ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

RESCIF
Réseau d'excellence des sciences de l'ingénieur de la Francophonie

Discrete Variables– Spatial Arrangement and Neighbourhood

An Introduction to Geographic Information Systems

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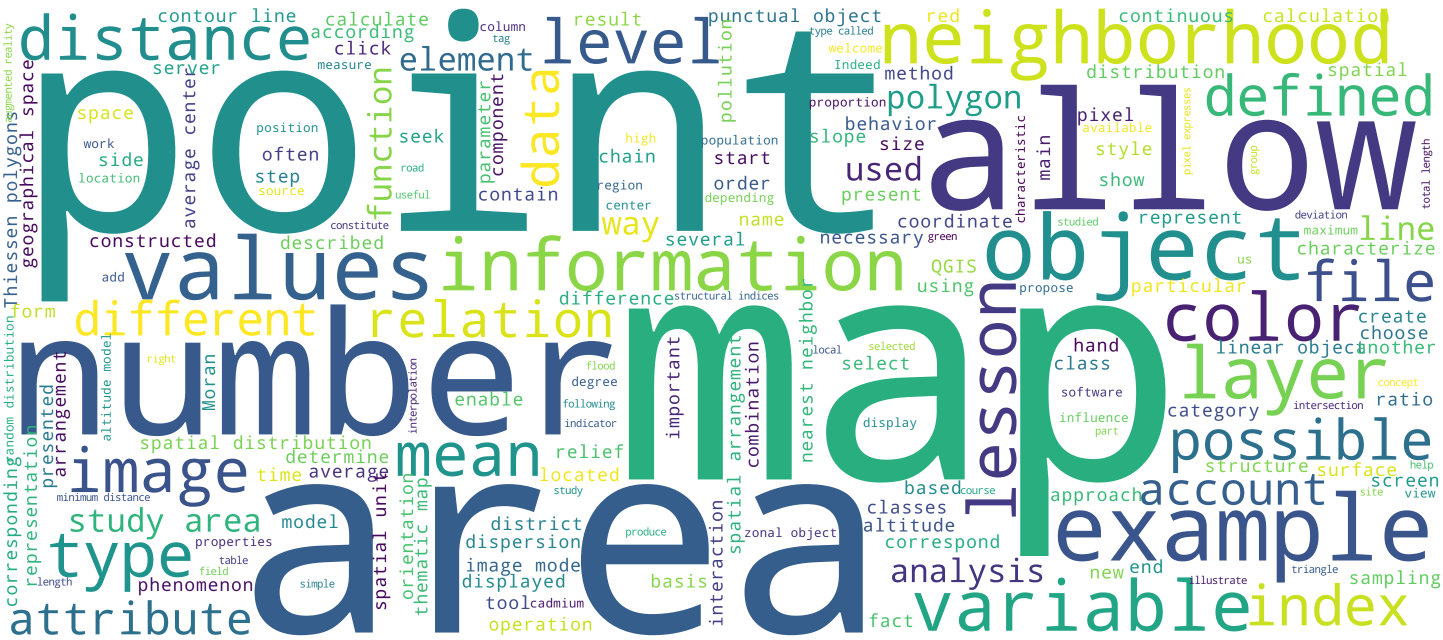

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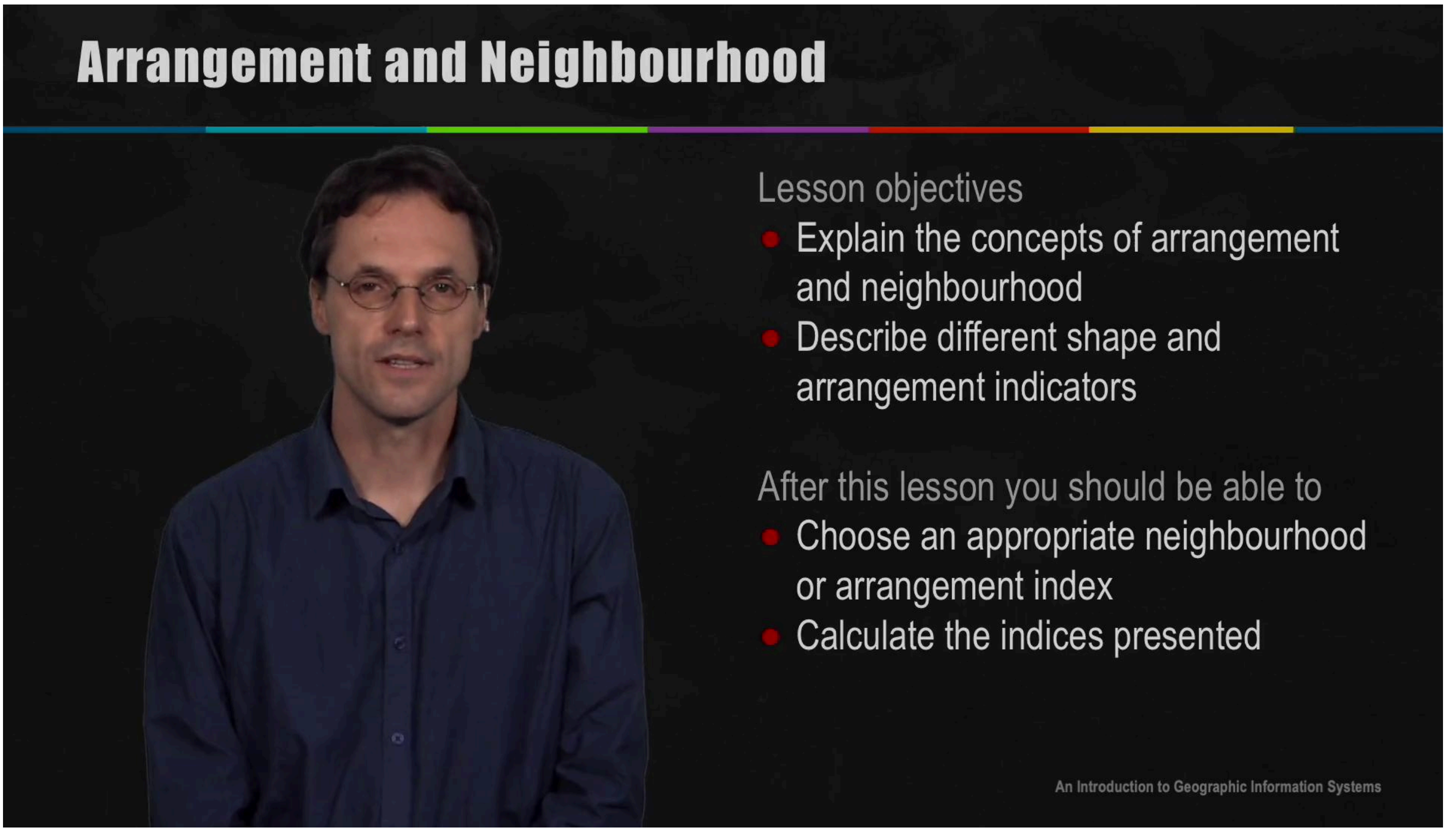


Hello and welcome to this lesson which is about the spatial arrangement and the spatial neighborhood of discrete variables presented in the previous lesson. Arrangement and neighborhood are notions that allow to describe the remarkable properties of a set of objects by means of indicators whilst so far, we have characterized the spatial units taken individually. By means of arrangement and neighborhood, we can thus analyze the spatial relations between several groups of spatial objects. The analysis of these relations is necessary for example during the search of the optimal location of a hospital, an operation during which we will seek to determine the area of influence of the institution as well as its accessibility. The goals of this lesson are to present the notions of spatial arrangement and neighborhood and to describe different indicators of groups of spatial objects. And this so that at the end of this lesson, you are able to select from them the best index of spatial arrangement or neighborhood arrangement according to your needs and of course also to calculate the value of that index.

