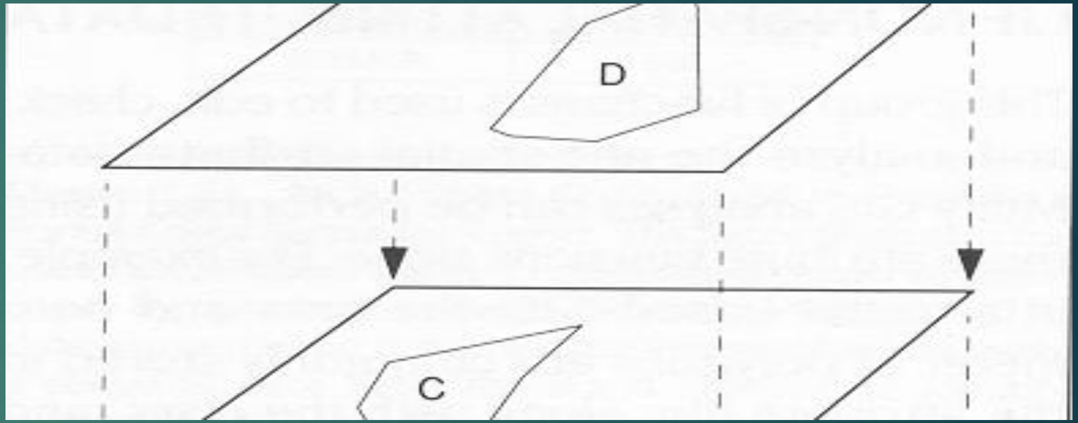
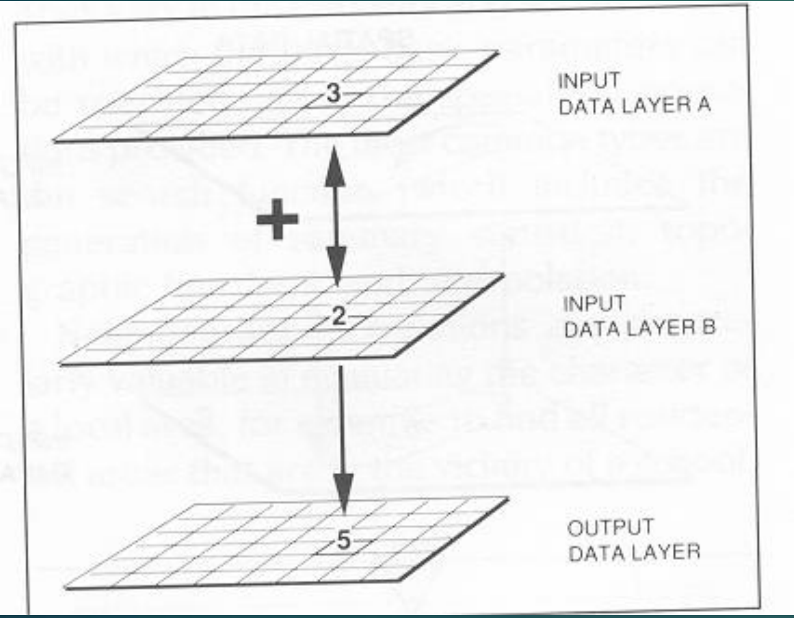
155GISE – Lecture 5

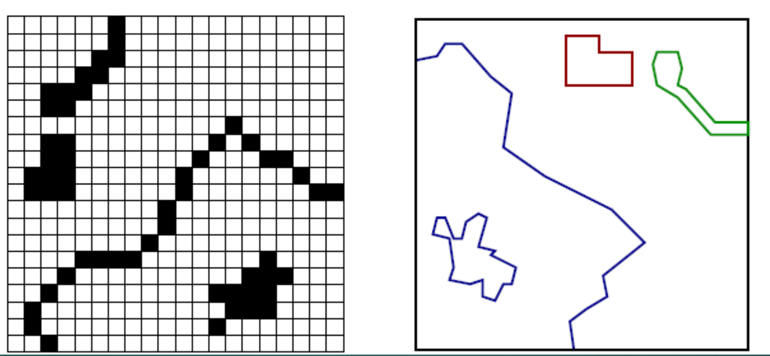
Raster data

Vector x raster model

Raster x vector model







Raster representation of spatial models
field shapes

Territory divided into partial **mosaic areas** (tessellation , tessera = mosaic cube)

cells do not actually exist - this is a model of the territory, i.e. a way of its representation

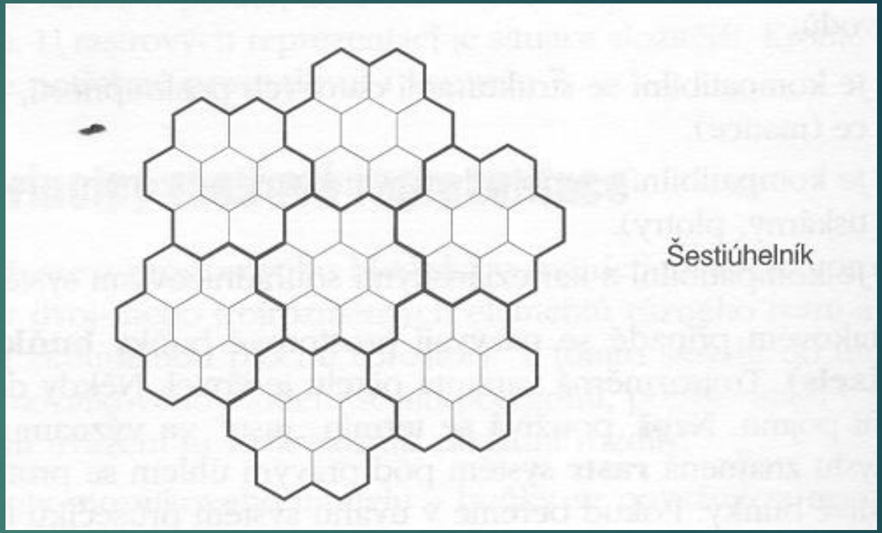
cells = basic areas of the divided space

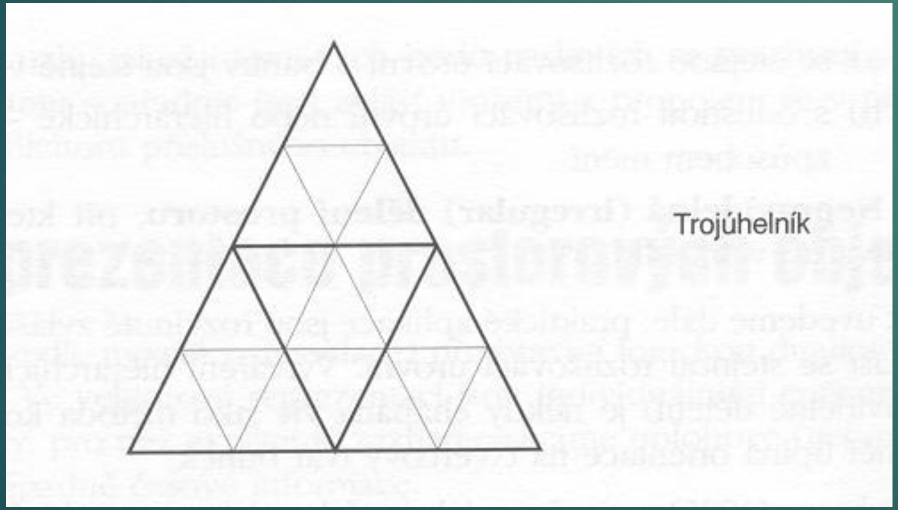
- **Types of division into sub-areas:**
  - regular
  - irregular

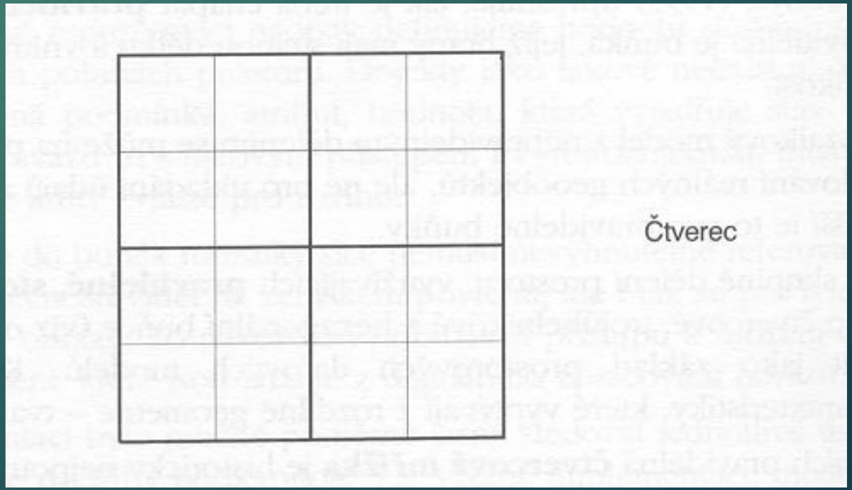
Raster representation of spatial models

field shapes

1. Regular division







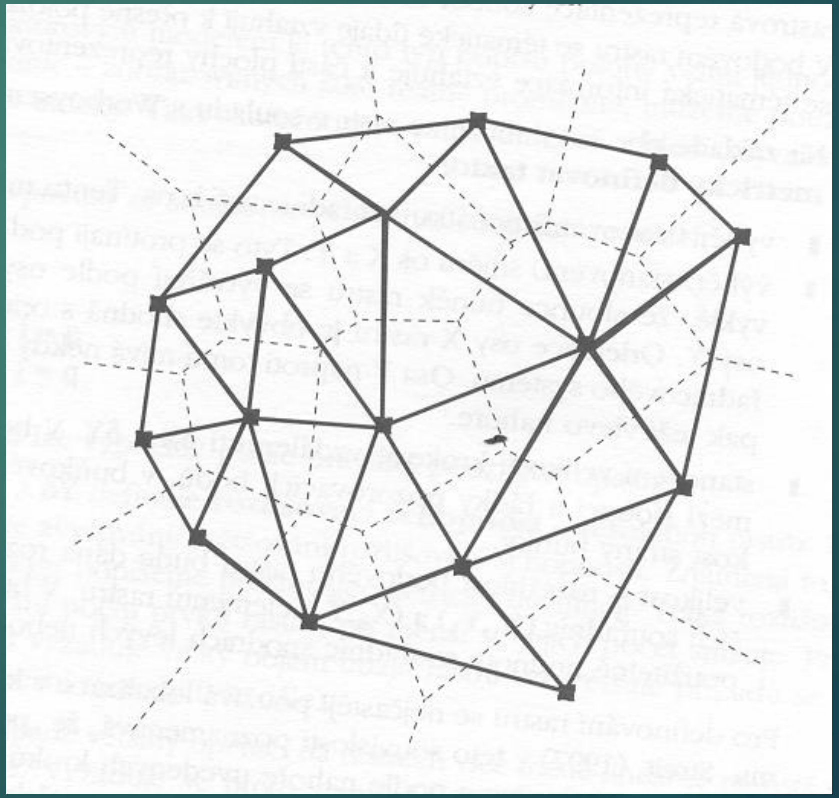
Raster representation of spatial models
field shapes

