Unit 6:

Lesson 2:

Discrete spatial variables

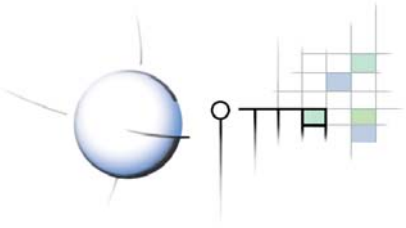# Transformation of spatial features

B-AN   Lesson 2 / Unit 6

Claude Collet

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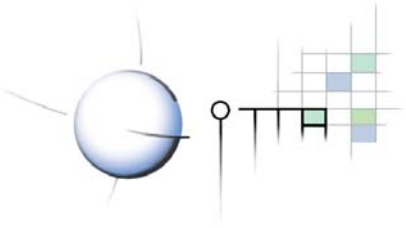
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Content of Lesson 2

Unit 1:   **Introduction**

Unit 2:   **Geometrical properties of individual features**

Unit 3:   **Pattern and neighbourhood of spatial features**

Unit 4:   **Weighted spatial pattern and neighbourhood**

Unit 5:   **Regionalization**
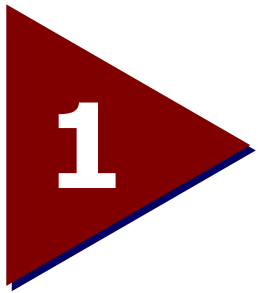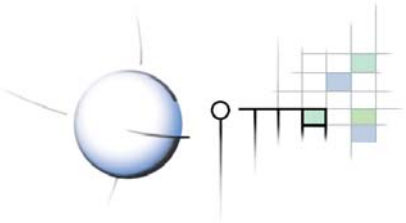
Unit 6:   **Transformation of spatial features**
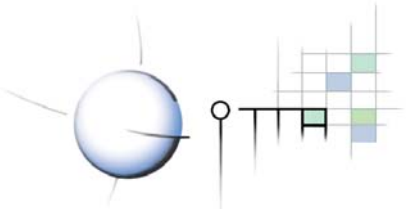
Unit 6: Transformation of spatial features

1: Introduction

2: Aggregation of spatial features

3: Breaking up (disintegration) of spatial features
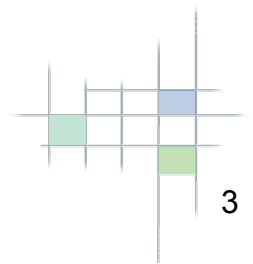
1 ▶ Introduction

Transformation of spatial features

It is often necessary to modify original spatial features (objects, cells)

- **During the constitution of the GDB**
  - When spatial units of observation do not match the spatial entities defined by the model of reality

- **During the exploitation of the GDB**
  - When sets of spatial features are combined or related to each other on the basis of their thematic and spatial properties
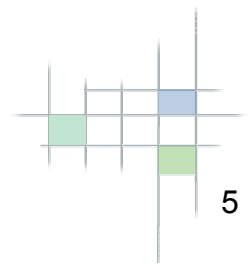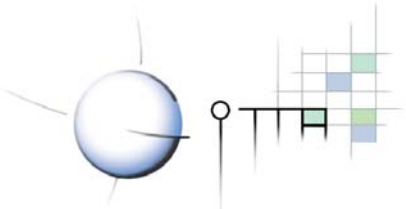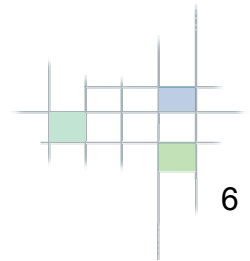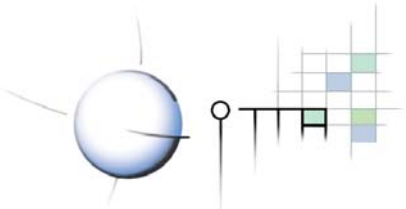
Transformation of spatial features

The reasons for such transformations are related to the mode of description of the reality

- **In object mode**
  - The thematic dependency of the spatial feature existence leads to frequent transformations during the exploitation of the GDB

- **In image mode**
  - The change in cell resolution during the constitution of the GDB
  - The construction of regions from the original units of observation (cells) implies a transformation process
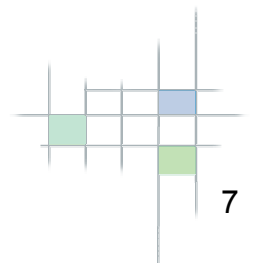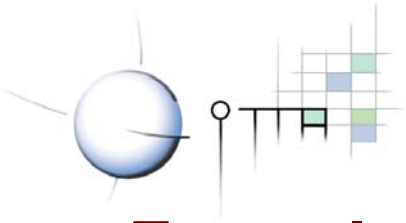
Transformation of spatial features

The two complementary transformation processes are the "aggregation" and the "breaking up"

- **Spatial aggregation:**
  - Spatial features are grouped on the basis of common spatial and/or thematic properties

- **Spatial breaking up:**
  - Spatial features are broken apart according to spatial and/or thematic criteria