Notes

Summary

0m 31s

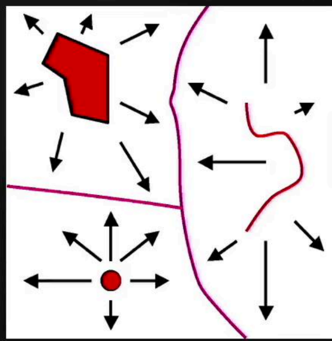
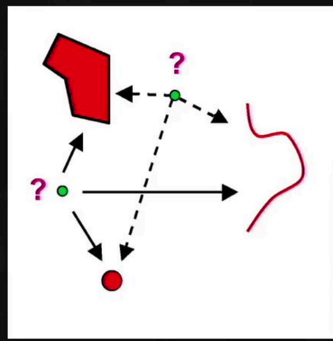
Arrangement and Neighbourhood

Describe a set of objects with a single indicator

- Arrangement : organization of objects relative to one another
- Neighbourhood : minimum distance to an object or objects (more restrictive topological concept)

Arrangement and neighbourhood are defined according to 3 criteria:

- Position
- Dispersion
- Proximity

Index	Planar space, geometric dimension
Position	E.g. mean centre, median centre
Dispersion	E.g. standard deviation, interquartile range
Proximity	E.g. planar distance

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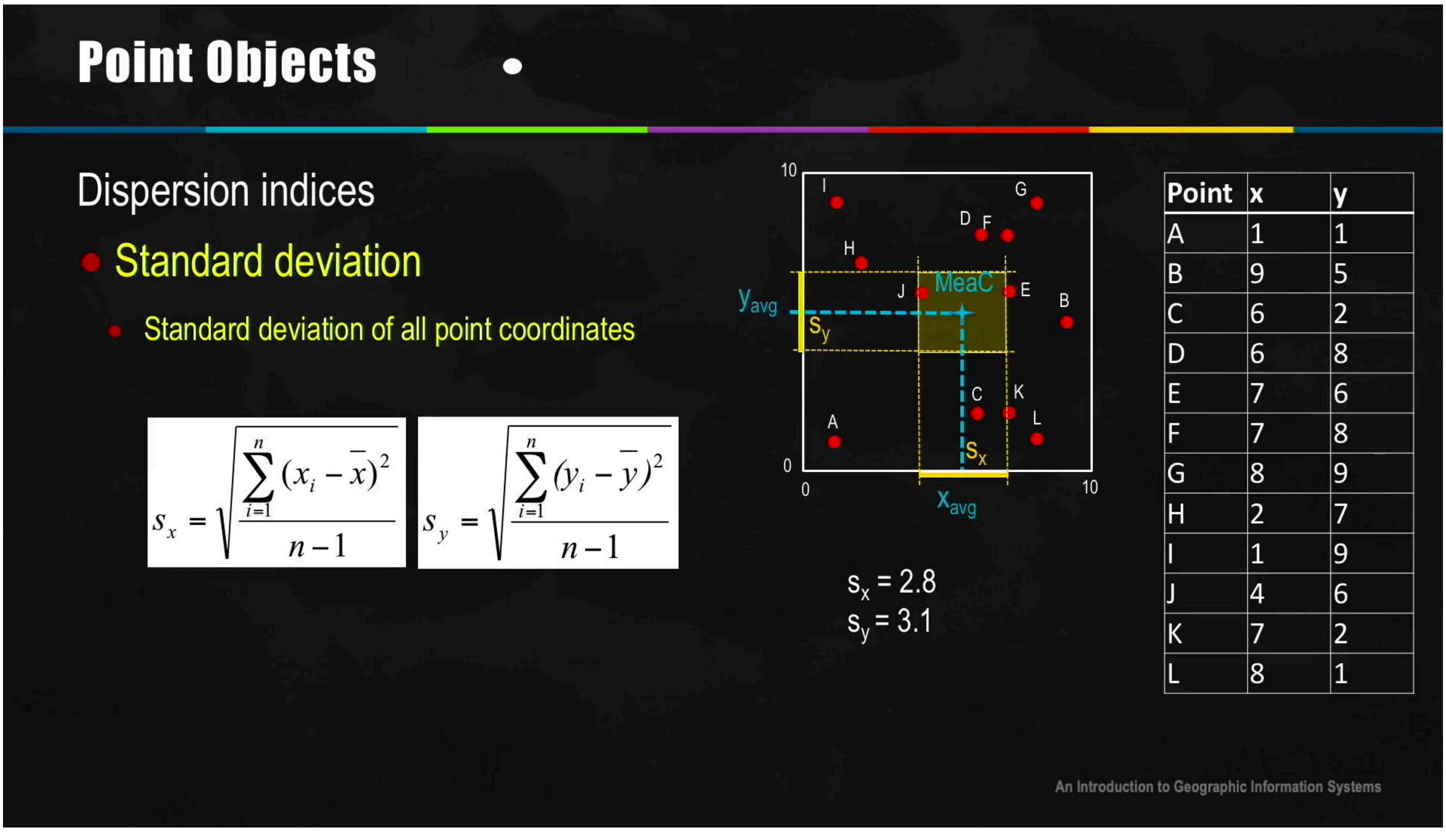
The spatial arrangement is the relative organization of objects in the geographical space. In that case, the emphasis is on the fields of influence of objects. The neighborhood must be understood in a geometric and topological sense, so the set of relations perceived which allow us to locate objects from each another. The neighborhood is thus a spatial notion which allows to answer the question of who is next to who. With the neighborhood, we will work with the concept of object distances from each other. The central point of arrangement and neighborhood notions lies in the nature of the geographical space in relation to a considered phenomenon. A distance for example depends on the means of transport used and the characteristics of the journey if we take into account the slope or the quality of the road. From the point of view of the geographical space modeling, in this lesson we consider only the geometric dimension, without taking into account the thematic dimension. The space is therefore plane, homogeneous and isotropic. In this context, arrangement and spatial neighborhood are described by three criteria: the position, the dispersion and the proximity, that we will address in the case of punctual, surface and linear objects.