2 . Irregular division - triangles

Triangles are created from measured points

Polygons can be created from triangles:

From the lines that are the axes of the sides of the triangles



Raster representation of spatial models

field shapes

Delaunay triangles – data at irregularly placed points

They are such triads that no other point from the data set falls into the circumscribed circle

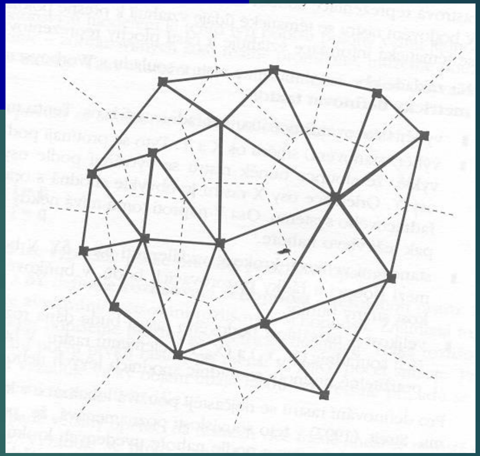
Voronoi diagram = **Thiessen polygons** (= **Dirichlet tessellation**) =

- the vertices are the centers of the circles described by the Delaunay triangles ,
- the edges are perpendicular to the edges Del . triangle . at the centers of these edges

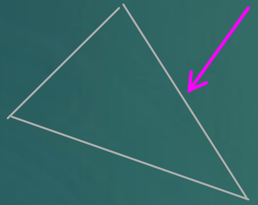
- These objects are dual to each other

Raster representation of spatial models

field shapes

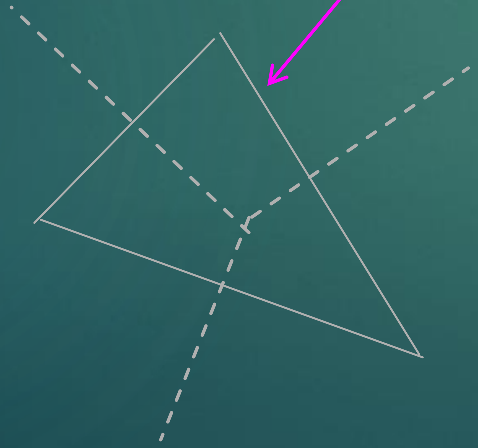


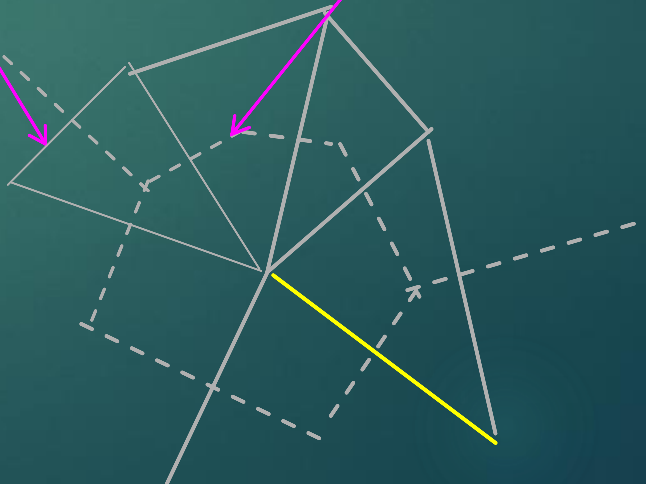
2 . Irregular divisions are not typically raster data



The Delauneys triangles
Their creation see ch. Digital terrain models

Voronoi diagram = Thiessen polygons

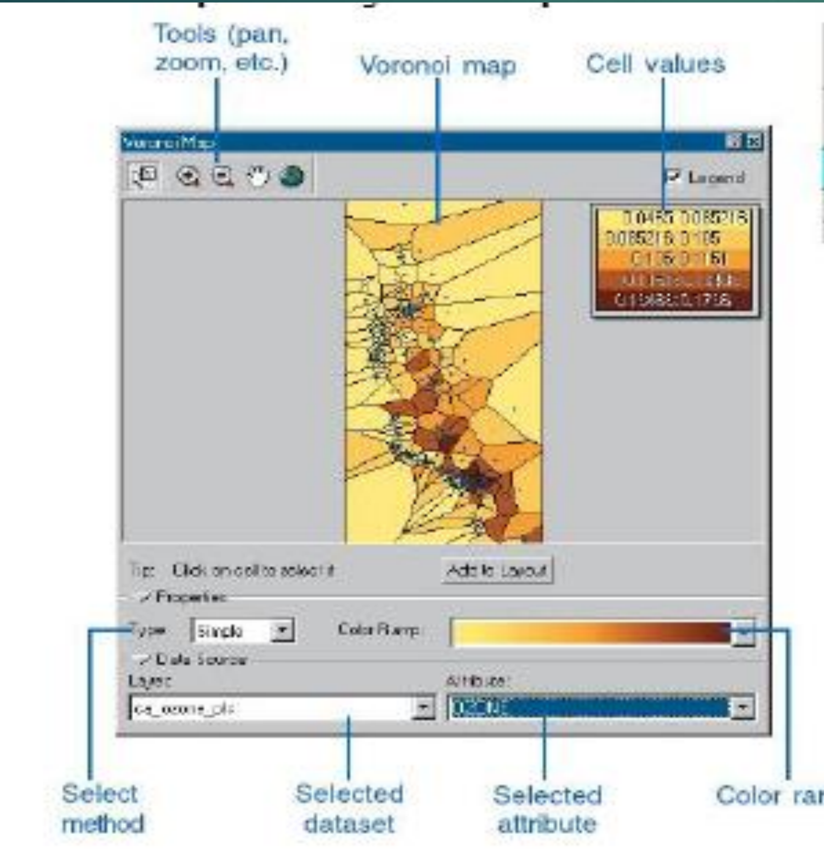


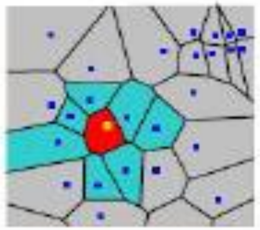


Raster representation of spatial models
field shapes

Voronoi diagram = Thiessen polygons

2 . Irregular division





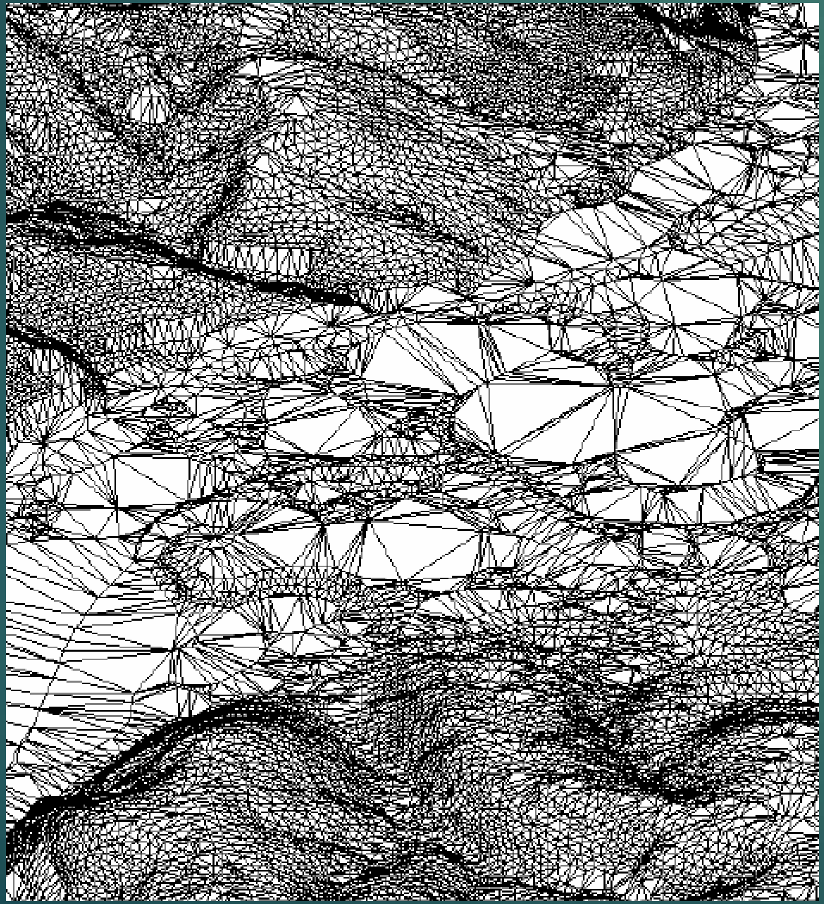
Delauney triangles – here only the vertices of the original triangles, i.e. the measured values,