  From a thematic point of view this action is critical as it implies an inferential process, just like regionalizalisation
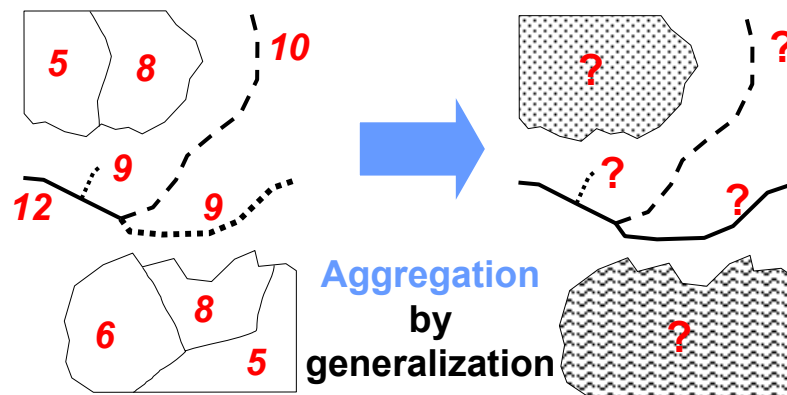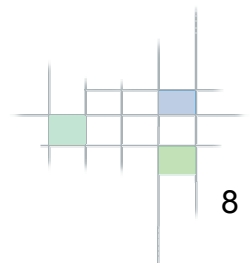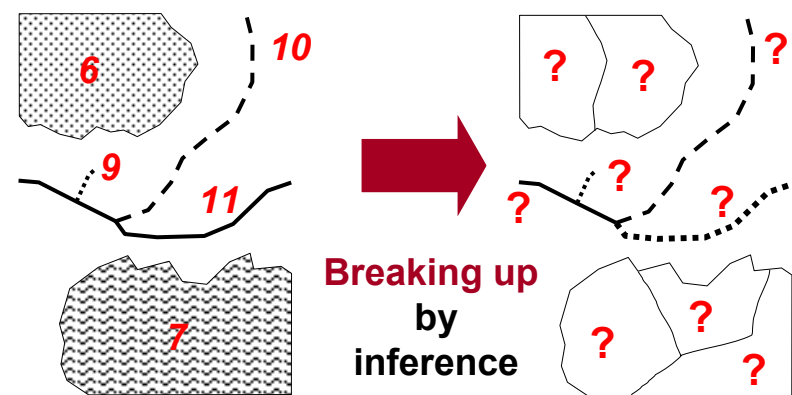
Example of spatial feature transformation processes

What thematic property should be assigned to each derived spatial feature ?

Aggregation process
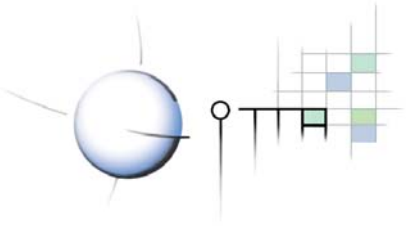
Breaking up process

Aggregation by generalization

Breaking up by inference

2 ► Aggregation: a spatial generalization
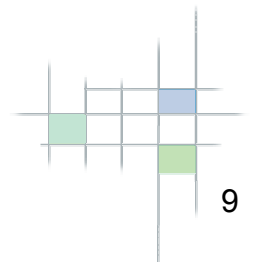
Aggregation process

The process of aggregation results in grouping existing spatial features: spatial objects or cells

- **This process transforms existing spatial features. This rises two major questions:**
  - Why existing features should be aggregated ?
  - What are effects of this aggregation on resulting features ?
    - in the spatial dimension
    - in the thematic dimension

Why existing features should be aggregated ?

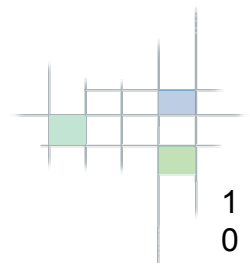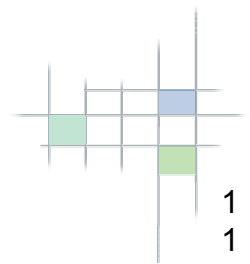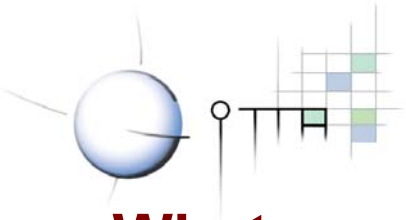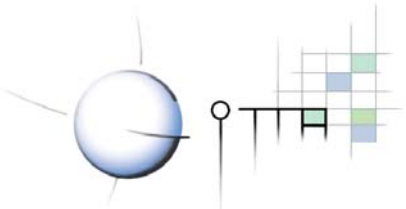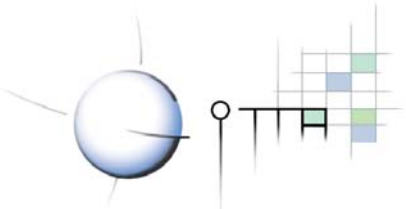*There are two frequent reasons*

- **To simplify or to generalize units of observation by grouping**

    - This grouping process can be seen as a spatial scale change (scale reduction)

- **To simplify or to generalize the diversity of thematic properties**

    - This grouping process can be seen as a thematic scale change (scale reduction)

What are effects of aggregation on resulting features ?

Aggregation generates new spatial features. How to derive properties for these resulting features ?

- **Spatial properties** of resulting features can be easily derived
    - computation of geometrical, neighbourhood and pattern properties

- **Thematic properties** should express the global behavior of aggregated features
    - production of summarizing thematic indices
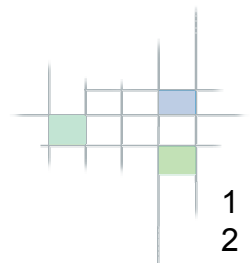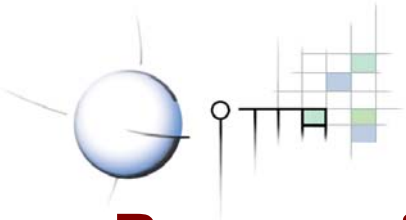
Reasons for aggregating features ?