Notes

Summary

1m 48s

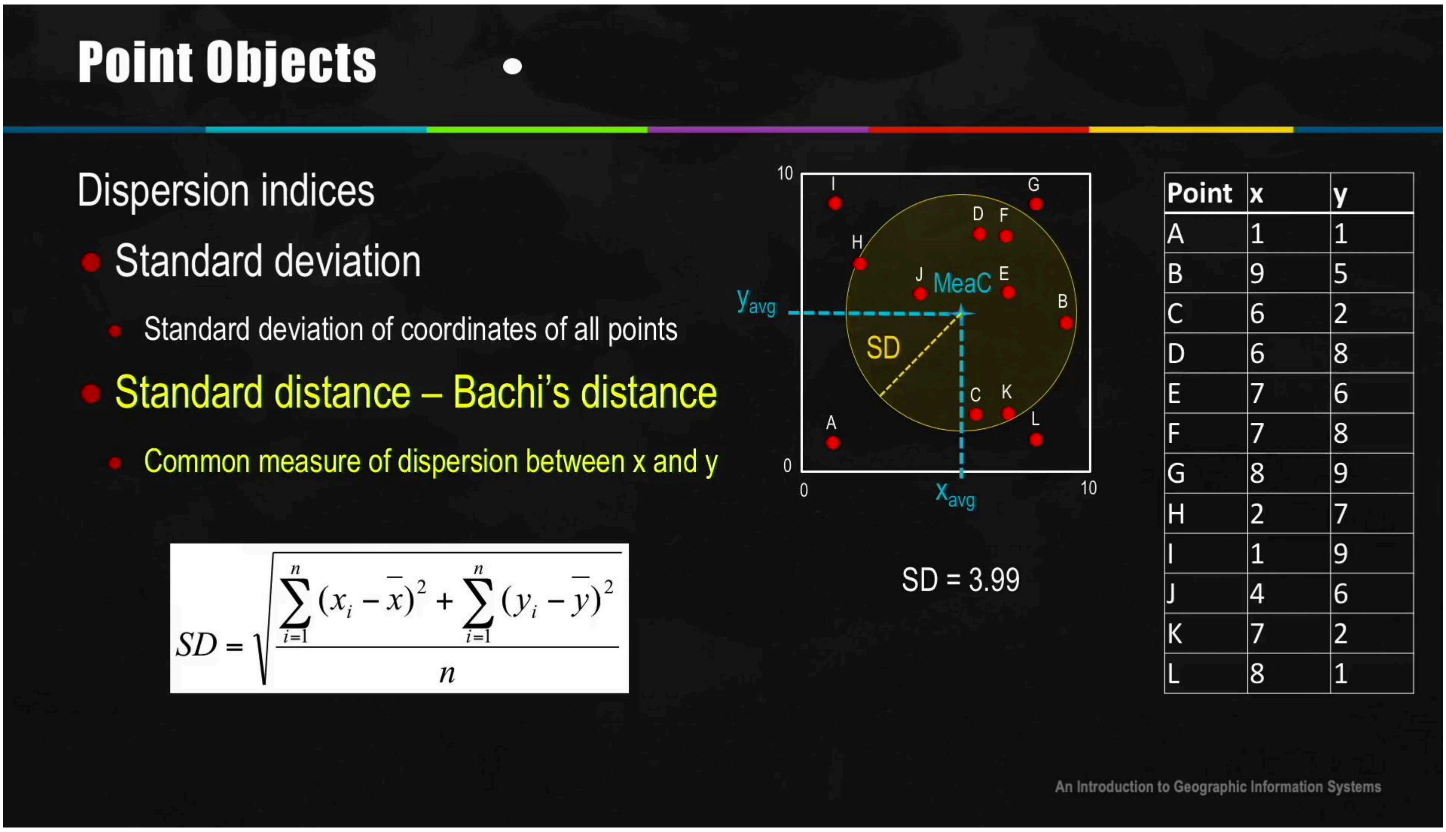


In the case of punctual objects, there is no need to treat separately the object or image modes. The spatial distribution indicators which are now presented are described in object mode. We will use the distribution of the twelve punctual objects that are displayed here in red to illustrate these indicators. We begin with the position indices. There are two. The first is the average center which is defined by the mean coordinates of X and Y. The average center is also called center of gravity or barycenter. The second is the median center. It is defined by the medians of the coordinates of X and Y. This index is more robust than the average center because it is less influenced by positions whose coordinates are extreme. Let's move on to statistical indices of dispersion. The dispersion is described in particular by the standard deviation S of the coordinates of X and Y. These two intervals delimit a zone whose interpretation depends on the phenomenon being studied.

Notes

Summary

3m 18s



The dispersion can also be described by a common measure in X and Y in relation to the average center and which is called standard distance DS, or Bachi distance. The DS radius is obtained by adding the sum of the deviations from the mean of the square longitudes to the sum of the deviations from the mean of the square latitudes, divided by the number of points considered. The advantage of this approach is to propose a unique descriptor for the two axes of coordinates X and Y.

Notes

Summary

4m 23s

Point Objects

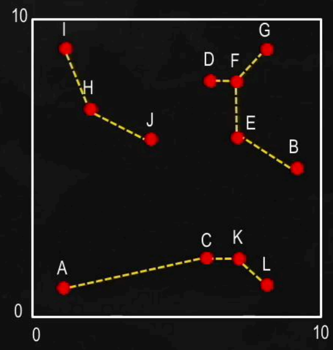
Spatial arrangement indices

- **R Index** – nearest neighbour index
  - Compares an observed distribution to a theoretical random distribution

$$R = \frac{average\ distance\ to\ nearest\ neighbour}{average\ distance\ for\ a\ random\ distribution}$$

$$R = \frac{\bar{d}}{d_{rand}} \quad \text{or} \quad \bar{d} = \frac{1}{n}\sum_i d_i \quad \text{and} \quad d_{rand} = \frac{1}{2\sqrt{n/S}}$$

S = area of study zone n = number of points



$\bar{d}$ = 1.89

d_{rand} = 1.44

Pair	Distance
AC	5.1
BE	2.2
CK	1.0
DF	1.0
EF	2.0
FD	1.0
GF	1.4
HI	2.2
IH	2.2
JH	2.2
KC	1.0
LK	1.4

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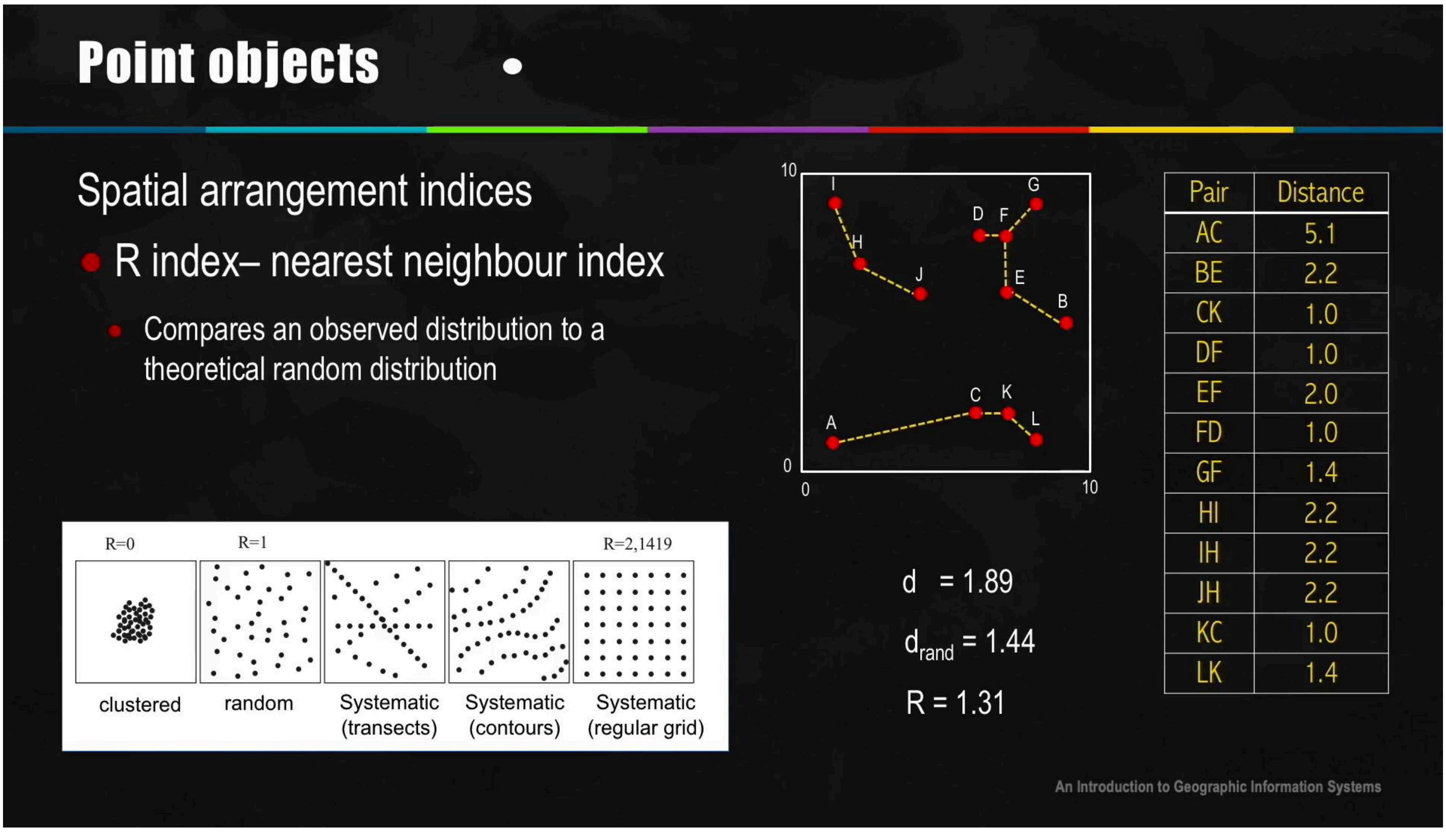
The spatial arrangement indices of punctual objects are very important tools to ensure geographical representativeness of a sampling. For cost reasons, we limit ourselves most often to raise the valuesin some points of the space which are considered representative instead of measuring a continuous or discontinuous phenomenon in any point in space. Here, as a first step, we characterize the distribution of sampling points by an index of the nearest neighbor called R index. This index compares an observed distribution of points to a random distribution. The R index is the ratio between the average distance to the nearest neighbor and the average distance for a random distribution.