the polygon area is assigned the value of this measured point

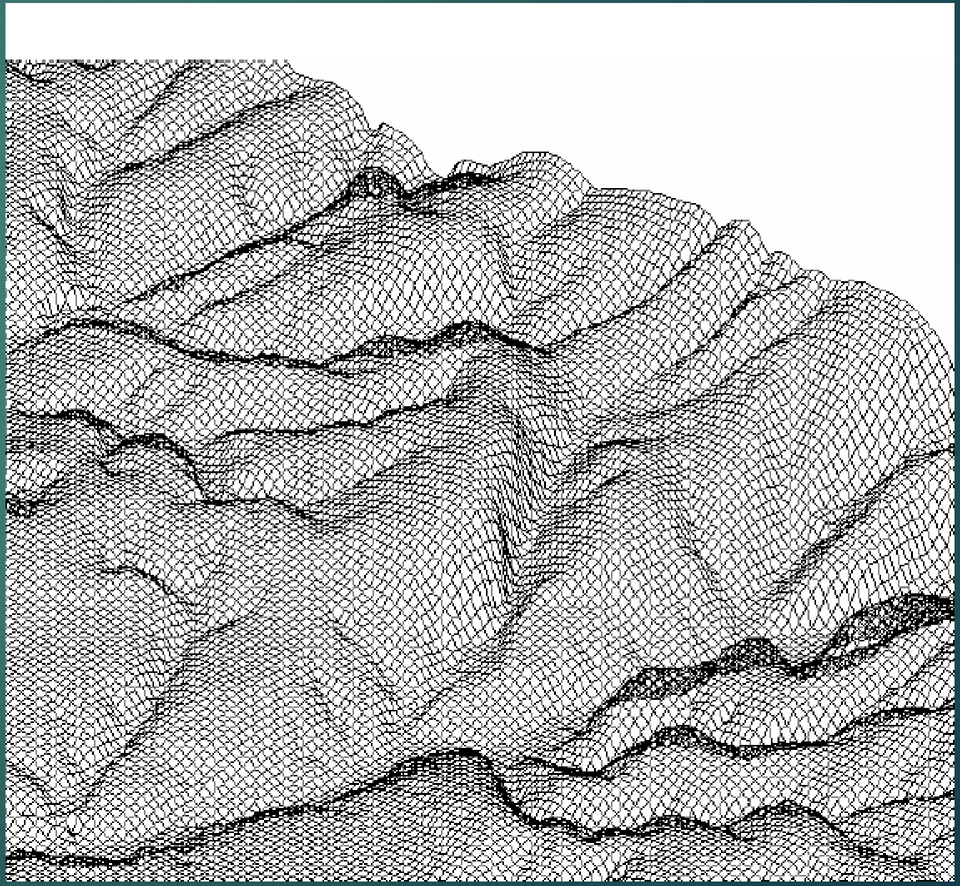
Raster representation of spatial models

field shapes

triangular network

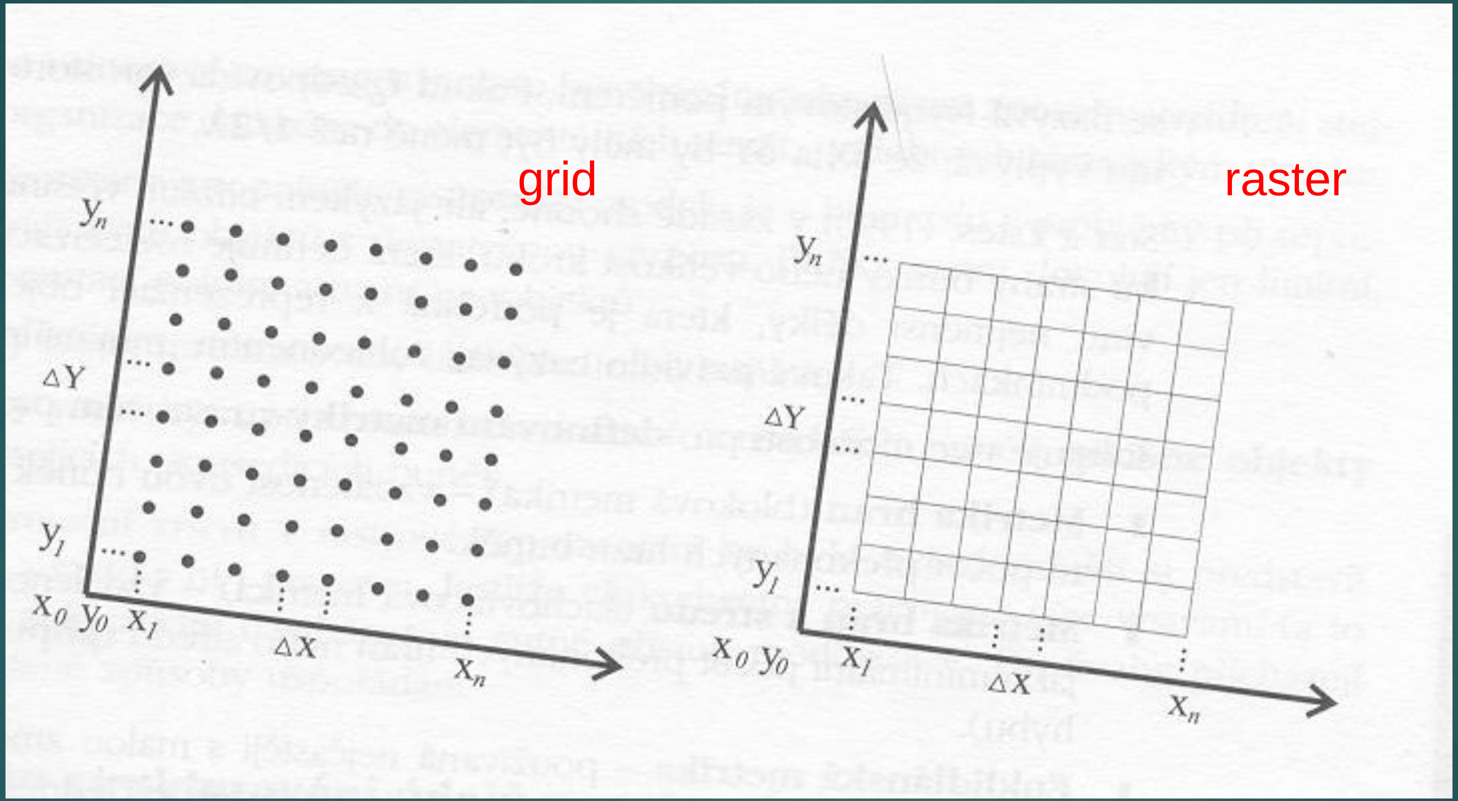


grid network - see below



Raster representation of spatial models

grid x raster

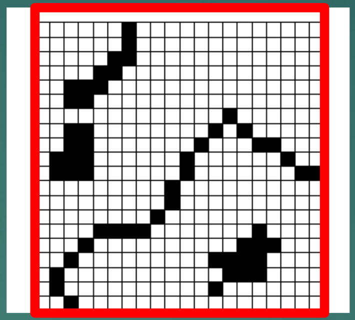


grid – values given in

raster nodes – values in pixels, these are values for entire pixel areas, the value is stored in the center of the pixel

Raster representation of spatial models
model creation

Modeling process - procedure:



1. definition of spatial frame F (area size and detail of division into fields = cells = pixels)
2. finding suitable domains for attribute (range of values stored in individual cells)
3. selection of phenomenon values in the spatial framework (what will be the content of the values in the cells – classes – altitudes, types of soil, …)
4. then analyzes can already be performed using calculations with functions (what will be calculated, ...)

Raster representation of spatial models
creation of a model - creation of a spatial framework

1 . the task is to design a field model = creating a spatial framework

i.e. division into a **final mosaic of planar elements** (eg pixels)

area elements = locations

surface elements - sometimes replaced by points (grid)

Raster representation of spatial models
creation of a model - creation of a spatial framework

The model has a so-called finite structure

- regular = quadrilaterals, ..
  - cell raster = cell raster - RS data, mapping
  - dot raster = point raster – elevation chart (grid)
- irregular = triangles (e.g. from points measured on Earth)

there are mutual conversions between them (vector raster)

modeled phenomena expressed by sample values, they are not continuous values, it is only a model

Raster representation of spatial models
, creation of a model, creation of a spatial framework

Euclidean space = plane is most often used

space model based on fields (pixels, triangles, ...) formed by a finite number ***n*** spatial fields f_i spatial frame *F)*

$f_i : 1 \leq i \leq n$

every spatial field has a computable/measurable function f_i *F* frame meeting values

attribute domains A_i (the domain determines the range of applicable values of the given attribute)

Raster representation of spatial models

creation of a model - creation of a spatial framework

To make the model computable :

- the number of fields (CELLS, PIXELS) forming the spatial frame must be **finite**
- function f_i in all fields must be defined (unknown value = zero),
- domain of attributes must be defined = a subset **of real numbers (integer , double precision , ...)** and these are then the **z *values* (values** of the given attribute) of the Euclidean space *x,y* – e.g. DTM

Raster representation of spatial models
regular grid - creating a spatial frame

Geometrical definition of a regular grid:

1. Determining the origin of coordinates X_0, Y_0
2. Determining the direction of the coordinate axes (Y often reversed compared to math axes, origin is top left)
3. Set the pixel size of the raster $\Delta x , \Delta y$
4. Raster size - number of pixels multiplied $\Delta x \, . \, \Delta y$ (valid for square pixels, where $\Delta x = \Delta y$) or the product of the differences of the minimum and maximum coordinates in both directions

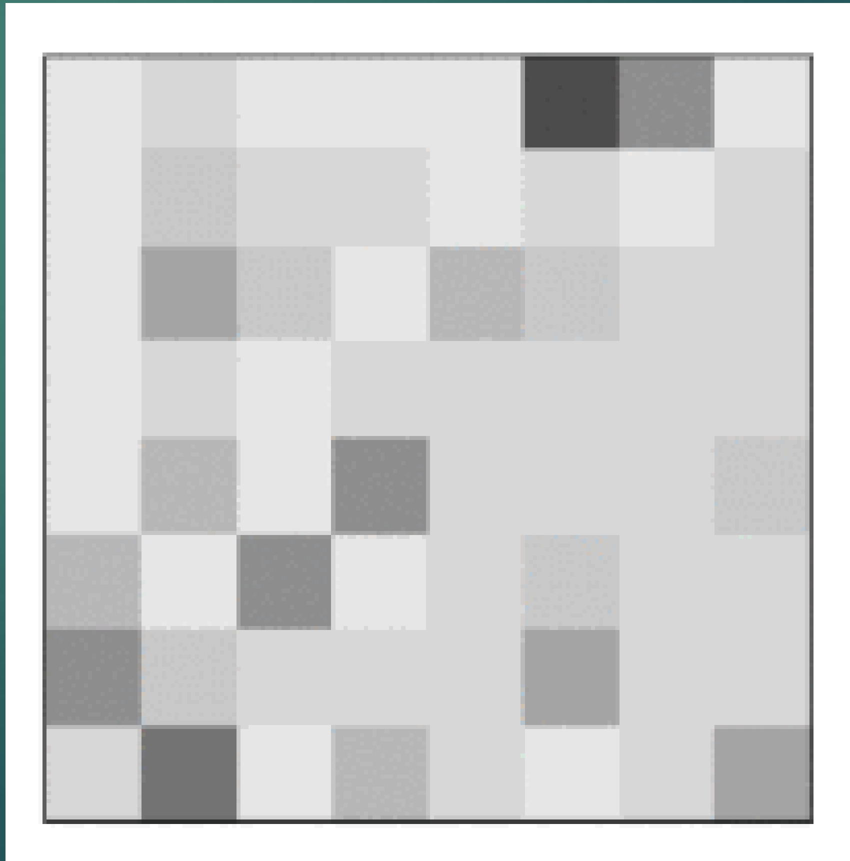
Raster representation of spatial models

regular grid - creating a spatial frame

For **<u>a regular square</u>** (rectangular) representation, the spatial frame is divided into

columns (columns)

lines (rows)