Aggregated features result from:

- **A grouping based on thematic properties**
  - aggregation criteria are strictly thematic

- **A grouping based on spatial properties**
  - aggregation criteria are strictly spatial

- **A grouping based on combined thematic and spatial properties**
  - aggregation criteria are both thematic and spatial

Thematic criteria of aggregation (1)
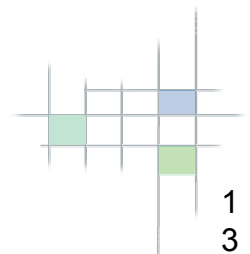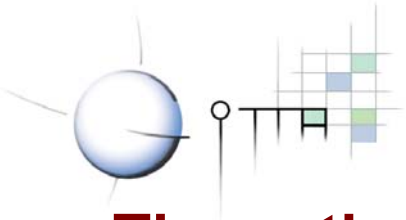
Aggregation based on thematic criteria is obtained by grouping properties

- **The grouping of thematic properties can lead to the aggregation of spatial features sharing the same resulting property**

- **Thematic aggregation can be applied either to spatial objects (object mode) or to cells (image mode)**

- **This aggregation can be restricted by spatial contiguity rule**

- **The effect of this aggregation on spatial entities depends on:**
  - the extent of the grouping process (diversity reduction)
  - the spatial distribution of the resulting properties
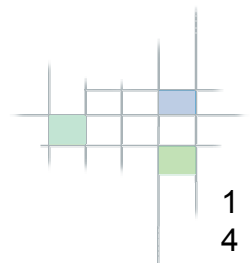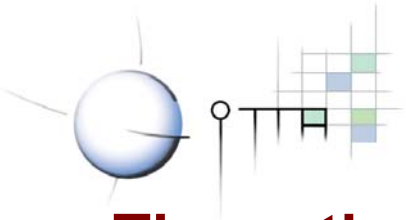
Thematic criteria of aggregation (2)

What thematic properties should assign to resulting features for other measured phenomena ?

- **When aggregated features are generated, it is then necessary to derive properties for other phenomena from measured properties on original units of observation**

- **Allocation of thematic properties requires the use of operators previously presented in the assignation process:**

  - central tendency operators: mode, median, mean
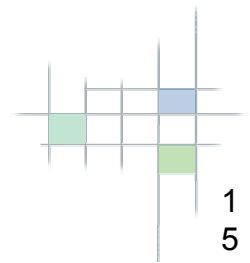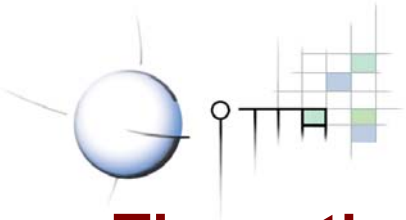 - dispersion operators: diversity, inter-quantiles, standard deviation, amplitude, ...

Thematic criteria of aggregation (3)

What thematic properties to assign to resulting features for other measured phenomena? (cont'd)

- **However this allocation can involve other specific operators:**
  - the sum
  - operators wheighted by the relative significance of aggregated features:
    - wheight of a thematic characteristic (number of inhabitants, …)
    - wheight of a spatial characteristic (area, size, …)
    - such wheighted operators can be percentage, wheighted mean, …

In order to define the most appropriated operator to be applied, the nature of the phenomenon (variable) as well as its level of measurement should be considered with great attention
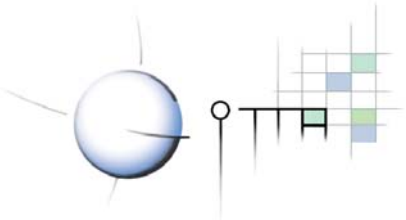
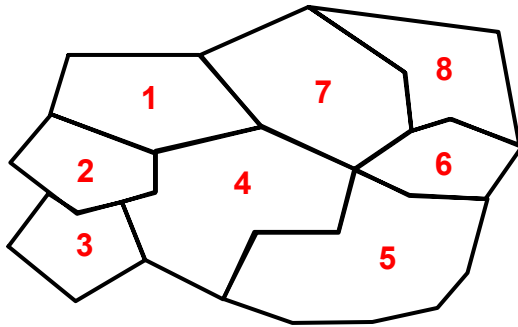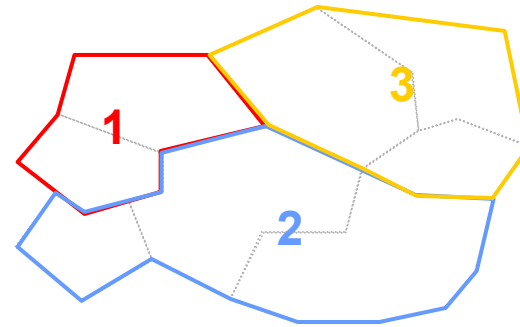# Thematic criteria of aggregation (4)

Illustration of the aggregation process

Spatial features: Districts

Spatial aggregation based on a thematic criterion

Spatial features: Counties

District	County	Population	% Working
1123	12	118	45
1125	12	231	56
1126	14	132	61
1130	14	376	44
1131	14	217	52
1133	15	158	63
1134	15	184	58
1135	15	261	47

Thematic allocation by labeling

ID	County	Population	% Working
1	12	349	52
2	14	725	50
3	15	603	55

Sum operator

Weighted operator !