Notes

Summary

4m 54s

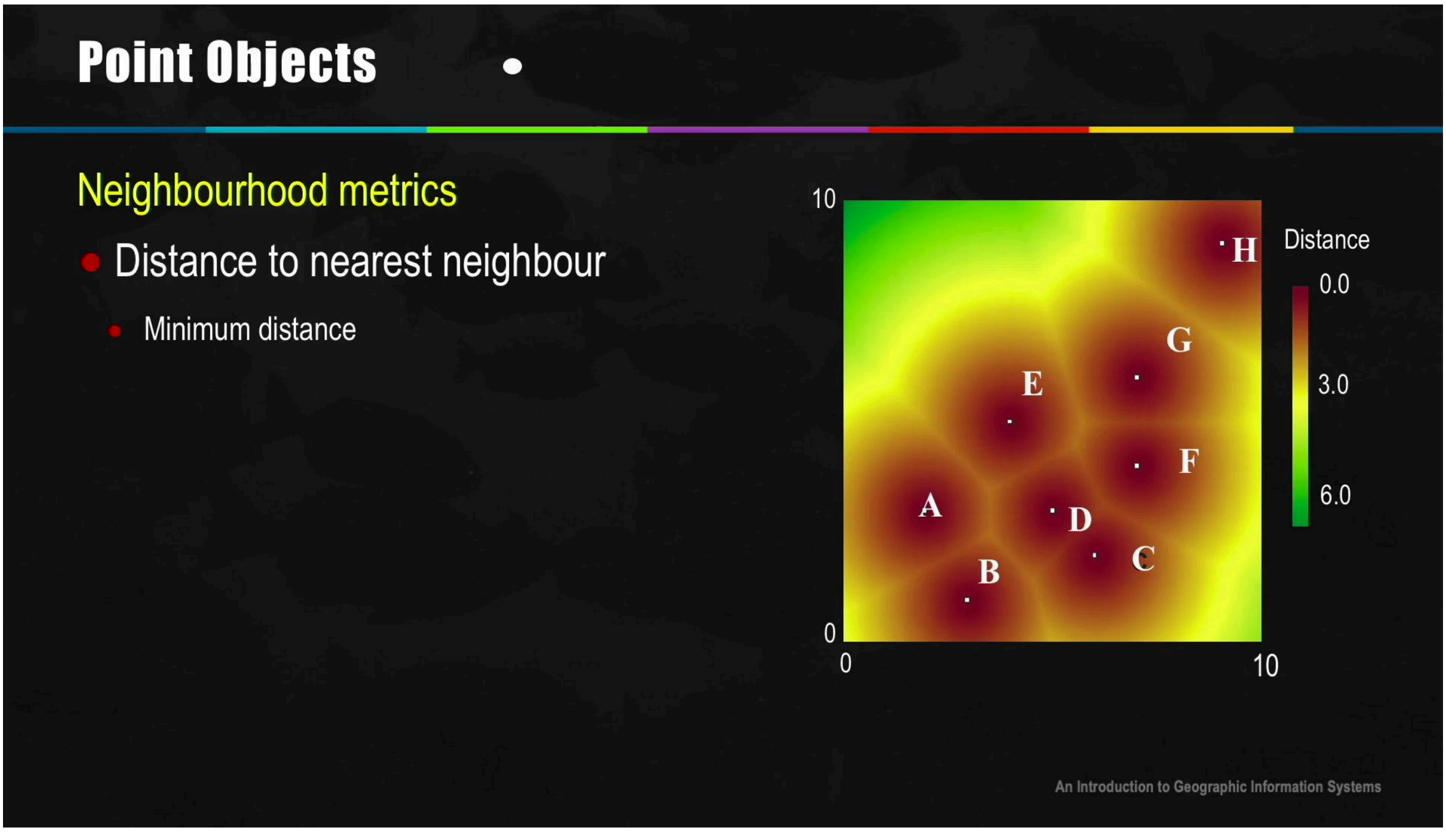


And here D from I is the distance from point I to its nearest neighbor, S is the area of the study area and N is the number of measuring points. There are a number of typical spatial distributions that we are likely to encounter in the case where the area of the sampled domain is known. These are the group distribution for which R is equal to 0, the random distribution for which R is equal to 1 and we also have systematic spatial distributions which correspond to a given sampling strategy, for example, performed along transects, either along directional axes, or along contour lines, or finally, a systematic spatial distribution for which sampling is carried out in a regular mesh.

Notes

Summary

5m 43s

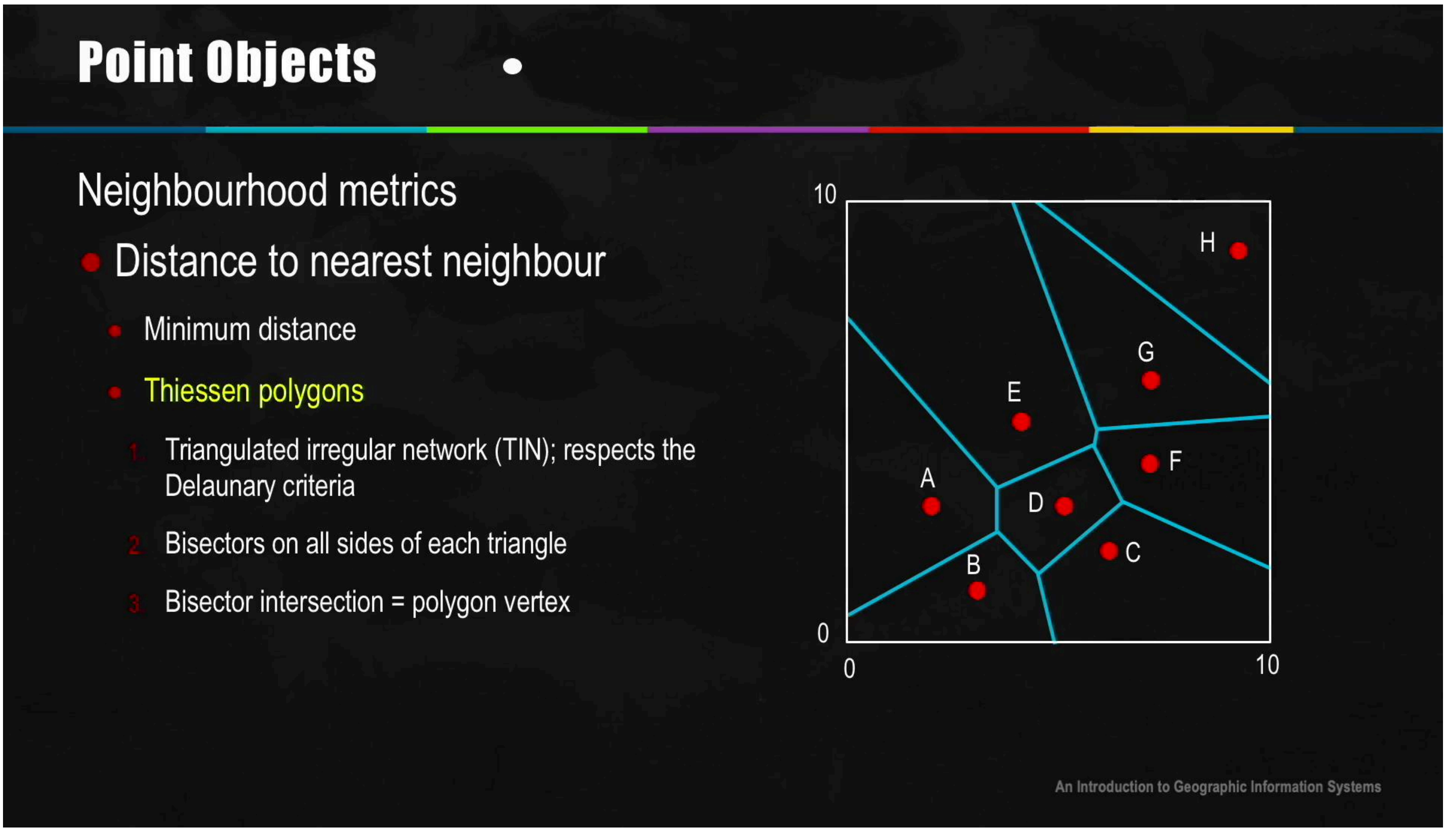


When we seek to characterize the spatial distribution of a cloud of points, we should also be interested in the relations that exist between them and the neighborhood relation which we already discussed in module 1 is one of them. The neighborhood is defined by the minimum distance to one or more objects. This distance can be expressed continuously, like here on the screen, in image mode, the color of each pixel expresses the distance to the nearest point. The distance can also be expressed discreetly. We will seek to represent the areas in which all the points are closer to a particular object than of all the others. In that case, the space is divided into Thiessen's polygons.