- column has a width Δx
- line has a height Δy

For a square cell: $\Delta x = \Delta y$

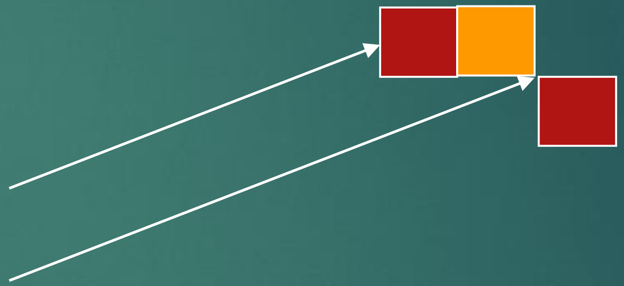
Raster representation of spatial models
regular grid - creating a spatial frame

Δ x, Δy – indicates the resolution of the raster (raster resolution)

Topology - each pixel - 2 types of neighbors:

common edge – full neighbor (full)

common point – diagonal neighbor



square pixels - 8 neighbors - 4 full and 4 diagonal

Raster representation of spatial models
volume of data of a regular square raster

Raster model:

total data volume given

1. **by the total number of** cells/pixels

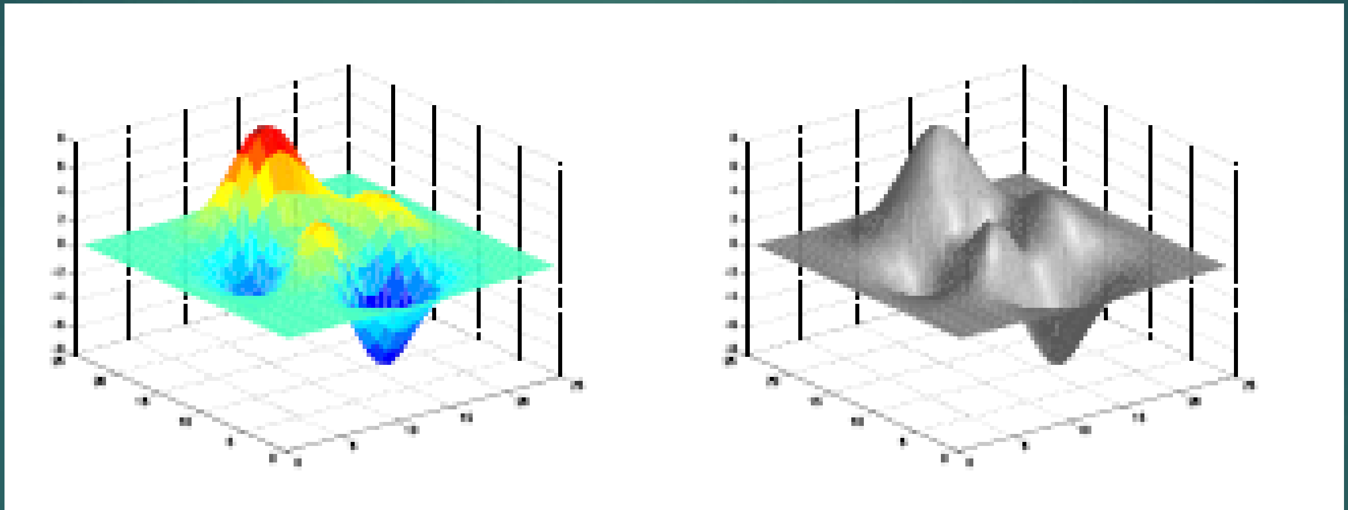
2. **multiplied** by the value , which is given by the value corresponding to the number of bits for the given layer/plane (for 1-bit data **= 1/8 byte** , 8-bit data **= 1 byte,** 24-bit data = **3 bytes**)

3. **and multiplied** by number of layers=planes

This type of model tends to have a larger volume of data than a vector model

Raster representation of spatial models

model creation



Raster model:

Attribute is expressed as a value that can be displayed

- **in 3D** or
- **only by color in 2D -** the color expresses the attribute value - a legend must be attached

Raster representation of spatial models

value in an array

Each field/cell/pixel of the model in one layer

contains 1 value for the given information,

if the class does not exist in a given place or is unknown , it has a value equal to zero, it is referred to as NULL

Raster representation of spatial models

Attribute domains

Attribute Value Types (Cells)

Values measured in different ways:

1. **nominal** – the created field is referred to as categorical

arithmetic operations cannot be performed with them,

with the exception of carefully selected values (sums of coded values)

e.g.

- *boolean values - yes, no,*
- *designation of land use classes with numbers - water pixels with a value of 1, forest pixels with a value of 2 - the values can be swapped, but the information content remains)*
- ***Calculation example with nominal values: sum of coded values:***

1st class values 1 – 20

2nd class values 1000, 1100, 1200, 1300,

From the sum of 1220, I know that this is the area where the 1st class with a value of 20 and the 2nd class occur. with a value of 1200

2. **ordinal** - quantifies by including values **on a linear scale** ,

they can be compared by size but

comparisons of the degree of difference cannot be made

- *year of foundation 900 , year of foundation 1800 - the second building is not twice as old as the first*
- *temperature in °C, temperature in °F - doubling one is not equal to doubling the other, the difference can be expressed*

3. interval - quantities defined using a

position on an interval scale without specifying a fixed point

some arithmetic operations are **possible**

0 – 200 mm/year of rainfall, 201 – 400 mm/year of rainfall …

4. proportional - measurement on a proportional scale for a given zero point,

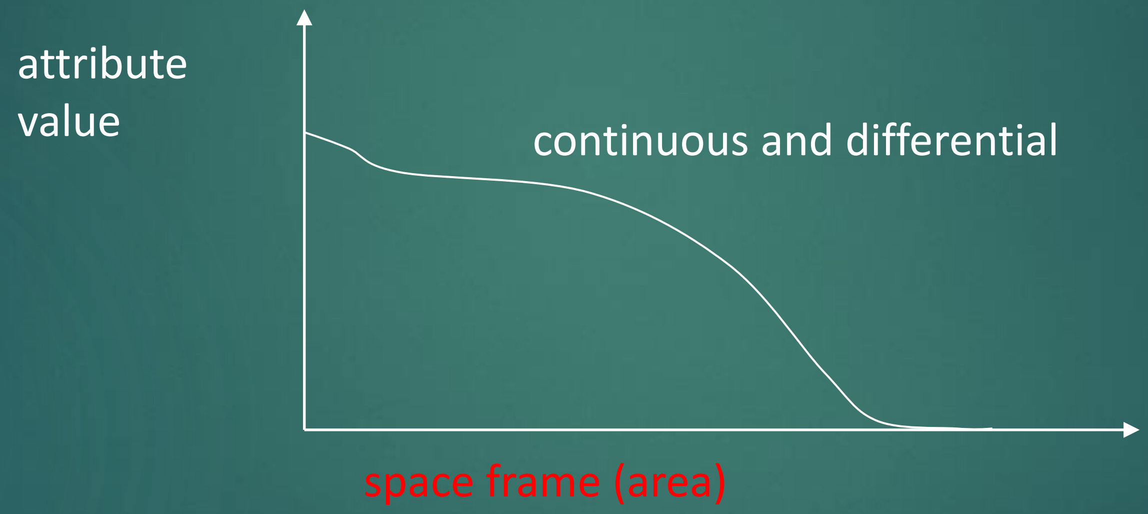
arithmetic operations are **possible**

age, frequency, speed, length of time

Raster representation of spatial models

1. **continuous attribute values differential** = continuous

small changes in position cause small changes in attribute values

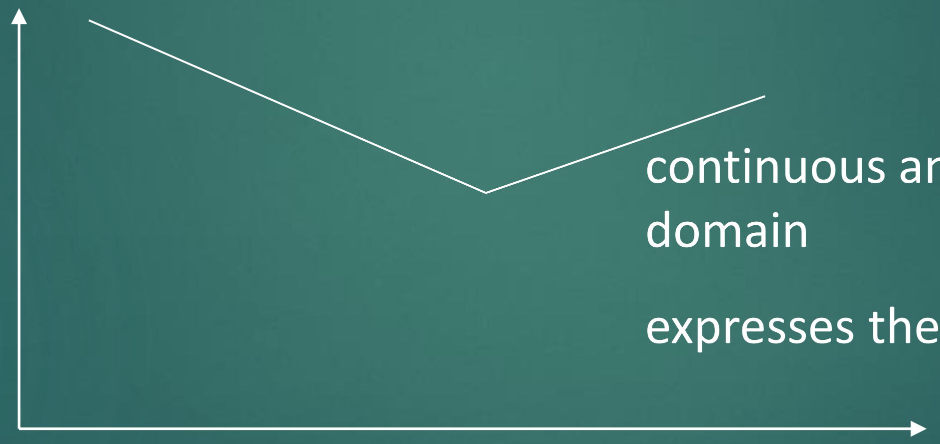


differential field - if the function describing the attribute is differential and has a defined slope (the function is monotonic)