Allocation method
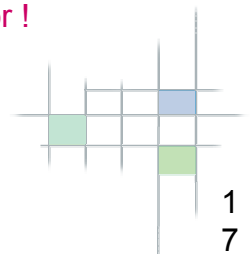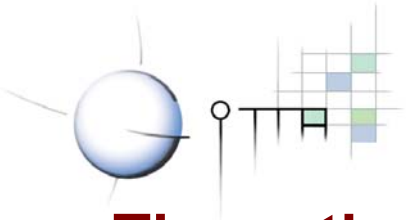
Thematic criteria of aggregation (5)

Example of thematic criteria based aggregation

- ## The CORINE Land Cover GDB :
    - This European Union database offers 3 different levels of land cover categories:
        - level 1 with 5 categories
        - level 2 with 15 categories
        - level 3 with 44 categories
    - The change from level 3 to level 2 or 1 implies a grouping of properties. This leads to the aggregation of original spatial units -contiguous and sharing the same thematic property- into new spatial features.
    - For each resulting feature it would then be possible to derive for this land cover theme:
        - the central tendency as the modal category
   - other indices such as the diversity of original categories
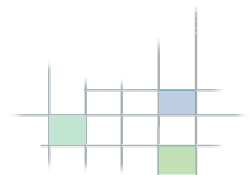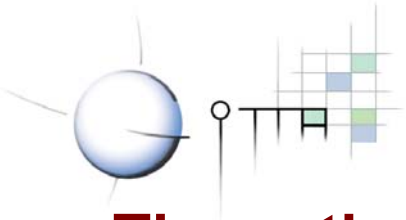
Thematic criteria of aggregation (6)

Example of thematic criteria based aggregation

- **Administrative units GDB (Swiss district statistics) :**
  - Typical national statistics are built at a district level. Such rich databases contain information covering physical social, economical as well as demographical themes.
  - Grouping these districts into counties or cantons (states) on the basis their administrative code produces new spatial enties.
  - Thematic properties can be derived and assigned to these new features for each original variable in the database:
    - the central tendency of aggregated properties using an appropriate statistical operator
    - other indicators such as the dispersion index of original properties
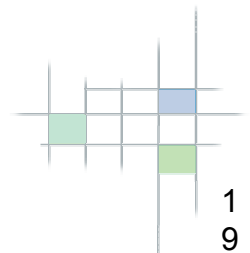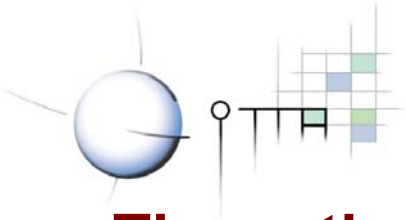
Thematic criteria of aggregation (7)
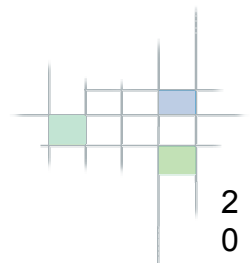
Practice thematic allocation of aggregated features

- **Aggregation of "districts" into "counties" :**

    Derive thematic properties of aggregated features (counties) for the following variables in the table below

    - Total population: number of inhabitants (Population)

    - % of young resident: <18 year old (% Youths)

    - Major economic sector: 1, 2 or 3 (Economic sector)

    - Landscape quality: 1 to 10 notation (Landscape quality)

    - For each variable:
        - identify the nature of the phenomenon described by the variable
        - define the level of measurement and the measurement unit
        - define the aggregation operator to be applied
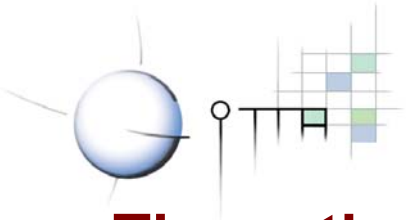
Thematic criteria of aggregation (8)

## *Practice thematic allocation of aggregated features (cont'd)*

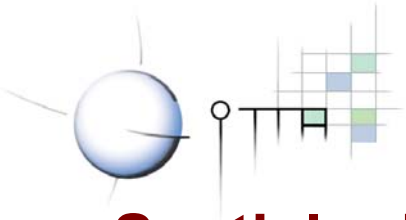- **Original data at "district" level :**

ID	District	County	Population	% Youths	Economic sector	Landscape quality	
1	1123	12	118	21	3	6	
2	1125	12	231	23	3	8	
3	1126	14	132	36	2	5	
4	1130	14	376	31	1	8	
5	1131	14	217	29	1	9	
6	1133	15	158	41	2	5	
7	1134	15	184	30	1	8	
8	1135	15	261	39	2	6	

- **Derived data at "county" level :**

| ID	County	Population	% Youths	Economic sector	Landscape quality
1	12				
2	14				
3	15				
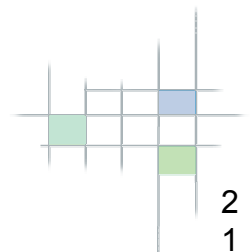
Spatial criteria of aggregation (1)

Spatial properties like size, shape or proximity can be used as criteria for aggregating spatial features

- **The spatial contiguity is one of the most current property used to group features, either alone or combined with other criteria**

- **Scaling change or generalization process make use of spatial criteria**

- **Spatial aggregation can be applied either to spatial objects (object mode) or to cells (image mode)**
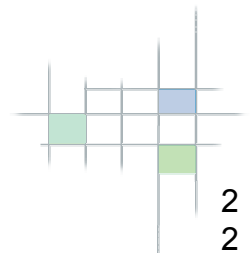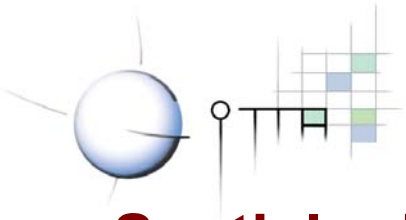
Spatial criteria of aggregation (2)

What thematic properties should assign to resulting features for other measured phenomena ?

