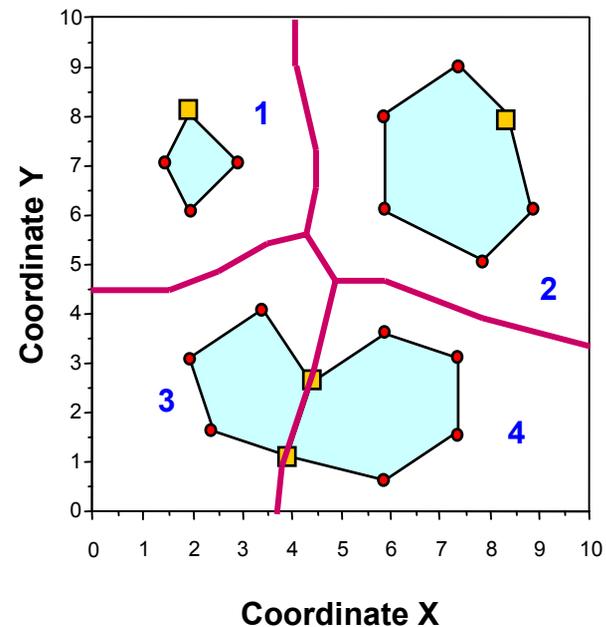


Areal objects: Areas of largest proximity

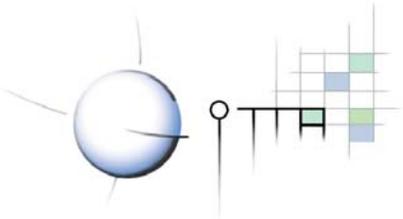
Properties

- The space is divided into areas with the largest proximity to each areal feature
- Any location within each area is closer to its areal feature than any other
- These areas of largest proximity can be associated to the previously presented **Thiessen** or **Voronoi's polygons**

Areas of largest proximity



Areas of largest proximity to the 4 areal features

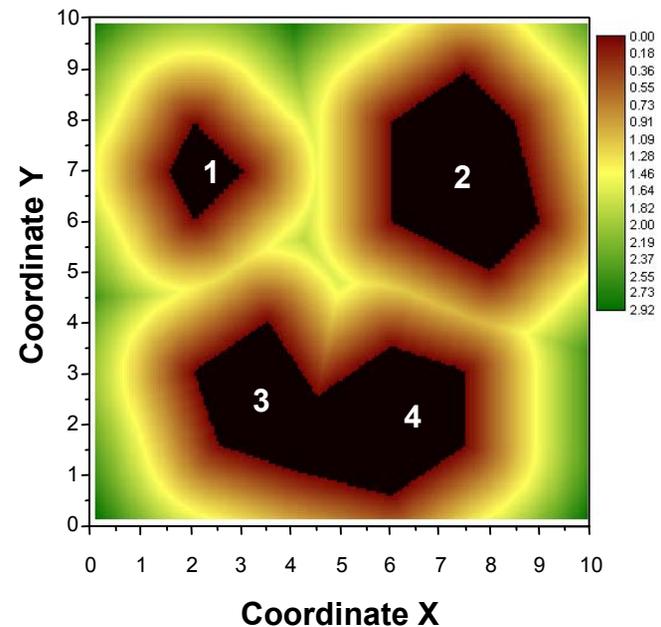


Areal regions: Minimum distance

Properties

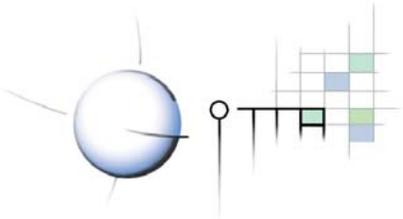
- Distance image from each cell to the nearest areal region, the **minimum plane (horizontal, crow fly) distance**
- The graphical representation suggests limits of areas of largest proximity
- Image values express the **proximity (distance)** to the nearest areal region, but without identifying it !

Minimum plane distance



Maximum of minimum distances: 2.92

Mean of minimum distances: 0.83

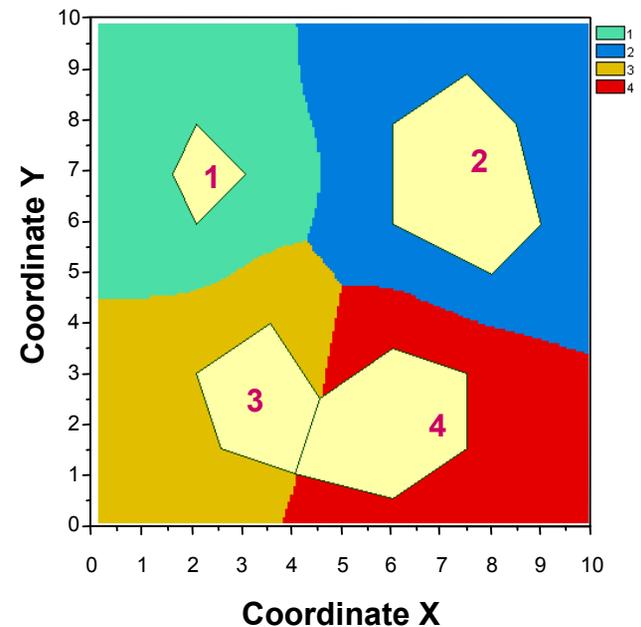


Linear regions: Regions of largest proximity

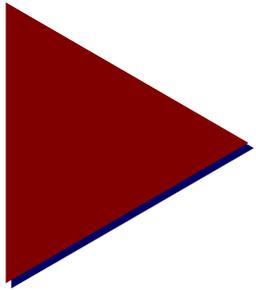
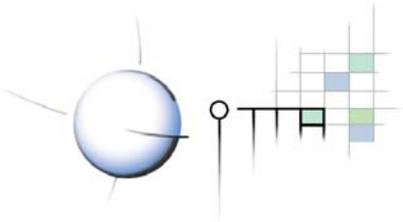
Properties

- Image cells are assigned to the areal region with the largest proximity
- Space is divided into areal regions of **largest proximity** to their areal feature
- Image values **identify the areal region** having the largest proximity. This information adds to the distance value computed above

Regions of largest proximity



Attribution to the closest areal region



End of Unit