Notes

Summary

6m 29s

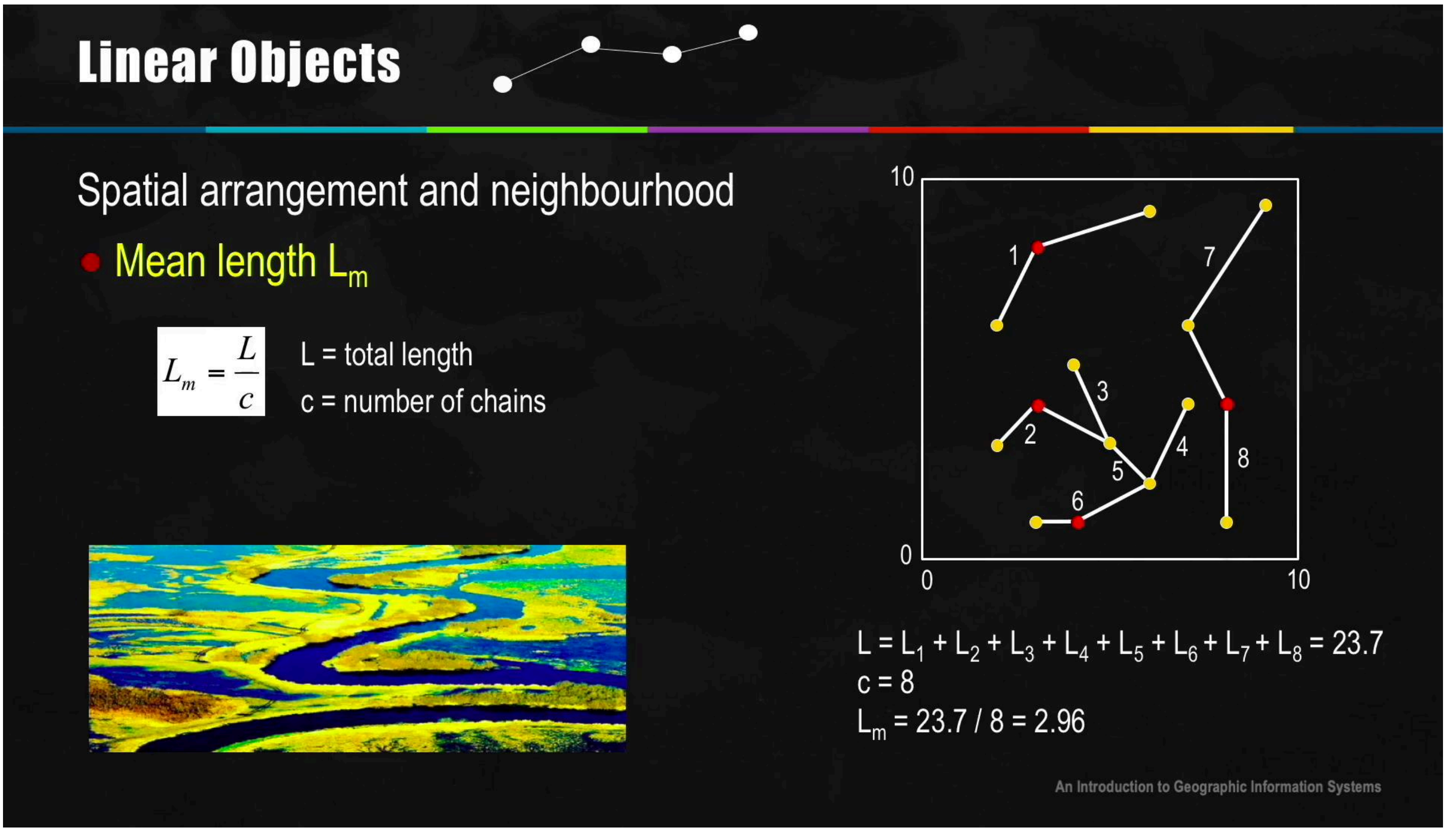


To build Thiessen's polygons, we use a triangulated network, TIN, for Triangulated Irregular Network, which is constructed by connecting the support points with each other so as to form a triangular mesh network. A TIN verified according to the Delaunay criterion respects the rule according to which the circumscribed circle of each of the triangles contains no other points. From the triangulated network, we will build the mediators of each of the sides of the triangles and the intersection between the mediators defines the vertices of Thiessen's polygons. Thiessen's polygons are also called Voronoi's diagrams, Voronoi's decompositions, Voronoi's partitions or Voronoi's polygons or Dirichlet's tessellations.

Notes

Summary

7m 12s

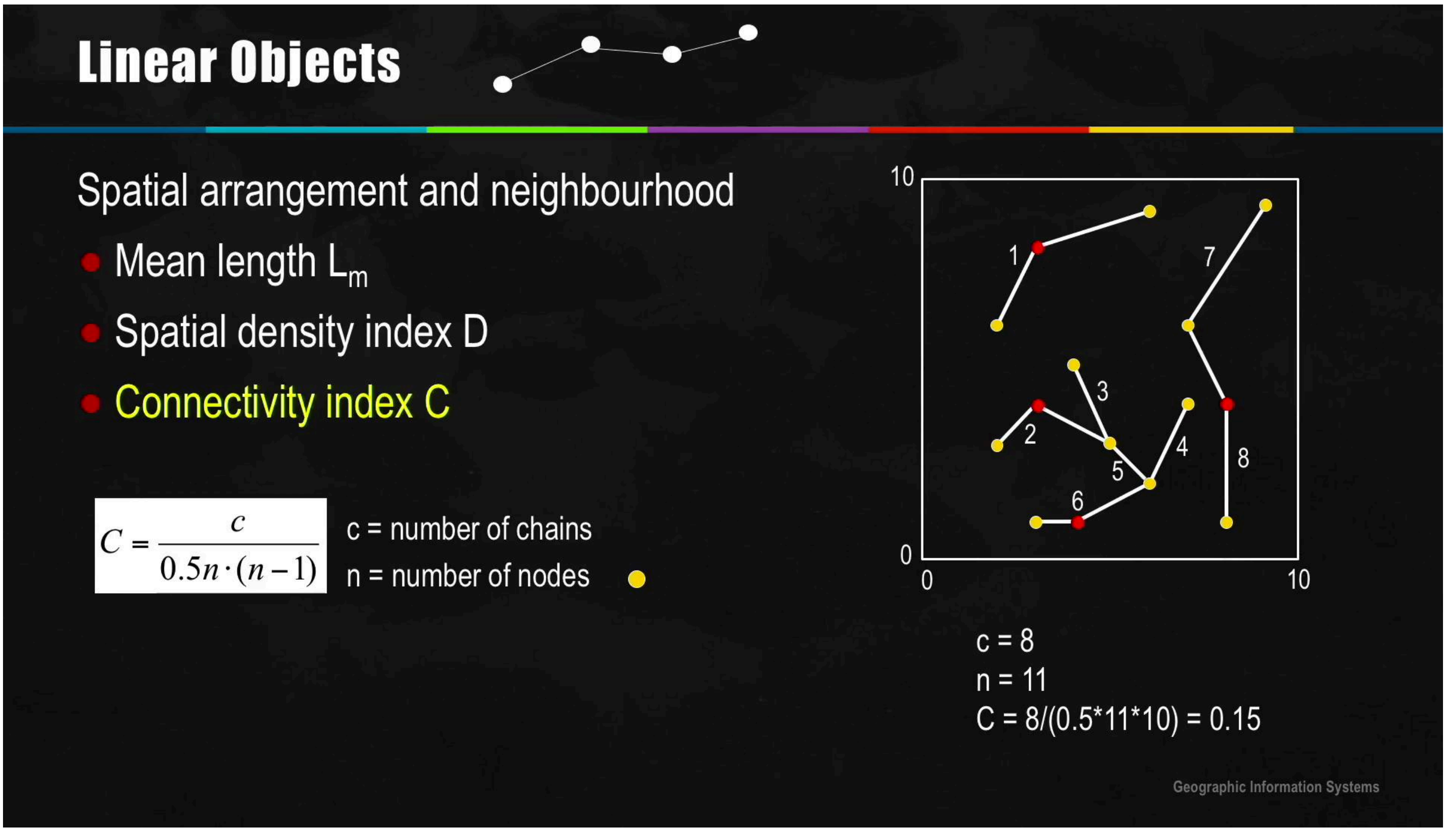


Let us now turn to the analysis of the spatial arrangement and neighborhood of linear objects. Linear objects generally represent a network, a hydro-graphic network or a road network for example. There are several descriptors of the spatial arrangement and neighborhood of this type of objects. To start, the average size Tm is defined by the ratio between the total length of chains and the number of chains.