- **The process of allocating thematic properties to the aggregated features makes used of the same operators as those presented for thematic based grouping:**

  - the sum operator

  - central tendency operators: mode, median, mean

  - dispersion operators: diversity, inter-quantiles, standard deviation, amplitude, ...

  - Operators weighted by the relative importance among aggregated features
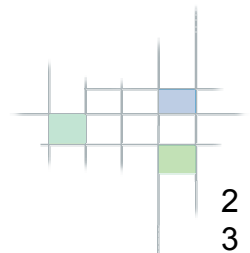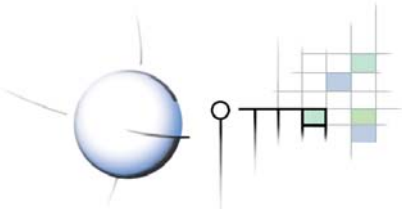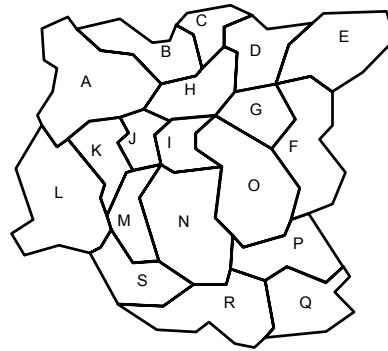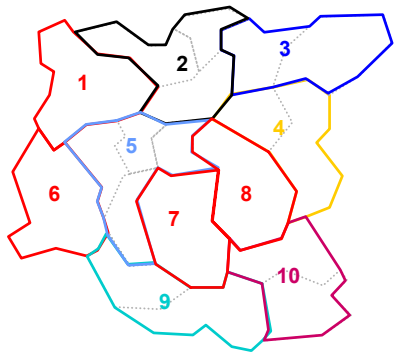
Spatial criteria of aggregation (3)

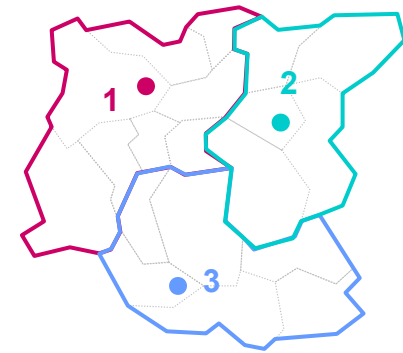## *Examples of aggregation process based on spatial criteria*

the 4 features
(1,6,7,8) in red color
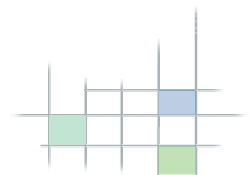were not aggregated

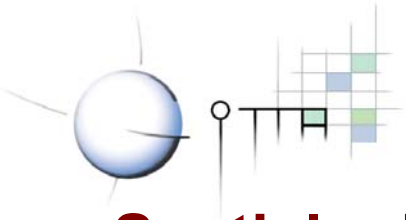**19 spatial features
(districts)**

• localisation des
  3 services

Aggregation based on the criteria:
  - **size** (>9km^2) and
  - **contiguity**
produces 10 features

**Aggregation based on the
nearest proximity to a service
produces 3 features**

B-AN / L2
**Discrete spatial
variables**

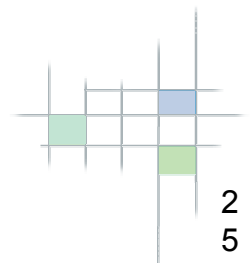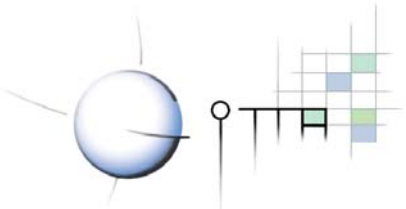**U6: Transformation
of spatial features**

October 15, 2003

2
4

Spatial criteria of aggregation (4)

Scale or resolution change by aggregating regular spatial units (cells)

- **A cell size increase of an image is obtained by an aggregation process**
  - Cells to be aggregated are contiguous within an aggregation window

- **The resolution of aggregated cells is a multiple of the original resolution**

- **The allocation of a thematic property to each aggregated cell is obtained by a statistical operator:**
  - Central tendancy operators: mode, median
  - Dispersion operators: diversity, inter-quartile