Raster representation of spatial models

2. Continuous and non-differential fields = attribute values

attribute
value



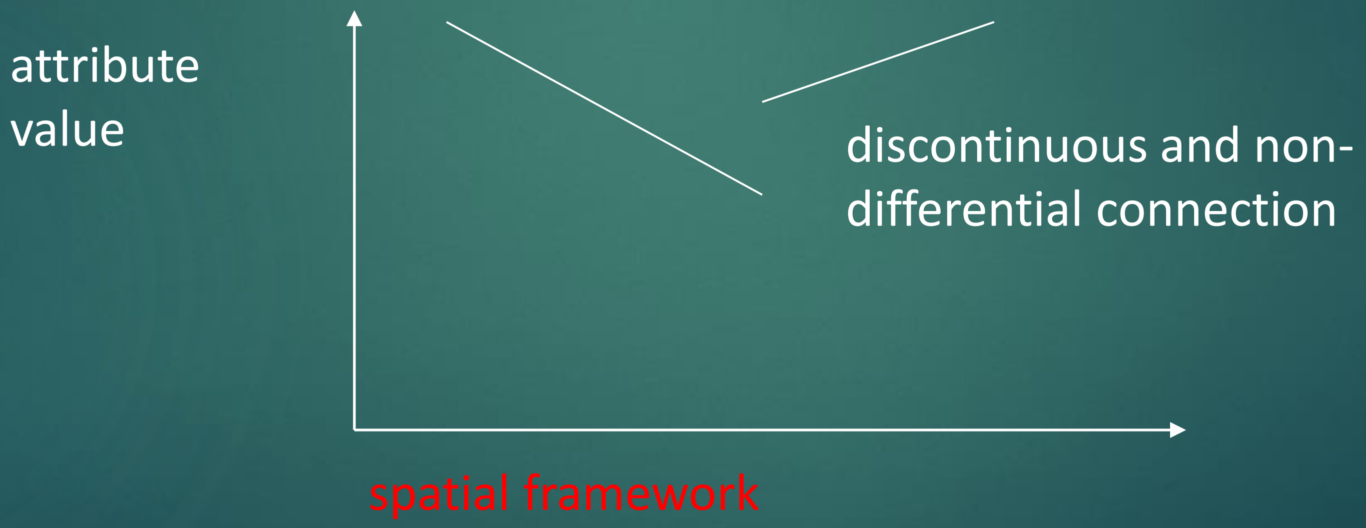
continuous and non-differentiable domain

expresses the context of values

spatial framework = defined territory

Raster representation of spatial models

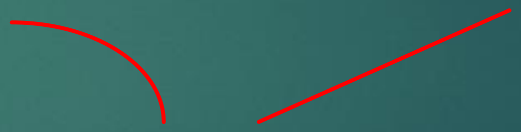
3. discontinuous and non-differential field = attribute values



Raster representation of spatial models

Spatial change can be:

- **fluent** - (e.g. movement in space) - **can be interpolated** between states
- **sudden** - **cannot be interpolated**



Raster representation of spatial models
Attribute domains

Types of fields according to behavior in space

1. Field **isotropic** - properties independent of direction
2. **Anisotropic** field - direction dependent properties - (more common in the real world)

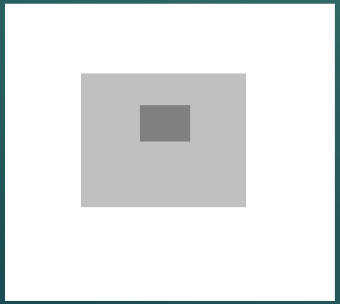
Raster representation of spatial models

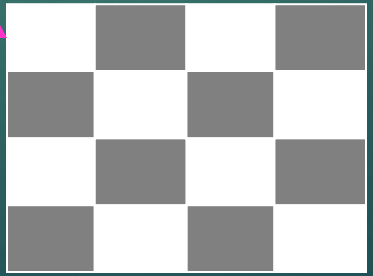
Attribute domains

Relationships between adjacent field values

spatial autocorrelation - "everything is related to everything else, but closer things more so" - measures the degree of clustering

1. **positive autocorrelation** - tendency to cluster similar values
2. **negative autocorrelation** - similar values are distant from each other





Raster representation of spatial models

Definition **of the topic**

Definition of the **theme** of raster layers (=what values are in the raster fields)

1. object approach

– e.g. topographic map – built-up area, field, forest – separate classes in one raster – corresponding areas of the classes are displayed in one color, i.e. they contain pixels with the same value

2. layered access

one raster represents one class with different values – e.g. a map of average temperatures - different values in pixels represent different average temperatures of an area

They can be combined

Object, element, element class

raster GIS = field model

Spatial objects

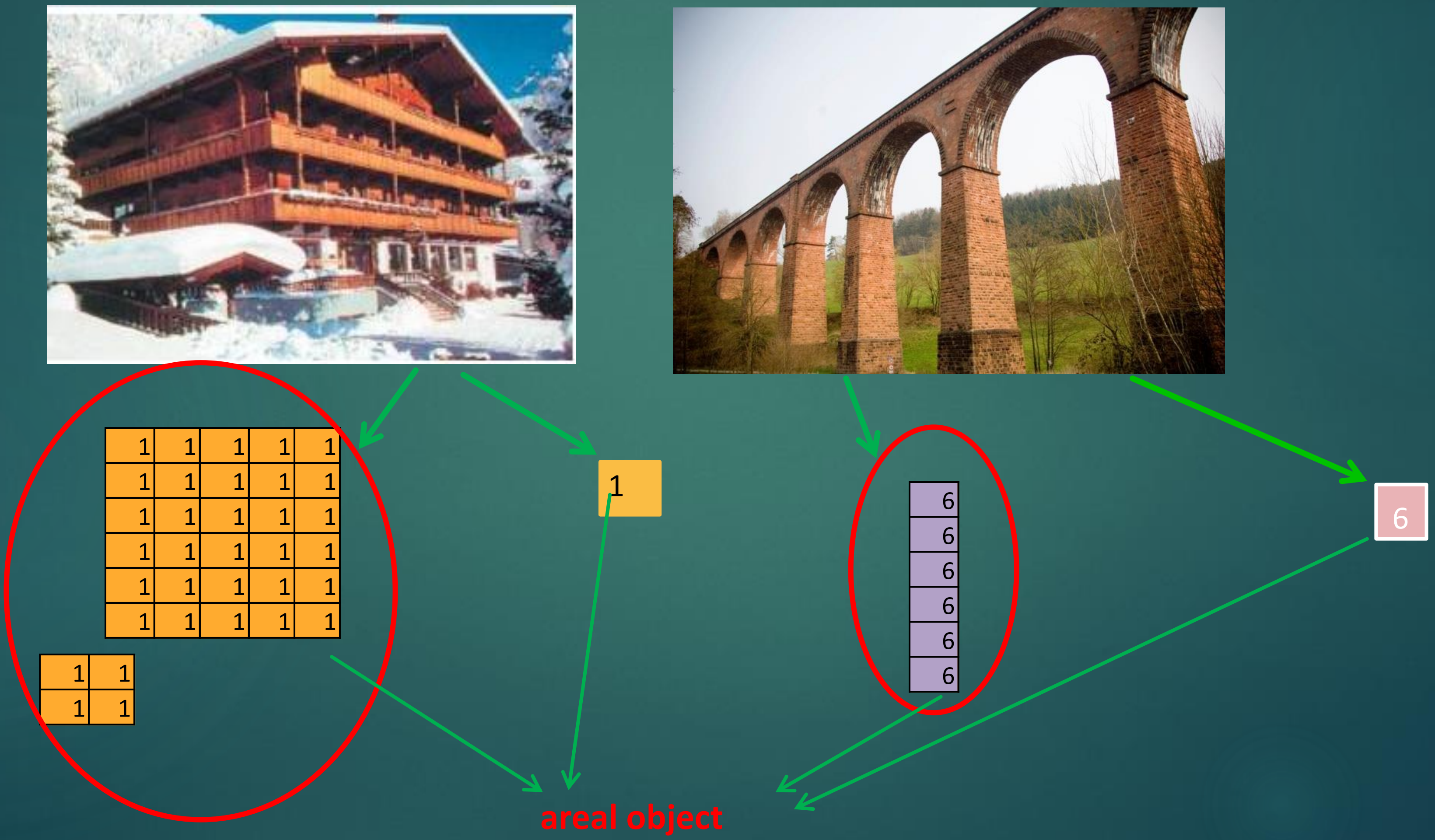
Geometric dimension of **raster objects in raster GIS**

- dimensionless - 0-D - points (value 13)
- one dimensional - 1-D – line objects (value 2)
- two dimensional - 2-D – surface objects of finite size (value 1, 15, 3)
- three dimensional - 3-D - solids of finite volume with finite surface area (polyhedrons)

Object, element, element class

raster GIS = field model

Choice of data creator - but the object will always be areal



Object, element, element class

raster GIS = field model

Descriptive data in raster GIS

Descriptive properties = attributes

- they specify individual elements - they define dimensionally or qualitatively properties
- **feature class** = (*family house*) expressed as a field value **in the raster layer**
- **each its attribute listed in a new raster layer**

Object, element, element class

raster GIS = field model

Descriptive data in raster GIS

56	153	153	153	153
56	56	153	153	153
56	56	153	153	153
56	56	56	153	153
56	56	56	153	153
56	56	56	153	153
56	56	56	153	153

Attribute (nominal value)

Owner **(= text string, expressed as owner ID)**

- **ID = 56**
- **ID 153**

For this type of data , the field model is usually disadvantageous

Object, element, element class

raster GIS = field model

Descriptive data in raster GIS

Attribute - nominal boolean value

***connection to the public water supply* = boolean   yes = 1, no = 0**

0	1	1	1	1
0	0	1	1	1
0	0	1	1	1
0	0	0	1	1
0	0	0	1	1
0	0	0	1	1
0	0	0	1	1

Object, element, element class

raster GIS = field model

Descriptive data in raster GIS

Attribute - ordinal value

area - I can code the values

The year the houses were completed

Code: code value

0. area outside buildings

1. 1990

2. 1995

3. 1997

4. 2002

1	1	0	3	3	0	0
1	1	0	3	3	0	0
1	1	0	0	3	3	0
1	1	0	0	0	3	0
1	1	0	0	0	0	0
0	0	0	5	5	0	0
0	0	0	5	5	5	0
0	0	0	0	5	5	0
0	0	0	0	0	5	0
0	0	0	4	4	0	0
0	0	0	4	4	4	0
0	0	0	0	4	4	0

Object, element, element class

raster GIS = field model

Descriptive data in GIS

Attribute - interval value - I have to code the values

last fix = date, if a raster GIS is required, it is advantageous to divide it into interval values of the attribute:

1	1	1	1
3	1	1	1
3	1	1	1
3	2	2	2
3	2	2	2
3	2	2	2
2	2	2	2

Code meaning attribute

1 until 31.12.1979

2 1.1. 1980 – 31.12. 1990

3 after 1.1. 1991

Raster representation of spatial objects

How is raster data stored?