Notes

Summary

8m 14s

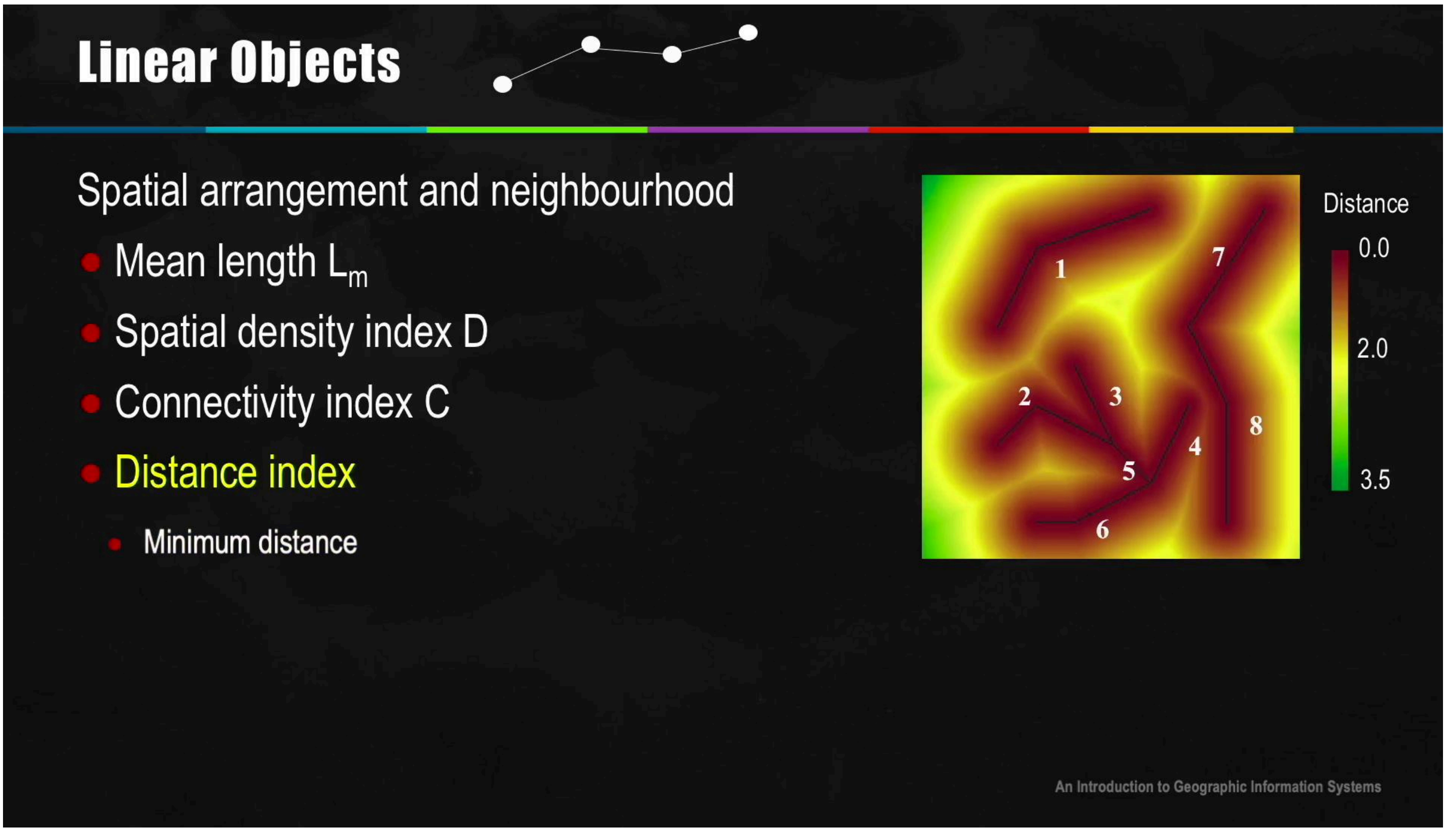


Note that the red dots here connect segments of the same chain. The spatial density index D is the ratio between the total length of the network and the area of the zone under consideration. The index C of connectivity reflects the degree of complexity of a network. It is equal to the number of chains divided by a denominator which expresses the number of combinations two by two between the nodes, but this without taking into account the fact that the segment is connected or not. Here the index is 0.15 since C is equal to 8 chains divided by 0.5 times 11 nodes times 10.

Notes

Summary

8m 42s



The minimum distance index is defined in the same way as for punctual objects. In image mode, the color of each pixel expresses the distance to the nearest pixel belonging to a segment.

Notes

Summary

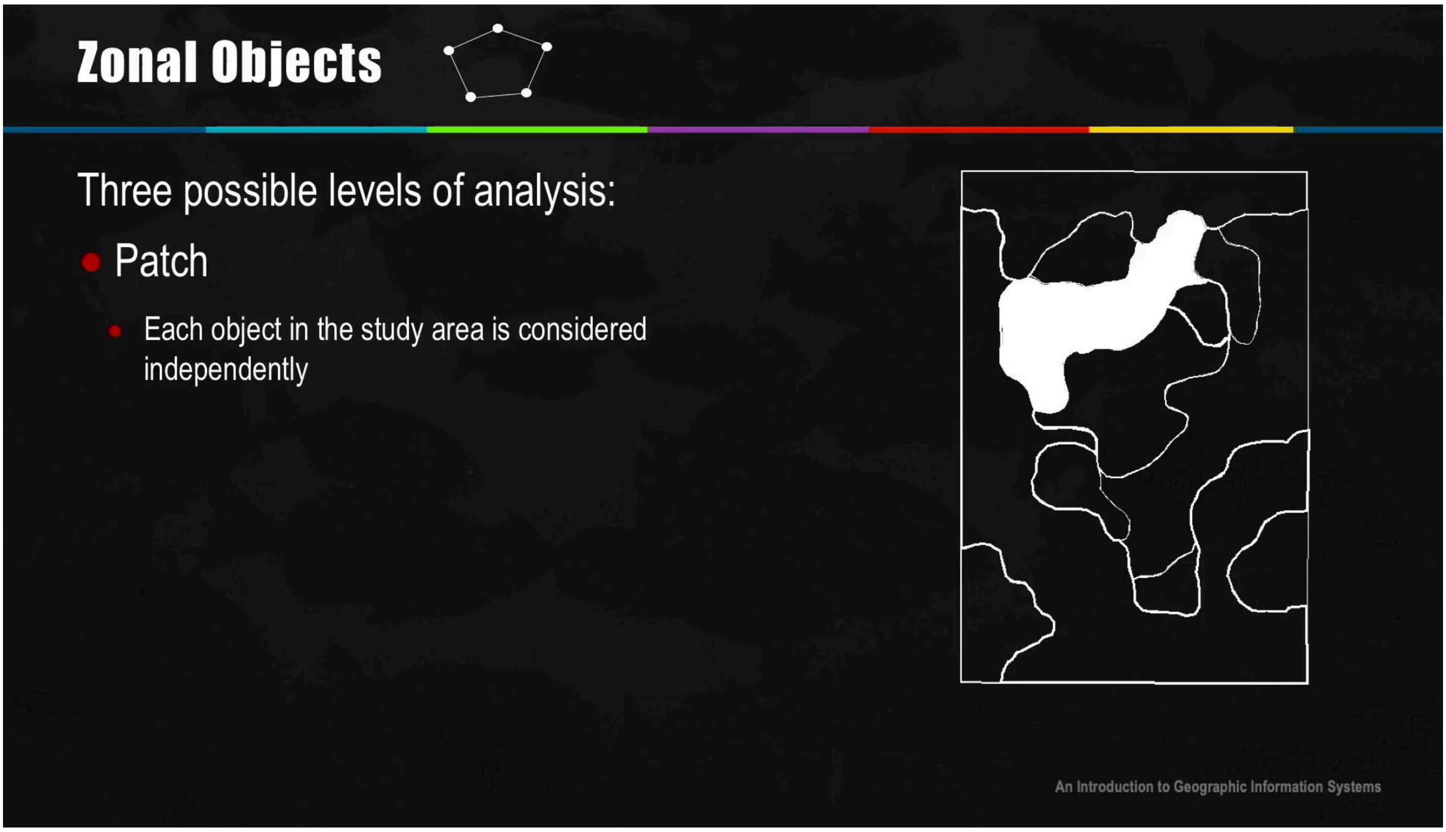
9m 26s

Areas of closer proximity to chains are also constructed in the same way as for punctual objects, so on the basis of an irregular triangular network built on the basis of the nodes, then using the intersection of the mediators of the sides of the triangles to obtain the vertices of Thiessen's polygons.