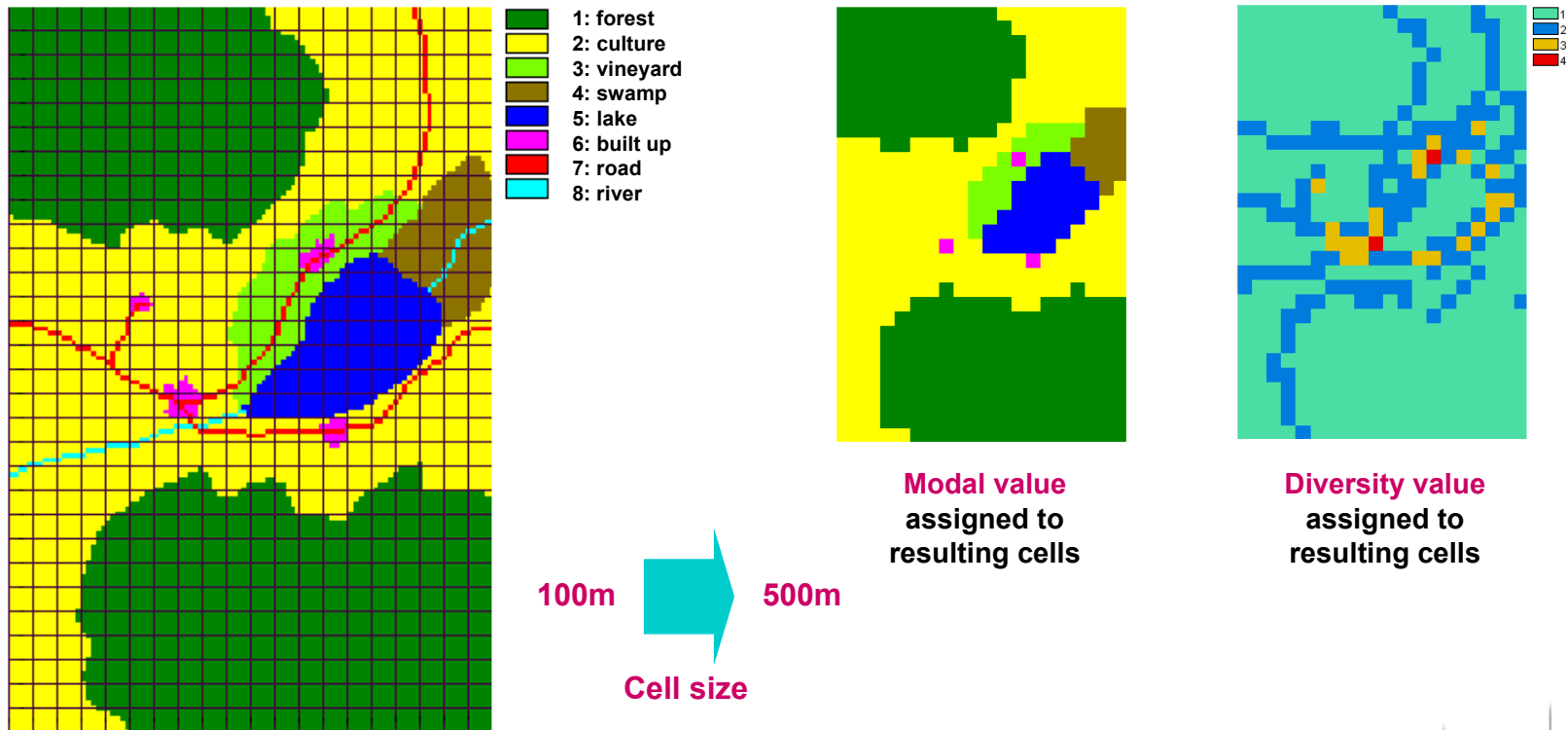# Spatial criteria of aggregation (5)

Examples of aggregation process based on spatial criteria :

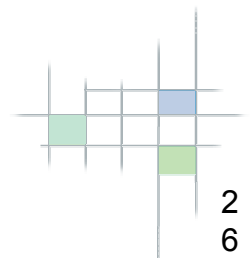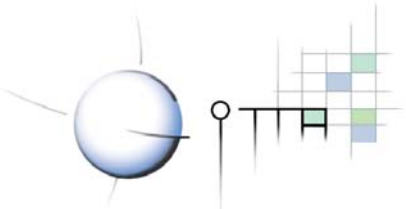### Scale or resolution change by aggregation for a nominal variable

1: forest
2: culture
3: vineyard
4: swamp
5: lake
6: built up
7: road
8: river

Modal value
assigned to
resulting cells

Diversity value
assigned to
resulting cells

100m → 500m

Cell size

Aggregation grid overlayed on original landcover image

B-AN / L2
Discrete spatial variables

U6: Transformation of spatial features

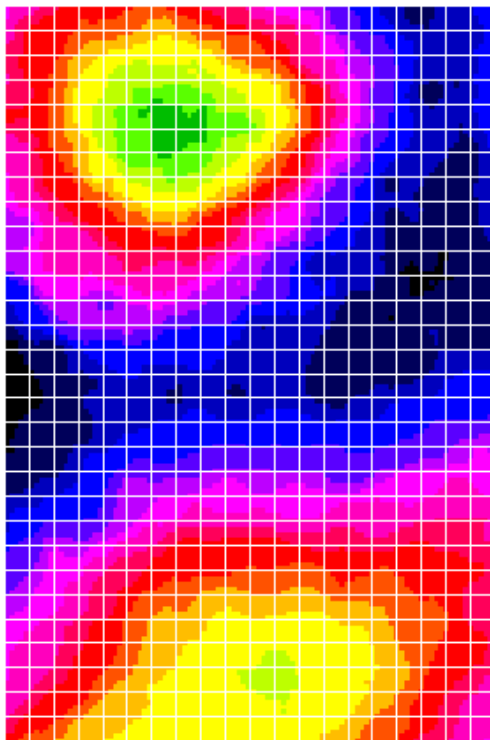October 15, 2003

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Spatial criteria of aggregation (6)

Examples of aggregation process based on spatial criteria :