Individual information levels in the raster = layers – here are : **cells**

Individual information levels in the vector = **layers** = at ESRI called, for example, coverages, here they are:

Point = 1 pixel

Line = sequence of adjacent pixels

Area = contiguous group of adjacent pixels

Raster representation of spatial objects

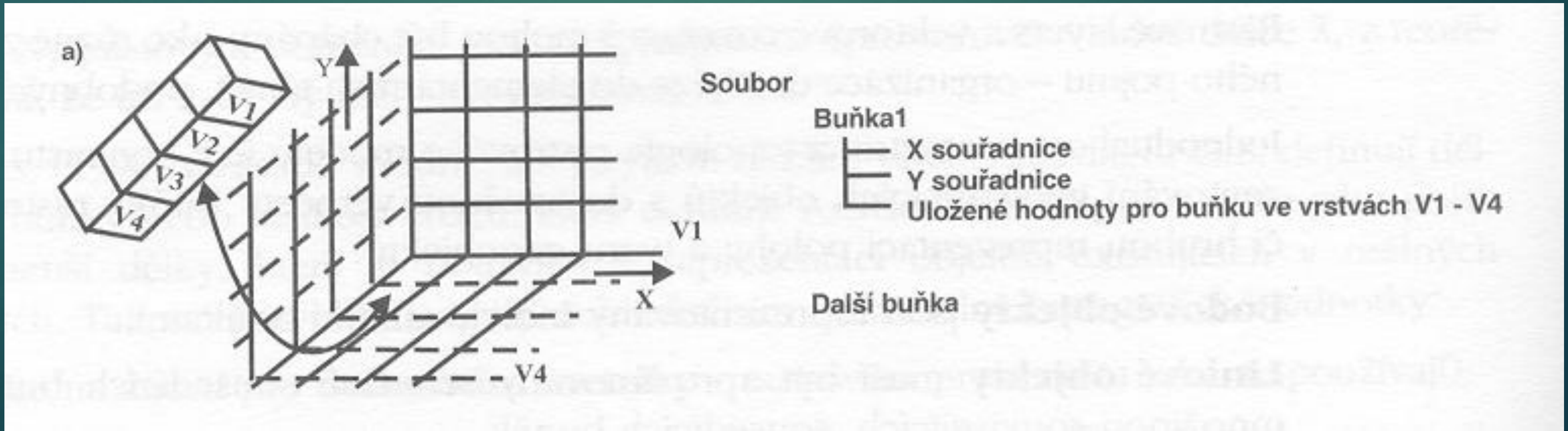
Ways of structuring data in raster representation :

that is, how data is stored for a raster GIS

1. Direct cell dating

= by cells - cell defined by

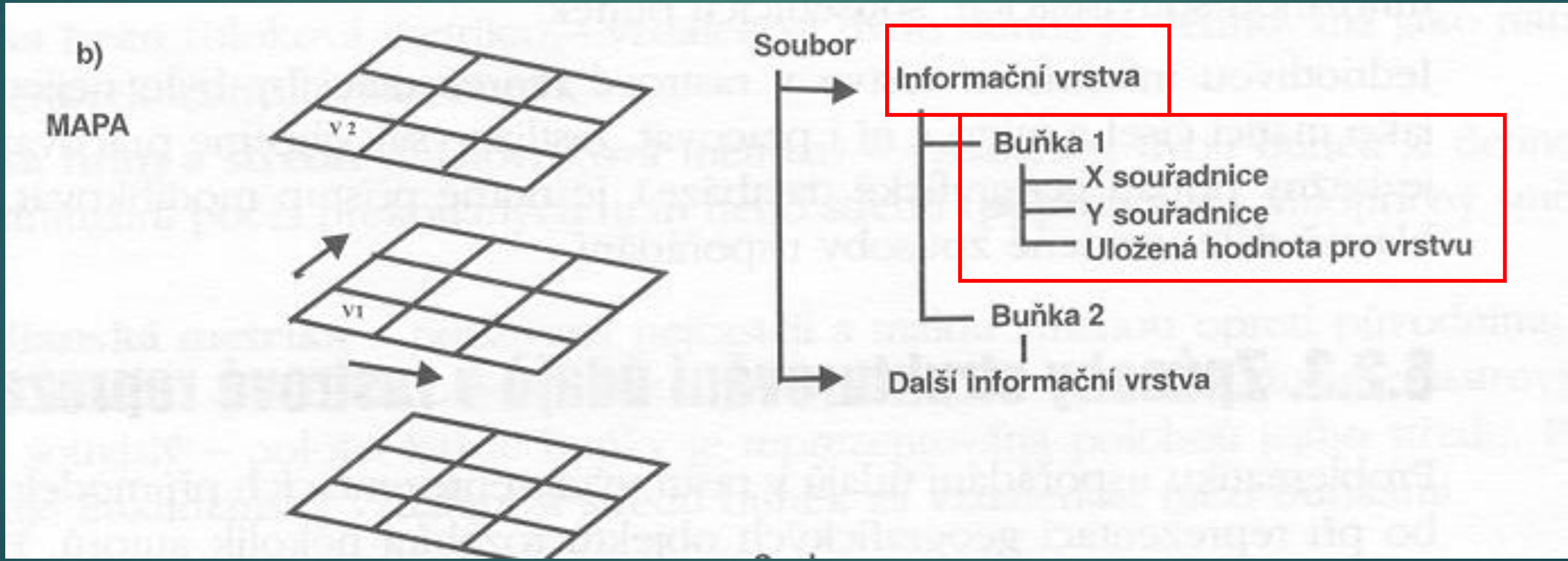
- Coordinates *X,Y*
- or *i,j* (column and row position) – attribute column given for the layer/class v1, v2, … for the thus determined pixel



Raster representation of spatial objects

Ways of structuring data in a raster representation - continued :

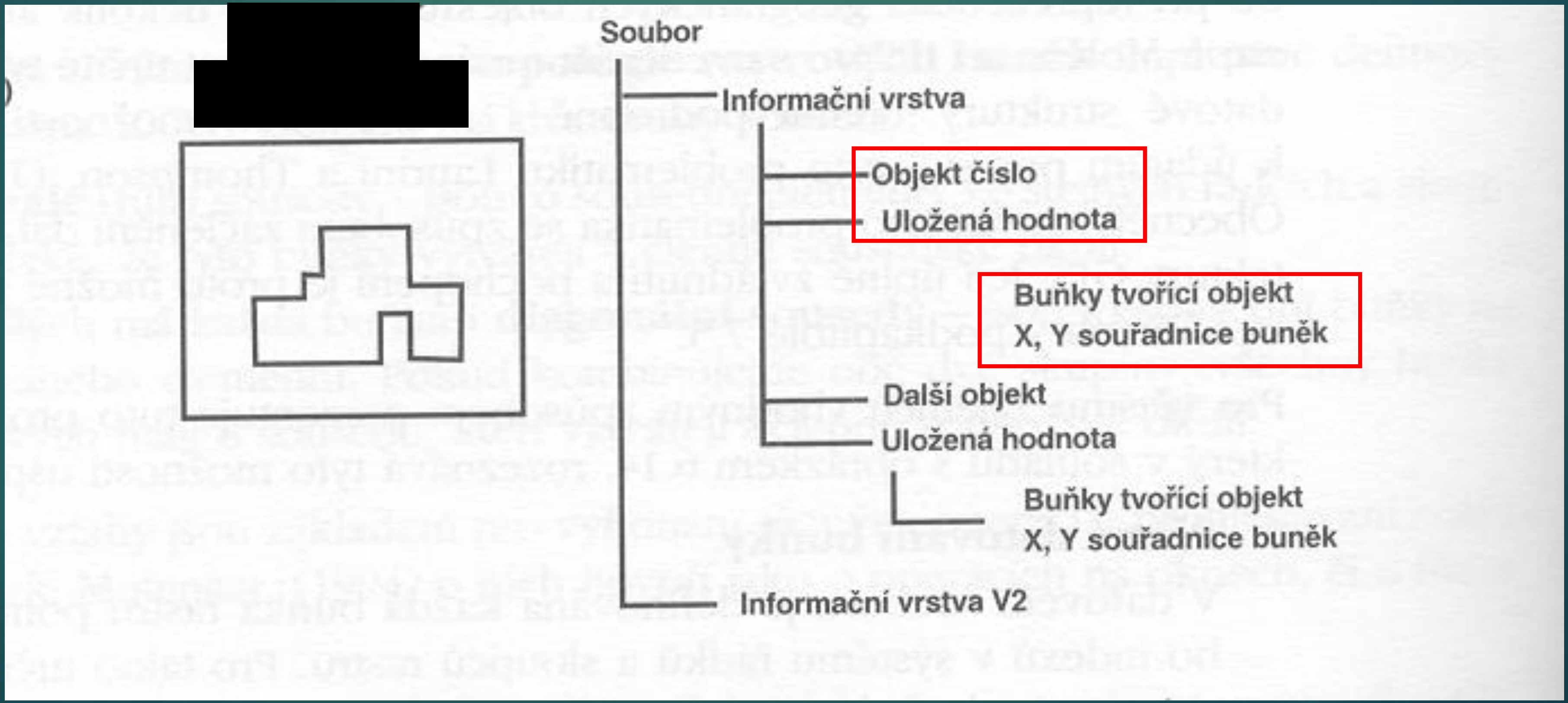
2 . Direct dating of the information layer = by layers



Raster representation of spatial objects

Ways of structuring data in a raster representation - continued:

3. direct dating of the object = by objects



Raster data compression

uncompressed data volumes are large

A. RLE – run length encoding :

Data, i.e. values in cells 1 1 1 1 3 3 2 2 2 2 2 2 3 3 3 3

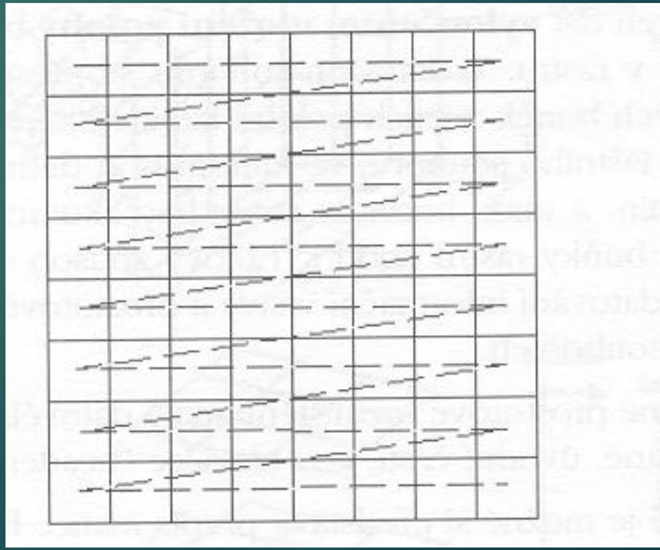
Data after RLE compression : (1 4)(3 2)(2 6)(3 4)

(the value in pixels and the number of repetitions are given, i.e. we have 2 of the first 4 values)

Raster representation - compression

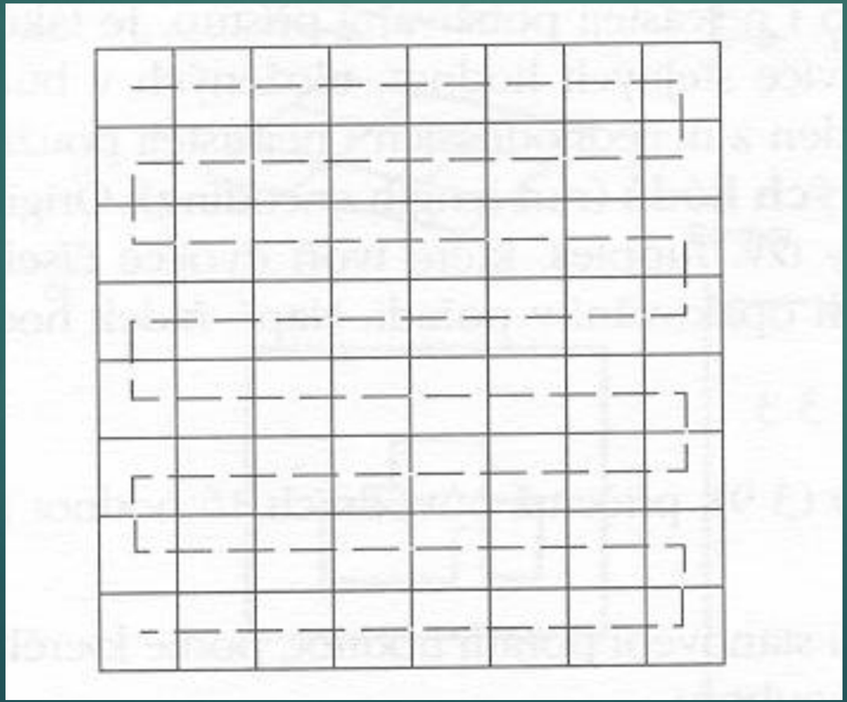
A. RLE - different options for determining the order of values for compression:

A1. Following the lines for RLE – row-ordering – (each row starts on the left) does not respect close values of neighboring pixels



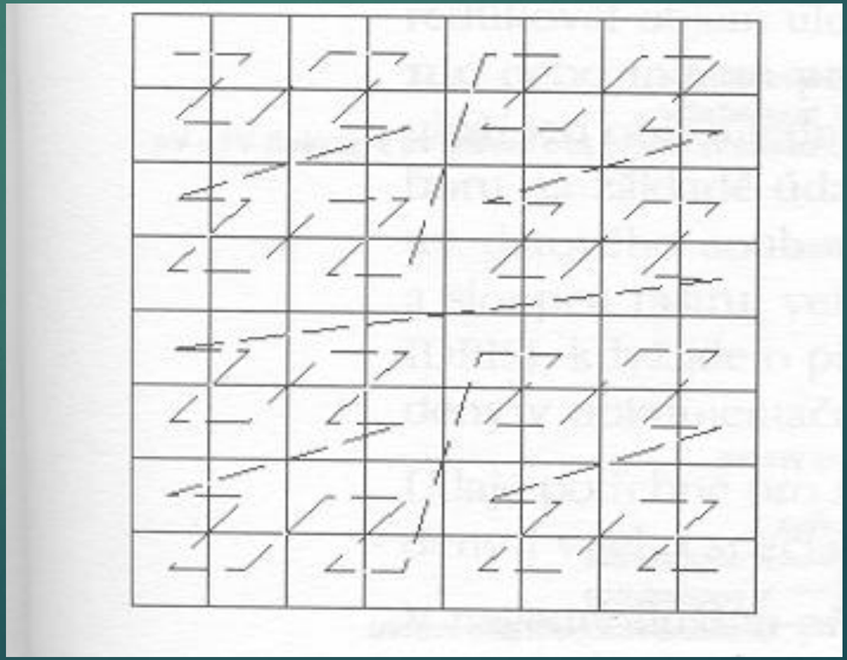
Raster representation - compression

A2. Row-by-row progression for RLE – row prime/ horizontal ordering – respects close values of pixels close to the beginning and end of the line



A3. Morton's order for RLE – Morton / Quadrant ordering

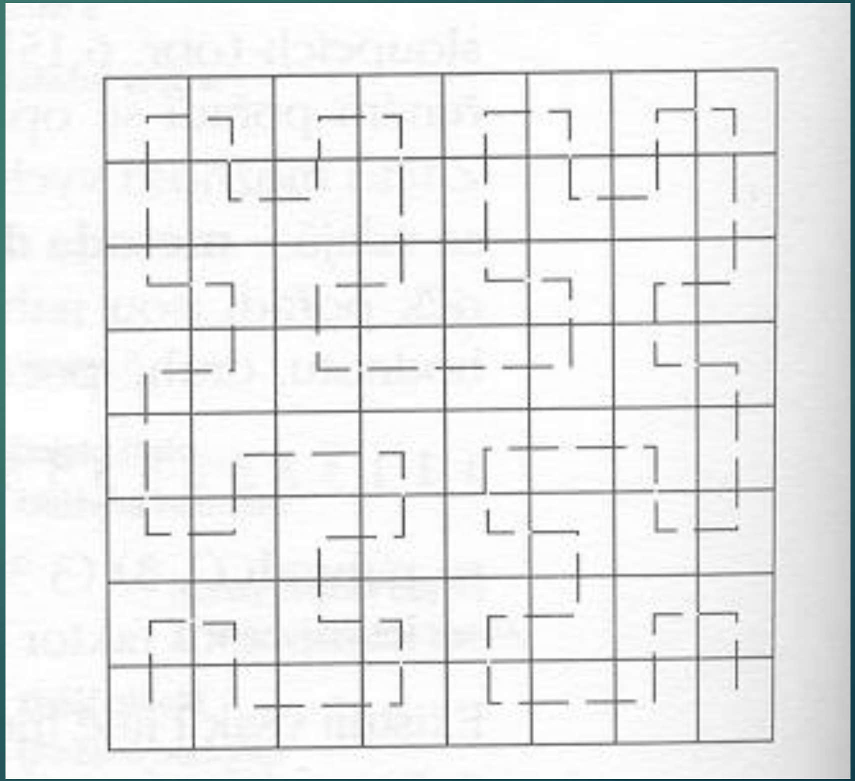
Changes of direction diagonally - more appropriate respect of values close to each other in the immediate vicinity over **4 lines**



Raster representation - compression

A4 . Peano order for RLE – Peano / Hilbert ordering

changes of direction in the perpendicular direction – more appropriate respect for values in the immediate vicinity

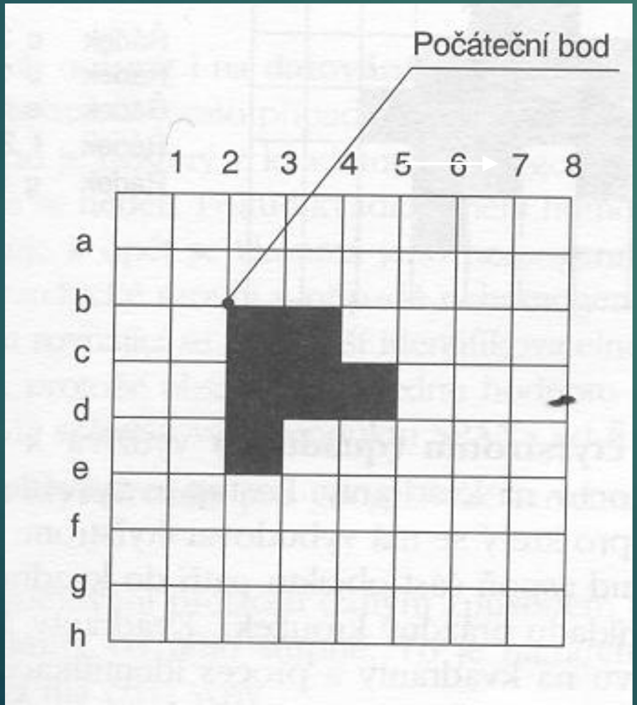


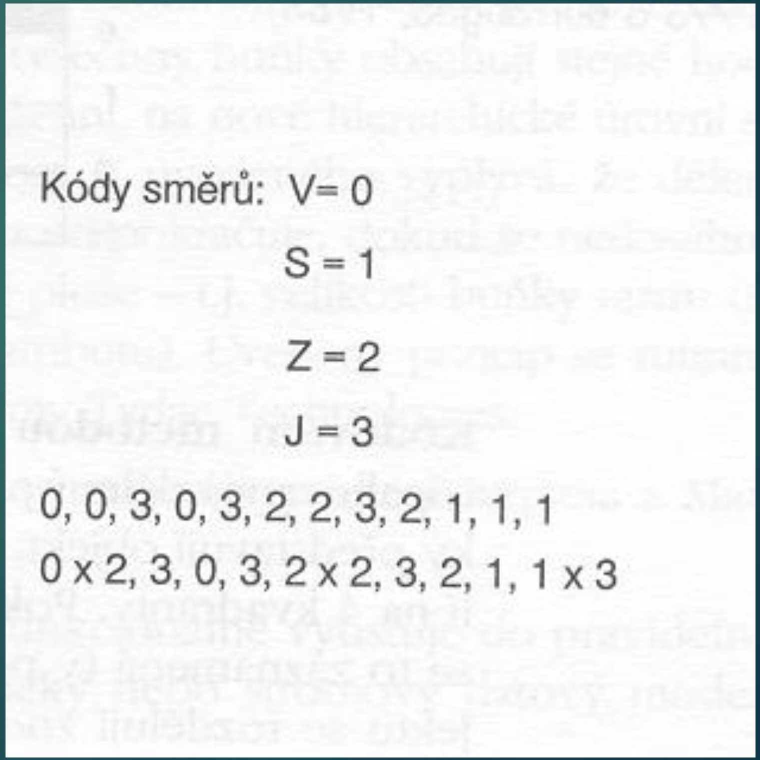
Raster representation - compression

B. String Codes (chain codes)

define boundaries by encoding directions along object boundaries -

It is intended for starting cells (row i , column j) and then the direction for one pixel is always determined