Notes

Summary

9m 38s

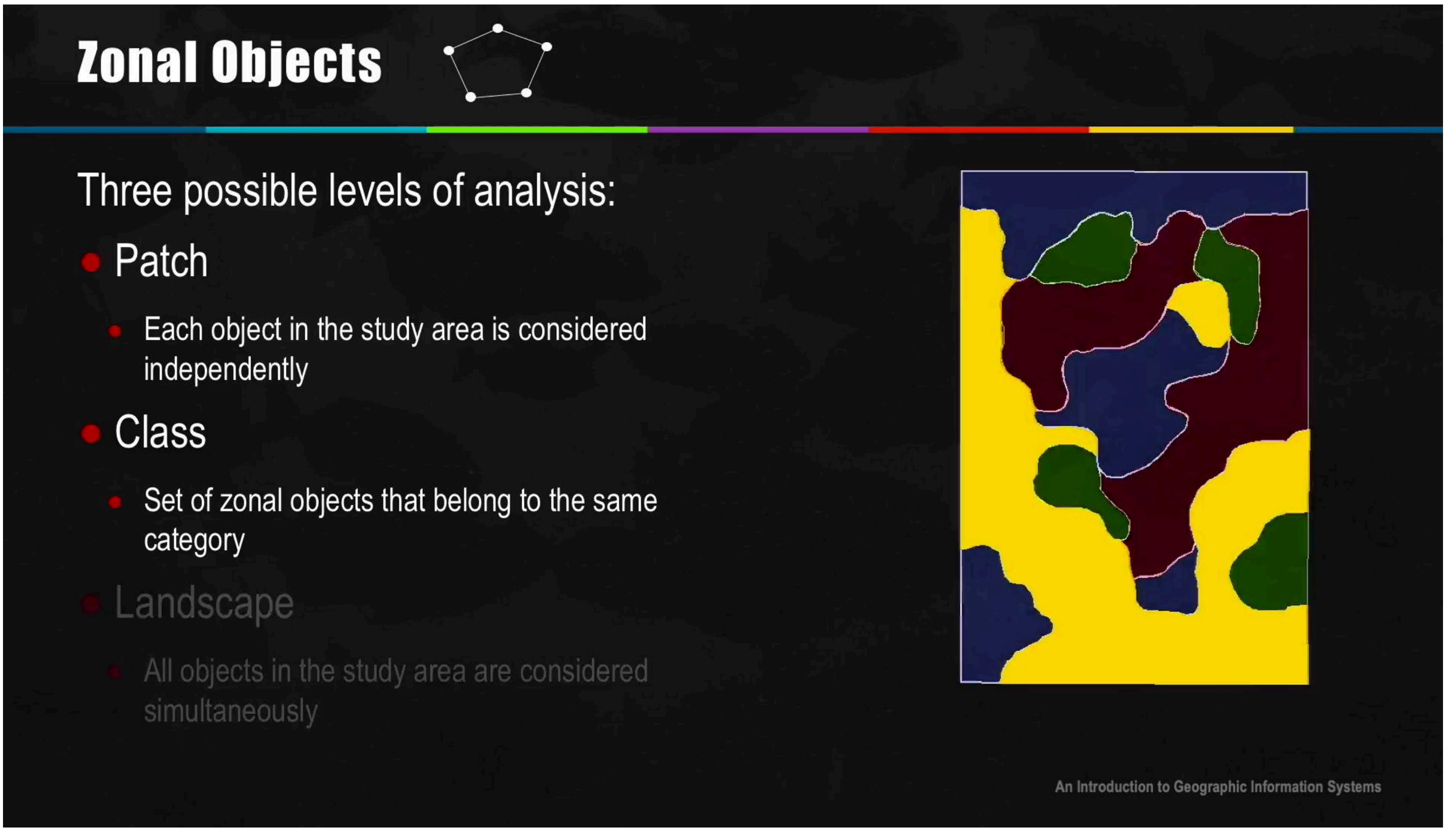


The review of the arrangement and neighborhood of surface or zonal objects is very useful in landscape analysis. The idea is to characterize the observed arrangements in reference to categories of size, shape, to thematic categories, perhaps even a combination of these. We will examine the arrangement of objects, either by thematic classes or categories, or for all the classes combined. The arrangement here is synonymous with structure and that is why the corresponding indices are called structural indices. We propose here a selection of structural indices in landscape analysis. There are three types. The first type, called patch, is centered on each surface object of the study area.

Notes

Summary

10m 08s

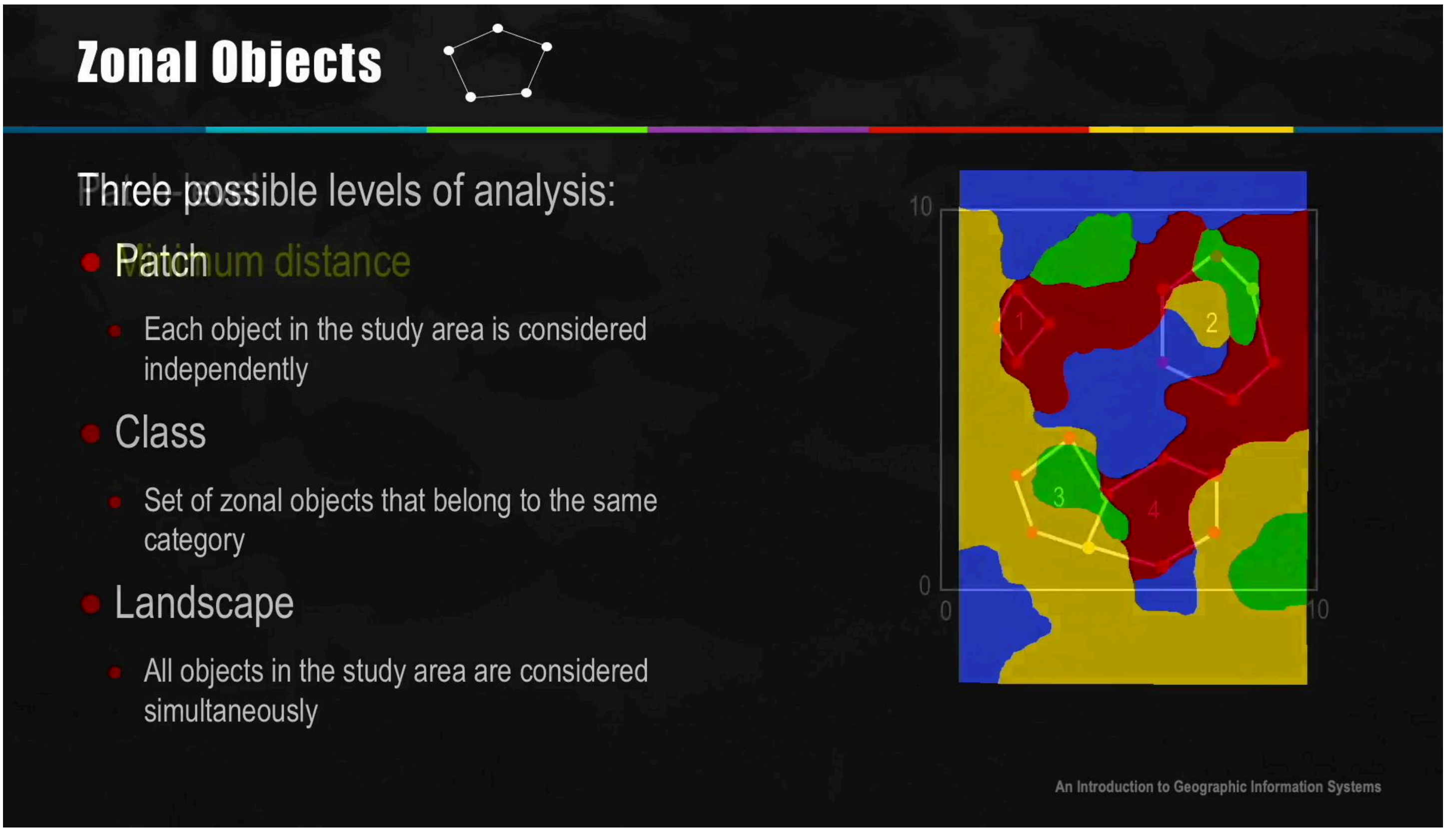


The second type, called class, considers all the zonal objects assigned to the same category.