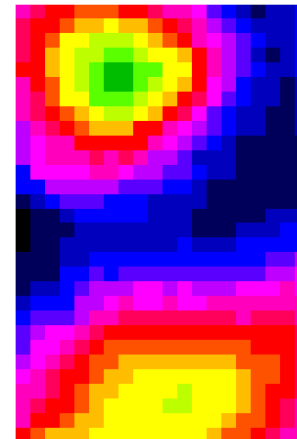### Scale or resolution change by aggregation for a nominal variable
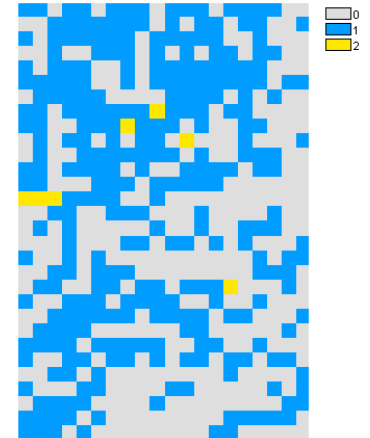

Median value assigned to resulting cells

Inter-quartile value assigned to resulting cells
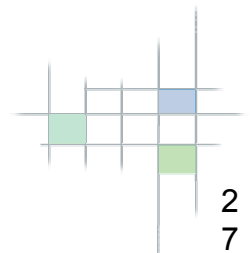
100m → 500m

Cell size

Aggregation grid overlayed on original 16 elevation classes image
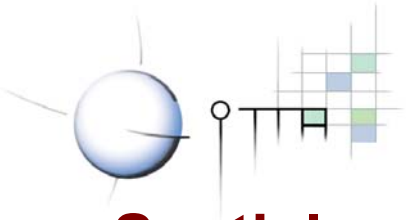
B-AN / L2
Discrete spatial variables

U6: Transformation of spatial features

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Spatial and thematic criteria of aggregation (1)

Very often spatial features are grouped based on combined spatial and thematic criteria

- **The most common spatial criterium is contiguity**

  Examples:
  - In image mode the "region" is the corresponding concept of "object". A region is made of a set of contiguous cells sharing the same thematic property (attribute)
  - In image mode such concepts as urban district, biotops, watershed or road network assume that their elements share the same thematic property and are spatially contiguous

- **Other spatial criteria: size, shape, proximity**
  - Their combination with thematic criteria is often more complex as they can produce different possible aggregation patterns. An optimum should then be considered (see "political redistricting process")
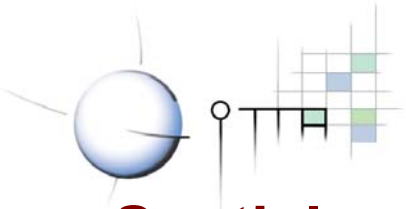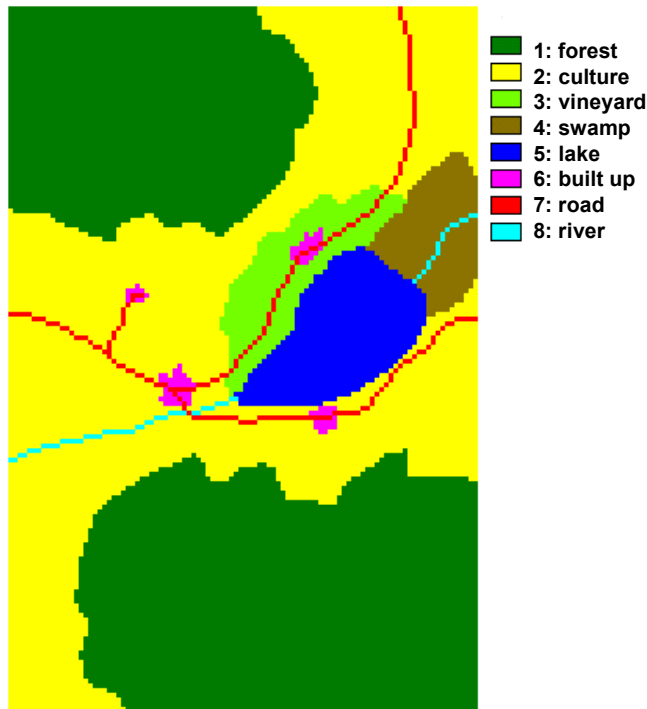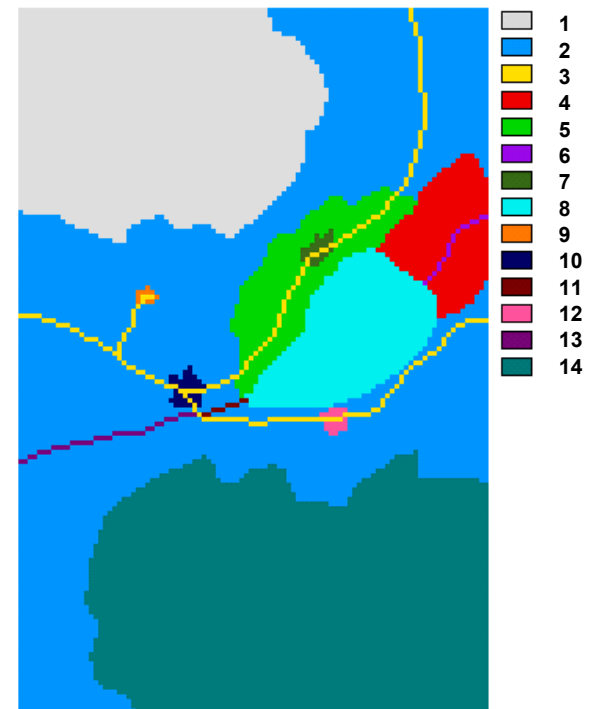
Spatial and thematic criteria of aggregation (2)
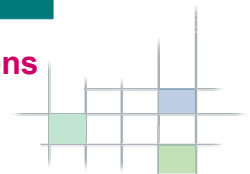
Example: Production of regions in image mode