Kódy směrů: V= 0

S = 1

Z = 2

J = 3

0, 0, 3, 0, 3, 2, 2, 3, 2, 1, 1, 1

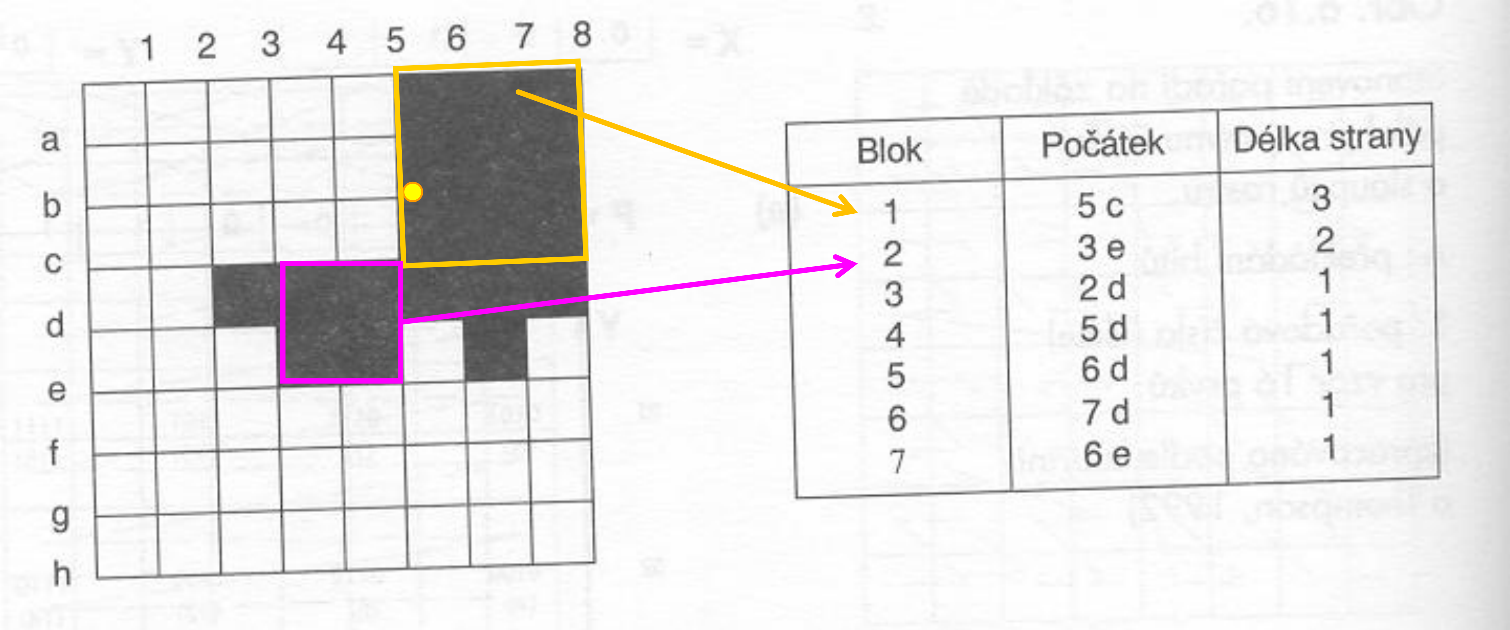
0 x 2, 3, 0, 3, 2 x 2, 3, 2, 1, 1 x 3

Raster representation - compression

C. Block codes - square (block codes)

It is given

1. the position of the reference points at the bottom left and
2. size of square blocks

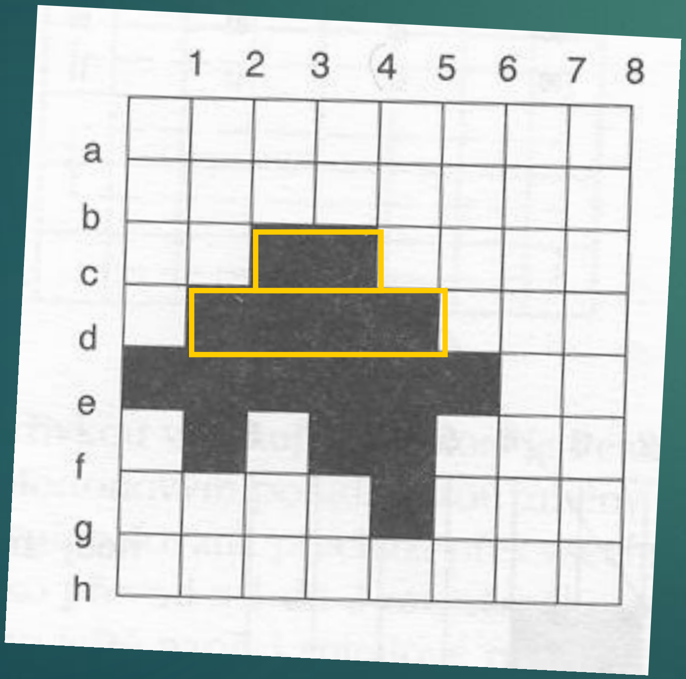


Blok	Počátek	Délka strany
1	5 c	3
2	3 e	2
3	2 d	1
4	5 d	1
5	6 d	1
6	7 d	1
7	6 e	1

Raster representation - compression

D. Coding of line sections (run length encodes)

indicates the start and end of a range of cells in rows



Řádek	c	3,4
Řádek	d	2,5
Řádek	e	1,6
Řádek	f	2,2 4,5
Řádek	g	5,5

Raster representation - compression

E. Quadtree coding

Coding using repeated division into 4 quadrants by halving the sides

The goal is to get squares in which there is only a cell or more cells forming one object, i.e. the cells in it have the same value

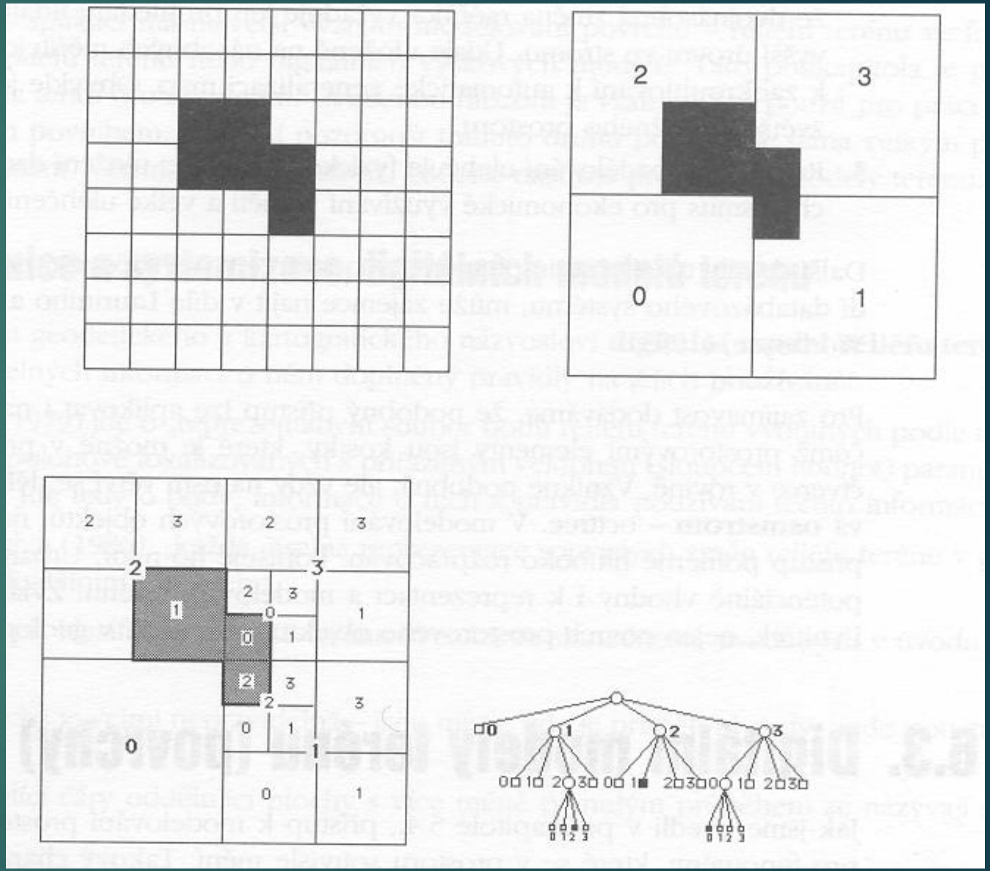


Figure shows the levels of partitioning by the quadtree method presented here

Change of map projection, transformation of the coordinate system

- Changes to the map projection – currently already part of GIS – just choose the right way

- Coordinate system transformation:

1. Linear conformal transformation (similarity)

$$x' = mx\cos\beta + my\sin\beta + a$$

$$y' = -mx\sin\beta + my\cos\beta + b$$

Helmert transformation – Least Squares method of adjustment

Change of map projection, transformation of the coordinate system

2. Polynomial transformations – 1st – nth order

Equation for 1st order (affine):

$$x' = ax + by + c$$

$$y' = dx + ey + f$$