Notes

Summary

11m 00s



Finally, the third type, called landscape, covers the entire study area. You should note that these various indices which are based on a limited number of variables are often highly correlated. It is the skills of the analyst which will enable to select the most relevant index. In image mode, the proposed procedures and indices are substantially the same. The zonal object becomes a zonal region.

Notes

Summary

11m 11s

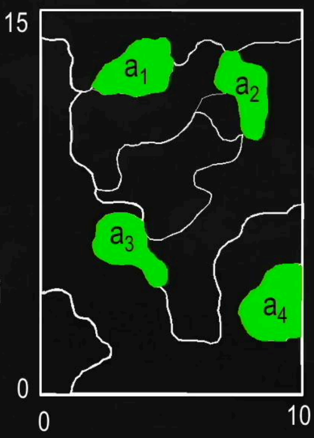
Zonal Objects

Class-level

- Different indices that combine:
  - Object area
  - Object perimeter
  - Number of objects
- Simple indices
  - Mean patch size (MPS)
  - Edge density (ED)
- Complex indices
  - Mean patch fractal dimension (MPFD)

$$MPFD = \frac{1}{n_i} \sum_j \frac{2\ln(p_{ij})}{\ln(a_{ij})}$$

n_i = number of objects in class i



Object	p	a
1	8.4	9.9
2	8.5	2.9
3	9.0	3.2
4	8.9	4.5

n = 4
MPFD = 2.7

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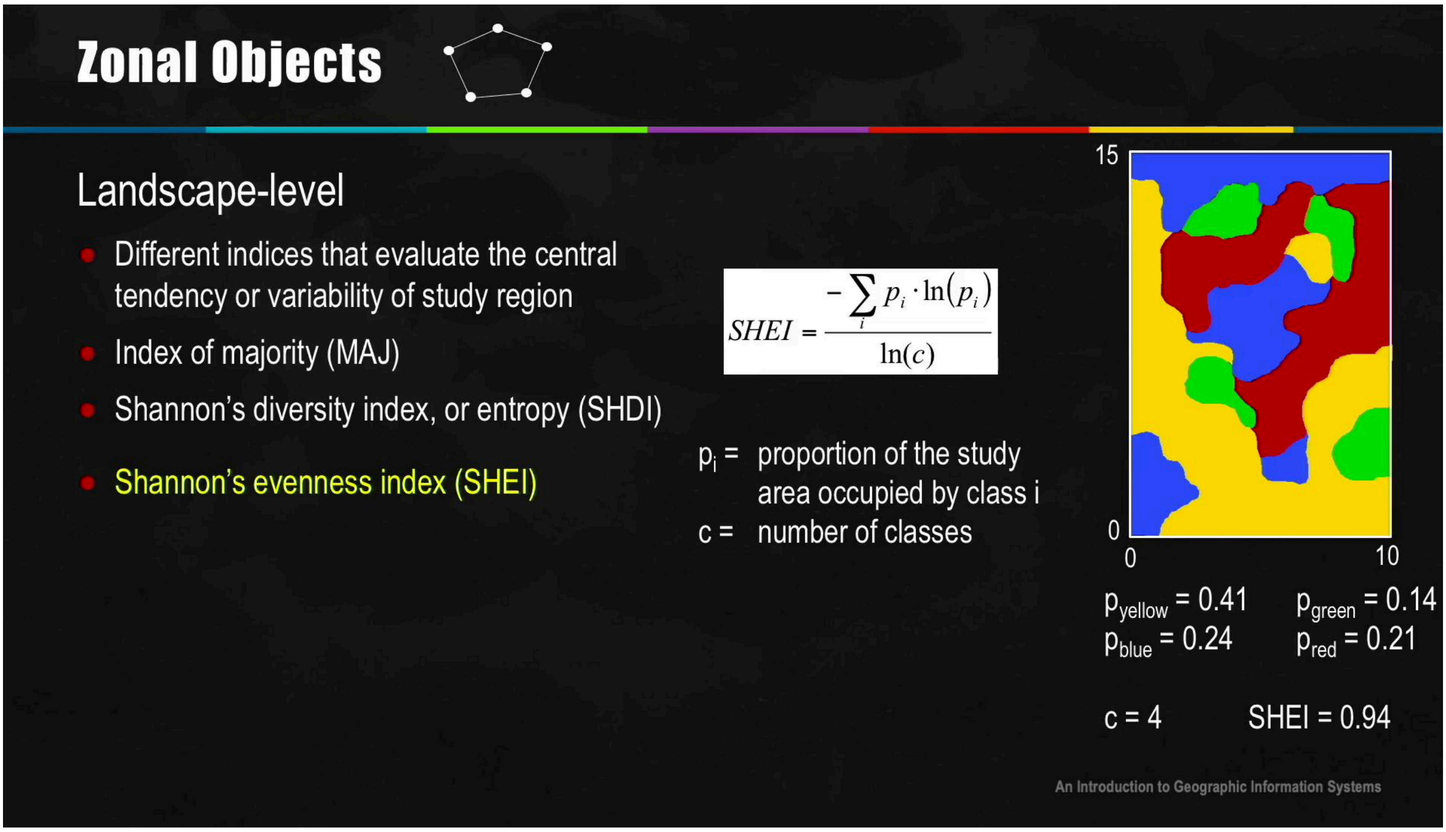
At the entity or patch level, the minimum distance index is defined in the same way as for punctual and linear objects. In image mode, the color of each pixel expresses the distance to the nearest pixel belonging to a surface entity. Areas of closer proximity to entities are also constructed in the same way as for linear objects. At the level of classes categories, there are many geometric indices of structure which combine the area and the perimeter of the objects, as well as the number of these. Among the simple indicators, let's retain here an index of mean patch size of the same class, called MPS, which is equal to the area of class Ac, divided by the number of objects of the same class. Another indicator of simple class is the ED edge density index, which is equal to the ratio between the sum of the perimeters of the objects belonging to a class I, and the sum of the areas of objects belonging to the same class. There are also more complex indices, like the mean fractal index, which is constructed on the basis of the fractal dimension of each patch. The fractal dimension D is a size that translates the way an irregularly shaped surface fills the space. The formula for the mean fractal index presented here is based on a definition which is based on the dimension of homothety in fractal geometry.

Notes

Summary

11m 41s



We now turn to the structural indices of surface objects considered at the landscape level. It is possible at this level to produce indices of thematic structures which account for the central tendency, that is to say from the variability of the thematic properties in all the studied region. To start the majority index MOD provides the value or category whose area is the majority. The Shannon Diversity Index or entropy, is mainly based on the proportion of the area of the study area which is occupied by the category I. The SHDI is equal to 0 when the study area is composed of a single category and is homogeneous. Its value increases according to the number of categories, as well as the trend towards uniformity of the areas of each category. The Claude Shannon's entropy is originally a mathematical function which corresponds to the amount of information contained or delivered by a source of information. And to conclude, Shannon's regularity index is also based on the proportion of the area of the study area occupied by category I, but we consider this time the ratio between this proportion and the natural logarithm of the number of distinct classes which are present in the study region.

Notes

Summary

13m 16s

Zonal Objects

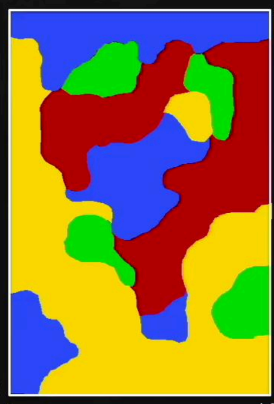
Landscape-level

- Different indices that evaluate the central tendency or variability of study region
- Index of majority (MAJ)
- Shannon's diversity index, or entropy (SHDI)
- Shannon's evenness index (SHEI)

$$SHEI = \frac{-\sum_i p_i \cdot \ln(p_i)}{\ln(c)}$$

p_i = proportion of the study area occupied by class i

c = number of classes



$p_{yellow} = 0.41$ $p_{green} = 0.14$

$p_{blue} = 0.24$ $p_{red} = 0.21$

c = 4 SHEI = 0.94

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The value of the regularity index SHEI approaches 0 when the areas of each category type are very different. And the index is equal to 1 when the areas of each of the types are perfectly equal, translated by a regularity in the landscape.

Notes

Summary

14m 40s