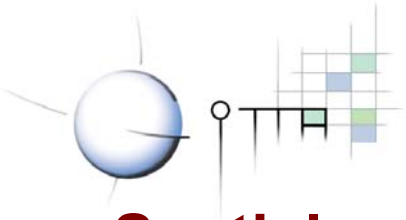**Combination of extended contiguity with identical thematic property criteria**

Landcover: 150'000 spatial entities

Aggregation into 14 regions

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Spatial and thematic criteria of aggregation (3)

Other examples

- **Process of political or administrative redistricting**

  Examples:
  - Existing spatial units should be aggregated into larger features in order to optimize a service, access, ..., or even to guarantee a political majority

- **Definition of sale territories**
  - The delineation of sales territories assigned to salesmen is based on thematic criteria such as the density and profiles of potential customers as well as on spatial criteria such as contiguous places and efficient travel path. Such territories can be built based on aggregation of district units for which socio-economical statistics are available.
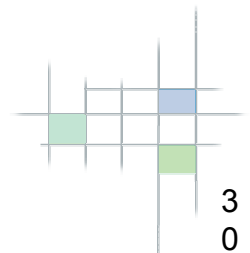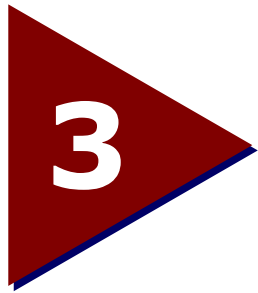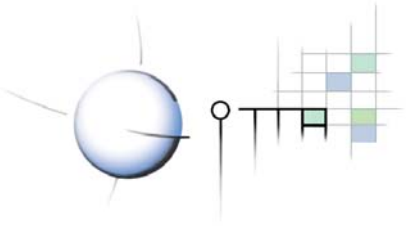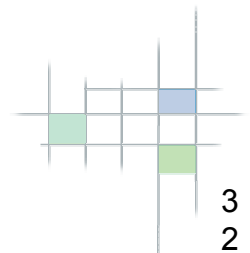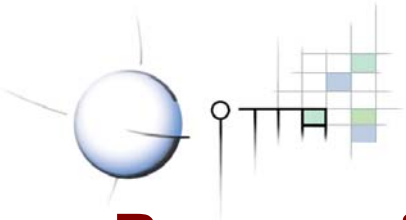
3 ► Breaking up of spatial features (disintegration)
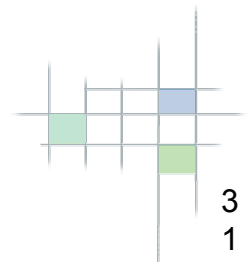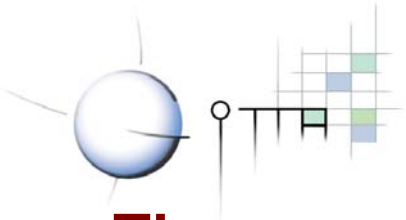
The process of breaking up

The process of breaking up generates the fragmentation of units of observation: spatial objects or cells

- **This process transforms existing spatial features. This leads to two types of questions:**
  - What procedures generate the breaking up of spatial features?
  - What are effects of this breaking up on resulting features ?
   - about their spatial dimension
    - about their thematic dimension

Reasons for breaking up features

What procedures generate the breaking up of spatial features ?

- **When two or more sets of spatial features are "overlaid" based on the combination of their thematic or spatial attributes**
  - This situation is specific to the object mode in which spatial objects are intimately related to themes

- **When changing to a larger scale (increase resolution)**
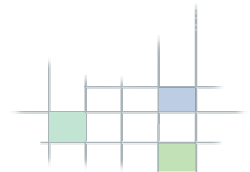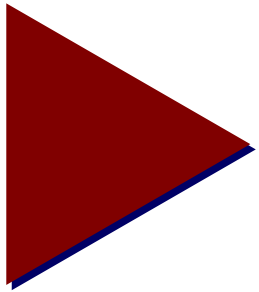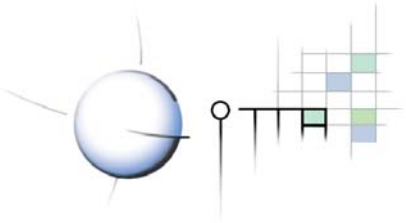 - This situation mainly occurs in image mode but can be present too in object mode
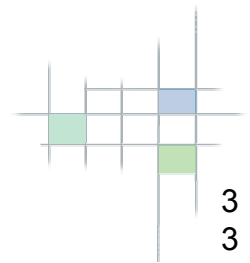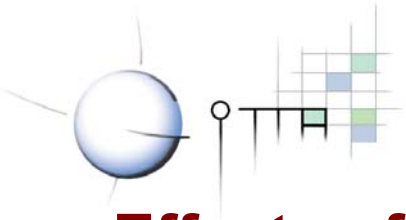
Effects of breaking up on spatial information

The breaking up process products new spatial features. How to derive their properties as they were not previously measured ?

- **Spatial properties** of generated features can easily be generated
  - Geometrical properties: location, size, shape, ...
  - Spatial relationships: pattern, proximity, ...

- **Thematic properties** of new features are more problematic to derive as there is no evidence about their spatial distribution within original units of observation
  - An inference process should take place, based on solid assumption about the distribution of the measured property among each "fragment" of the original unit of observation

End of Unit 6

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